

CONVERTIBLE AIRCRAFT CAPABLE OF HOVERING

Cross-Reference to Related Applications

5 This Patent Application claims priority from Italian Patent Application No. 21180396.0 filed on June 18, 2021, the entire disclosure of which is incorporated herein by reference.

Technical Field of the Invention

10 The present invention relates to a convertible aircraft, i.e., an aircraft that is switchable between a first configuration of hovering flight or flight along a predominantly vertical trajectory and a second forward flight or cruise configuration.

State of the Art

15 In the aviation sector, aeroplanes are normally used for high cruising speeds, in particular greater than 150 knots and high altitudes, e.g. above 30,000 feet. At cruising speeds and high altitudes, aeroplanes
20 use fixed wings to generate the lift necessary to sustain the plane. A sufficient value of this lift can only be obtained by accelerating the aeroplane on runways of considerable length. These runways are also necessary to allow the same aeroplanes to land.

25 In contrast, helicopters normally have lower cruising speeds than aeroplanes and generate the necessary lift for sustenance through the rotation of the main rotor blades. As a result, helicopters can land/take off without the need for a horizontal speed
30 and using particularly small surfaces. Moreover, helicopters are able to hover and to fly at relatively low altitudes and speeds, resulting thus as particularly manoeuvrable and suitable for demanding manoeuvres such as rescuing people in the mountains or at sea.

Nevertheless, helicopters have inherent limitations in terms of maximum operational altitude, which is around 20000 feet, and maximum operational speed, which cannot exceed 150 knots.

5 In order to meet the demand for aircraft that have the same manoeuvrability and flexibility of use as the helicopter and at the same time overcome the inherent limitations mentioned above, convertiplanes are known and which constitute a type of convertible aircraft.

10 An example of a convertiplane is described in patent application US-B-10,011,349.

In more detail, the convertiplane described in the aforesaid application essentially comprises:

15 - a fuselage extending along a first longitudinal axis; and

20 - a pair of half-wings projecting cantilevered from respective parts of the fuselage that are opposite to each other, and having respective free ends opposite to the fuselage and aligned along a second transverse axis that is substantially orthogonal to the first longitudinal axis.

The convertiplane further comprises:

25 - a pair of nacelles housing the respective motors; and
- a pair of rotors that are rotatable around respective third axes and operatively connected to respective motors.

30 The rotors can be inclined relative to the wing around a fourth axis, preferably parallel to the second axis.

The convertiplanes are also able to selectively assume:

- the first "helicopter" configuration, wherein the rotors are arranged with the respective third axes that

are substantially vertical and orthogonal to the first axis of the convertiplane and orthogonal to the respective motors; or

- the second "aeroplane" configuration, wherein the
5 rotors are arranged with respective third axes that are substantially parallel to the first axis of the same convertiplane and coaxial to the respective engines.

Recently, several proposals for convertible aircraft with electric propulsion have been developed.

- 10 Among them, patent application WO-A-2020/105045 describes a convertible aircraft comprising essentially:

- an airframe elongated according to a longitudinal direction of the aircraft;
- a pair of half-wings projecting cantilevered from
15 respective sides of the airframe; and
- a portion of the tail formed by two aerodynamic surfaces forming a V.

The aircraft described in WO-A-2020/105045 further comprises:

- 20 - two pairs of first rotors with axis fixed with respect to the airframe and arranged so as to form a polygon surrounding the centre of gravity of the aircraft; and
- two pairs of second rotors with tilting axis with
25 respect to the airframe.

In more detail, the first rotors and second rotors are controllable independently of each other so as to provide respective first and second thrusts that can be adjusted independently of each other.

- 30 A pair of second rotors is arranged at free ends of respective half-wings while the other pair of second rotors is arranged at free ends of respective aerodynamic surfaces of the tail portion.

The second rotors are inclinable between a first

position wherein the respective second axes are arranged orthogonal to the longitudinal direction of the aircraft and provide a vertical thrust, and a second position wherein respective second axes are arranged parallel to the longitudinal direction of the aircraft and provide a thrust parallel to the forward direction of the aircraft.

Consequently, the aircraft can selectively assume:

- the first configuration, wherein the second rotors are arranged in the first position and cooperate with the first rotors to provide the vertical thrust necessary to sustain the aircraft; and
- the second configuration, wherein the second rotors are arranged in the second position and provide the horizontal thrust necessary to move the aircraft forward, while the first rotors and half-wings provide the vertical thrust necessary to sustain the aircraft.

The position of the second rotors at the free ends of the respective half-wings causes problems of aeroelastic interaction with the half-wings themselves, thus determining a potential risk situation for the safety of the aircraft.

The need is felt in the sector to have a convertible aircraft capable of hovering and forward flying with a flight envelope sufficiently large that it is as little subject as possible to the aforesaid problems of aeroelastic interaction between the second rotors and the respective half-wings.

More specifically, there is a need to reduce the aforesaid problems of aeroelastic interaction, requiring a particularly reduced number of components.

The need is also felt in the sector to realize a convertible aircraft capable of meeting the high safety standards necessary for urban use and/or requiring a

limited energy supply.

Lastly, the sector is aware of the need to realize a convertible aircraft capable of being reconfigured so as to be able to carry out missions even at long
5 distances or to be able to reduce consumption or to be able to achieve high flight performance.

Subject and Summary of the Invention

Aim of the present invention is to realize a convertible aircraft which allows to satisfy at least
10 one of the needs specified above in a simple and economical way.

EP-A-3659669 discloses a convertible aircraft according to the preamble of claim 1

According to the invention, this aim is achieved by
15 a convertible aircraft capable of hovering as claimed in claim 1.

