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Title

Propulsion system for an aerial vehicle and aerial vehicle comprising the propulsion system

Background

- 5 The present disclosure relates to improvements associated with propulsions system for an aerial vehicle, in particular for an unmanned aerial vehicle (UAV), as well as to an aerial vehicle for manned or unmanned transport, in particular a drone, comprising the propulsion system.

Unmanned aerial vehicles (UAVs), also known as drones, are used in various fields, such as civilian and military fields. UAV may for example be used for transport of goods, for recognitions flights but also for
10 transport of people, such as medical transport or passenger transport.

A further development in UAV technology has been the development of Vertical Take-Off and Landing (VTOL) UAVs. As their name hints, these UAV take-off and land vertically, thereby requiring less landing space. These drones are also capable to hover and maintain position above a specific spot.

- It is an aim of the present disclosure to provide an improved propulsions system for an aerial vehicle,
15 e.g. for an UAV. The improvements may also relate to an aerial vehicle for manned or unmanned transport, in particular a drone, the aerial vehicle comprising the propulsion system.

These and/or other aims are achieved by the subject-matter disclosed herein and/or by subject-matter set forth in the appended independent claims as will become apparent from the following description. Advantageous embodiments and refinements, inter alia, are subject to dependent claims.

20 **Summary**

- A first aspect of the present disclosure relates to a propulsion system for an aerial vehicle, in particular for an unmanned aerial vehicle, e.g. a drone, e.g. a vertical take-off and landing (VTOL) UAV. Another aspect of the present disclosure relates to an aerial vehicle, in particular an unmanned aerial vehicle (UAV), such as a drone, in particular a vertical take-off and landing (VTOL) UAV, comprising the
25 propulsion system of the first aspect

It is noted that features, which are disclosed herein in connection with the propulsion system of the first aspect, also apply to the aerial vehicle comprising the propulsion system of the first aspect. In general,

features disclosed in connection with different aspects, examples or embodiments can be combined with one another, even if such a combination is not explicitly described herein. Unless expressly stated otherwise, features disclosed herein above and below apply for all aspects, examples or embodiments of the disclosure, e.g. for the propulsion system and for the aerial vehicle. For example, if method-like
5 features are described they should be understood so as to also relate to the propulsion system and/or the aerial vehicle being configured for carrying out or performing these features.

It is noted that advantages of embodiments described herein relate both to the propulsion system and to the aerial vehicle comprising the propulsion system, e.g. a propulsion system that is lighter results in a lighter aerial vehicle. A propulsion system that is more energy efficient, results in the aerial vehicle
10 being more energy efficient.

In an embodiment the propulsion system comprises an air duct, a motor system and a fan. The air duct comprises a first end and a second end. The air duct extends along a longitudinal axis from the first end of the air duct to the second end of the air duct. The fan and the motor system are arranged inside the air duct. The motor system is configured to rotate the fan. The motor system comprises a first electric
15 motor and a second electric motor.

In the following, the propulsion system will be described for a motor system comprising a first electric motor and a second electric motor. The system is however not restricted to only two electric motors. The features relating to the first electric motor and/or to the second electric motors may also hold for a further motor, e.g. a third electric motor. The motor system may comprise however also non-electric
20 motors.

A propulsion system is defined as a machine that produces thrust to push an object, e.g. the propulsion system, forward. In the following application, the object is usually pushed through air. The thrust may be generated through acceleration of a gas, e.g. air, by an engine, e.g. a motor, e.g. an electric motor, thereby producing a force on the engine.

According to at least one embodiment, the air duct has a substantial cylindrical hollow shape extending along a longitudinal axis. According to at least one embodiment, the air duct comprises a first end and a second end. The first end may be arranged opposite to the second end along the longitudinal axis. The air duct extends from the first end of the air duct to the second end of the air duct.

The first end of the air duct defines an air flow inlet of the air duct, e.g. an inlet of the air duct through which air may enter the air duct, for example during operation of the propulsion system. The second end of the air duct defines an air flow outlet of the air duct, e.g. an outlet of the air duct through which air, e.g. the air that entered the air duct through the first end, e.g. through the air flow inlet, may leave
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the air duct, for example during operation of the propulsion system. The air duct may define an air flow path from the first end of the air duct to the second end of the air duct.

As used herein the direction towards the first end of the air duct may also be called an "upwards" direction and the direction towards the second end of the air duct may also be called a "downwards" direction. Similarly, the "top" of the propulsion system, may be defined as a section of the propulsion system proximate to the first end of the air duct. The "bottom" of the propulsion system may be defined as a section of the propulsion system proximate to the second end of the air duct. The respective holds for the aerial vehicle comprising the propulsion system of the first aspect, as described later on.

According to at least one embodiment, the first end of the air duct defines a first circumferential plane. According to at least one embodiment, the second end of the air duct defines a second circumferential plane. The first circumferential plane and/or second circumferential plane are substantially perpendicular to the longitudinal axis.

According to at least one embodiment, the air duct comprises an inner surface and an outer surface. The inner surface of the air duct defines a substantially cylindrical form having a first radius. The first radius corresponds to the inner radius of the air duct, e.g. of the hollow cylinder.

The outer surface of the air duct defines a substantially cylindrical form having a second radius. The second radius corresponds to the outer radius of the air duct, e.g. of the hollow cylinder.

The difference between the second radius and the first radius, i.e. of the outer radius and the inner radius, defines the thickness of the air duct, e.g. the thickness of the wall of the air duct. The outer radius is bigger than the inner radius.

According to at least one embodiment, the first radius may be between 10 cm and 1000 cm, between 20 cm and 800 cm, between 100 cm and 500 cm, for example between 200 cm and 400 cm.

According to at least one embodiment, the first radius may be equal to or more than 10 cm, 20 cm, 50 cm, 80 cm, 150 cm, 250 cm, 350 cm, 450 cm, 550 cm, 650 cm, 750 cm, 850 cm, 950 cm.

According to at least one embodiment, the first radius may be equal to or less than 1000 cm, 900 cm, 800 cm, 700 cm, 600 cm, 500 cm, 400 cm, 300 cm, 200 cm, 100 cm, 70 cm, 40 cm, 15 cm.

According to at least one embodiment, the second radius may be between 20 cm and 1000 cm, between 20 cm and 800 cm, between 100 cm and 500 cm, for example between 200 cm and 400 cm.

According to at least one embodiment, the second radius may be equal to or more than 20 cm, 50 cm, 80 cm, 150 cm, 250 cm, 350 cm, 450 cm, 550 cm, 650 cm, 750 cm, 850 cm, 950 cm.

According to at least one embodiment, the second radius may be equal to or less than 1000 cm, 900 cm, 800 cm, 700 cm, 600 cm, 500 cm, 400 cm, 300 cm, 200 cm, 100 cm, 70 cm, 40 cm, 30 cm.

The size of the air duct is however not limited to the above values. The air duct may be arbitrarily scalable depending on the required use.

- 5 According to at least one embodiment, the air duct defines an air flow path radially delimited by the inner surface of the air duct. The air flow path may extend from the first end, e.g. the air flow inlet, to the second end, e.g. the air flow outlet, of the air duct.

- 10 According to at least one embodiment, the first end of the air duct comprises inlet lips. The inlet lips may be an integral part of the air duct. The inlet lips may correspond to a curvature of the wall of the air duct. The inlet lips may be radially outwardly curved, e.g. be a radially outwardly curved section of the wall of the air duct at the first end of the air duct. The inlet lips may be an additional element, attached to the first end of the air duct.

- 15 According to at least one embodiment, the second end of the air duct comprises outlet lips. The outlet lips may be an integral part of the air duct. The outlet lips may correspond to a curvature of the wall of the air duct. The outlet lips may be radially outwardly curved, e.g. be a radially outwardly curved section of the wall of the air duct at the second end of the air duct. The outlet lips may be an additional element, attached to the second end of the air duct.

- 20 The inlet lips and/or the outlet lips offer a better geometry for the inlet and/or for the outlet of the air into and/or from the air duct. The inlet lips, for example increase an inlet surface for air inlet of the air duct. The outlet lips for example increase an outlet surface for air outlet of the air duct. The inlet lips and/or the outlet lips have a curvature configured to ameliorate air flow through and/or around the respective inlet lip and/or outlet lip. The air flow is thereby more laminar when entering (in the case of the inlet lips) or leaving (in the case of the outlet lip) the air flow path of the air duct. As such it greatly increases efficiency of the propulsion system and the propulsion quality.

- 25 According to at least one embodiment, the inlet lip has a shape substantially corresponding or mimicking a NACA profile, thereby optimizing air flow through, in particular, around the inlet lip.

According to at least one embodiment, the outlet lip has a shape substantially corresponding or mimicking a NACA profile, thereby optimizing air flow through, in particular, around the outlet lip.

- 30 According to at least one embodiment, the air duct is made of composite material and/or carbon fiber-reinforced plastic.

According to at least one embodiment, the air duct comprises a first reinforcing collar and/or a second reinforcing collar. The first reinforcing collar may be arranged at the first end of the air duct, e.g. around the outer surface of the air duct at the or proximate to the first end of the air duct. The second reinforcing collar may be arranged at the second end of the air duct, e.g. around the outer surface of the air duct at the or proximate to the second end of the air duct.

The first reinforcing collar and/or second reinforcing collar have the function of reinforcing the air duct at their respective location, e.g. at the first end of the air duct and/or at the second end of the air duct, respectively. Such a reinforcement increases the structural stability of the air duct and hence of the propulsion system and of the aerial vehicle comprising the propulsion system.

