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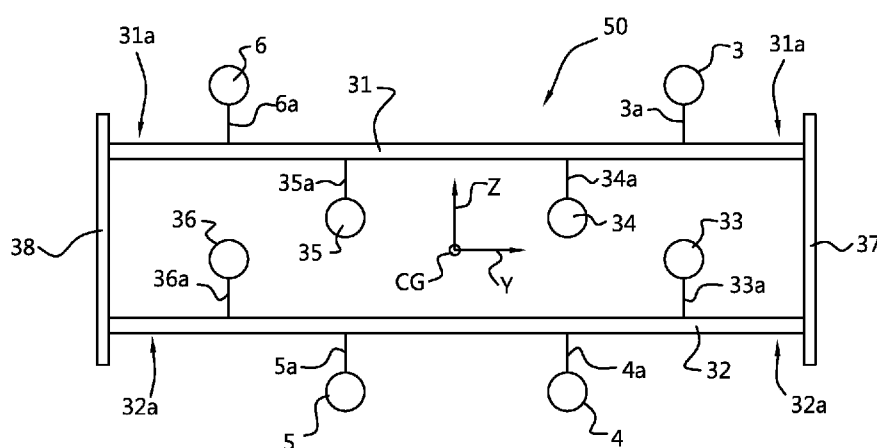
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(54) Title: AERIAL VEHICLE WITH ANGULARLY DISPLACED PROPULSION UNITS

Fig. 5



(57) Abstract: An aerial vehicle (50) for vertical take-off and landing and horizontal flight comprises two wings (31, 32) extending substantially parallel to a Y-axis in spanwise direction, substantially parallel to an X-axis in chordwise direction, and extending substantially parallel to a Z-axis in thickness direction. The wings are substantially symmetrical with respect to a XZ-plane. The aerial device comprises at least four propulsion units (3, 4, 5, 6), each propulsion unit being rigidly mounted to the wings with a respective nacelle and configured to generate a force vector along a respective imaginary force vector line, said force vector line, for a subset of at least two of the propulsion units, when projected on the XY-plane, being oriented at a first angle with respect to the X-axis, and when projected on the XZ-plane, is further oriented at a second angle with respect to the X-axis.

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Aerial vehicle with angularly displaced propulsion units

- 5 The present invention relates to an aerial vehicle, preferably an unmanned aerial vehicle, adopted for vertical take-off and landing as well as horizontal flight.

Aerial vehicles with vertical landing and take-off capabilities and at least four propulsion units, for example quadcopters, are well-known in the art and have a widespread
10 commercial availability. Most of these quadcopters have the capability to take off and land vertically, while also being capable of performing horizontal flight. Usually, the propulsion units of such quadcopters are rigidly mounted to the body of the quadcopter, such that the body of the quadcopter is tilted over 90 degrees when the aerial vehicle transfers from hovering or vertical flight to horizontal flight. It is however also possible to mount the
15 propulsion units of the aerial vehicle in such a way that the propulsion units are tilted when the aerial vehicle transfers from vertical to horizontal flight. This latter principle is often used in larger, manned, aerial vehicles with vertical take-off and landing capabilities that are also able to perform horizontal flight, to keep the body of the aerial vehicle substantially in the same orientation. A well-known example of such an aerial vehicle is the V-22 Osprey. The
20 invention relates to the first type of vehicles, where the propulsion units are rigidly mounted with respect to the body of the aerial vehicle and where the aerial vehicle tilts when it transfers between vertical and horizontal flight.

Such aerial vehicles with rigidly mounted propulsion units usually have their propulsion units
25 arranged in a vertical direction when the aerial vehicle is in a hovering position. A problem for this type of aerial vehicles is that the manoeuvrability of such an aerial vehicle is low. It is relatively difficult to guide them along a curved flightpath, for example to perform a yaw manoeuvre. For the scope of this document, a yaw manoeuvre is defined as a rotation around the X-axis of the aerial vehicle. This definition is valid in both vertical flight as well as
30 horizontal flight.

To improve the yaw characteristics in the hovering position, several solutions are known in the art. One solution is to increase the thrust of the propulsion units on one side of the aerial vehicle, for example by speeding up the rotors of these propulsion units, and/or decrease
35 the thrust of the propulsion units on an opposite side, for example slowing down the rotors of such propulsion units. This moves the aerial vehicle in a particular direction. This however leads to a relatively slow response.

Another proposed solution is to arrange movable ailerons on the aerial vehicle. These ailerons can then be moved up or down to initiate a yaw manoeuvre. This solution however increases the complexity of the aerial vehicle significantly, which is unwanted.

- 5 In Hochstenbach, Menno, and Cyriel Notteboom: "Ontwerp en bouw van een onbemand vliegtuig voor autonoom pakkettransport met gecontroleerde transitie van verticaal opstijgen naar voorwaartse vlucht", Diss. Master Thesis, KU Leuven, 2014, section 3.1.3, it is proposed to tilt propellers of an aerial vehicle 10 degrees around an undefined axis. This tilting of the propellers improves the yaw characteristics of the aerial vehicle.

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It is an object of the invention to improve the manoeuvrability of an aerial vehicle which is adapted for vertical take-off and landing as well as horizontal flight. It is a further object to improve the yaw characteristics of such an aerial vehicle.

- 15 This object is achieved by an aerial vehicle according to claim 1.

The force vector and the force vector line are linked in that the force vector is a physical quantity: the force generated by the propulsion units, having a magnitude in absolute value and a direction. The force vector line has the same direction or spatial orientation as the
20 force vector. The force vector line is an imaginary line, an elongation of the force vector along its positive and its negative direction.

- By arranging the propulsion units in such a way that the projection of their force vector line on both the XZ-plane and the XY-plane is at an angle with respect to the X-axis, the force
25 vector may be optimally tilted to generate a moment around the centre of gravity of the aerial vehicle. Typically, an even number of propulsion units is inclined to generate a moment around the centre of gravity, such that in equilibrium flight, for the example where two propulsion units are inclined, a first propulsion unit generates a positive moment around the centre of gravity of the aerial vehicle and a second propulsion unit generates a negative
30 moment around the centre of gravity of the aerial vehicle, thus counter-acting the moment of the first propulsion unit and balancing the aerial vehicle. These generated moments improve the manoeuvrability of the aerial vehicle. For the example of an aerial vehicle with two propulsion units that are inclined with respect to the XY-plane and with respect to the XZ-plane, when a pilot wants to perform a yaw manoeuvre with the aerial vehicle, one
35 propulsion unit is typically set to generate a larger thrust force. By increasing this thrust force, the moment around the centre of gravity of the aerial vehicle is increased, and a yaw manoeuvre is resulting. To further improve this effect, the other inclined propulsion unit

could be set to generate a smaller thrust force. This will then decrease the counter-acting moment of this other propulsion unit, leading to a larger net moment around the centre of gravity, and thus an improved performance of a yaw manoeuvre.

- 5 Where the above text mentions "projected on", it is meant that a cross-sectional view of the aerial vehicle is taken, said cross-sectional view being parallel to the respective plane. The force vector is then drawn in this cross-section.

10 Where the above text mentions "a subset" it is meant as some, or all. In the example where the aerial vehicle comprises four propulsion units, "a subset of at least two" includes two, three and four. In the example where the aerial vehicle comprises eight propulsion units, "a subset of at least two" includes two, three, four, five, six, seven, or eight. Thus, in some embodiments the force vectors of all propulsion units are inclined with respect to the XY-plane and the XZ-plane, while in other embodiments only some, at least two, of the force
15 vectors of the propulsion units are inclined with respect to the XY-axis and the XZ-axis. When only some of the force vectors of the propulsion units are inclined with respect to the XY-plane and the XZ-plane, the other force vectors may be substantially parallel to the X-axis, or they may be oriented at an angle different from 0 degrees, positive or negative, with respect to the X-axis when the force vector is projected on the XY-plane or the XZ-plane.

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The force vector is inclined with respect to the X-axis both in its projection on the XY-plane and in its projection on the XZ-plane. As such, the angle between the X-axis and the force vector in these projected views is not zero. The angle may however be either positive or negative.

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Although the text of this application has so far only mentioned horizontal and vertical flight directions, it should be understood by those skilled in the art that it is also possible to make turns, to ascend and descend, and to make other flight manoeuvres besides only flying horizontally and vertically with the proposed aerial vehicle. Pure horizontal flight and pure
30 vertical flight are not the limiting flight options. For some designs it may even be possible to fly upside-down in the horizontal flight mode or in the vertical flight mode. Whether sustained flight in these orientations is possible, is mainly dependent on the used wing profile.

In an embodiment, a first pair of the at least four propulsion units is arranged symmetrically
35 relative to the XZ-plane at a first side of one of the wings, and a second pair of the at least four propulsion units is arranged symmetrically relative to the XZ-plane at a second side of said wing opposite to the first side. According to this embodiment, the aerial vehicle may for

example comprise four propulsion units. These propulsion units are then pair-wise arranged in two pairs of two propulsion units. Each pair is symmetrically arranged with respect to the XZ-plane or symmetry plane of the wing: for each propulsion unit on the left side of the wing there is a mirrored propulsion unit on the right side of the wing. Each mirrored couple of propulsion units then forms a pair. Analogously, the aerial vehicle may comprise 6, 8, 10, or another even number of propulsion units. By arranging the propulsion units via this pair-wise arrangement, a static equilibrium of forces is achieved with respect to the XZ-plane of the aerial vehicle when all propulsion units deliver the same amount of thrust.