Brief Description of the Drawings

For a better understanding of the present invention, seven preferred non-limiting embodiments are
20 described below, purely by way of example and with the aid of the attached drawings, wherein:

- Figure 1 is a perspective view of a first embodiment of a convertible aircraft realized according to the dictates of the present invention arranged in a
25 first configuration;

- Figure 2 is a perspective view of the aircraft of Figure 1 arranged in a second configuration;

- Figure 3 is a front view of the aircraft of Figures 1 and 2 arranged in the second configuration;

30 - Figure 4 is a side view of the aircraft of Figures 1 to 3 arranged in the second configuration;

- Figure 5 shows first details of the aircraft of Figures 1 to 4;

- Figures 6a to 6h show respective control

manoeuvres of the aircraft of Figures 1 to 5;

- Figures 7a to 7f show respective emergency manoeuvres of the aircraft of Figures 1 to 5;

- Figure 8 shows a core which is common to
5 different architectures of the aircraft of Figures 1 to 5;

- Figure 9 shows in perspective view a first architecture of the aircraft of Figures 1 to 8;

- Figure 10 shows in perspective view some
10 components of the first architecture of the aircraft in Figure 9, with parts removed for clarity's sake;

- Figure 11 schematically shows a propulsion system implemented in the first architecture in Figures 9 and 10;

- Figure 12 shows in perspective view a second
15 architecture of the aircraft of Figures 1 to 8;

- Figure 13 shows in perspective view a third architecture of the aircraft of Figures 1 to 8;

- Figure 14 shows in perspective view some
20 components of the second and third architecture of the aircraft in Figure 9, with parts removed for clarity's sake;

- Figure 15 schematically shows a propulsion system implemented in the second and third architecture of
25 Figures 13 and 14;

- Figure 16 shows in perspective view some details of the fourth architecture of the aircraft of Figures 1 to 8;

- Figure 17 shows in perspective view in partially
30 exploded enlarged scale and according to a first viewing angle the fourth architecture of Figure 16;

- Figure 18 shows in perspective view one with a second viewing angle the fourth architecture of Figures 16 and 17;

- Figure 19 shows in perspective view the fourth architecture of Figures 16 to 18;

- Figure 20 is a perspective view of a second embodiment of a convertible aircraft realized according to the dictates of the present invention arranged in the first configuration; and

- Figure 21 is a perspective view of the aircraft in Figure 20 arranged in the second configuration.

**Detailed Description of Preferred Embodiments of
the Invention**

With reference to Figures 1 to 19, 1 denotes an aircraft capable of hovering.

In more detail, the aircraft 1 is selectively switchable between:

- a first configuration (Figure 1), wherein it performs a hovering manoeuvre or moves forward along a predominantly vertical trajectory; and

- a second configuration (Figure 2), wherein it is in a forward flight condition and proceeds along a mainly horizontal trajectory.

It must be specified that in the following present disclosure, expressions such as "upper", "lower", "at the front", "at the back" and the like are used referring to forward flight conditions or "hovering" of the convertiplane 1 shown in Figures 1 to 2.

It is possible to identify a triplet of axes integral to the aircraft 1 and originating at a centre of gravity O of the aircraft 1 itself formed by:

- a longitudinal axis Y of the same aircraft 1;
- an axis X orthogonal to the axis Y; and
- an axis Z orthogonal to the axes X, Y.

In a known manner, the rotations of the aircraft 1 around the axes Y, X, Z are associated with the following manoeuvres:

- roll, i.e. rotation about the axis Y (Figures 6b, 6f);
- pitch, i.e. rotation about the axis X (Figures 6c, 6g); and
- 5 - yaw, i.e. rotation about the axis Z (Figures 6d, 6h).

The aircraft 1 essentially comprises:

- an airframe 2 which is elongated along the axis Y and defining a nose 4 and a tail 5 of the aircraft 1;
- 10 - a pair of half-wings 3 extending cantilevered from respective mutually opposite sidewalls 62 of the airframe 2 and transversely to the axis Y; and
- a tail portion 6 projecting cantilevered from the tail 5 of the airframe 2 transversely to the airframe 2.

15 With reference to normal forward flight operating conditions, the aircraft 1 proceeds in a direction that is oriented from tail 5 to nose 4.

The half-wings 3 are intended to provide a first lift value to the aircraft 1 which is adapted to sustain the aircraft 1 arranged in the second configuration.

20 The half-wings 3 comprise respective free ends 15 opposite the airframe 2.

The half-wings 3 extend superiorly to the airframe 2.

In the case shown, the semi-axes 3 comprise:

- 25 - respective root portions 11 diverging from each other, proceeding from the airframe 2 towards the respective free ends 15; and
- respective end portions 12 arranged superiorly to the airframe 2, defining the respective ends 15 and
- 30 substantially parallel to each other.

The tail portion 6 is preferably T-shaped and comprises, in turn:

- a fin 7 intended to provide lateral stability to the aircraft 1 arranged in the second configuration; and

- a cup of aerodynamic surfaces 8 projecting cantilevered from respective mutually opposite sides of the fin 7, comprising respective free ends 16, and adapted to generate a second lift/downforce value to ensure a desired degree of longitudinal stability to the aircraft 1 itself arranged in the second configuration.

Preferably, the aircraft 1 further comprises a pair of canard-type aerodynamic surfaces 9 projecting cantilevered from respective mutually opposite sides of the nose 4 of the airframe 2 and adapted to generate a third lift/downforce value to ensure the desired degree of longitudinal stability to the aircraft 1 itself arranged in the second configuration.

The aerodynamic surfaces 9 comprise, in turn:

- respective root portions 17 projecting cantilevered from and connected to respective sidewalls 62 of the airframe 2; and

- respective end portions 18 arranged on the opposite side of the corresponding root portions 17 with respect to the airframe 2.

In particular, the root 17 and end 18 portions are coplanar with each other.

In the case shown in Figure 3, the wingspan L1 of the half-wings 3 is greater than the wingspan L2 of the aerodynamic surfaces 8.

The wingspan L2 of the aerodynamic surfaces 9 is greater than the wingspan L3 of the aerodynamic surfaces 8.

In the case shown, the wingspan of the aerodynamic surfaces 8 ranges between 40 and 50% of the wingspan of the aerodynamic surfaces 9.

The wingspan of the aerodynamic surfaces 9 ranges between 70 and 90% of the wingspan of the half-wings 3.

In this description, the term "wingspan" means the distance between opposite free ends 17, 18 of the

respective half-wings 3 and aerodynamic surfaces 8, 9.

The aerodynamic surfaces 9 are arranged inferiorly to the half-wings 3. The half-wings 3 are arranged inferiorly to the aerodynamic surfaces 8.

5 In the shown case, the aerodynamic surfaces 8 comprise respective appendages 14 which are movably connected thereto to adjust the second lift value and to contribute to the control of the aircraft 1.