The first reinforcing collar and/or the second reinforcing collar stabilize and strengthen the air duct. Additionally, the first reinforcing collar and/or the second reinforcing collar may have the function of carrying and/or bearing some of the heavier loads, e.g. heavier elements, of the propulsion system, as will be explained later.

The first reinforcing collar and the second reinforcing collar may be connected to each other by at least one reinforcing strut, e.g. four reinforcing struts, extending longitudinally along the outer surface of the air duct. The propulsion system may for example comprise four reinforcing struts. The four reinforcing struts may be arranged radially symmetrically around the outer surface of the air duct.

The connection of the first reinforcing collar and of the second reinforcing collar through the reinforcing struts, offers a better load distribution, so that the load of elements of the propulsion system is distributed from the first reinforcing collar and/or from the second reinforcing collar to the second reinforcing collar and/or to the first reinforcing collar, through the reinforcing struts.

The propulsion system may also comprise further reinforcing collars, for example a third reinforcing collar. The third reinforcing collar may for example be arranged on the outer surface of the air duct between the first reinforcing collar and the second reinforcing collar, e.g. along the longitudinal axis between the first and the second reinforcing collar.

According to at least one embodiment, the propulsion system further comprises at least two, e.g. three, four, five, six or more, radial guide vanes arranged at the first end of the air duct. The propulsion system may for example comprise four radial guide vanes.

According to at least one embodiment, the at least two radial guide vanes extend from the inner surface of the air duct towards a centric longitudinal axis of the air duct. The centric longitudinal axis may be an axis being parallel to the longitudinal axis of the extension of the air duct and passing through the center point of the hollow cylinder defined by the air duct. In other words, the centric longitudinal axis passes

through the center points of the first circumferential plane and/or of the second circumferential plane defined by the first end of the air duct and the second end of the air duct, respectively. The first circumferential plane and the second circumferential plane are each perpendicular to the centric longitudinal axis. Any element being perpendicular to the longitudinal axis is perpendicular to the centric longitudinal axis.

In other words, the radial guide vanes extend radially inwards towards the centric longitudinal axis. The term "radially inwards" in this application describes a radial direction towards the hollow cylinder, e.g. towards the centric longitudinal axis. "Radially outwards" describes a radial direction away from the centric longitudinal axis of the air duct. In aerospace engineering the "radial guide vanes" may also be called "axial guide vanes", as the point of reference is the extension of the guide vanes in an axial direction, e.g. in a direction parallel to the longitudinal axis.

Each radial guide vane may have a first vane end connected to the inner surface of the air duct, e.g. the inner surface of the hollow cylinder. Each radial guide vane may extend radially inwards from the inner surface of the air duct towards the centric longitudinal axis of the air duct. According to at least one embodiment the radial guide vanes may have a substantially straight shape, for example an I-shape.

According to at least one embodiment, the radial guide vanes may have a Y-shape. The two arms of the "Y" may correspond to two first vane ends. The two first guide vane ends may be connected to the inner surface of the air duct. The radial guide vanes may however also have different shapes, such as a "X" shaped or similar. According to at least one embodiment, the propulsion system comprises a combination of shapes of radial guide vanes, for example two radial guide vanes being Y-shaped and two straight radial guide vanes.

According to at least one embodiment, the first reinforcing collar is arranged on a section of the outer surface of the air duct corresponding to a section of the inner surface of the air duct to which the radial guide vanes, e.g. the first vane end, are connected. In other words, the first reinforcing collar on the outer surface of the air duct and the section of the inner surface of the air duct to which the radial guide vanes are connected to, lie substantially on a same plane. The plane is perpendicular to the longitudinal axis.

The load carried by the radial guide vanes, as will be described later, is therefore distributed not only to the air duct by the radial guide vanes, but also supported by and distributed to the first reinforcing collar. This is particularly advantageous as it minimizes the tendency of deformation of the air duct and of the radial guide vanes. In particular it reduces excessive stress placed on the radial guide vane considerably.

The load carried by the radial guide vanes may also be distributed to the second reinforcing collar through the reinforcing struts, in the respective embodiments, such that the overall load is distributed throughout the propulsion system, e.g. through the first reinforcing collar and/or through the second reinforcing collar and/or the reinforcing struts. This distribution of loads reduces the wear of features, e.g. of the radial guide vanes. It further stabilizes the overall architecture of the propulsion system in case of landing and harsh landing scenarios, e.g. in case of unplanned malfunctions.

According to at least one embodiment, the at least two radial guide vanes extend along the first circumferential plane defined by the first end of the air duct. In other words, the radial guide vane extend along a plane being perpendicular to the longitudinal axis, e.g. the centric longitudinal axis, and in particular along the first end of the air duct, e.g. along the first circumferential plane.

According to at least one embodiment, the at least two radial guide vanes extend from the inner surface of the air duct towards the centric longitudinal axis of the air duct and towards the second end of the air duct. In other words, the radial guide vanes in such an embodiment, do not extend along a parallel plane with respect to the first circumferential plane. In even other words, the radial guide vanes extend along a plane which is not perpendicular to the longitudinal axis. In such an embodiment, the radial guide vanes form a first angle between the radial guide vanes and the first circumferential plane defined by the first end of the air duct.

Such an embodiment improves the aerodynamic inlet conditions at the first end, e.g. at the air flow inlet, due to the effect of a stretched inlet.

According to at least one embodiment, the first angle is between 0° and 45° . The first angle may be for example, 0° , 5° , 10° , 15° , 20° , 25° , 30° , 35° , 40° , 45° .

According to at least one embodiment, the propulsion system may comprise one or more radial guide vanes extending along a plane which is not perpendicular to the longitudinal axis and one or more radial guide vanes extending along a plane which is perpendicular to the longitudinal axis.

According to at least one embodiment, the at least two radial guide vanes are arranged radially symmetrically on the air duct, on the inner surface of the air duct. The radial guide vanes may divide the first end, e.g. the air flow inlet, of the air duct in subsections. In an embodiment with four radial guide vanes, the air flow inlet is divided into four subsections delimited by the radial guide vanes.

The radial vane guides may also comprise or at least mimic a NACA profile, thereby ameliorating the air flow around the vanes, e.g. into the air duct.

According to at least one embodiment, the propulsion system further comprises a mounting platform to which the radial guide vanes connect. The mounting platform may be arranged on a center section of a

circumference formed by the hollow cylinder and perpendicular to the longitudinal axis, e.g. on a radially center section of the centric longitudinal axis. The radial guide vanes may comprise a second vane end connected to the mounting platform. The second vane end may be arranged opposite to the first vane end.

- 5 In other words, the radial guide vanes may extend radially inwards towards a mounting platform and connect with the mounting platform. The radial guide vanes may extend from the inner surface of the air guide radially inwards towards the mounting platform and connect with the mounting platform.

The mounting platform may be held in its position by its connection with the radial guide vanes.

- 10 According to at least one embodiment, the mounting platform is arranged on the first circumferential plane defined by the first end of the air duct. Alternatively, the mounting platform is arranged further towards the second end of the air duct, e.g. downwards, with respect to the first circumferential plane defined by the first end of the air duct. In other words, the mounting platform may be longitudinally offset towards the second end of the air duct with respect to the first end, e.g. with respect to the first circumferential plane.

- 15 According to at least one embodiment, the radial guide vanes have a wider section towards the inner surface of the air duct, e.g. towards the first vane end.

According to at least one embodiment, the radial guide vanes are made of the same material as the air duct, e.g. of carbon fiber-reinforced plastic. Alternatively, the radial guide vanes may comprise or be made of a different material than the air duct.

- 20 According to at least one embodiment, the mounting platform is configured to allow connection of further elements of the propulsion system and/or of the aerial vehicle to the mounting platform.

According to at least one embodiment, the mounting platform has a circular shape.

According to at least one embodiment, the mounting platform is configured to be connect or releasable connected with a payload compartment.

- 25 The advantage of such a configuration lies particularly in the fact that the load of the payload compartment is distributed from the mounting platform to the at least two radial guide vanes and further to the air duct. In embodiments with the first reinforcing collar, the load is further distributed to the first reinforcing collar and optionally through the reinforcing struts to the second reinforcing collar, in the respective embodiments.

This results in a better overall load distribution of the payload system, e.g. payload compartment, and less stress on the propulsion system. The propulsion system is thereby more secure and less structural load carrying, which offers the ability for optimal aerodynamic and thermodynamic design.

5 According to at least one embodiment, the motor system of the propulsion system is connected to the radial guide vanes. The motor system may be connected to the mounting platform. The motor system is arranged inside the air duct.

According to at least one embodiment, the motor system is arranged on a surface of the mounting platform facing the second end of the air duct, e.g. facing downwards.

10 According to at least one embodiment, the motor system extends along the longitudinal axis towards the second end of the air duct. In particular, the motor system may be arranged along the centric longitudinal axis towards the second end of the air duct. The motor system may be arranged in a position which minimizes turbulences with the air flow passing through the air flow path, i.e. from the first end to the second end.

According to at least one embodiment, the motor system is completely arranged inside the air duct.

15 Arranging the motor system inside, e.g. completely inside, the air duct has the advantage of centralizing the weight of the propulsion system thereby increasing the stability and the predictability of the propulsion system and of the aerial vehicle comprising the propulsion system during operation, e.g. during movement of the propulsion system and of the aerial vehicle through air.