It is observed that it is also possible to have an odd number of propulsion units, i.e. 5, 7, 9, etc. propulsion units, but this will generally make control of the aerial vehicle more difficult. In each projection plane, so the XY-plane and the XZ-plane, the force vector is arranged at an angle, said angle having an absolute value between 0 and 45 degrees for the inclination with respect to the XY-plane, and an absolute value between 0 and 45 degrees for the inclination with respect to the XZ-plane. The angle can thus be positive or negative.

In a preferred embodiment, the propulsion units of the aerial vehicle comprise propellers or rotors. When a rotor is sped up to create a larger thrust force and when a rotor is displaced with respect to the centre of gravity, the speeding up of the rotor will generate a moment around the centre of gravity. The sign of that moment is depending on the rotational direction of the rotor (clock-wise or counter-clockwise). Preferably, the moment generated by the inclination of the thrust force of a respective propulsion units is of the same sign as the sign of the moment generated by the speeding up of the respective rotor.

The sign of the moment around the centre of gravity of the aerial vehicle generated by the inclination of the propulsion unit is depending on the orientation of the force vector with respect to the XY-plane and the XZ-plane.

In one preferred embodiment, the force vectors of the subset of the at least two propulsion units diverge with respect to the XY-plane and converge with respect to the XZ-plane. This will be explained in more detail further below, with reference to the drawings.

In another preferred embodiment, the force vectors of the subset of the at least two propulsion units converge with respect to the XY-plane and diverge with respect to the XZ-plane. This will be explained in more detail further below, with reference to the drawings.

Typically, the force vectors of the subset of the at least two of the at least four propulsion units will have the same orientation relative to the X-axis in one or both of the XY-plane and the XZ-plane. For example: they are either all converging with respect to the X-axis of the XY-plane, or they are all diverging with respect to the X-axis of the XY-plane.

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According to one embodiment, the force vectors of the subset of the at least two of the propulsion units diverge with respect to the XY-plane.

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According to another embodiment, the force vectors of the subset of the at least two of the propulsion units converge with respect to the XY-plane.

According to one embodiment, the force vectors of the subset of the at least two of the propulsion units diverge with respect to the XZ-plane.

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According to another embodiment, the force vectors of the subset of the at least two of the propulsion units converge with respect to the XZ-plane.

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According to a preferred embodiment, the absolute value of the first angle, so the angular orientation of the thrust or force vector projected on the XY-plane, is between 0 and 25 degrees, in particular between 5 and 20 degrees with respect to the X-axis. When the thrust force has a larger angle with respect to the XY-plane, the force component along the X-axis become smaller. This is generally unwanted as it decreases the propulsive part of the thrust force.

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According to a preferred embodiment, the absolute value of the second angle, so the angular orientation of the thrust or force vector projected on the XZ-plane, is between 0 and 25 degrees with respect to the X-axis, in particular between 5 and 20 degrees. When the thrust force has a larger angle with respect to the XZ-plane, the force component along the X-axis become smaller. This is generally unwanted as it decreases the propulsive part of the thrust force.

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According to a preferred embodiment, the absolute value of the second angle, i.e. the inclination of the thrust or force vector projected on the XZ-plane relative to the X-axis, is larger than the absolute value of the first angle, i.e. the inclination of the thrust or force vector projected on the XY-plane relative to the X-axis. Typically, the displacement along the Y-axis of the attachment point of the force vector is larger than the displacement along the Z-axis of the attachment point of the force vector with respect to the origin of the axis system. The inclination of the force vector when projected on the XZ-plane may then be

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larger than the inclination of the force vector when projected on the XY-plane to achieve a similar improving effect on the manoeuvrability of the aerial vehicle.

This is however completely depending on the exact position of the propulsion units with respect to the centre of gravity, i.e. the displacement of the propulsion units along the Y-axis, and along the Z-axis. In other embodiments, it is conceivable that the absolute value of the first angle is larger than the absolute value of the second angle.

According to a preferred embodiment of the invention, the force vectors of the subset of the at least two of the propulsion units are projected on the YZ-plane, wherein imaginary lines can be defined between the locations of the propulsion units and the centre of gravity of the aerial vehicle, which lines are perpendicular to the force vectors. Both the force vectors and the propulsion units are thus projected on the YZ-plane, wherein the location of the propulsion units is defined by their offset with respect to the centre of gravity of the aerial vehicle in the projection on the YZ-plane. When said imaginary line is perpendicular to the force vector, the generated moment of the thrust force is found to be optimal in its contribution to the yaw movement. When this line is not perpendicular to the thrust force, but when the thrust force is inclined with respect to the X-axis, this is in general also beneficial for the yaw movement, but a preferred, optimum configuration, considering manoeuvrability, is when the imaginary line between the location of the propulsion unit and the centre of gravity of the aerial vehicle is perpendicular to the force vector.

According to a preferred embodiment of the invention, the propulsion units are motor/propeller units, blades of said motor/propeller units preferably being arranged substantially perpendicular to said force vector line. Propellers are the most often used propulsion units in unmanned quadcopters. It is also possible to use some sort of jet engine as propulsion unit, for example a microturbine.

It is possible to define a mounting line for each propulsion unit, said mounting line prescribing the spatial orientation, more specifically the inclination, of the propulsion unit with respect to the axis system of the aerial vehicle. This mounting line may coincide with the force vector line, but that is not necessary. When the propulsion unit is a propeller, this propeller is preferably perpendicularly arranged with respect to the mounting line of the propulsion unit such that the mounting line and the force vector line coincide. The aerial vehicle could however also be designed in such a way that the mounting line of the propeller is displaced with respect the force vector line. In that case, rotors of the propeller are arranged in a different spatial orientation compared to the perpendicular arrangement with

respect to the mounting line. The rotor could for example be tilted forward with respect to the perpendicular arrangement.

In a preferred embodiment, the propulsion units are arranged in a tractor configuration
5 during horizontal flight. An alternative embodiment would be to arrange the propellers in a pusher configuration during horizontal flight.

In a preferred embodiment, each wing of the aerial vehicle comprises two wingtips and wingtip fences at both wingtips. It would also be possible to have straight wingtips, pointed
10 wingtips, raked wingtips, sharklets, or winglets at the end of the wingtip. It is preferred however to use wingtip fences as they provide the most stability.

The aerial vehicle comprises multiple wings. The aerial vehicle may for example comprise two wings, such that a double wing aircraft results when the aerial vehicle is in horizontal
15 flight. The aerial vehicle may also comprise more than two wings.

The multiple wings may have a common wingtip fence at each wingtip as this enhances the structural rigidity of the aerial vehicle. The aerial vehicle may also have more than four propulsion units, for example six or eight propulsion units.

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According to a preferred embodiment, four propulsion units being rigidly mounted to each wing, so that the aerial vehicle comprises eight propulsion units,

- four of said eight propulsion units, preferably the four propulsion units that are closest to the centre of gravity of the aerial vehicle, being mounted such that
25 their force vector line is substantially parallel to the X-axis of the axis system,
- the other four of said eight propulsion units, preferably the four propulsion units that are furthest away from the centre of gravity of the aerial vehicle, being mounted such that the force vector line, when projected on the XY-plane, of each one of said other four propulsion units is oriented at said first
30 angle with respect to the X-axis, and the force vector line, when projected on the XZ-plane further is oriented at said second angle with respect to the X-axis.

Preferably, the propulsion units that have a vertically directed force vector in hovering mode
35 are placed closest to the centre of gravity of the aerial vehicle, while the propulsion units that are further away from the centre of gravity of the aerial vehicle have a propulsion unit that generate a force vector that is inclined with respect to the X-axis. These propulsion units that

are placed further away from the centre of gravity are able to create the largest yaw moment thus being more efficient in initiating a yaw manoeuvre compared to the propulsion units that are closer to the centre of gravity.

- 5 Preferably, the propulsion units are symmetrically arranged in this embodiment. A first pair of the eight propulsion units is for example arranged symmetrically relative to the XZ-plane at a first side of the first wing, while a second pair of the eight propulsion units is arranged symmetrically relative to the XZ-plane at a second side of the first wing opposite to the first side of the first wing. A third pair of the eight propulsion units is arranged symmetrically
- 10 relative to the XZ-plane at a first side of the second wing, and a fourth pair of the eight propulsion units is arranged symmetrically relative to the XZ-plane at a second side of the second wing opposite to the first side of the second wing.

Preferably, the two wings of the aerial vehicle are connected by common wingtip fences.

- 15 Other connections between the two wings are also conceivable, such as a connection more inboard with respect to the wingtips.

- In another embodiment of the aerial vehicle comprising two wings and eight propulsion units, six of the eight propulsion units are mounted such that their force vector lines, when
- 20 projected on the XY-plane, are oriented at said first angle with respect to the X-axis, when projected on the XZ-plane, are further oriented at said second angle with respect to the X-axis.