The aircraft 1 also comprises:

- 10 - a pair of rotors 20a, 20b which are rotatable about respective fixed axes B, C with respect to the airframe 2;
 - a pair of rotors 21a, 21b which are rotatable about respective fixed axes D, E with respect to the airframe 2;
 and
15 - a pair of rotors 22a, 22b which are rotatable about respective axes F, G and inclinable with respect to an axis H between a first position assumed when the aircraft 1 is in the first configuration and a second position assumed when the aircraft 1 is in the second configuration.

20 In the shown case, the axes F, G of the rotors 22a, 22b are inclinable with respect to the axis H by more or less fifteen degrees towards the nose 4 or the tail 5 with respect to the axis Z.

The aircraft 1 further comprises a unit 71 (shown
25 schematically in Figures 11 and 15) receiving at input a plurality of control signals provided by the crew, an autopilot or a remote control system, and programmed to provide as output a plurality of commands to command the rotors 20a, 20b; 21a, 21b; 22a, 22b so that they provide
30 desired values of the relative thrusts T1, T2; T3, T4; T5, T6 (Figures 6a-6h).

In more detail, the control unit 71 is programmed to command the rotors 20a, 20b; 21a, 21b; 22a, 22b to generate respective independent thrusts T1, T2; T3, T4; T5, T6.

More particularly, the control unit 71 is programmed to command the rotors 20a, 20b; 21a, 21b; to generate respective thrusts T1, T2 (T3, T4) having a resultant which is parallel to the axis Z, either when the aircraft 1 is in the first configuration or when the aircraft 1 is in the second configuration.

The control unit 71 is programmed to command the rotors 20a, 20b; 21a, 21b to generate respective zero thrusts T1, T2; T3, T4 under predetermined operating conditions and when the aircraft 1 is in the first configuration.

The axes B, C; D, E and F, G are arranged symmetrically to the axis Y.

In the case shown, the axes B, C, D and E are parallel to each other and parallel to the axis Z.

The axes B, D, F; C, E, G are aligned with each other parallel to the axis Y when the aircraft 1 is arranged in the first configuration.

The axis H is parallel to the axis X.
The axes F, G are arranged parallel to the axis Z when the rotors 22a, 22b are arranged in the first position.

The axes F, G are arranged orthogonally to the axes B, C; D, E and parallel to the axis Y when the rotors 22a, 22b are arranged in the second position.

The thrusts T1, T2; T3, T4 have a main component parallel to the respective axes B, C; D, and orthogonal to the axis Z either when the aircraft 1 is arranged in the first configuration or when the aircraft 1 is arranged in the second configuration.

The thrusts T5, T6 have a main component which is parallel to the axes B, C; D, E and the axis Z when the aircraft 1 is arranged in the first configuration and a main component to the axis Y when the aircraft 1 is arranged in the second configuration.

In one embodiment, the rotors 20a, 20b; 21a, 21b; 22a, 22b are with fixed pitch.

Preferably, the rotors 20a, 20b; 21a, 21b; 22a, 22c are driven by respective electric motors.

5 The aircraft 1 also comprises:

- a pair of supports 30a, 30b in order to support respective rotors 20a, 20b in a fixed manner with respect to respective aerodynamic surfaces 9;

- a pair of supports 31a, 31b in order to support
10 respective rotors 21a, 21b in a fixed manner with respect to the airframe 2; and

- a pair of supports 32a, 32b in order to support respective rotors 22a, 22b to respective half-wings 3 in an inclinable manner with respect to the axis H.

15 Advantageously, the supports 32a, 32b are spaced apart from the ends 15 of the respective half-wings 3, with reference to an extension direction of the half-wings 3.

More precisely, the supports 32a, 32b are carried by respective root portions 11 of respective half-wings 3.

20 The supports 30a, 30b are spaced apart from the ends 16 of the respective aerodynamic surfaces 9, with reference to an extension direction of the aerodynamic surfaces 9.

In particular, the supports 30a, 30b are conformed as respective rods projecting cantilevered below from
25 respective aerodynamic surfaces 9 anteriorly to the nose 4.

In the shown case, the supports 30a, 30b are fixed to respective root portions 17 of corresponding aerodynamic surfaces 9.

The axes B, C are arranged anteriorly to the nose 4.

30 The supports 31a, 31b are conformed as rods projecting cantilevered from respective sidewalls 62 of the airframe 2 laterally to the fin 7, posteriorly to the respective half-wings 3 and anteriorly to the respective aerodynamic surfaces 8.

The rotors 21a, 21b are arranged laterally to the fin 7 and inferiorly to the respective aerodynamic surfaces 8, and posteriorly to the respective half-wings 3.

5 The axes D, E are arranged anteriorly to the respective aerodynamic surfaces 8.

The supports 32a, 32b comprise:

- respective rods 33a, 33b projecting cantilevered anteriorly in a fixed manner from respective half-wings 3; and
- 10 - respective pins 34a, 34b that are rotatable about corresponding rods 33a, 33b parallel to the axis H and supporting respective rotors 22a, 22b about respective axes F, G.

15 The pins 34a, 34b are interposed between the respective half-wings 3 and the nose 4 along the axis Y.

The rotors 22a, 22b are interposed between the respective half-wings 3 and the nose 4 along the axis Y either when the aircraft 1 is arranged in the first configuration or when the aircraft 1 is arranged in the second configuration.

20

The rotors 22a, 22b are arranged superiorly to the respective half-wings 3 when the aircraft 1 is arranged in the first configuration, and anteriorly to the respective half-wings 3 when the aircraft 1 is arranged in the second configuration.

25

The fin 7 extends from both the upper and lower sides of the tail 5 of the airframe 2.

The aircraft 1 also comprises (Figures 3 and 4):

- a pair of first carriages 45 carried by respective
- 30 aerodynamic surfaces 9; and
- a carriage 46 carried by the fin 7 in a position opposite to the aerodynamic surfaces 9.

Preferably, the airframe 2 defines a compartment 60 and a plurality of openings 61 for access to the

compartment 60.

The compartment 60 may accommodate crew or passengers, or instrumentation or cargo to be transported, depending on how the aircraft is used 1.

5 The openings 61 are located at sidewalls 62 of the airframe 3.

The openings 61 are, moreover, arranged in a zone 63 which is delimited along the axis Y between the half-wings 3 and the aerodynamic surfaces 9.