20 By arranging the motor system inside the air duct, the motor system is further at least partially cooled automatically through the air flow passing through the air duct. The motor system therefore requires fewer cooling means and is therefore lighter. The motor system arranged inside the air duct is also more protected from outside (e.g. environmental) influences. The propulsion system and/or the aerial vehicle with such a propulsion system is/are therefore more reliable and less prone to incur damages.

25 The arrangement of the motor system inside the air duct and on the centric longitudinal axis has the further advantage of increase stability, due to its alignment on the axis.

Through the connection of the motor system to the mounting platform and/or to the radial guide vanes, the load of the motor system is distributed on the radial guide vanes and to the air duct and optionally to the first reinforcing collar. This results in a better overall load distribution of the propulsion system and thereby better propulsions qualities. The motor system is a heavy element of the propulsion system and of the aerial vehicle. It is advantageous if its load is not carried centrally by one single element but distributed throughout the system, as is done through the radial guide vanes and/or the first reinforcing

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collar and/or the second reinforcing collar and/or the reinforcing struts connecting the first reinforcing collar and the second reinforcing collar.

The motor system may have a substantial cylindrical form, e.g. may be encased in a cylindrical housing, e.g. in a cylindrical case. The motor system may have a radius smaller than or equal to the radius of the mounting platform. The motor system may have a radius bigger than or equal to the radius of the mounting platform.

According to at least one embodiment, the motor system is arranged in a section of the air duct extending along the longitudinal axis from between a fifth to a third of the longitudinal length of the inner duct, seen from the first end of the air duct towards the second end of the air duct.

- 10 According to at least one embodiment, the fan is attached to the motor system. The fan is configured to be rotated by the motor system. The rotation of the fan generates a pressure difference that pulls air from the air flow inlet and moves it towards the air flow outlet. The movement of the fan generates an aerodynamic lift force capable of uplifting the aerial vehicle.

- 15 By having the fan attached to the motor system the load of the fan is also distributed through the motor system to the mounting platform and/or to the radial guide vanes, to the air duct and optionally to the first reinforcing collar and/or to the second reinforcing collar. Again, this results in a better load distribution in the propulsion system.

According to at least one embodiment, the fan is arranged inside the air duct further towards the second end of the air duct with respect to the motor system.

- 20 According to at least one embodiment, the fan is arranged on a fan region of the air duct. According to at least one embodiment, the fan region encompasses between a fifth and a third of the length of the air duct, e.g. a fourth, seen from the first end of the air duct towards the second end of the air duct.

According to at least one embodiment, the fan is arranged at a fourth of the length of the air duct seen from the first end of the air duct towards the second end of the air duct.

- 25 The more longitudinally offset the motor system is arranged with respect to the first end of the air duct towards the second end (e.g. the nearer the motor system is to the second end of the air duct) and the more longitudinally offset the fan is arranged with respect to the first end of the air duct towards the second end of the air duct (e.g. the nearer the fan is arranged to the second end of the air duct) the better the aerodynamic conditions. The ameliorated aerodynamic conditions occur because the air duct decreases the turbulence in the air flow through the air flow path and make the air flow more laminar.
- 30 This increases the efficiency of the entire propulsion system and aerial vehicle. In at least one

embodiment, the distance between the fan and the first end of the air duct, e.g. the air flow inlet, is between 10% and 30% of the total duct length. This has proven to be particularly energy efficient.

According to at least one embodiment, the fan is connected to the motor system via a shaft. According to at least one embodiment, the motor system is configured to rotate the shaft in order to rotate the fan.

According to at least one embodiment, the fan comprises a plurality of fan blades. According to at least one embodiment, the fan blades extend from the shaft radially towards the inner surface, e.g. radially outwards.

According to at least one embodiment, the fan blades are between 10 cm and 1000 cm, between 20 cm and 800 cm, between 100 cm and 500 cm, for example between 200 cm and 400 cm, long.

According to at least one embodiment, the fan blades may be equal to or more than 10 cm, 20 cm, 50 cm, 80 cm, 150 cm, 250 cm, 350 cm, 450 cm, 550 cm, 650 cm, 750 cm, 850 cm or 950 cm, long.

According to at least one embodiment, the fan blades may be equal to or less than 1000 cm, 900 cm, 800 cm, 700 cm, 600 cm, 500 cm, 400 cm, 300 cm, 200 cm, 100 cm, 70 cm, 40 cm or 15 cm long.

According to at least one embodiment, the fan blades are between 1 cm and 40 cm, between 2 cm and 30 cm, between 5 cm and 20 cm, for example between 10 cm and 15 cm, wide.

According to at least one embodiment, the fan blades may be equal to or more than 1.5 cm, 3 cm, 4 cm, 7 cm, 12 cm, 17 cm, 25 cm, or 35 cm, wide.

According to at least one embodiment, the fan blades may be equal to or less than 32 cm, 22 cm, 18 cm, 14 cm, 11 cm, 8 cm, 5 cm, 4 cm, or 3 cm wide.

According to at least one embodiment, the fan blades are arranged at an angle between 0° and 60°, e.g. 0°, 5°, 10°, 15°, 20°, 25°, 30°, 35°, 40°, 45°, 50°, 55°. with respect to a plane being perpendicular to the longitudinal axis. According to at least one embodiment, the fan blades extend between 98% and 100%, (e.g. 99%) of the radius of the circumference defined by the inner surface of the inner duct.

According to at least one embodiment, the air duct comprises further guide vanes arranged further towards the second end of the air duct than the fan, e.g. further downwards than the fan. The further guide vanes have the function of minimizing swirling of the propulsion system.

The motor system of the propulsion system comprises at least two electric motors, a first electric motor and a second electric motor. The first electric motor and the second electric motor are arranged inside the air duct, e.g. completely inside the air duct.

5 The first electric motor may be configured to operate the propulsion system, e.g. by rotating the fan, e.g. by rotating the shaft. During normal operation of the propulsion system, the first electric motor is the motor operating the fan. The first electric motor may be a main electric motor of the propulsion system.

10 According to at least one embodiment, the second electric motor may be a motor-generator. The second electric motor may be configured to rotate the fan, e.g. rotate the shaft. The second electric motor may be configured as a back-up electric motor, configured to operate the propulsion system, e.g. by rotating the fan, in case the first electric motor, e.g. the main electric motor, is malfunctioning, not functioning at all or does not have any power. There are however several other situations where it might be advantageous to use the second electric motor during normal operation of the propulsion system.

15 According to at least one embodiment, the second electric motor is configured to operate independently from the first electric motor. According to at least one embodiment, the first electric motor is configured to operate independently from the second electric motor.

20 According to at least one embodiment, the second electric motor is arranged further towards the second end of the air duct than the first electric motor, e.g. further downwards than the first electric motor. The second electric motor may be arranged between the fan and the first electric motor. Alternatively, the first electric motor may be arranged between the fan and the second electric motor. The first electric motor and/or the second electric motor may be arranged, e.g. connected, to the shaft, e.g. to the same shaft.

25 According to at least one embodiment, the propulsion system further comprises a clutch. The clutch connects both with the first electric motor and the second electric motor and with the shaft.

The clutch may be configured to disengage the first electric motor, e.g. the main motor, from the shaft.

According to at least one embodiment, the clutch is configured to allow the second electric motor to rotate the shaft without resistance from the first electric motor, when the first electric motor is disengaged from the shaft.

30 The clutch may be configured to disengage the second electric motor, e.g. the back-up motor, from the shaft.

According to at least one embodiment, the clutch is configured to allow the first electric motor to rotate the shaft without resistance from the second electric motor, when the second electric motor is disengaged from the shaft.

The provision of a second electric motor, in particular as a back-up motor, greatly increase the safety and reliability of the propulsion system. Especially if used for unmanned drones, such as VTOL UAVs, the provision of a back-up system is particularly useful, e.g. in order to prevent uncontrollable plummets, for example by bringing the propulsion system safely to ground through the use of the second electric motor, when the first electric motor has problems.

Using two electric motor, i.e. a first electric motor and a second electric motor, increases the drive train efficiency, thereby providing a more energy efficient propulsion system. The use of electric motors, e.g. of the first electric motor and of the second electric motor also decreases the need of fossil fuels thereby playing a positive impact on the environment and measures against global warming.

The use of the clutch, configured to let either the first or the second electric motor rotate the shaft without resistance of the other electric motor, further diminishes energy consumption, making the present propulsion system, greatly energy efficient, in particular during take-off and landing.

According to at least one embodiment, the second electric motor is mounted on the shaft between the first electric motor and the fan. Alternatively, the first electric motor is mounted on the shaft between the second electric motor and the fan.

These alternative positioning have proven to be particularly advantageous in the overall geometry of the propulsion system and in particular of the air duct. Arranging the first electric motor and the second electric motor on the shaft furthermore improve the overall air flow quality of the air flowing through the air flow path of the air duct. In particular it minimizes turbulences. Furthermore, mounting the first electric motor and the second electric motor on the same shaft minimizes the need of further shafts and connections of the first electric motor and/or second electric motor to the fan. It therefore leads to a more compact propulsion system and a minimization of elements and weight.

The described arrangements of the first electric motor and the second electric motor have further the advantage of improving the center of gravity of the propulsion system and therefore of the aerial vehicle. Such arrangements also require less cable length when interconnecting the features, e.g. to the battery system. This results in an improved electrical wiring interconnect system (EWIS).

According to at least one embodiment, the first electric motor and/or the second electric motor are brushless axial flux electric motors. The propulsion system is however not limited to such brushless axial flux electric motors.