- In yet another embodiment of the aerial vehicle comprising two wings and eight propulsion
- 25 units, each one of the eight propulsion units is mounted such that its force vector line, when projected on the XY-plane, is oriented at said first angle with respect to the X-axis, when projected on the XZ-plane further is oriented at said second angle with respect to the X-axis.

- The skilled person will understand that it is also possible to make an aerial vehicle according
- 30 to the invention comprising any number of wings and any number of propulsion units, for example a two-wing aerial vehicle with four, six, eight, ten, or another number of propulsion units, or a triple-wing aircraft with four, six, eight, ten, or another number of propulsion units. Any subset of the at least two of the propulsion units can then be angularly displaced with respect to both the XY-plane and the XZ-plane of the aerial vehicle.

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These and other aspects of the invention will be more readily appreciated as the same becomes better understood by reference to the following detailed description and

considered in connection with the accompanying drawings in which like reference symbols designate like parts.

Figure 1 schematically shows a front view of a first embodiment of an aerial vehicle, in a
5 direction of arrow I as depicted in Figure 2 and Figure 3.

Figure 2 schematically shows a top view of the aerial vehicle of Figure 1, in a direction of
arrow II as depicted in Figure 1 and Figure 3.

10 Figure 3 schematically shows a side view of the aerial vehicle of Figure 1, in a direction of
arrow III as depicted in Figure 1 and Figure 2.

Figure 4 schematically shows a cross-sectional view of a wing profile.

15 Figure 5 schematically shows a front view of a second embodiment of an aerial vehicle.

Figure 6 schematically shows a front view of a third embodiment of an aerial vehicle.

Figure 7 schematically shows a front view of a fourth embodiment of an aerial vehicle.

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Figure 8 schematically shows a front view of a fifth embodiment of an aerial vehicle.

Figure 9 schematically shows a front view of a sixth embodiment of an aerial vehicle.

25 Figure 10 schematically shows a front view of a seventh embodiment of an aerial vehicle.

Figures 1 to 3 show a first embodiment of an aerial vehicle 1. The aerial vehicle 1 is adopted
for vertical take-off and landing as well as horizontal flight, and all flight manoeuvres in
between these conditions, such as an ascend, descend, turn, roll, yaw, or hover manoeuvre,
30 including a combination of these flight manoeuvres. Depending on the wing profile, the
aerial vehicle 1 may even be able to fly upside-down in the horizontal orientation.

The aerial vehicle 1 has a center of gravity CG, as is indicated in all Figures. In the center of
gravity CG, an origin of an imaginary right hand sided axis system is defined. The axis
35 system comprises an X-axis X, a Y-axis Y and a Z-axis Z. Furthermore, an XY-plane can be
defined, spanned by the X-axis X and the Y-axis Y and going through the origin of the axis

system. The XY-plane is recognizable in Figure 2, where a top view of the aerial vehicle 1 is given.

Similarly, an XZ-plane and a YZ-plane can be defined. The XZ-plane is spanned by the X-axis X and the Z-axis Z and goes through the origin of the axis system. The XZ-plane is recognizable in Figure 3, where a side view of the aerial vehicle 1 is given. The YZ-plane is spanned by the Y-axis Y and the Z-axis Z and goes through the origin of the axis system. The YZ-plane is recognizable in Figures 1, 6, and 10, where a front view of the aerial vehicle 1 is given.

As stated before, the yaw manoeuvre is defined within the scope of this text as a rotation around the X-axis X of the aerial vehicle, in both horizontal and vertical flight and any other flight direction. A roll manoeuvre is then defined as a rotation around the Z-axis of the aerial vehicle, and a pitch manoeuvre is then defined as a rotation around the X-axis of the aerial vehicle, in all flight directions.

It is noted that the aerial vehicle 1 is predominantly described in its hovering mode throughout this application.

Figure 4 shows a wing profile. This is a generic wing profile and not the only wing profile that can be used for a wing 2 of the aerial vehicle 1. The wing profile of Figure 4 is primarily shown to introduce some terminology. The wing profile of Figure 4 has a leading edge LE and a trailing edge TE. The leading edge LE and the trailing edge TE can be connected with an imaginary line: the chord line C. Perpendicular to the chord line C, the thickness T of the wing profile is defined. As shown in Figure 1, a length of the wing 2 is referred to as the span B of the wing 2, or the wingspan.

A first embodiment of the aerial vehicle 1 is shown in Figures 1 to 3. In this embodiment, the aerial vehicle comprises a wing 2 with wingtips 2a. The wing 2 as shown in Figure 2 has a substantially rectangular shape, but that is not necessary. A person skilled in that art will understand that many different wing shapes are possible, including but not limited to an elliptical shape with rounded wingtips 2a, a shape where the chord C of the wing profile is longer near the center of gravity CG than at the wing tips 2a, or a shape where the chord C of the wing profile is longer near the wing tips 2a than near the center of gravity CG. An imaginary line in spanwise direction that connects the leading edges LE of different wing profiles of the wing 2 shown in Figure 2 is substantially straight, but may also be curved. Many different wing shapes / wing profiles are possible. However, as the shape of the wing /

wing profile is not characterizing for the invention, the text will not further elaborate on possible wing shapes and/or wing profile shapes.

With respect to the imaginary axis system, the at least one wing 2 of the aerial vehicle 1 is oriented such that the wing 2 extends substantially parallel to the Y-axis Y in spanwise direction, substantially parallel to the X-axis X in chordwise direction, and substantially parallel to the Z-axis Z in thickness direction. The wing 2 is substantially symmetrical with respect to the XZ-plane of the aerial vehicle 1, in other words, the left half of the wing 2 in Figures 1 and 2 is substantially mirrored with respect to the right half of the wing 2 in Figures 1 and 2.

In the embodiment of Figures 1 to 3, the aerial vehicle 1 comprises four propulsion units 3, 4, 5, 6. In all shown embodiments these propulsion units are motor/propeller units, but alternatives are also possible. For example, it is possible to use some sort of jet engine as propulsion unit, for example a microturbine. Each propulsion unit 3, 4, 5, 6 is configured to generate a thrust force which can be characterized by a force vector F working along an imaginary force vector line L. The force vector line L is an elongation of the force vector F in both in the positive and negative direction. It has the same spatial orientation as the force vector F.

Each propulsion unit 3, 4, 5, 6 is rigidly mounted on the wing 2 with a respective nacelle 3a, 4a, 5a, 6a. As the propulsion units 3, 4, 5, 6 are rigidly mounted on the wing 2, it is not possible to tilt or displace the propulsion units 3, 4, 5, 6 with respect to the rest of the aerial vehicle 1. As such, the aerial vehicle 1 is tilted when the aerial vehicle 1 transfers from horizontal flight to vertical flight or when the aerial vehicle 1 transfers from vertical flight to horizontal flight.

The force vector F, in vertical flight, is generally directed upwards in a direction opposite the gravity force. Also when the aerial vehicle 1 descends in vertical flight, the force vector F is smaller than the gravitational force, but is still directed upwards.

The force vector F has substantially the same magnitude (in absolute value) for all propulsion units 3, 4, 5, 6 in Figures 2 and 3. The skilled person will understand that each propulsion unit 3, 4, 5, 6 will be able to generate a range of thrust forces F. For example, when a manoeuvre is initiated, at least one of the propulsion units 3, 4, 5, 6 should provide a different thrust force. This will be described in more detail below.

As indicated in Figures 2 and 3, the force vector line L, and thus the force vector F, is oriented at a first angle α_1 , α_2 with respect to the X-axis X of the XY-plane and at a second angle β_1 , β_2 with respect to the X-axis X of the XZ-plane for all four propulsion units 3, 4, 5, 6.

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In an alternative embodiment, shown in Figures 6 and 10, only a subset of at least two propulsion units 3, 4, 5, 6 is oriented at a first angle α_1 , α_2 with respect to the X-axis X of the XY-plane and at a second angle β_1 , β_2 with respect to the X-axis X of the XZ-plane. In Figures 6 and 10, this is the case for propulsion units 3 and 4. Alternatively, this could also be the case for the propulsion units 3 and 6, or the propulsion units 4 and 5, or the propulsion units 5 and 6.

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In Figure 2, the force vectors F of all propulsion units 3, 4, 5, 6 converge with respect to the X-axis X, when the force vector F is projected on the XY-plane. For this converging orientation, the angle α_1 , α_2 is defined as negative. The force vectors F of the propulsion units 3, 4, 5, 6 may however also diverge with respect to the X-axis X, when the force vector F is projected on the XY-plane, the sign of the angle α_1 , α_2 being positive. Preferably, in the embodiment of Figure 2, the force vectors F of all propulsion units 3, 4, 5, 6 either diverge or converge with respect to the X-axis X, when the force vector F is projected on the XY-plane. When some force vectors F converge and other force vectors F diverge, control of the aerial vehicle becomes difficult.

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The absolute value of the first angle α_1 , α_2 is between 0 and 45 degrees, i.e., between -45 degrees and +45 degrees, with the exclusion of 0 degrees. Preferably, the absolute value of the first angle α_1 , α_2 is between 0 and 25 degrees, such as between 5 and 20 degrees.