10 When it is arranged on the ground in the first configuration, the aircraft 1 defines an aisle 64 for access to the opening 61. The aisle 64 is delimited along the axis Y between the half-wings 3 and the aerodynamic surfaces 9 and parallel to the axes B, C between the ground
15 and the supports 32a, 32b of the rotors 22a, 22b arranged in the second position (Figure 5).

Thanks to the fact that the rotors 20a, 20b are arranged anteriorly to the relevant aerodynamic surfaces 9 and the rotors 22a, 22b are arranged superiorly to the
20 relevant half-wings 3a, 3b, the aisle 64 is clear and easily accessible during boarding/disembarking of passengers and/or loading/unloading of baggage.

With reference to Figures 6a-6d and to the first configuration, the aircraft 1 is controlled as follows.

25 Under steady state conditions, the thrusts T1, T2, T3, T4, T5, T6 allow the aircraft 1 to be sustained with a certain degree of redundancy (Figure 6a).

In order to perform a roll manoeuvre (Figure 6b), the control unit 71 is programmed to command the rotors 20a, 20b, 21a, 21b, 22a, 22b so that the thrusts T1, T3, T5 are
30 higher (lower) than the thrusts T2, T4, T6.

For example, the rotors 20a, 20b, 21a, 21b, 22a, 22b are commanded by the control unit 71 so as to increase (decrease) the thrusts T1, T3, T5 and to decrease

(increase) the thrusts T2, T4, T6.

This generates three differential thrusts of concordant sign T1-T2; T3-T4 and T5-T6 which generate a torque and a consequent rotation of the aircraft around the axis Y.

In order to perform a pitch manoeuvre (Figure 6c), the control unit 71 is programmed to command the rotors 20a, 20b, 21a, 21b, 22a, 22b so that the thrusts T1, T2 are equal to each other higher than (lower than) the thrusts T3, T4 equal to each other.

For example, the rotors 20a, 20b, 21a, 21b are commanded so as to increase (decrease) the thrusts T1, T2 and to decrease (increase) the thrusts T3, T4.

This generates two differential thrusts of concordant sign T1-T3 and T2-T4 which generate a torque and a consequent rotation of the aircraft around the axis X.

In order to perform a yaw manoeuvre (Figure 6d), the control unit 71 is programmed to orient the axis F of the rotor 22a towards (opposite side of) the nose 4 and the axis G of the rotor 22b towards (opposite side of) the tail 5.

This generates two components of the thrusts T5, T6 that are parallel to the axis Y and discordant to each other which generate a torque and a consequent rotation of the aircraft around the axis Z.

With reference to Figures 6e-6h and to the second configuration, aircraft 1 is controlled as follows.

Under steady state conditions (Figure 6e), the control unit 71 is programmed to command the rotors 20a, 20b so that the respective thrusts T1, T2 ensure the correct trimming of the aircraft 1 - that is, the correct adjustment of the overall lift/downforce value depending on the required speed and weight conditions of the aircraft 1 - while and deactivates the rotors T5, T6 so that the

thrusts T3, T4 are zero.

In order to perform a roll manoeuvre (Figure 6f), the control unit 71 is programmed to command the rotors 20a, 20b so that the thrust T1 is higher (lower) than the thrust
5 T2.

For example, the rotors 20a, 20b, are commanded to increase (decrease) thrust T1 and to decrease (increase) thrust T2.

This generates a differential thrust T1-T2 which
10 generates a torque and a consequent rotation of the aircraft around the axis Y.

In order to perform a pitch manoeuvre (Figure 6g), the control unit 71 is programmed to command the rotors 20a, 20b, 22a, 22b so as to increase (decrease) the thrusts T1, T2 equal to each other and to adjust the thrusts T5, T6
15 equal to each other.

This generates a torque and a consequent rotation of the aircraft around the axis X.

In order to perform a yaw manoeuvre (Figure 6h), the control unit 71 commands the rotors 22a, 22b so that the
20 thrust T1 is greater (lower) than the thrust T6.

For example, the rotors 22a, 22b are controlled by the control unit 71 so that the thrust T5 is greater (lower) than the thrust T6.

This generates a torque and a consequent rotation of the aircraft around the axis Z.
25

The control unit 71 is, moreover, programmed to reduce the thrusts T1, T2; T3, T4 of the rotors 20a, 20b; 21a, 21b as the axes F, G of the rotors 22a, 22b progressively
30 approach a condition of parallelism with the axis Y and the speed of the aircraft 1 increases.

The aircraft 1 has a modular conformation and is adapted to be reconfigured according to the operational needs so as to assume a plurality of different

architectures.

In more detail, the aircraft 1 can assume:

- a first architecture (Figures 9 to 11) which is preferably used for urban mobility and passenger transport applications;
- a second architecture (Figures 12, 14 and 15), wherein it is used as a utility category aircraft;
- a third architecture (Figures 13, 14 and 15), wherein it is used to transport VIP passengers; or
- a fourth architecture (Figures 16 to 19), wherein it is used as a remote-controlled aircraft.

In more detail, the aircraft 1 comprises:

- a common core 100 (Figure 8); and
- a plurality of modules 110; 120, 130; and 140 interfacing with the core 100 to realize the first, second, third and fourth aircraft architecture 1, respectively.

The core 100 comprises, in turn:

- the airframe 2, the tail portion 6, the fin 7 (Figure 8), and the rotors 20a, 20b; 21a, 21b; 22a, 22b; and
- an all-electric propulsion system 70 to command the rotors 20a, 20b, 21a, 21b, 22a, 22b independently of each other (Figure 11).

Preferably, the core 100 comprises the root portions 11, 17 of the half-wings 3 and the aerodynamic surfaces 9, respectively.

The system 70 comprises, in more detail (Figure 11):

- the control unit 71 adapted to receive the control signals of the aircraft 1 at input; and
- a plurality of electric motors 72a, 72b, 73a, 73b, 74a, 74b commanded by the control unit 71 and adapted to command respective rotors 20a, 20b, 21a, 21b, 22a, 22b so that they generate respective thrusts T1, T2, T3, T4, T5, T6.

The system 70 further comprises a plurality of electric batteries 81, which electrically power the electric motors 72a, 72b, 73a, 73b, 74a, 74b.