According to at least one embodiment, the first electric motor and/or the second electric motor can be configured such as to not require an engine control unit (ECU). This could be achieved for example through the use of multilevel batteries. The propulsion system is however not limited to this embodiment.

- 5 According to at least one embodiment, the first electric motor and the second electric motor may be configured to simultaneously and/or independently rotate the fan, e.g. the shaft. The first electric motor and the second electric motor may for example be used, e.g. may be configured to be operated, simultaneously during take-off and landing of the aerial vehicle. During taxi the aerial vehicle may use only one electric motor, e.g. the first electric motor. Take-off and landing are operations that require
10 more power than normal taxi. Using both the first electric motor and the second electric motor is therefore advantageous.

According to at least one embodiment, the first electric motor is an axial flux brushless DC or any other type of electric engine.

- According to at least one embodiment, the propulsion system comprises a battery system. The battery
15 system may be configured to power the first electric motor and/or the second electric motor. The battery system may be configured to power any other element of the propulsion system and/or of the air vehicle requiring power, e.g. flight control system, navigation system, sensors, lights, etc..

- The battery system may comprise at least one battery pack comprising at least one battery. The battery system may comprise more than one battery pack, e.g. 2, 3, 4, 5, 6 or more battery packs. According to
20 at least one embodiment the battery system comprises four battery packs.

Each battery pack may comprise one or more battery modules, e.g. 2, 3, 4 or more battery modules. Each battery module may comprise one or more battery cells. The one or more battery cells can be cylindrical cells, pouch cells and/or prismatic cells. Different battery cells may be comprised in a battery module. Some battery modules of the battery system may have different battery cell types.

- 25 According to at least one embodiment, one or more or all battery packs and/or batteries cells of the battery pack have different characteristics. The characteristics may be one or more or all of energy, power, capacity, size and shape. According to at least one embodiment, one or more batteries pack and/or batteries of the battery pack have the same characteristics. The characteristics may be one or more or all of energy, power, capacity, size and shape. The characteristics of the one or more battery
30 packs and are however not limited to the one mentioned.

According to at least one embodiment, the battery system may be a failsafe battery storage system.

According to at least one embodiment, the battery system is located on the outer surface of the air duct. The battery system may be located in a region proximate to the second end of the air duct. The battery system may be arranged on and/or attached to the second reinforcing collar. The second reinforcing collar therefore may carry and/or bear the load of the battery system.

- 5 In certain embodiment, the load of the battery system may also be distributed to the first reinforcing collar through the reinforcing struts connecting the first reinforcing collar to the second reinforcing collar.

According to at least one embodiment, the battery system is positioned at a distance of more than 5 degrees based on the radial orientation of the fan. In particular the axial distance of the battery system
10 to the fan is between 5 degrees and 30 degrees, between 10 degrees and 20 degrees, e.g. 15 degrees, based on the radial orientation of the fan.

According to at least one embodiment, the battery system is a rechargeable battery system.

According to at least one embodiment, the battery system is configured to be replaceable. Providing a replaceable battery system has the advantage of guaranteeing a nearly continuously usable propulsion
15 system. When a battery system is empty or nearly empty, it can be replaced without requiring battery loading time. As such the propulsion system can immediately be used again with a new, e.g. full battery system. The empty battery system can be loaded independently.

According to at least one embodiment, the air duct comprises ventilation inlets and outlets configured to cool the battery system.

20 According to at least one embodiment, the propulsion system further comprises a flap system. The flap system has the function of directing the air passing through the air flow path in the air duct and escaping the air duct from the second end. The flap system thereby provides the means for yaw, roll and pitch of an aerial vehicle comprising the propulsion system.

According to at least one embodiment, the flap system is arranged in the air duct, e.g. proximate to the
25 second end of the air duct. According to at least one embodiment, the wherein the distance between the flap system and the blades of the fan, seen along the longitudinal axis is at least between 20% and 50%, e.g. 30%, 40%, of the air duct length.

The propulsion system may also comprise a servo system for example being connected to the flap system. The servo system is arranged outside of the air duct, e.g. on the second reinforcing collar.

30 According to a second aspect of the disclosure an aerial vehicle is provided, the aerial vehicle comprises the propulsion system according to one or more of the previously described embodiments. In particular

the propulsion system may be an aerial vehicle. This means that the propulsion system can function as an independent aerial vehicle, e.g. a drone. As such all feature relating to the aerial vehicle may also relate to the propulsion system, e.g. if the aerial vehicle comprises a payload compartment, the propulsion system may comprise a payload compartment, if the aerial vehicle comprises landing gear

5 the propulsion system may comprise landing gear.

The aerial vehicle may be a drone, for example a VTOL, for example an eVTOL (electrical VTOL), for example a ducted fan eVTOL UAV.

The propulsion system may be used by the aerial vehicle as a main propulsion system or as a single propulsion system. According to at least one embodiment, the aerial vehicle comprises one or more of

10 the propulsion systems of the above described embodiments.

According to at least one embodiment, the aerial vehicle comprises a housing at least partially radially surrounding the air duct, e.g. the outer surface of the air duct, of the propulsion system. The housing may be connected to the first end of the air duct, e.g. to the first reinforcing collar. In particular the housing may act as a skirt, surrounding the air duct, e.g. the outer surface of the air duct, of the

15 propulsion system from the first end of the air duct towards the second end of the air duct. The housing may for example be integrally formed with the air duct.

The housing may have an aerodynamic shape such as to promote the propulsion through air of the aerial vehicle and thereby reducing turbulences and energy consumption. This results in a more stable and predictable operation of the aerial vehicle.

20 According to at least one embodiment the housing comprises a circular main body with four recesses. The recesses may extend from the second end of the air duct towards the first end of the air duct. Parts of the air duct are visible through the recesses of the housing. This shape of the aerial vehicle, e.g. of the housing, has proven to be particularly energy efficiency during movement of the aerial vehicle through air. It also reduces the overall weight of the propulsion system and/or of the aerial vehicle.

25 The aerial vehicle, according to at least one embodiment comprises landing gear. The landing gear assists the aerial vehicle in landing and are the elements or are the only elements of the aerial vehicle touching ground when the aerial vehicle is on the ground or is landing.

The landing gear may have an aerodynamical shape. Such an aerodynamical shape may be convenient for creating or assisting in creating lift and to stabilize the aerial vehicle.

30 The landing gear may comprise landing struts extending from the fist end of the air duct, e.g. from the first reinforcing collar, towards the second end of the air duct. The landing struts may extend from the

first end of the air duct towards the second end of the air duct, e.g. downwards, and radially outwards from the first end of the air duct. The landing struts may be such, e.g. may be long enough, that in a landed position of the aerial vehicle the air duct does not contact the ground.

According to at least one embodiment the landing struts may be configured such, that in a landed position, e.g. in a position in which the aerial vehicle is on the ground, the second end of the air duct is substantially between 0 cm and 200cm, e.g. 10cm, 25 cm, 50 cm, 100 cm, 150 cm, distant from the ground.

The landing struts may be connected to the first reinforcing collar. The load borne by the first reinforcing collar, e.g. the load of the motor system, of the fan and/or of the payload compartment is therefore distributed to the landing struts and the landing struts bear the weight borne by the first reinforcing collar. This is especially useful when the aerial vehicle, e.g. the propulsion system, is on the ground. The weight of motor system, of the fan and/or of the payload compartment is distributed and borne (also) by the landing struts, therefore minimizing load spikes on single elements, e.g. on the radial guide vanes.

In embodiments in which the propulsion system comprises also a second reinforcing collar and reinforcing struts connecting the first reinforcing collar with the second reinforcing collar, the load borne by the second reinforcing collar, e.g. of the battery system, is also distributed to the landing struts.

According to at least one embodiment, the four recesses define four elements of the housing configured to at least partially cover the landing struts.

According to at least one embodiment, the aerial vehicle further comprises a payload compartment configured to carry a load to be transported by the aerial vehicle. The payload compartment may be releasably connected and/or releasably mounted to the mounting platform.

According to at least one embodiment, the payload compartment is releasably connected to the surface of the mounting platform facing the opposite side of the motor system. In other words, the payload compartment extends upwards from the mounting platform. The payload compartment, when mounted may stand out from the first end of the air duct.

According to at least one embodiment, the payload compartment has connecting means to releasably connect the payload compartment to the mounting platform. The mounting platform may have mounting means. The connecting means of the payload compartment may connect with respective mounting means on the mounting platform. The connecting means of the payload compartment may be arranged in a connecting section of the payload compartment. The payload compartment may have various shapes and configurations. It has proven to be advantageous if the sides of the payload

compartment converge towards each other in a portion of the payload compartment facing the air duct, when mounted. This ameliorates the air flow around the payload compartment during operation of the aerial vehicle, e.g. of the propulsion system.

In a mounted position the payload compartment is arranged centrally with respect to the first circumferential plane. As such, when the propulsion system is in operation and air flows into the air duct from the first end, the air flow needs to pass around the payload compartment.

The payload compartment is further configured such as to guarantee an efficient air flow into the first end of the air duct. This might be achieved through an aerodynamic shape of the payload compartment, for example through its converging section as explained above. The air flow may be substantially less turbulent and more laminar when entering the air duct.

The payload compartment may be configured to carry light weight elements, e.g. medicaments. The payload compartment may however also be configured as a cabin to transport one or more persons. As such, the whole aerial vehicle and the whole propulsion system are scalable.