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In Figure 3, the force vectors F of all propulsion units 3, 4, 5, 6 diverge with respect to the X-axis X, when the force vector F is projected on the XZ-plane. For this diverging orientation, the angle β_1 , β_2 is defined as positive. The force vectors F of the propulsion units 3, 4, 5, 6 may however also converge with respect to the X-axis X, when the force vector F is projected on the XZ-plane, the sign of the angle β_1 , β_2 being negative. Preferably, in the embodiment of Figure 2, the force vectors F of all propulsion units 3, 4, 5, 6 either diverge or converge with respect to the X-axis X, when the force vector F is projected on the XZ-plane. When some force vectors F converge and other force vectors F diverge, control of the aerial vehicle becomes difficult.

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The absolute value of the second angle β_1 , β_2 is between 0 and 45 degrees, i.e., between -45 degrees and +45 degrees, with the exclusion of 0 degrees. Preferably, the absolute value of the second angle β_1 , β_2 is between 0 and 25 degrees, such as between 5 and 20 degrees

5

The embodiment of Figures 1 to 3 has optional wing fences 7, 8 at the wingtips 2a of the wing 2. It would also be possible to have straight wingtips, pointed wingtips, raked wingtips, sharklets, or winglets at the end of the wingtip 2a. It is preferred however to use wingtip fences as they provide the most stability to the aerial vehicle.

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Further visible in Figures 2 and 3 is an imaginary mounting line M. The mounting line M defines the orientation of the propulsion unit 3, 4, 5, 6 with respect to the X-axis X of the axis system. In Figure 2, the projection of the mounting line M on the XY-plane coincides with the force vector line F. The mounting line M can however also be oriented at a different angle than the force vector line F with respect to the X-axis X of the axis system.

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In Figure 3, the mounting line M is substantially parallel to the X-axis X in the projection of the mounting line M on the XZ-plane, while the force vector line L is inclined with respect to the X-axis X. It is also conceivable that the force vector line L and the mounting line M coincide in the XZ-plane, i.e. that they are both inclined with respect to the X-axis at the same angle.

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When the force vector line F and the mounting line M coincide, and when the propulsion units 3, 4, 5, 6 comprise propellers, the rotors / propellers extend perpendicularly with respect to the mounting line M of the propulsion units 3, 4, 5, 6. When the force vector line F and the mounting line M are at a different inclination compared to the X-axis X, and the propulsion units 3, 4, 5, 6 comprise propellers, the propellers are displaced from their perpendicularly extending position with respect to the mounting line M of the propulsion units 3, 4, 5, 6. In that case, the propellers may for example be tilted forward with respect to an imaginary line perpendicular to the mounting line M.

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In the embodiment of Figures 2 and 3, the mounting line M coincides with the force vector line L when the force vector F is projected on the XY-plane and the mounting line M diverges from the projection of the force vector F on the XZ-plane. This is just an exemplary embodiment. The mounting line M and the force vector line L may coincide or may diverge in any projection on any plane of the axis system. It is also possible that the mounting line M and the force vector line L of some of the propulsion units 3, 4, 5, 6 coincide, while the

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mounting line M and the force vector line L of some of the propulsion units 3, 4, 5, 6 do not coincide.

In Figures 2 and 3, the first angle α_1 , α_2 respectively the second angle β_1 , β_2 of all force
5 vectors F generated by the propulsion units 3, 4, 5, 6 with respect to the X-axis X of the XY-plane and to the XZ-plane, respectively, is different. The first angle α_1 is different from the angle α_2 . In particular, the angle α_2 of the outboard pair of propulsion units 3, 6 is larger than the angle α_1 of the inboard pair of propulsion units 4, 5. The value of the first angle α_1 , α_2 may for example be proportional to the distance between the centre of gravity CG of the
10 aerial vehicle 1 and the respective propulsion unit 3, 4, 5, 6. The angles α_1 and α_2 may however also be the same for all propulsion units 3, 4, 5, 6. In one embodiment (not shown) the angle β_1 , β_2 , the angle between the projection of the force vector F on the XZ-plane and the X-axis X of the XZ-plane, is larger for the propulsion units 3, 6 that are placed at a larger distance from the wing 2 than for the propulsion units 4, 5, which propulsion units 4, 5 are
15 placed closer to the wing 2. In the shown embodiment, the angle β_1 , β_2 is substantially the same for all propulsion units 3, 4, 5, 6.

Figures 6 and 10 show an embodiment wherein the force vectors F of the subset of two propulsion units 3 and 6 are inclined with respect to the XY-plane and with respect to the
20 XZ-plane. The force vectors F of the subset of two of the propulsion units 3, 6 are projected on the YZ-plane, wherein imaginary lines I are defined between the locations of the propulsion units 3, 6 and the centre of gravity CG of the aerial vehicle, which lines I are perpendicular to the force vectors F. In the embodiment of Figures 6 and 10, the force vector F of the other propulsion units 5, 6 are not inclined with respect to any plane of the
25 axis system, and point substantially in the vertical direction. For the propulsion units 3 and 6, when this imaginary line I is perpendicular to the force vector F, the generated moment of the thrust force F is found to be optimal in its contribution to the yaw movement. When this line I is not perpendicular to the thrust force F, but when the thrust force F is inclined with respect to the X-axis, this is in general also beneficial for the yaw movement, but the optimal
30 configuration, considering manoeuvrability, is when the imaginary line I between the location of the propulsion unit 3, 6 and the centre of gravity CG of the aerial vehicle is perpendicular to the force vector F.

The location of the propulsion units 3, 4, 5, 6 is defined by their offset with respect to the
35 centre of gravity CG of the aerial vehicle in the projection on the YZ-plane YZ.

In the embodiments of Figures 6 and 10, the propulsion units 3, 4, 5, 6 comprise propellers or rotors.

In Figure 10, the propulsion unit 3 is arranged in a first quadrant Q1 of the YZ-plane. The rotor of the propulsion unit 3 is rotating in a clockwise orientation. As is common for quadcopters, the propulsion unit 5 in a third quadrant Q3 of the YZ-plane is then also rotating in a clockwise direction and the propulsion units 4 and 6, arranged in the second and fourth quadrants Q2 and Q4 of the YZ-plane are rotating in a counter-clockwise direction. As a reaction force to this rotating motion, the propellers of the propulsion units 3, 4, 5, 6 introduce a natural moment M3, M4, M5, M6 around the centre of gravity CG of the aerial vehicle 100, in the opposite direction of the rotating direction of the rotors. The moments M3 and M5 of the propulsion units 3, 5 in the first and the third quadrant Q1, Q3 of the YZ-plane are counter-clockwise moments; the moments M4 and M6 of the propulsion units 4, 6 in the second and the fourth quadrant Q2, Q4 of the YZ-plane are clockwise moments. In equilibrium flight, these natural moments M3 – M6 are balanced, resulting in a net moment of zero around the centre of gravity CG. The moments M3 – M6 are indicated in Figure 10 by means of an arrow.

As visible in Figure 10, the propulsion units 3 and 4 are mounted to the wing 2 of the aerial vehicle 100 such that their force vectors F diverge with respect to the XY-plane and converge with respect to the XZ-plane. This way of mounting introduces an additional, artificial, moment around the centre of gravity CG of the aerial vehicle 100, with a magnitude of F times l. The artificial moment generated by one propulsion unit 3 is counter-clockwise; the artificial moment generated by the other propulsion unit 4 is clockwise. The artificial moments of the propulsion units 3 and 4 counteract each other in equilibrium flight.

When a pilot wants to perform a counter-clockwise yaw manoeuvre, in the embodiment of Figure 10, the propulsion unit indicated by reference number 3 may increase its thrust force. By increasing its thrust force, two simultaneous, co-working effects take place.

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Firstly, the natural counter-clockwise moment M3 around the centre of gravity CG of the aerial vehicle is increased, giving the aerial vehicle the tendency to make a counter-clockwise yaw manoeuvre.

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Secondly, the thrust vector F of the propulsion unit 3 is increased, yielding a larger artificial counter-clockwise moment around the centre of gravity CG of the aerial vehicle. This also gives the aerial vehicle the tendency to make a counter-clockwise yaw manoeuvre.

As the two effects support each other, this leads to an improved (faster) yaw manoeuvre.

In a similar way, to make a clockwise yaw manoeuvre in the embodiment of Figure 10, the thrust force of the other propulsion unit 4 of the subset of the propulsion units should be
5 increased.

By contrast, Figure 6 shows an aerial vehicle where the propulsion units 3 and 5 in the first quadrant Q1 and the third quadrant Q3 of the YZ-plane are rotating in a counter-clockwise orientation, leading to a reaction force with respect to the centre of gravity of the aerial
10 vehicle: the clockwise moment M3, M5 from the propulsion units 3, 5, and where the propulsion units 4 and 6, arranged in the second and fourth quadrants Q2 and Q4 of the YZ-plane are rotating in a clockwise direction, leading to a counter-clockwise moment M4, M6 from the propulsion units 4, 6 with respect to the centre of gravity of the aerial vehicle.

15 In Figure 6, the propulsion units 3 and 4 are mounted to the wing 2 of the aerial vehicle 110 such that their force vectors F converge with respect to the XY-plane and diverge with respect to the XZ-plane: opposite of the orientation of the propulsion units 3, 4, in Figure 10.