5 With reference to Figure 9, the module 110 provides the aircraft 1 with the first architecture.

The module 110 defines the compartment 60, which forms a compartment for the passengers and relative baggage. The compartment 60 is accessible through the air 64 for the operations of passenger boarding/disembarking and baggage loading/unloading.

10 With reference to Figures 11 and 13, the modules 120, 130 provide the aircraft 1 with the second and third architecture, respectively.

In particular, similar to the module 110, the module 15 120, 130 defines the compartment 60 for passengers and relative baggage. The compartment 60 is accessible through the aisle 64.

The module 120, 130 comprises a hybrid propulsion system 75 (Figures 14 and 15), which comprises the components of the system 70.

20 The system 75 of the modules 120, 130 comprises, in particular:

- the system 70;
- a first section 76; and
- 25 - a second section 77.

The section 76 comprises, in turn:

- a heat engine 80, e.g. a Diesel engine; and
- a plurality of generators 82 driven by the heat engine 80 and selectively connectable with the electric
- 30 motors 72a, 72b, 73a, 73b, 74a, 74b.

The section 77 comprises, in turn:

- a heat engine 90; and
- a plurality of electric generators 91 that are driven by the heat engine 90 and selectively connectable

with the electric motors 72a, 72b, 73a, 73b, 74a, 74b.

In particular, the heat engine 90 has a maximum power that is greater than the heat engine 80.

Similarly, the generators 91 have a maximum power that
5 is greater than the generators 82.

Preferably, when the aircraft 1 is in the first configuration for a short time interval and the rotors 20a, 20b, 21a, 21b, 22a, 22b must generate a large power for a short time interval, the control unit 71 is programmed to
10 electrically connect either the generators 91 or the batteries 81 to the electric motors 72a, 72b, 73a, 73b, 74a, 74b.

When the aircraft 1 is in the first configuration for a long time interval and the rotors 20a, 20b, 21a, 21b,
15 22a, 22b must generate a large power for the aforesaid long time interval, the control unit 71 is programmed to electrically connect both generators 82, 91 powered by respective heat engines 80, 90 to the corresponding electric motors 72a, 72b, 73a, 73b, 74a, 74b.

When the aircraft 1 is in the second configuration, the control unit 71 is programmed to connect the heat engine 80. The heat engine 80 drives, in turn, the generator 82, which electrically powers the electric motors 72a, 72b, 73a, 73b, 74a, 74b and, preferably, to recharge
20 the batteries 81 through the generator 82.

Under emergency conditions and consequent failure of the heat engines 80, 90, the control unit 71 is programmed to electrically connect the batteries 81 to the electric motors 72a, 72b, 73a, 73b, 74a, 74b.

With reference to Figures 16 to 19, the module 140
30 provides the aircraft 1 with the fourth architecture.

In more detail, the module 140 comprises, similarly to the module 130, the heat engines 80 and 90 and the electric generators 91, 82.

The system 75 of the module 140 is totally identical to that of the modules 120, 130.

The module 140 also defines a cargo housing compartment 60 equipped with a sliding ramp that can be
5 folded into the compartment 60.

Alternatively, the compartment 60 houses (Figures 17 and 18):

- a sub-module 141 occupying the entire compartment 60 for large sized payloads; or
- 10 - a pair of sub-modules 142 each occupying half of the volume of the compartment 60 and defining respective compactly sized payloads, e.g., additional electric batteries 85 to electrically power the rotors 20a, 20b, 21a, 21b, 22a, 22b when the aircraft 1 is in the first
15 configuration; or
- a sub-module 142 and a sub-module 143 similar to the sub-module 142 but provided with a socket 144 for charging the electric batteries 81, 85 arranged at a belly of the airframe 2.

20 Each module 110, 120, 130, 140 further comprises (Figures 9, 12, 13 and 19):

- respective end portions 12 for corresponding half-wings 3; and
- respective end portions 18 for corresponding
25 aerodynamic surfaces 9.

In this way, the half-wings 3 and the aerodynamic surfaces 9 are optimised according to the flight envelope that are characteristic of the first, second, third and fourth architecture.

30 In use and with reference to Figure 6a, the aircraft 1 lands and takes off arranged in the first configuration with the rotors 22a, 22b arranged in the first position wherein the relative thrusts T5, T6 are directed parallel to the axis Z (Figure 6a).

The aircraft 1 moves forward in the second configuration with the rotors 22a, 22b arranged in the second position wherein the respective thrusts T5, T6 are arranged parallel to the axis Y.

5 In the first configuration, the lift required to sustain the aircraft 1 is delivered by the rotors 20a, 20b; 21a, 21b and 22a, 22b.

 In order to perform a roll manoeuvre (Figure 6b), the control unit 71 is programmed to command the rotors 20a,
10 20b, 21a, 21b, 22a, 22b so that the thrusts T1, T3, T5 are higher (lower) than the thrusts T2, T4, T6.

 This generates three differential thrusts of concordant sign T1-T2; T3-T4 and T5-T6 which generate a torque and a consequent rotation of the aircraft around the
15 axis Y.

 In order to perform a pitch manoeuvre (Figure 6c), the control unit 71 is programmed to command the rotors 20a, 20b, 21a, 21b, 22a, 22b so that the thrusts T1, T2 are equal to each other higher (lower) than the thrusts T3, T4
20 equal to each other.

 This generates two differential thrusts of concordant sign T1-T3 and T2-T4 which generate a torque and a consequent rotation of the aircraft around the axis X.

 In order to perform a yaw manoeuvre (Figure 6d), the
25 control unit 71 is programmed to command the rotor 22a so that the axis F is oriented towards (opposite side of) the nose 4 and the rotor 22b so that the axis G is oriented towards (opposite side of) the tail 5.

 This generates two components of the thrusts T5, T6
30 that are parallel to the axis Y and discordant to each other which generate a torque and a consequent rotation of the aircraft around the axis Z.

 During the transition from the first to the second configuration of the aircraft, the control unit 71 is

programmed to reduce the thrusts T1, T2; T3, T4 of the rotors 20a, 20b; 21a, 21b as the axes F, G of the rotors 22a, 22b progressively approach a condition of parallelism with the axis Y and the speed of the aircraft 1 increases.