According to at least one embodiment, the aerial vehicle further comprises a navigation system and/or a flight control system. In particular the payload compartment may comprise the navigation system and/or flight control system. The navigation system and/or flight control system may be arranged on an upper section of the payload compartment, e.g. in a section opposite to the contacting section of the payload compartment. As such, the navigation system and/or flight control system may be on the highest point of the aerial vehicle. This is beneficial as interferences to the navigational system, e.g. by the air duct, are minimized.

According to at least one embodiment the flight control system is arranged in the payload compartment.

According to at least one embodiment, the aerial vehicle further comprises a sensor system. In particular the payload compartment may comprise the sensor system. According to at least one embodiment, the sensor system comprises at least one of the following sensors: Radar, Lidar, RGB camera, antennas, cameras, air speed sensors, lights and more.

According to at least one embodiment, the aerial vehicle may comprise fixed wings. The fixed wings may be attached to the air duct, e.g. to the first reinforcing collar, or to the second reinforcing collar, or for example to a third reinforcing collar of the air duct, or to the payload compartment, or to a combination of the mentioned options.

Brief description of the drawings

Exemplary embodiments of the present disclosure are described in detail below with reference to the attached figures. Although the exemplary embodiments of the present disclosure are shown in the drawings, it should be understood that the present disclosure may be implemented in various forms and is not limited by the embodiments described herein.

- 5 The drawings are not necessarily to scale. In certain instances, details that are not necessary for an understanding of an embodiment or that render other details difficult to perceive may have been omitted.

The same or equally acting elements are provided with the same reference signs. In the drawings the following is illustrated in:

Figure 1 an isometric view of an exemplary embodiment of a propulsion system and aerial vehicle.

- 10 **Figure 2** a top view of an exemplary embodiment of a propulsion system and aerial vehicle.

Figure 3 a bottom view of an exemplary embodiment of a propulsion system and aerial vehicle.

Figure 4 a schematic cross section of an exemplary embodiment of a propulsion system and aerial vehicle.

- 15 **Figure 5** a schematic cross-section of an exemplary embodiment of a propulsion system and aerial vehicle.

Figure 6 a simplified schematic exemplary embodiment of an arrangement of a motor system inside an air duct in an exemplary embodiment of a propulsion system.

Description of exemplary embodiments

20

The reference numerals used in the description of **Figures 1** to **Figure 6** may be used in any one of **Figures 1** to **Figure 6**.

- 25 As can be seen from **Figure 1**, the propulsion system 10 comprises an air duct 12. The air duct 12 has a substantially cylindrical form, in particular a hollow cylindrical form. The air duct 12 in this exemplary embodiment is made of carbon fiber-reinforced plastic. The air duct 12 extends from a first end 13 towards a second end 14 along a longitudinal axis L1. The first end 13 is opposite the second end 14. As can be seen from **Figure 1** the first end 13 defines a first circumferential plane 62. The first circumferential plane 62 is substantially perpendicular to the longitudinal axis L1. The air duct further
- 30 comprises an inner surface 15 and an outer surface 16. The first end 13 defines an air flow inlet. The second end 14 defines an air flow outlet (see e.g. **Figure 5**).

The propulsion system 10 of **Figure 1** also comprises radial guide vanes 20, in particular four radial guide vanes 20 (only two visible in **Figure 1**). The radial guide vanes 20 are arranged at the first end 13 of the air duct 12. The radial guide vanes 20 extend from the inner surface 15 of the air duct 12 towards a centric longitudinal axis CL1. The centric longitudinal axis CL1 is an axis passing through the centre point of the air duct 12 and being parallel to the longitudinal axis L1. The radial guide vanes 20 therefore extends radially inwards towards the centric longitudinal axis CL1.

The propulsion system 10 and the aerial vehicle 100 of **Figure 1** comprises a first reinforcing collar (not shown). The first reinforcing collar is arranged on a section of the outer surface 16 of the air duct 12 corresponding to a section of the inner surface of the air duct 12 to which the radial guide vanes 20, e.g. the first vane end (not shown) are connected. In other words, the first reinforcing collar and the connection point of the first vane end to the inner surface 15 of the air duct 12 may lie substantially on a same plane, the plane being perpendicular to the longitudinal axis L1. As such the load on the radial guide vanes 20, for example the load of the payload compartment 400 is distributed on the first reinforcing collar.

The radial guide vanes 20 extend from the inner surface 15 of the air duct 12 towards the centric longitudinal axis CL1 of the air duct 12 along a plane perpendicular to the centric longitudinal line CL1. In other embodiments, the radial guide vanes 20 may extend from the inner surface 15 of the air duct 12 towards the centric longitudinal axis CL1 of the air duct 12 and towards the second end 14. In such an embodiment the radial guide vanes 20 form a first angle between the radial guide vanes 20 and the first circumferential plane defined by the first end 13 of the air duct 12. The angle may be 10°. In other words, the radial guide vanes 20 in such an embodiment, do not extend along a parallel plane with respect to the first circumferential plane 62.

In this exemplary embodiment, the radial guide vanes 20 are arranged radially symmetrically along the circumference of the air duct. The first end 13 is thereby divided into subsections. The radial guide vanes 20 in this exemplary embodiment have a profile mimicking a NACA profile in order to render the air flow through the first end 13, e.g. the air flow entering the air duct 12, more laminar. The first vane end, hence the end of the radial guide vane connected to the inner surface of the air duct, may comprise a wider section than in other sections. The radial guide vanes 20 are made of the same material as the air duct 12 in this exemplary embodiment. However, the material could also be different.

The radial guide vanes 20 connect to a mounting platform 22 (not shown in **Figure 1**). Specifically, each radial guide vane 20 comprises a second vane end connected to the mounting platform 22 (not shown).

The mounting platform 22 is arranged more towards the second end 14 of the air duct 12 with respect to the first circumferential plane 62 defined by the first end 13. In other words, the mounting platform

22 is longitudinally offset from the first end 13 of the air duct 12 towards the second end 14 of the air duct 12

In different embodiments, however, the mounting platform 22 may be arranged on the plane defined by the first circumferential plane 62.

- 5 In the exemplary embodiment of **Figure 1**, the propulsion system 10 also comprises a fan 40, of which only one fan blade 42 is visible in the figure. The fan 40 is configured to be rotated by the motor system (not shown) as will be shown more in detail in **Figure 5** and **Figure 6**.

As can be seen from **Figure 1** the air duct 12 also comprises a second reinforcing collar 18b. the second reinforcing collar 18b is arranged around the outer surface 16 of the air duct 12 at the second end 14.

- 10 The reinforcing collars have the function of reinforcing the air duct 12. Furthermore, the load of the elements attached directly or indirectly to the first reinforcing collar and/or second reinforcing collar 18b is at least partly distributed through the first reinforcing collar and second reinforcing collar 18b. The first reinforcing collar and the second reinforcing collar 18b are connected to each other by at least one reinforcing strut, e.g. four reinforcing struts 19 (see **Figure 5**), extending longitudinally along the
15 outer surface 16 of the air duct 12. The air duct 12 may also comprise further reinforcing collars.

- The first end 13 and the second end 14 of the air duct 12 also comprises lips 17, specifically inlet lips and outlet lips (not shown in **Figure 1**). The lips 17 are curved lips 17 being radially outwardly curved and thereby increasing the area of the air flow inlet and of the air flow outlet around the first end 13 and the second end 14. In this exemplary embodiment the inlet lips and outlet lips are built integrally with the
20 air duct 12. The inlet lips and outlet lips have both a NACA profile, or at least mimic a NACA profile.

- As can be seen in **Figure 1**, the aerial vehicle 100 comprises (or is) the propulsion system 10 and further comprises a housing 200 at least partially radially surrounding the air duct 12, e.g. the outer surface 16 of the air duct 12. The housing 200 is connected to the first reinforcing collar. In this exemplary embodiment the housing 200 is integrally formed with the air duct 12. The housing 200 has an
25 aerodynamic shape such as to promote the propulsion through the air of the aerial vehicle 100.

- In this exemplary embodiment the housing 200 comprises a substantially circular main body with four recesses 210 (only two visible). The recesses 210 extend from the second end 14 towards the first end 13 of the air duct. Parts of the air duct 12, e.g. parts of the outer surface 16 of the air duct 12, are visible through the recesses 210 of the housing 200. This shape of the housing 200, e.g. of the aerial vehicle
30 100, has proven to be particularly energy efficiency during movement of the aerial vehicle 100 through air. It also minimizes the weight of the aerial vehicle 100.

The aerial vehicle 100 in this exemplary embodiment also comprises landing gear 300. The landing gear 300 are the element contacting the ground when the aerial vehicle 100 lands or is stationed on the ground. The landing gear 300 comprises landing struts 310. The landing struts 310 extend from the first end 13 towards the second end 14 of the air duct 12 and radially outwards from the first end 13. The
5 landing gear 300, e.g. the landing struts 310 are configured long enough so that in a landed position, e.g. in a position in which the aerial vehicle is on the ground, the air duct dose not touch the ground. The air duct may be 10 cm from the ground. In other words, the landing struts 310 may be the only element touching ground.

The landing gear may have an aerodynamical shape, as for example schematically shown in Figure 1.

10 Such an aerodynamical shape may be convenient for creating or assisting in creating lift and to stabilize the aerial vehicle.