When a pilot wants to perform a clockwise yaw manoeuvre, in the embodiment of Figure 6,
20 the propulsion unit indicated by reference number 3 may increase its thrust force F . By increasing its thrust force F , two simultaneous, co-working effects take place.

Firstly, the natural clockwise moment around the centre of gravity CG of the aerial vehicle is increased, giving the aerial vehicle the tendency to make a clockwise yaw manoeuvre.

Secondly, the thrust force F of the propulsion unit 3 is increased, yielding a larger artificial
25 clockwise moment around the centre of gravity CG of the aerial vehicle. This also gives the aerial vehicle the tendency to make a clockwise yaw manoeuvre.

As the two effects support each other, this leads to an improved (faster) yaw manoeuvre.

In a similar way, to make a counter-clockwise yaw manoeuvre in the embodiment of Figure
30 6, the thrust force F of the other propulsion unit 4 of the subset of the propulsion units should be increased.

It is noted that the above gives a simplified description of what happens in reality. When one or more propulsion units 3, 4, 5, 6 increase the thrust force thereof, the aerial vehicle will not
35 only have the tendency to yaw, but also to roll, to pitch, and to climb. For example, in the embodiment of Figure 10, when only the thrust force F of propulsion unit 3 is increased, the aerial vehicle want to climb because there is a larger thrust force, the aerial vehicle wants to

yaw because there is a larger moment around the X axis, the aerial vehicle wants to roll because the thrust force delivered by the right propulsion units 3, 4, is larger than the thrust force delivered by the left propulsion units 5, 6 and the aerial vehicle wants to pitch as the thrust force delivered by the forward propulsion units 3, 6 is larger than the thrust force delivered by the aft propulsion units 4, 5. Typically, control software is implemented to counteract these effect; by not only increasing the thrust force of propulsion unit 3, but also adapting the thrust force of the other propulsion units 4, 5, 6, such that a smooth handling is experienced by the pilot.

10 The embodiment of Figures 1 to 3 has its propulsion units 3, 4, 5, 6 mounted in a tractor configuration. Alternatively, the propulsion units 3, 4, 5, 6 could also be placed in a pusher configuration.

In the embodiment of Figures 1 to 3, a first pair 3, 6 of the at least four propulsion units 3, 4, 5, 6, is arranged symmetrically relative to the XZ-plane at a first side of the at least one wing 2, and a second pair 4, 5 of the at least four propulsion units 3, 4, 5, 6 is arranged symmetrically relative to the XZ-plane at a second side of the at least one wing 2 opposite to the first side.

The propulsion units 3, 4, 5, 6 can however also be arranged in another arrangement, i.e., not symmetrically.

Figure 5 shows an embodiment of an aerial vehicle 50 according to the invention. In this embodiment, the aerial vehicle comprises two wings 31, 32, each wing 31, 32 having respective wingtips 31a, 32a. These wingtips 31a, 32a have common wingtip fences 37, 38 at each wingtip 31a, 32a. Four propulsion units 3, 34, 35, 6 are rigidly mounted on wing 31 through nacelles 3a, 34a, 35a, 6a, respectively. Four further propulsion units 33, 4, 5, 36 are rigidly mounted on wing 32 through nacelles 33a, 4a, 5a, 36a, respectively.

Of these eight propulsion units 3, 4, 5, 6, 33, 34, 35, 36, four propulsion units 33, 34, 35, 36 are mounted in such a way that their force vector F is substantially parallel to the X-axis X of the axis system. In the embodiment of Figure 5, the propulsion units 33, 34, 35, 36 are placed between the wings 31, 32.

The other four propulsion units 3, 4, 5, 6 are mounted in such a way that their force vector F , when projected on the XY-plane, is oriented at a first angle α_1 , α_2 with respect to the X-axis X and, when projected on the XZ-plane, is oriented at a second angle β_1 , β_2 with respect to the X-axis X .

In the embodiment of Figure 5, four propulsion units 3, 4, 5, 6 are inclined with respect to the X-axis X, but it is also possible that more propulsion units are inclined with respect to the X-axis X, for example two or six or eight of the propulsion units 3, 4, 5, 6, 33, 34, 35, 36. It is also possible that the aerial vehicle 50 of Figure 5 is adapted to contain another number of propulsion units, for example four, or six, or ten.

Yet other multi-wing embodiments are possible, although these are not shown. It would for example be possible to design an aerial vehicle with three wings and at least four propulsion units.

Other embodiments of the aerial vehicle are shown in Figures 7, 8 and 9. The Figures show an aerial vehicle 70, 80, 90, respectively, adopted for vertical take-off and landing as well as horizontal flight, wherein an imaginary right-hand sided axis system is defined, wherein an origin of the axis system is arranged at a centre of gravity CG of the aerial vehicle, wherein said axis system comprises an X-axis X, a Y-axis Y and a Z-axis Z, wherein an XY-plane through said origin is spanned by said X-axis X and said Y-axis Y, wherein an XZ-plane through said origin is spanned by said X-axis X and said Z-axis Z, and wherein a YZ-plane through said origin is spanned by said Y-axis Y and said Z-axis Z. The aerial vehicle comprises one wing 2 (Figure 7) as an exemplary embodiment, or two wings 31, 32 (Figures 8, 9), as an embodiment according to the invention, said wings 2, 31, 32 extending substantially parallel to the Y-axis Y in spanwise direction, said wings 2, 31, 32 extending substantially parallel to the X-axis X in chordwise direction, and said wings 2, 31, 32 extending substantially parallel to the Z-axis Z in thickness direction. The wings 2, 31, 32 are substantially symmetrical with respect to the XZ-plane of said axis system. The aerial vehicle 60, 70, 80, 90 further comprises at least four propulsion units 3, 4, 5, 6, each propulsion unit 3, 4, 5, 6 being rigidly mounted to the wing 2, or to the wings 31, 32, respectively, with a respective nacelle 3a, 4a, 5a, 6a and configured to generate a force vector F along a respective imaginary force vector line L, said force vector line L, for a subset of at least two of the propulsion units, when projected on the XY-plane, being oriented at a first angle α_1 , α_2 with respect to the X-axis X, the absolute value of said first angle α_1 , α_2 being between 0 and 45 degrees, and said force vector line L, for the subset of at least two of the propulsion units, when projected on the XZ-plane, further being oriented at a second angle β_1 , β_2 with respect to the X-axis X, the absolute value of said second angle β_1 , β_2 being between 0 and 45 degrees.

In the embodiment of the aerial vehicle 70 as shown in Figure 7, a first pair of propulsion units 3, 6 and a second pair of propulsion units 4, 5 are arranged symmetrically relative to

the XZ-plane of the axis system. At the same time, the propulsion units 3, 4 and the propulsion units 5, 6 are arranged symmetrically relative to the XY-plane of the axis system. In the embodiment of the aerial vehicle 80 as shown in Figure 8, the wings 31 and 32 are fixed to each other at the centre of gravity CG at an angle larger than 0 degrees relative to each other. The four propulsion units 3, 4, 5, 6 are mounted at the ends of the wingtips 31a, 32a.

In the embodiment of the aerial vehicle 90 as shown in Figure 9, the wings 32, 31 are substantially parallel to each other. Wings 31, 32 are connected to each other through a connection member 92 arranged at the XZ-plane of the aerial vehicle 90. The four propulsion units 3, 4, 5, 6 are mounted at the ends of the wingtips 31a, 32a.

Although all shown embodiments comprise an even number of propulsion units 3, 4, 5, 6, 33, 34, 35, 36, aerial vehicles with an odd number of propulsion units are also conceivable, although this will make the control of the aerial vehicle more difficult.

As explained in detail above, an aerial vehicle for vertical take-off and landing and horizontal flight comprises at least one wing extending substantially parallel to a Y-axis in spanwise direction, substantially parallel to an X-axis in chordwise direction, and extending substantially parallel to a Z-axis in thickness direction. The wing is substantially symmetrical with respect to a XZ-plane. The aerial device comprises at least four propulsion units, each propulsion unit being rigidly mounted to the at least one wing with a respective nacelle and configured to generate a force vector along a respective imaginary force vector line, said force vector line, for a subset of at least two of the propulsion units, when projected on the XY-plane, being oriented at a first angle with respect to the X-axis, and when projected on the XZ-plane, is further oriented at a second angle with respect to the X-axis.

As required, detailed embodiments of the present invention are disclosed herein; however, it is to be understood that the disclosed embodiments are merely exemplary of the invention, which can be embodied in various forms. Therefore, specific structural and functional details disclosed herein are not to be interpreted as limiting, but merely as a basis for the claims and as a representative basis for teaching one skilled in the art to variously employ the present invention in virtually any appropriately detailed structure. Further, the terms and phrases used herein are not intended to be limiting, but rather, to provide an understandable description of the invention.

The terms "a"/"an", as used herein, are defined as one or more than one. The term plurality, as used herein, is defined as two or more than two. The term another, as used herein, is

defined as at least a second or more. The terms including and/or having, as used herein, are defined as comprising (i.e., open language, not excluding other elements or steps). Any reference signs in the claims should not be construed as limiting the scope of the claims or the invention.

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The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage.