5 In the second configuration shown in Figure 6e, the lift required to sustain the aircraft 1 is mostly provided by the half-wings 3. The rotors 20a, 20b; 21a, 21b can be optionally deactivated.

10 In more detail, the thrusts T1, T2 of the rotors 20a, 20b ensure the correct trimming of the aircraft 1 - i.e. the adjustment of the overall lift/downforce value under the required speed and weight conditions of the aircraft 1 - while the rotors 21a, 21b are deactivated so that the thrusts T3, T4 are zero.

15 In order to perform a roll manoeuvre (Figure 6f), the rotors 20a, 20b are controlled by the control unit 71 so that the thrust T1 is higher (lower) than the thrust T2.

20 This generates a differential thrust T1-T2, which results in a torque and a consequent rotation of the aircraft around the axis Y.

25 In order to perform a pitch manoeuvre (Figure 6g), the rotors 20a, 20b, 22a, 22b are controlled by the control unit 71, so as to increase (decrease) the thrusts T1, T2 equal to each other and to adjust the thrusts T5, T6 equal to each other.

 This generates a torque and a consequent rotation of the aircraft around the axis X.

30 In order to perform a yaw manoeuvre (Figure 6h), the rotors 22a, 22b are controlled by the control unit 71 so that the thrust T1 is greater (lower) than the thrust T6.

 This generates a torque and a consequent rotation of the aircraft around the axis Z.

 When the aircraft 1 is in the second configuration, the appendages 14 may be moved with respect to the relative

aerodynamic surfaces 8 in a concordant or discordant manner with each other, and thus contribute to the control of the aircraft 1.

5 In particular, the concordant movement of the appendages 14 results in a torque around the axis X and increases the second lift value.

Conversely, the discordant movement of the appendages 14 results in a torque around the axis Y on aircraft 1.

10 In the event of a failure of one or both of the rotors 20a, 20b; 22a, 22b with the aircraft 1 arranged in the second configuration (Figure 7d), the control unit 71 rotates the rotors 22a, 22b in the respective first positions, and increases the thrusts T1, T2, T3, T4 of the rotors 20a, 20b, 21a, 21b which are optionally still
15 operating and the thrusts, T5, T6 of the rotors, 22a, 22b (Figure 7a).

Similarly, in the event of failure of one or both rotors 22a, 22b with the aircraft 1 arranged in the second configuration (Figures 7e), the control unit 71 rotates the
20 rotors 22a, 22b in the respective first positions, and increases the thrusts T1, T2, T3, T4 of the rotors 20a, 20b, 21a, 21b and the thrusts T5, T6 of the rotors 22a, 22b which are optionally still operating (Figure 7b).

In this way, after a temporary compensation of the
25 missing thrust T1, T5 of the rotor 20a, 22a, the aircraft 1 assumes the first configuration, wherein it can land safely.

In the event of failure of the aircraft 1 in the first configuration (Figure 7c), the control unit 71 rotates the
30 rotors 22a, 22b in the respective second positions (Figure 7f). In this way, the aircraft 1 can efficiently glide in order to reach a landing site.

In the first architecture (Figures 9 to 11), the aircraft 1 is used for urban mobility and passenger

transport applications within the compartment 60 and the module 110 is interfaced with the core 100.

The passengers and the baggage, if any, access the compartment 60 through the aisle 64 when the aircraft 1 is
5 arranged in the first configuration.

The control unit 71 receives at input the control signals of the aircraft 1 and consequently commands the electric motors 72a, 72b, 73a, 73b, 74a, 74b so as to obtain respective desired thrusts T1, T2, T3, T4, T5, T6
10 from the respective rotors 20a, 20b, 21a, 21b, 22a, 22b.

The batteries 81 electrically power the electric motors 72a, 72b, 73a, 73b, 74a, 74b.

In the second and third architecture (Figures 12 to 15), the aircraft 1 realizes a Utility category aircraft or is deployed for VIP passenger transport, and the respective
15 modules 120, 130 are interfaced with the core 100.

In both cases, the passengers and the baggage are accommodated inside compartment 60.

When the aircraft 1 is in the first configuration for a short time interval, the heat engine 90 provides
20 mechanical power to the generators 91.

The batteries 81 and the generators 91 electrically power the electric motors 72a, 72b, 73a, 73b, 74a, 74b, which drive the respective rotors 20a, 20b, 21a, 21b, 22a, 22b into rotation.
25

If the high power required by the first hovering flight configuration is required for a long time interval, both heat engines 80, 90 provide mechanical power to the respective generators 82, 91. The generators 82, 91 are in
30 turn electrically connected to the electric motors 72a, 72b, 73a, 73b, 74a, 74b which drive the respective rotors 20a, 20b, 21a, 21b, 22a, 22b into rotation.

When the aircraft 1 transits to the second configuration wherein the power required for cruise flight

is lower than that required in the first configuration, the heat engine 90 is deactivated and the heat engine 80 alone drives the electric motors 72a, 72b, 73a, 73b, 74a, 74b and recharges the batteries 81.

5 In the event of a failure of the heat engines 80, 90, the batteries 81 power the electric motors 72a, 72b, 73a, 73b, 74a, 74b exclusively.

10 In the fourth architecture (Figures 16 to 18), the aircraft 1 is deployed as a remotely operated aircraft capable of carrying out long duration missions. Depending on the operational needs, either the sub-module 141, the sub-modules 142 or a sub-module 141 and a sub-module 143 are housed inside the compartment 60.

15 With reference to Figures 20 and 21, 1' denotes an aircraft according to a further embodiment of the invention.

20 The aircraft 1' is similar to the aircraft 1 and will be described below only insofar as it differs from the latter; equal or equivalent parts of the lubrication systems 1, 1' will be marked, where possible, by the same reference numbers.

25 In particular, the aircraft 1' differs from the aircraft 1 in that the tail portion 6' is cruciform and in that the supports 31a, 31b project cantilevered from respective sidewalls of the fin 7.

The aerodynamic surfaces 8' are arranged inferiorly to the respective rotors 21a, 21b.