The four recesses of the housing 200 of the aerial vehicle 100 define four elements of the housing 200 configured to at least partially cover the landing struts 310. The landing struts 310 in this exemplary embodiment are substantially completely covered by the four landing elements of the housing 200 and
15 only an end section can be seen in the figure.

The aerial vehicle 100 on this exemplary embodiment also comprises a mounted payload compartment 400. The payload compartment 400 extends upwards from the mounting platform 22. The payload compartment 400 is detachable form the propulsion system 10, in particular from the mounting platform 22 (not shown). The sides of the payload compartment 400 converge towards each other in a
20 portion 420 of the payload compartment 400 facing the air duct 12, seen from the payload compartment 400 when mounted.

The aerial vehicle 100 may also comprise fixed wings. The wings may for example be attached to the air duct 12.

Figure 2 shows a top view of an exemplary embodiment of a propulsion system 10 and aerial vehicle
25 100.

As can be seen form **Figure 2**, the first end 13 of the air duct 12 defines a first circumferential plane 62. The inner surface 15 of the air duct 12 defines an air flow path 60 from the first end 13 of the air duct 12 towards the second end 14 of the air duct 12.

The propulsion system 10 of this exemplary embodiment also comprises radial guide vanes 20 (shown
30 hatched) of which all four radial guide vanes are at least partially visible. The radial guide vanes 20 extend from the inner surface 15 of the air duct 12 towards the centre of the first circumferential plane 62, in particular towards a mounting platform 22 (not shown). The radial guide vanes 20 connect to the

mounting platform 22. In this exemplary embodiment the payload compartment 400 is attached to the mounting platform 22.

The radial guide vanes 20 in this exemplary embodiment are shaped as a Y, wherein the two arms of the "Y", correspond to two first vane ends 21a and 21b. The second vane end of the radial guide vane

5 connects to the mounting platform and is not visible in the figure.

The exemplary embodiment of the propulsion system 10 further comprises a first reinforcing collar 18a. The radial guide vanes 20 are connected to a section of the inner surface 15 lying substantially on the same plane as the first reinforcing collar 18a.

10 In this exemplary embodiment sections of the four fan blades 42 of the fan 40 are also visible. Although they are represented aligned with the radial guide vanes 20 in this exemplary embodiment, the fan blades 40 are configured to be rotated by the motor system (not shown).

In this exemplary embodiment the housing 200 extending radially outwardly from the first end 13 of the air duct 12 is also visible. The "corners" of the housing 200 represent landing gear 300.

15 As can be seen from **Figure 2**, the payload compartment 400 is arranged centrally with respect to the first circumferential plane 62. The shape of the payload compartment 400 is such that less turbulences occur and the air flow around the payload compartment 400 when entering the first end 13 of the air duct 12 is more laminar.

20 **Figure 3** shows a schematic bottom view of an exemplary embodiment of a propulsion system 10 and aerial vehicle 100. Elements arranged inside the air duct 12 or visible through the air duct 12 are not depicted in **Figure 3**.

As can be seen the air duct 12 comprises a second end 14 and a second reinforcing collar 18b arranged at the second end 14 in this exemplary embodiment. The second end 14 defines a second circumferential plane 64. On the corners of the housing 200 the landing struts 310 are visible. The landing struts 310 are mostly covered by the landing element of the housing 200.

25 The outer surface 16 of the air duct 12 defines a substantially cylindrical form having a second radius. The second radius corresponds to the outer radius O_r of the hollow cylinder, e.g. of the air duct 12. The difference between the outer radius O_r and the inner radius I_r defines the thickness of the air duct 12.

In this exemplary embodiment, the inner radius I_r is 50 cm, while the outer radius O_r is 60 cm. The propulsion system 10 is, however, not limited to these radiuses.

30 In **Figure 3** also the servo system 460 for a flap system (not shown) is visible.

Figure 4 shows schematic cross section of an exemplary embodiment of a propulsions system 10 and aerial vehicle 100.

The propulsion system 10 in this exemplary embodiment comprises an air duct 12 and a housing 200 surrounding the air duct 12. The housing 200 comprises recesses (not shown) which define landing elements 300. The landing element 300 cover most of the landing struts 310.

As can be further seen from, **Figure 4** the propulsion system 10 comprises a mounting platform 22. The mounting platform 22 is attached to the air duct 12 through the radial guide vanes 20.

On the side of the mounting platform 22 facing the second end 14, the motor system 30 is attached to the mounting platform 22. The motor system 30 is configured to rotate the fan 40. The motor system 30 and the fan 40 are both located inside, e.g. completely inside the air duct 12. The fan 40 is arranged inside the air duct 12 further towards the second end 14 of the air duct 12 with respect to the motor system 30.

The fan 40 is attached to the motor system 30. The rotation of the fan 40 generates pressure difference that pulls air from the air flow inlet 12 and moves it towards the air flow outlet 14. The movement of the fan 40 generates propulsion of the propulsion system 10.

In particular, the fan 40 is arranged on a fan region of the air duct 12, the fan region being arranged at a fourth of the length of the air duct 12 seen from the first end 13 of the air duct 12 towards the second end 14 of the air duct 12.

The fan 40 is connected to the motor system 30 through a shaft 36 (not shown). The fan blades 42 of the fan 40 extend from the shaft 36 radially towards the inner surface 15, e.g. radially outwards, of the air duct 12. The fan blades in this exemplary embodiment may be 490 cm long and 20 cm wide and are arranged at an angle of 30° with respect to a plane being perpendicular to the centric longitudinal axis CL1. The fan blades 42 extend ca. 99% of the radius of the circumference defined by the inner surface 15 of the air duct 12.

The air duct 12 may comprise further guide vanes arranged further towards the second end 14 of the air duct 12 than the fan 40. Such further guide vanes are not shown in this embodiment.

The motor system 30 of the propulsion system 10 comprises a first electric motor 32 and a second electric motor 34 (not shown in detail). The first electric motor 32 is configured to operate the fan 40 independently of the second electric motor 34 and *vice versa*. The first electric motor 32 and the second electric motor 34 may however also operate the fan 40 simultaneously, for example during take-off and landing of the aerial vehicle 100

The second electric motor 34 in this exemplary embodiment is a motor-generator. The second electric motor 34 is also configured to rotate the fan 40. The second electric motor 34 is configured as a back-up electric motor, configured to operate the propulsion system 10, e.g. by rotating the fan 40, in case the first electric motor 32, e.g. the main electric motor, is malfunctioning.

5 On the opposite side of the mounting platform 22, e.g. on the side not facing the second end 14 of the air duct 12 a payload compartment 400 is attached to the mounting platform 22. The payload compartment 400 is releasably attachable to the mounting platform 22. The payload compartment 400 comprises a navigation system 430 on its end opposite the mounting platform 22. The navigation system 430 is positioned on the highest point of the aerial vehicle 100 and/or as distant as possible from the air
10 duct 12. This increase reachability of the navigation system and therefore accuracy.

The payload compartment 400 also comprises a sensor system 440. The sensor system 440 comprises in this exemplary embodiment at least a camera 440.

The aerial vehicle 100 also comprises flap system 450 and a servo system 460 connected to the flap system 450.

15 The flap system 450 has the function of directing the air passing through the air flow path in the air duct 12. The flap system 450 provides the means for yaw, roll and pitch of the aerial vehicle 100 comprising the propulsion system 10. The flap system 450 is arranged in the air duct 12, e.g. proximate to the second end 14 of the air duct 12.

The distance between the flap system and the blades of the fan, seen along the longitudinal axis is at
20 20% of the longitudinal length of the air duct 12.

Figure 5 shows a schematic cross-section of the exemplary embodiment of **Figure 4**, where the propulsions system 10 and aerial vehicle 100 are rotated by 90°. Only the additional visible features compared to **Figure 4** will be described.

On the outer surface 16 of the air duct 12, towards the second end 14, a battery system 50 is attached
25 to the propulsion system 10. The battery system 50 is configured to power the motor system 30, e.g. the first electric motor 32 and the second electric motor 34 (not shown) and further systems such as the flight control system, navigation system, sensors and the servos.

In this exemplary embodiment the battery system 50, comprises four battery packs 52 (only two visible). The two visible battery packs are arranged radially opposite to each other on the outer surface 16 of the
30 air duct 12. The other two battery packs are arranged radially opposite to each other on the outer surface 16 of the air duct, 90 degrees rotated compared to the two battery packs visible in the figure. In

this exemplary embodiment the battery packs 52 of the battery system 50 have the same characteristics, e.g. sizes. In other embodiments they might have different characteristics, e.g. size and different amount. Each battery pack can comprise multiple battery modules, e.g. in this configuration each battery pack comprises 3 battery modules. Each battery module comprises multiple battery cells.

- 5 The battery cells can be of cylindrical shape, pouch, and/or prismatic, e.g. be cylindrical cells, pouch cells and/or prismatic cells.

In the exemplary embodiment of **Figure 5**, the propulsion system 10 further comprises struts 19, which connect a first reinforcing collar and a second reinforcing collar (not shown). The struts 19 extend along the outer surface 16 of the air duct 12, longitudinally from the first reinforcing collar to the second reinforcing collar.

In **Figure 5** the air flow through the air duct 12, e.g. during take-off, is shown through arrows 60. The air enters from the first end 13 into the air duct. This is achieved through operation of the fan 40. Inlet lips 17, which in this exemplary embodiment are an integral part of the air duct 12, and are curved radially outwardly, increase the air flow inlet through the first end 13 of the air duct 12. The air flow passes through the air duct 12 and leaves the air duct 12 from the second end 14. The flap system 450 may give the air flow different directions. In the simplified schematic view of **Figure 5** the air is pushed straight downwards.