C L A I M S

1. An aerial vehicle adopted for vertical take-off and landing as well as horizontal flight, wherein an imaginary right-hand sided axis system is defined, wherein an origin of the axis system is arranged at a centre of gravity of the aerial vehicle, wherein said axis system comprises an X-axis, a Y-axis and a Z-axis, wherein an XY-plane through said origin is spanned by said X-axis and said Y-axis, wherein an XZ-plane through said origin is spanned by said X-axis and said Z-axis, and wherein a YZ-plane through said origin is spanned by said Y-axis and said Z-axis,,

wherein the aerial vehicle comprises:

- two wings, extending substantially parallel to the Y-axis in spanwise direction, extending substantially parallel to the X-axis in chordwise direction, and extending substantially parallel to the Z-axis in thickness direction, said at least one wing being substantially symmetrical with respect to the XZ-plane of said axis system;
- at least four propulsion units, each propulsion unit being rigidly mounted to the wings with a respective nacelle and configured to generate a force vector along a respective imaginary force vector line,

wherein said force vector line, for a subset of at least two of the propulsion units, when projected on the XY-plane, is oriented at a first angle with respect to the X-axis, the absolute value of said first angle being between 0 and 45 degrees, and wherein said force vector line, for the subset of the at least two of the propulsion units, when projected on the XZ-plane, is further oriented at a second angle with respect to the X-axis, the absolute value of said second angle being between 0 and 45 degrees.

2. The aerial vehicle according to claim 1, wherein a first pair of the at least four propulsion units is arranged symmetrically relative to the XZ-plane at a first side of one of the wings, and a second pair of the at least four propulsion units is arranged symmetrically relative to the XZ-plane at a second side of said wing opposite to the first side.

3. The aerial vehicle according to claim 1 or 2, wherein the force vectors of the subset of the at least two of the propulsion units diverge with respect to the XY-plane.

4. The aerial vehicle according to claim 1 or 2, wherein the force vectors of the subset of the at least two of the propulsion units converge with respect to the XY-plane.

5. The aerial vehicle according to any one of the preceding claims, wherein the force vectors of the subset of the at least two of the propulsion units diverge with respect to the XZ-plane.
- 5 6. The aerial vehicle according to any one of claims 1 to 4, wherein the force vectors of the subset of the at least two of the propulsion units converge with respect to the XZ-plane.
- 10 7. The aerial vehicle according to one of the preceding claims, wherein the absolute value of said first angle is between 0 and 25 degrees, in particular between 5 and 20 degrees.
- 15 8. The aerial vehicle according to one of the preceding claims, wherein the absolute value of said second angle is between 0 and 25 degrees, in particular between 5 and 20 degrees.
- 20 9. The aerial vehicle according to any one of the preceding claims, wherein the absolute value of the second angle is larger than the absolute value of the first angle.
- 25 10. The aerial vehicle according to any one of the preceding claims, wherein the force vectors of the subset of the at least two of the propulsion units are projected on the YZ-plane, wherein imaginary lines can be defined between the locations of the propulsion units and the centre of gravity of the aerial vehicle, which lines are perpendicular to the force vectors.
- 30 11. The aerial vehicle according to any one of the preceding claims, wherein the propulsion units are motor/propeller units, blades of said motor/propeller units preferably being arranged substantially perpendicular to said force vector line.
- 35 12. The aerial vehicle according to claim 11, wherein the propulsion units are arranged in a tractor configuration during horizontal flight.
13. The aerial vehicle according to any one of the preceding claims, wherein each wing of the aerial vehicle comprises two wingtips and a wingtip fence at both wingtips.
14. The aerial vehicle according to claim 13, wherein said two wings of the aerial vehicle have common wingtip fences at each wingtip.

15. The aerial vehicle according to any one of the preceding claims, wherein four propulsion units are rigidly mounted to each wing, so that the aerial vehicle comprises eight propulsion units,

- four of said eight propulsion units, preferably the four propulsion units that are closest to the centre of gravity of the aerial vehicle, being mounted such that their force vector line is substantially parallel to the X-axis of the axis system,
- the other four of said eight propulsion units, preferably the four propulsion units that are furthest away from the centre of gravity of the aerial vehicle, being mounted such that the force vector line, when projected on the XY-plane, of each one of said other four propulsion units is oriented at said first angle with respect to the X-axis, and the force vector line, when projected on the XZ-plane further is oriented at said second angle with respect to the X-axis.