30 The aerodynamic surfaces 8' support the respective rotors 21a, 21b and have respective fairings 13' that are movable between:

- a first position wherein the respective cords have a lying position substantially orthogonal to the axes X, Y which is assumed when the aircraft 1 is in the first configuration, so as to limit the interference with the

flow of air directed downwards and generated by the rotors 21a, 21b (Figure 21); and

- a second position wherein the respective cords have a lying position substantially orthogonal to the axes Z, Y which is assumed when the aircraft 1 is in the second configuration (Figure 20) and wherein the rotors 21a, 21b are turned off or deactivated.

The fairings 13' at least partially accommodate the respective supports 31a, 31b and are movable with respect to said supports 31a, 31b between the respective first and second position.

The aircraft 1' also differs from the aircraft 1 in that the appendages 14' are arranged on respective aerodynamic surfaces 9 instead of on respective aerodynamic surfaces 8'.

The operation of the aircraft 1' differs from that of the aircraft 1 in that the fairings 13' are moved with respect to the relative aerodynamic surfaces 8' from the respective first to the respective second positions and vice versa, when the aircraft 1' transits from the second to the first configuration and vice versa.

From an examination of the characteristics of the aircraft 1, 1' according to the present invention, the advantages it allows to be obtained are evident.

In more detail, the rotors 22a, 22b are arranged spaced apart from the ends 15 of the respective half-wings 3, proceeding along the extension direction of the respective half-wings 3.

This greatly reduces the risks of aeroelastic interaction between the rotors 22a, 22b and the half-wings 3, greatly increasing the safety margin of the aircraft 1, 1'.

The aircraft 1, 1' further comprises four rotors 20a, 20b, 21a, 21b with respective fixed axes B, C, D, E and

respective thrusts T1, T2, T3, T4 that are adjustable independently of each other, and two rotors 22a, 22b with respective tilting axes F, G and thrusts T5, T6 adjustable independently of each other.

5 In this way, the aircraft 1, 1' can operate efficiently either in the first configuration or in the second configuration, and can control the roll, yaw and pitch movements with a lower number of rotors and relative components than the known solutions and discussed in the
10 introductory part of the present description, with obvious advantages in terms of cost and simplicity of maintenance.

 Moreover, in the event of failure of one of the rotors 20a, 20b, 21a, 21b, 22a, 22b with the aircraft 1 arranged in the second configuration, the control unit 71 returns
15 the rotors 22a, 22b optionally still operational to the respective first positions and increases the thrusts T1, T2, T3, T4, T5, T6 of the rotors 20a, 20b, 21a, 21b, 22a, 22b that are optionally still operational.

 In this way, the aircraft 1, 1' is arranged in the
20 first configuration and can land safely.

 It is important to point out that, in an embodiment, the aircraft 1, 1' achieves the aforesaid manoeuvrability by using rotors 20a, 20b, 21a, 21b, 22a, 22b with fixed pitch and, therefore, particularly economical and easy to
25 maintain.

 It is also important to note that the aircraft 1, 1' can fly in trimmed configuration and perform the aforesaid pitch, yaw and roll manoeuvres, simply by adjusting the thrusts T1, T2, T3, T4, T5, T6 of the rotors 20a, 20b, 21a, 21b, 22a, 22b and without the need to use the appendages
30 14.

 Consequently, on the one hand the aircraft 1, 1' does not need the appendages 14, 14'. On the other hand, the appendages 14, 14', if provided for redundancy, can be

realized with particularly reduced widths and with particularly small working angles, further simplifying the embodiment complexity of the aircraft 1, 1'.

5 The rotors 20a, 20b are arranged anteriorly to the aerodynamic surfaces 8. The rotors 22a, 22b are arranged superiorly to the respective half-wings 3 when the aircraft 1, 1' is in the first configuration and parked on the ground.

10 The aisle 64 for access to the compartment 60 is thus clear and easily accessible, facilitating the boarding/disembarking of passengers and the loading/unloading of goods.

The fin 7 extends either above or below the airframe 2.

15 As a result, the aircraft 1 has high lateral stability.

20 The fin 7 and the surfaces 9 carry respective carriages 45, 46, thus avoiding the need for additional support elements dedicated to them. In addition, a reduction in the aerodynamic resistance is achieved and access to the belly of the airframe 2 is left free.

25 The fairings 13' are moved with respect to the relevant aerodynamic surfaces 8' from the respective first to the respective second positions and vice versa, when the aircraft 1' transits from the second to the first configuration and vice versa. In this way, the interference between the downward flow generated by the rotors 21a', 21b' and the aerodynamic surfaces 8' is reduced, with a consequent increase in the figure of merit in the hovering
30 flight of the aircraft 1' arranged in the first configuration.

It is clear that the aircraft 1, 1' described and shown herein may be subject to modifications and variations without thereby departing from the scope of protection

defined by the claims.

In particular, the appendages 14 could be arranged on respective aerodynamic surfaces 9 instead of aerodynamic surfaces 8.

5 The aircraft 1, 1' may not comprise the aerodynamic surfaces 8, 8'.

The supports 31a, 31b may project cantilevered posteriorly from respective half-wings 3 instead of from respective sidewalls 62 of the airframe 2.

10 The axes B, C; D, E may not be parallel to the axis Z and may be inclined with respect to the axis Z by an angle ranging between - 15 and + 15 degrees. In particular, the axes B, C (D, E) could converge in the axis Z above or below the airframe 2.

15 At least some of or all of the rotors 20a, 20b, 21a, 21b, 22a, 22b could have variable pitch, at least some of them.

20 Finally, the aircraft 1, 1' may comprise either the appendages 14 arranged on the aerodynamic surfaces 8, 8' or the appendages 14' arranged on the aerodynamic surfaces 9, 9'

25 The aircraft 1, 1' could perform the aforesaid pitch, yaw and roll manoeuvres, using both appendages 14, 14'. The appendages 14, 14' can be operated as required by mixing their movement with the movement of the respective aerodynamic surfaces 9, 8.

In other words, by way of example, a movement of an appendage 14 corresponds to a predetermined movement of an appendage 14' and vice versa.