Figure 6 shows a simplified schematic exemplary embodiment of an arrangement of a motor system inside an air duct in an exemplary embodiment of a propulsion system 10.

20 The air duct 12 in this figure is shown only in parts and schematically through dashed lines. The air duct has an inner surface 15 of which only a portion is shown. The propulsion system 10 in this exemplary embodiment comprises four radial guide vanes 20 arranged at the first end 13 of the air duct 12 (only three visible). The radial guide vanes 20 are attached to the inner surface 15 of the air duct 12. The radial guide vanes 20 extend radially inwards from the inner surface 15 towards a mounting platform 22. The radial guide vanes 20 are connected to the mounting platform 22. The mounting platform 22 in this exemplary embodiment has a circular form.

On one side of the mounting platform 22, e.g. on the side facing the second end 14 of the air duct 12 a motor system 30 is attached to the mounting platform 22. The motor system 30 is inside, e.g. completely inside the air duct. The motor system 30 comprises a first electric motor 32 and a second electric motor 34. The first electric motor 32 and the second electric motor 34 are encased in a cylindrical housing. In this exemplary embodiment the cylindrical housing has a diameter smaller than the diameter of the mounting platform 22. Bigger cylindrical housings may however be envisaged.

The propulsion system 10 further comprises a fan 40 inside the air duct 12. The motor system is configured to rotate the fan 40. The fan 40 is attached to the motor system, e.g. to the first electric motor 32 and the second electric motor 34, through a shaft 36. The motor system 30, e.g. the first electric motor 32 and the second electric motor 34 are configured to rotate the shaft 36 in order to rotate the fan 40.

The propulsion system 10 further comprises a clutch (not shown). The clutch connects both with the first electric motor 32 and the second electric motor 34 and with the shaft 36. The clutch is configured to disengage the first electric motor 32 from the shaft 36. The clutch is configured to allow the second electric motor 34 to rotate the shaft 36 without resistance from the first electric motor 32, when the first electric motor 32 is disengaged from the shaft 36.

In this exemplary embodiment the clutch is also configured to disengage the second electric motor 34, e.g. the back-up motor, from the shaft 36. The clutch is configured to allow the first electric motor 32 to rotate the shaft 36 without resistance from the second electric motor 34, when the second electric motor 34 is disengaged from the shaft 36. Both the first and the second electric motor can operate simultaneously the fan. This is may for example be used during take-off.

The second electric motor 34 is attached to the shaft 36 between the fan 40 and the first electric motor 32. In this figure the shaft 36 is represented particularly long just for reasons of clarity and understanding the construction. Sizes and distances are however not representative in this or in any other figure.

Reference Signs

10	propulsion system
12	air duct
13	first end
14	second end
15	inner surface
16	outer surface
17	lips
18a	first reinforcing collar
18b	second reinforcing collar
19	reinforcing struts
20	radial guide vanes
21, 21a, 21b	first guide vane end
22	mounting platform
30	motor system
32	first electric motor
34	second electric motor
36	shaft
40	fan
42	fan blades
50	battery system
52	battery pack
60	air flow path
62	first circumferential plane
64	second circumferential plane
100	aerial vehicle
200	housing
210	recess
300	landing gear
310	landing struts
400	payload compartment
420	converging sections
430	navigation system
440	sensor system
450	flap system

460	servo system
Ir	inner radius air duct
Or	outer radius
L1	longitudinal axis
CL1	centric longitudinal axis.

Claims

1. A propulsion system (10) for an aerial vehicle (100) comprising:

an air duct (12) comprising a first end (13) and a second end (14), the air duct (12) extending along a longitudinal axis (L1) from the first end (13) to the second end (14),

5 a fan (40), and

a motor system (30) configured to rotate the fan (40), the motor system (30) comprising a first electric motor (32) and a second electric motor (34),

wherein the fan (40) and the motor system (30) are arranged inside the air duct (12).

10 2. The propulsion system (10) according to claim 1, further comprising at least two radial guide vanes (20) arranged at the first end (13) of the air duct (12), wherein the at least two radial guide vanes (20) extend from an inner surface (15) of the air duct (12) in a radially inwards direction.

3. The propulsion system (10) according to claim 1 or 2, further comprising a mounting platform (22), wherein the motor system (30) is attached to the mounting platform (22) and/or wherein the at least two radial guide vanes (20) are connected to the mounting platform (22).

15 4. The propulsion system (10) according to claim 3, wherein the mounting platform (22) is longitudinally offset towards the second end (14) of the air duct (12) with respect to the first end (13).

5. The propulsion system (10) according to any one of the preceding claims wherein the air duct (12) comprises a first reinforcing collar (18a) and/or a second reinforcing collar (18b), wherein the first reinforcing collar (18a) and/or the second reinforcing collar (18b) are arranged on an outer surface
20 (16) of the air duct (12),

wherein the first reinforcing collar (18a) is arranged at the first end (13) of the air duct (12) and/or wherein the second reinforcing collar (18b) is arranged at the second end (14) of the air duct (12).

6. The propulsion system (10) according to claim 5, when dependent on claim 2, wherein the first reinforcing collar (18a) on the outer surface (16) of the air duct (12) and the section of the inner
25 surface (15) of the air duct (12) to which the radial guide vanes (20) are connected to, lie substantially on a same plane, the plane being perpendicular to the longitudinal axis.

7. The propulsion system (10) of any one of claims 5 to 6, further comprising landing gear (300), the landing gear (300) comprising landing struts (310) extending from the first end (13) of the air duct (12)

towards the second end (14) of the air duct (12), wherein the landing struts (310) are connected to the first reinforcing collar (18a).

8. The propulsion system (10) of claim 7, wherein the landing gear (300) have an aerodynamical shape configured to create lift and/or configured to balance the propulsion system (10)

5 9. The propulsion system (10) according to any one of the preceding claims, wherein the fan (40) is connected to the motor system (30) via a shaft (36), and wherein the first electric motor (32) and the second electric motor (34) are configured to rotate the shaft (36) in order to rotate the fan (40).

10 10. The propulsion system (10) according to claim 9, further comprising a clutch, wherein the clutch is configured to disengage the first electric motor (32) and/or the second electric motor (34) from the shaft (36) and/or wherein the second electric motor (34) is mounted on the shaft between the first electric motor (32) and the fan (40).

11. The propulsion system (10) according to any one of the preceding claims, the fan (40) is arranged inside the air duct (12) further towards the second end (14) of the air duct (12) with respect to the motor system (30).

15 12. The propulsion system (10) according to any one of the preceding claims, further comprising a battery system (50), the battery system (50) being configured to power the first electric motor (32) and/or the second electric motor (34).

13. The propulsion system (10) according to claim 12, wherein the battery system (50) is located on the outer surface of the air duct (12) proximate to the second end (14) of the air duct (12).

20 14. The propulsion system (10) according to any one of claims 12 or 13 when dependent on claim 5, wherein the battery system (50) is attached to the second reinforcing collar (18b).

15. The propulsion system (10) according to any one of the preceding claims, wherein the first electric motor (32) and the second electric motor (34) are configured to simultaneously rotate the fan (40).

16. Aerial vehicle (100) comprising the propulsion system (10) of any one of the preceding claims.

25 17. The aerial vehicle (100) according to claim 16, further comprising a payload compartment (400) configured to carry a load to be transported by the aerial vehicle (100).