1/5

Fig. 1

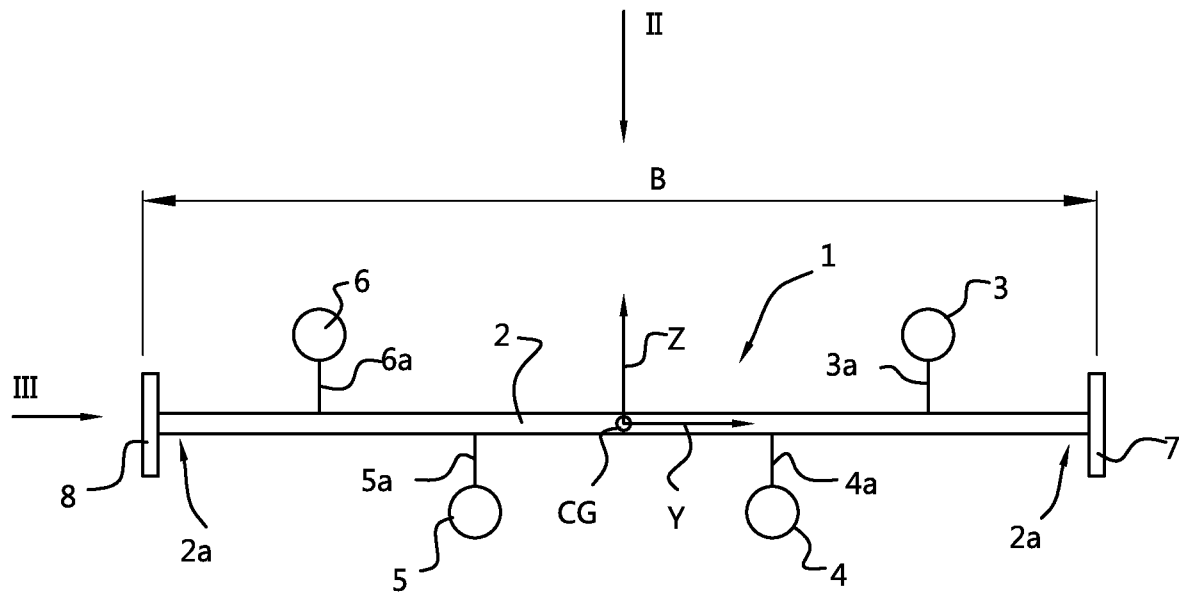


Fig. 2

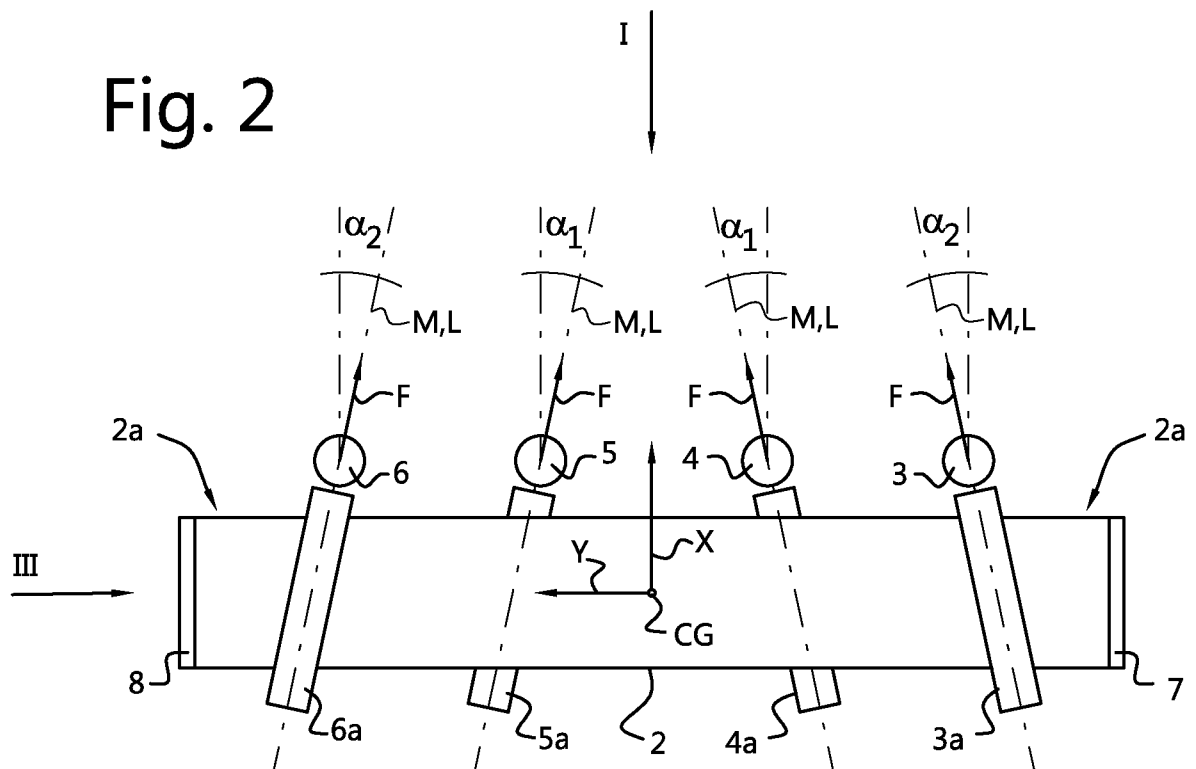


Fig. 3

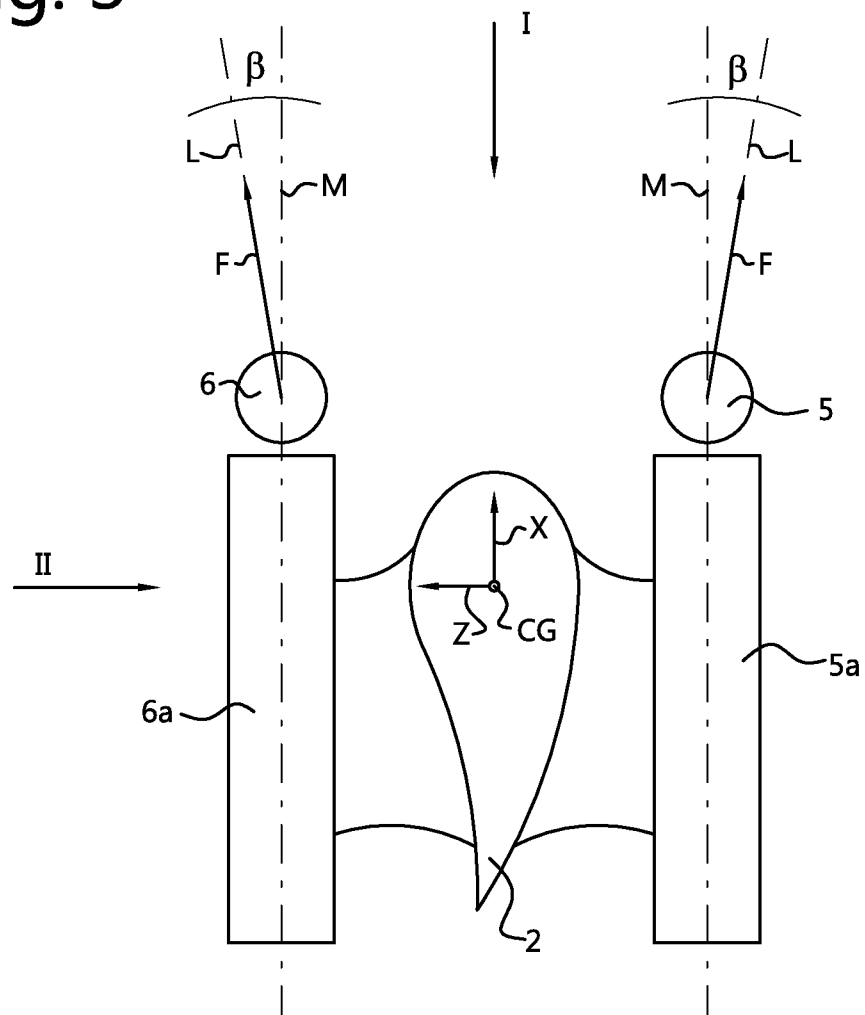


Fig. 4

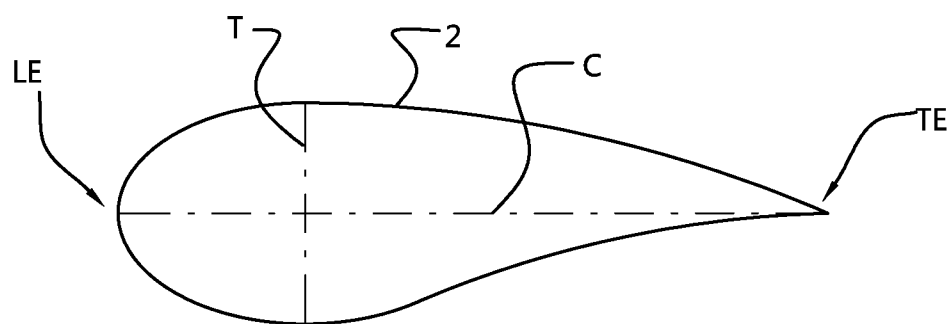


Fig. 5

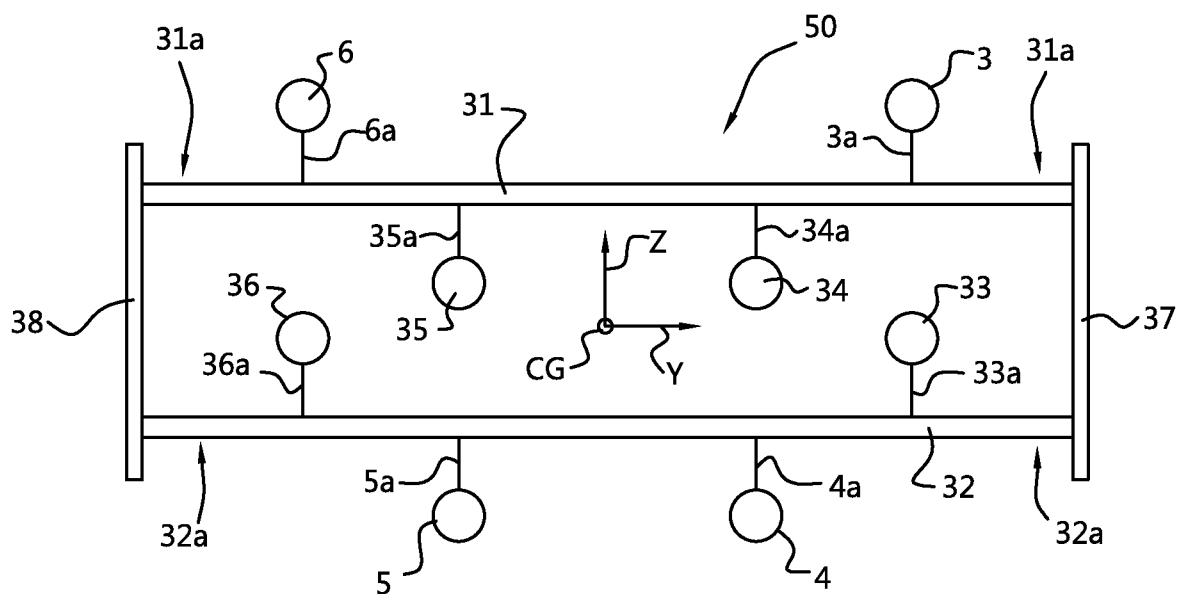


Fig. 6

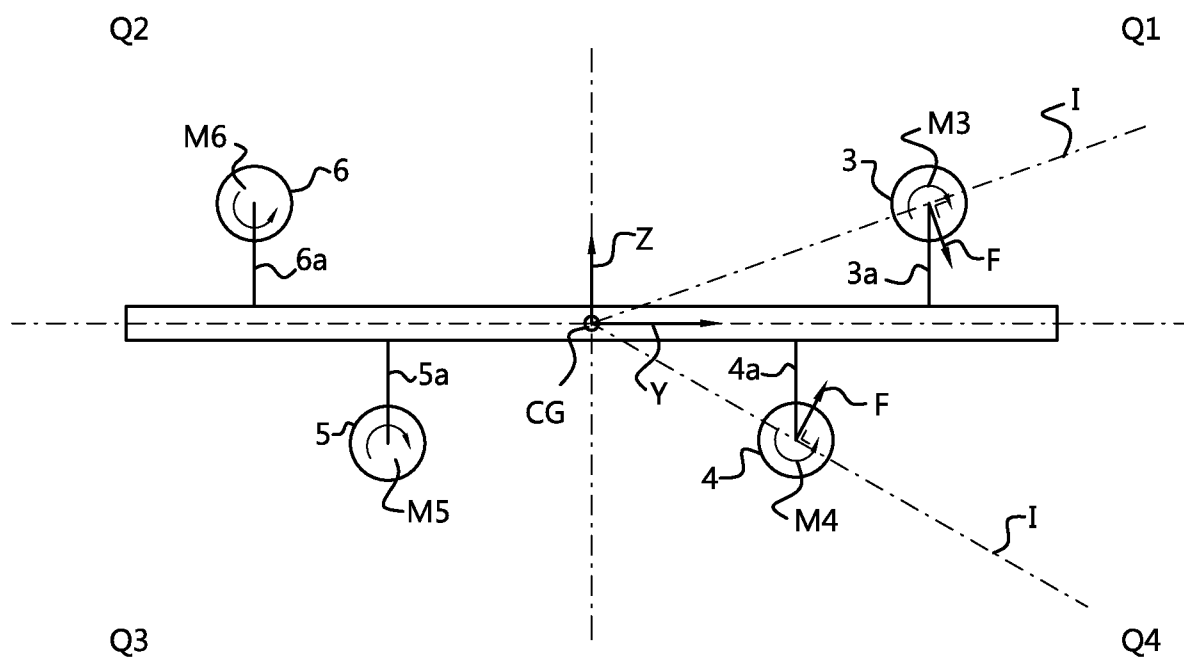


Fig. 7

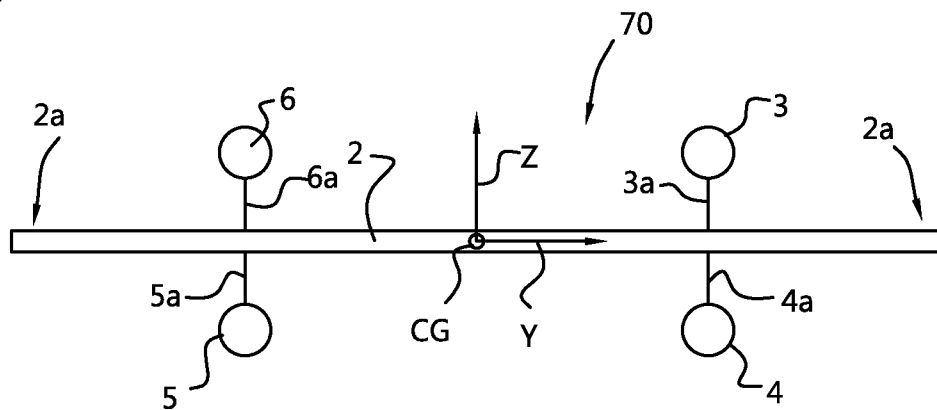


Fig. 8

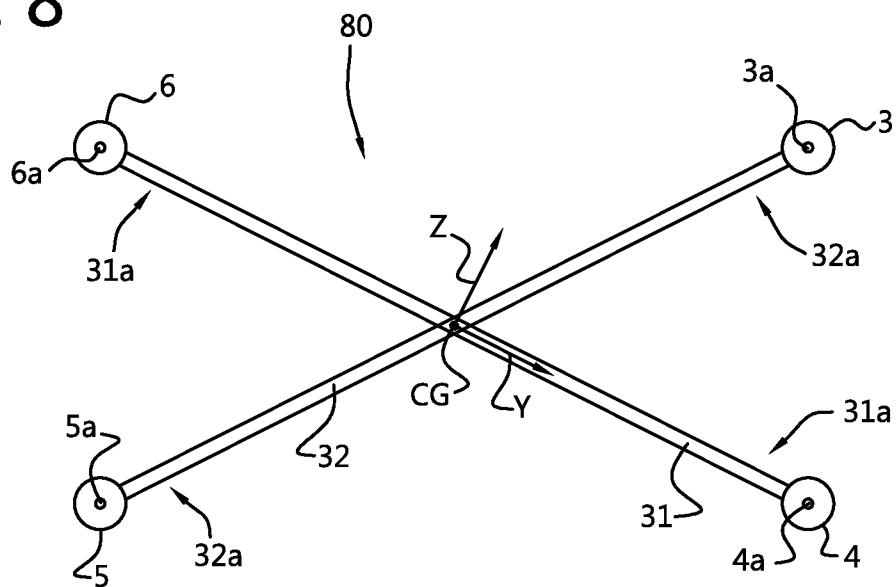


Fig. 9

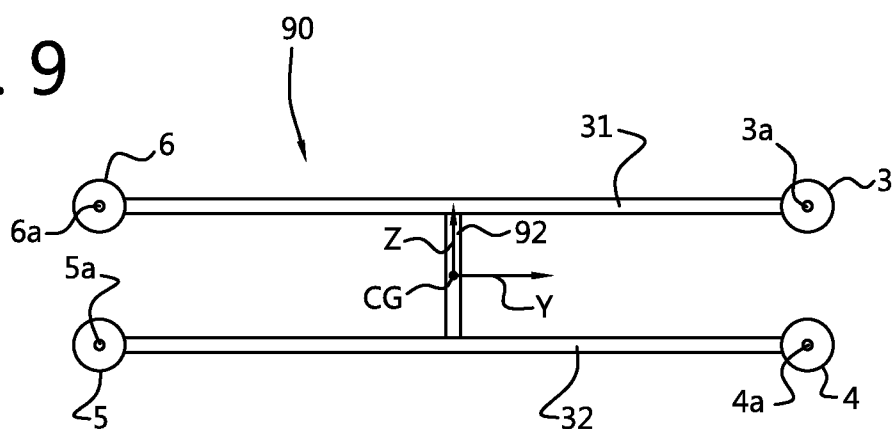
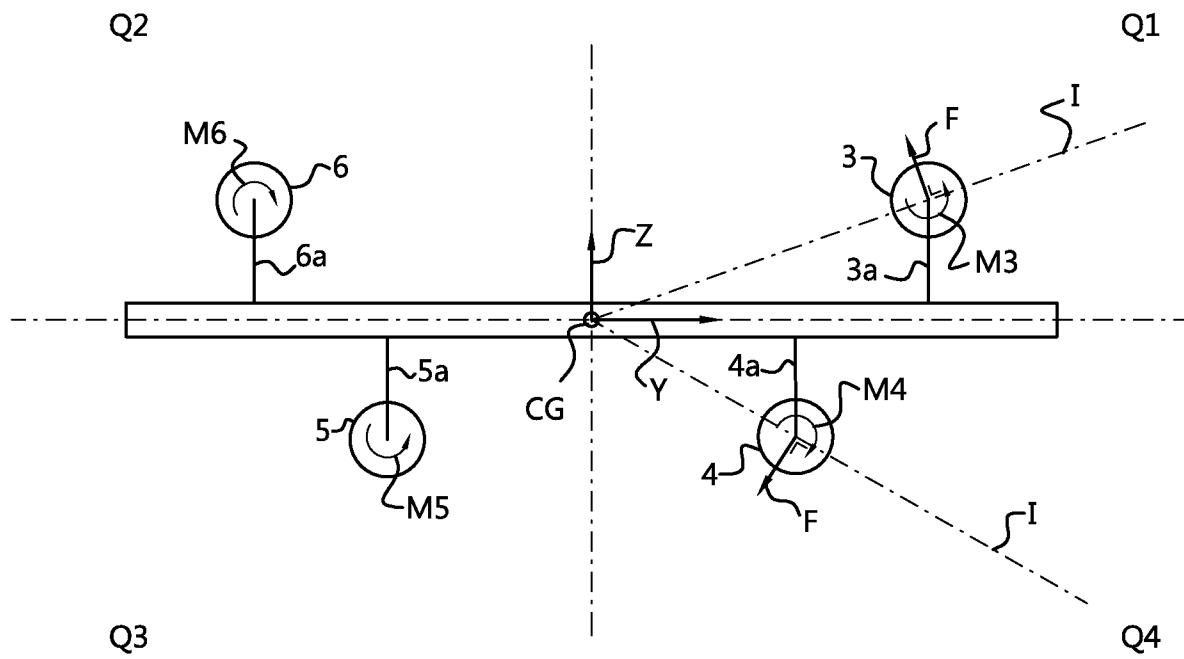


Fig. 10



INTERNATIONAL SEARCH REPORT

International application No

PCT/NL2017/050664

A. CLASSIFICATION OF SUBJECT MATTER

INV. B64C29/02 B64C39/02
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B64C B64D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
E	EP 3 260 370 A1 (PARROT DRONES [FR]) 27 December 2017 (2017-12-27) paragraphs [0044] - [0057]; figures -----	1,4,5,7, 12
E	WO 2017/210595 A2 (AEROVIRONMENT INC [US]) 7 December 2017 (2017-12-07) page 19, line 7 - page 25, line 3; figures 5-9 -----	1,3,6-8, 10-12
X	WO 2016/085610 A1 (XCRAFT ENTPR LLC [US]) 2 June 2016 (2016-06-02) paragraphs [0069], [0070]; figure 5 -----	1-12
Y	US 2005/178879 A1 (MAO YOUBIN [US]) 18 August 2005 (2005-08-18) paragraph [0043]; figure 3 ----- -/--	1-14



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"P" document published prior to the international filing date but later than the priority date claimed