30

CLAIMS

1.- Convertible aircraft (1, 1') comprising:

- an airframe (2) defining a first longitudinal axis (Y) of said aircraft (1, 1');

5 - a pair of half-wings (3) arranged on respective mutually opposite sides of sidewalls (62) of said airframe (2) and generating, in use, a first lift or downforce value;

10 - a first and a second rotor (20a, 20b) which are rotatable respectively about a second and a third axis (B, C) and fixed with respect to said airframe (2), and operable independently of each other so as to generate respectively a first and a second thrust value (T1, T2) independent of each other;

15 - a third and a fourth rotor (21a, 21b) which are rotatable, respectively, about a fourth and fifth axis (D, E) and fixed with respect to said airframe (2), and operable independently of each other so as to generate, respectively, a third and a fourth thrust value (T3, T4) independent of each other;

20 said second and third axis (B, C) being arranged respectively on a first and a second sidewall (62) that are opposite to each other of said airframe (2) symmetrically with respect to said first axis (Y);

25 said fourth and fifth axis (D, E) being arranged on respective sides of said first and second sidewall (62) of said airframe (2) symmetrically with respect to said first axis (Y);

 said aircraft (1, 1') further comprising:

30 - a fifth and a sixth rotor (22a, 22b) carried by respective said half-wings (3), which are rotatable respectively about a sixth and seventh axis (F, G) inclinable with respect to said airframe (2), and operable independently of each other so as to generate respectively

a fifth and a sixth thrust value (T5, T6) independent of each other;

said sixth and seventh axis (F, G) being arranged on respective sides of said first and second sidewall (62) of said airframe (2) symmetrically with respect to said first axis (Y);

said aircraft (1, 1') being switchable between:

- a first hovering or take-off/landing flight configuration wherein said sixth and seventh axis (F, G) are arranged orthogonal to said first axis (Y); and

- a second forward flight configuration wherein said sixth and seventh axis (F, G) are arranged parallel to or inclined with respect to said first axis (Y);

characterized by comprising first supports (32a, 32b) adapted to support said fifth and sixth rotor (22a, 22b) with respect to the relative half-wings (3); said first supports (32a, 32b) being arranged at a distance from respective free ends (15) of respective said half-wings (3) according to an extension direction of said half-wings (3); wherein said fifth and sixth rotors (22a, 22b) are interposed between said first and second rotor (20a, 20b) and said third and fourth rotor (21a, 21b) along said first axis (Y);

said first, third and fifth axis (B, D, F) being aligned with each other along said first axis (Y) when said aircraft (1, 1') is arranged in said first configuration;

- said second, fourth and sixth axis (C, E, G) being aligned with each other along said first axis (Y) when said aircraft (1, 1') is arranged in said first configuration;

said second, third, fourth and fifth axis (B, C, D, E) being parallel to each other.

2.- Aircraft according to Claim 1 wherein said first supports (32a, 32b) extend in front of said half-wings (3), with reference to a normal operating position of said

aircraft (1, 1') arranged, in use, in said second configuration.

3.- Aircraft according to claim 1 or 2, wherein said fifth and sixth rotor (22a, 22b) are arranged above the
5 respective said half-wings (3) and in front of the respective said half-wings (3), when said aircraft (1, 1') is in said first configuration and with reference to said normal operating position.

4.- Aircraft according to any one of the preceding
10 claims, wherein said aircraft (1, 1') comprises only one said fifth rotor (22a) and only one said sixth rotor (22b).

5.- Aircraft according to any one of the preceding claims, further comprising:

- a fin (7) which is arranged at a tail (6) of said
15 airframe (2); and

- second supports (31a, 31b) which are provided to support said third and fourth rotor (21a, 21b) with respect to said airframe (2); said second supports (31a, 31b) being arranged on respective mutually opposite sidewalls (62) of
20 said fin (7) and posteriorly to respective said half-wings (3), with reference to a normal operating position of said aircraft (1, 1') arranged, in use, in said second configuration.

6.- Aircraft according to Claim 5, wherein said fin
25 (7) extends from both the upper and lower sides of said airframe (2); and/or

wherein said fin (7) carries a first carriage (46).

7.- Aircraft according to Claim 6, wherein said fin
(7) comprises a pair of first aerodynamic surfaces (8, 8')
30 which are fixed and project cantilevered from respective mutually opposite sides (62) of said fin (7); said first aerodynamic surfaces (8, 8') being adapted to generate, in use, a second lift/downforce value.

8.- Aircraft according to Claim 7, wherein said third

and fourth rotors (21a, 21b) are arranged below said first aerodynamic surfaces (8), with reference to a normal operating position of said aircraft (1) arranged, in use, in said second configuration; and/or

5 wherein said second rotors (21a, 21b) are arranged superiorly to said first aerodynamic surfaces (8'), with reference to a normal operating position of said aircraft (1') arranged, in use, in said second configuration; said first surfaces (8') being at least partially movable with
10 respect to said fin (7) between a first position and a second position which are assumed when said aircraft (1') is arranged, respectively, in said first and second configuration; said first surfaces (8') having respective first areas and respective second areas having an extent
15 lower than respective said first areas; said second areas and first areas being arranged inferiorly to respective said second rotors (21a, 21b) when said aircraft (1') is arranged, in use, in said first and second configuration, respectively; and/or

20 wherein said first and second axis (B, C) are arranged, in use, anteriorly to one end (4) of said airframe (2) opposite to said third and fourth axis (D, E); and/or

 further comprising:

25 - a pair of second aerodynamic surfaces (9) adapted to provide third lift/downforce values and projecting cantilevered from respective opposite sides (62) of said airframe (2); said second aerodynamic surfaces (9) being adapted to generate, in use, a third lift/downforce value;
30 and

 - third supports (30a, 30b) adapted to support said first and second rotor (20a, 20b) and which are fixed to said second aerodynamic surfaces (9).

 9.- Aircraft according to Claim 8, wherein said half-

wings (3) are interposed along said first axis (Y) between said first and second aerodynamic surfaces (8, 9); and/or

5 further comprising third aerodynamic control surfaces (14) movably connected to respective said second aerodynamic surfaces (9) or connectable to respective said first aerodynamic surfaces (8, 8').

10 10.- Aircraft according to Claim 8 or 9, when dependent on claim 5, wherein said second aerodynamic surfaces (9) carry a second carriage (45).

11.- Aircraft according to any one of the preceding claims, wherein:

- at least one of the first, second, third, fourth, fifth and sixth rotor (20a, 20b, 21a, 21b, 22a, 22b) has fixed pitch; and/or

15 wherein at least one of said first, second, third, fourth, fifth and sixth rotor (20a, 20b, 21a, 21b, 22a, 22b) is electrically driven.

20