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search

17 January 2018

Date of mailing of the international search report

26/01/2018

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Authorized officer

Vermeulen, Tom

INTERNATIONAL SEARCH REPORT

International application No

PCT/NL2017/050664

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	Menno Hochstenbach ET AL: "Design and control of an unmanned aerial vehicle for autonomous parcel delivery with transition from vertical take-off to forward flight - VertikUL, a quadcopter tailsitter", 1 January 2013 (2013-01-01), XP055176330, DOI: 10.1260/1756-8293.7.4.395 Retrieved from the Internet: URL: http://www.tmlleuven.be/thesisprijs/laureaates/2014Hochstenbach_Notteboom_samenvatting.pdf [retrieved on 2015-03-13] point 5.1 and figure 10 -----	1-14
Y	US 2014/097290 A1 (LENG MARKUS [US]) 10 April 2014 (2014-04-10)	1-14
A	paragraph [0036]; figures -----	15
A	FR 2 903 380 A1 (QUERRY STEPHANE LUC SABASTIEN [FR]) 11 January 2008 (2008-01-11) abstract; figures -----	1-15
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A	WO 2010/015866 A2 (UNIV MANCHESTER [GB]; CROWTHER WILLIAM [GB]; PILMOOR MATTHEW [GB]; LAN) 11 February 2010 (2010-02-11) abstract; figures -----	1-15
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