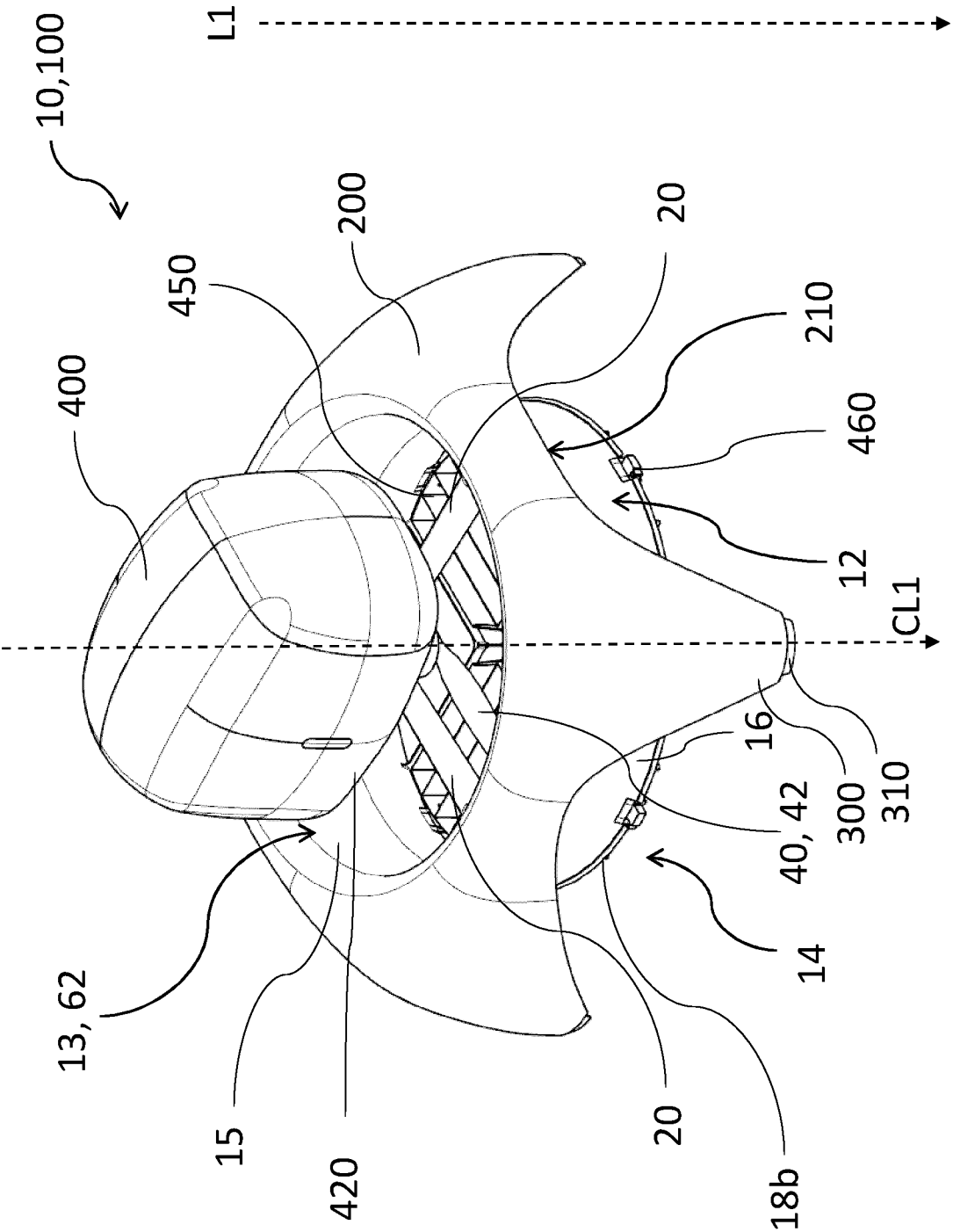


Figure 1

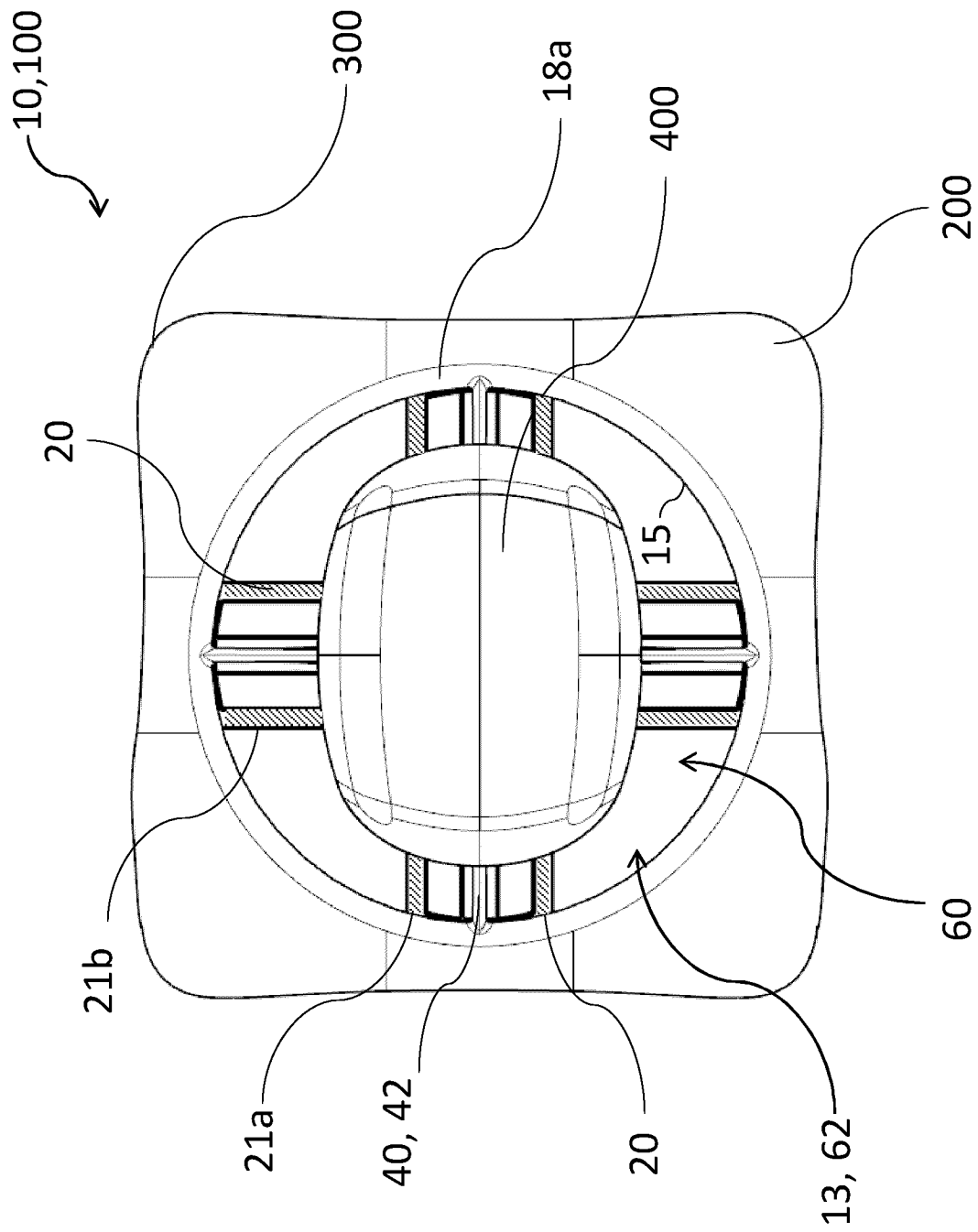


Figure 2

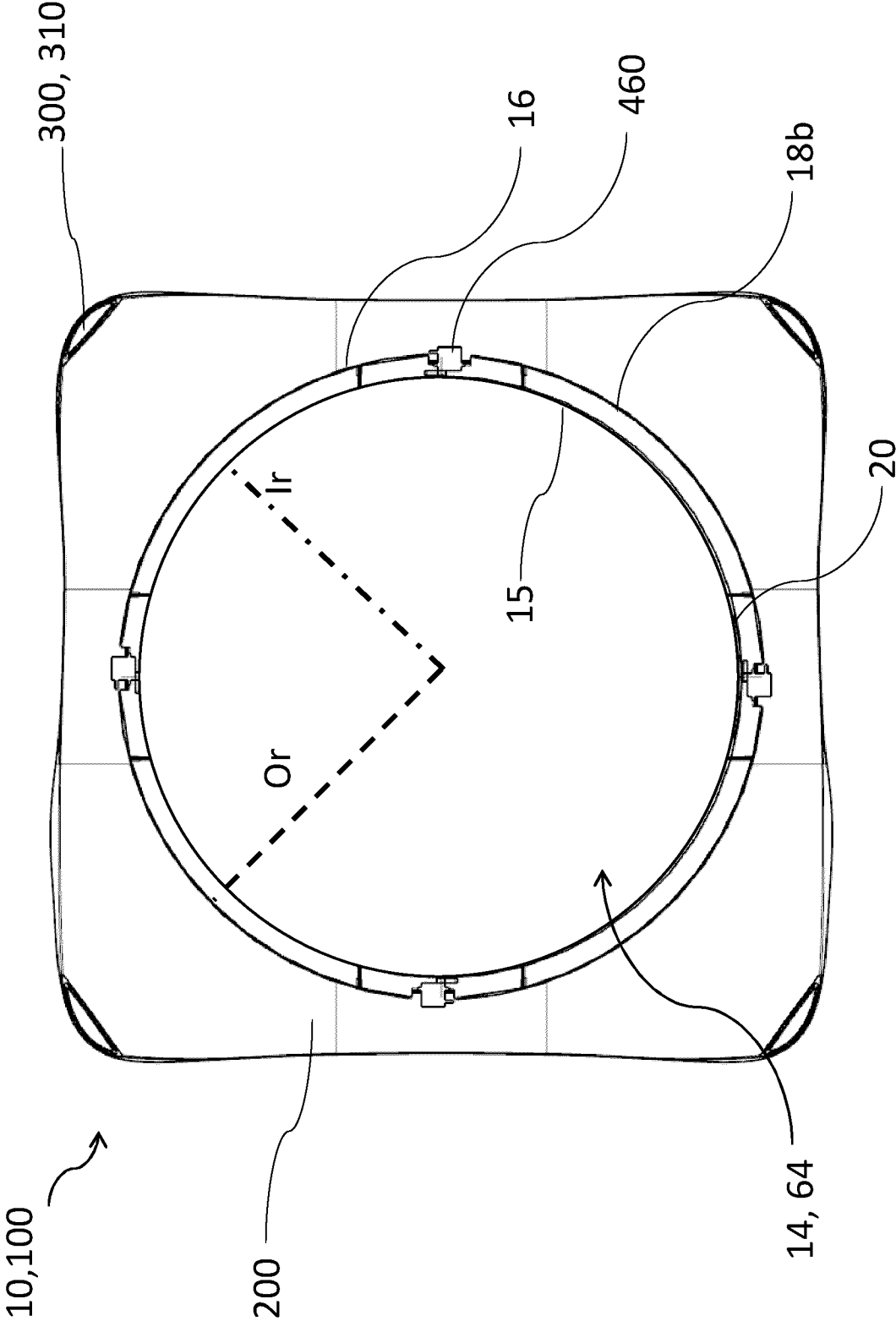


Figure 3

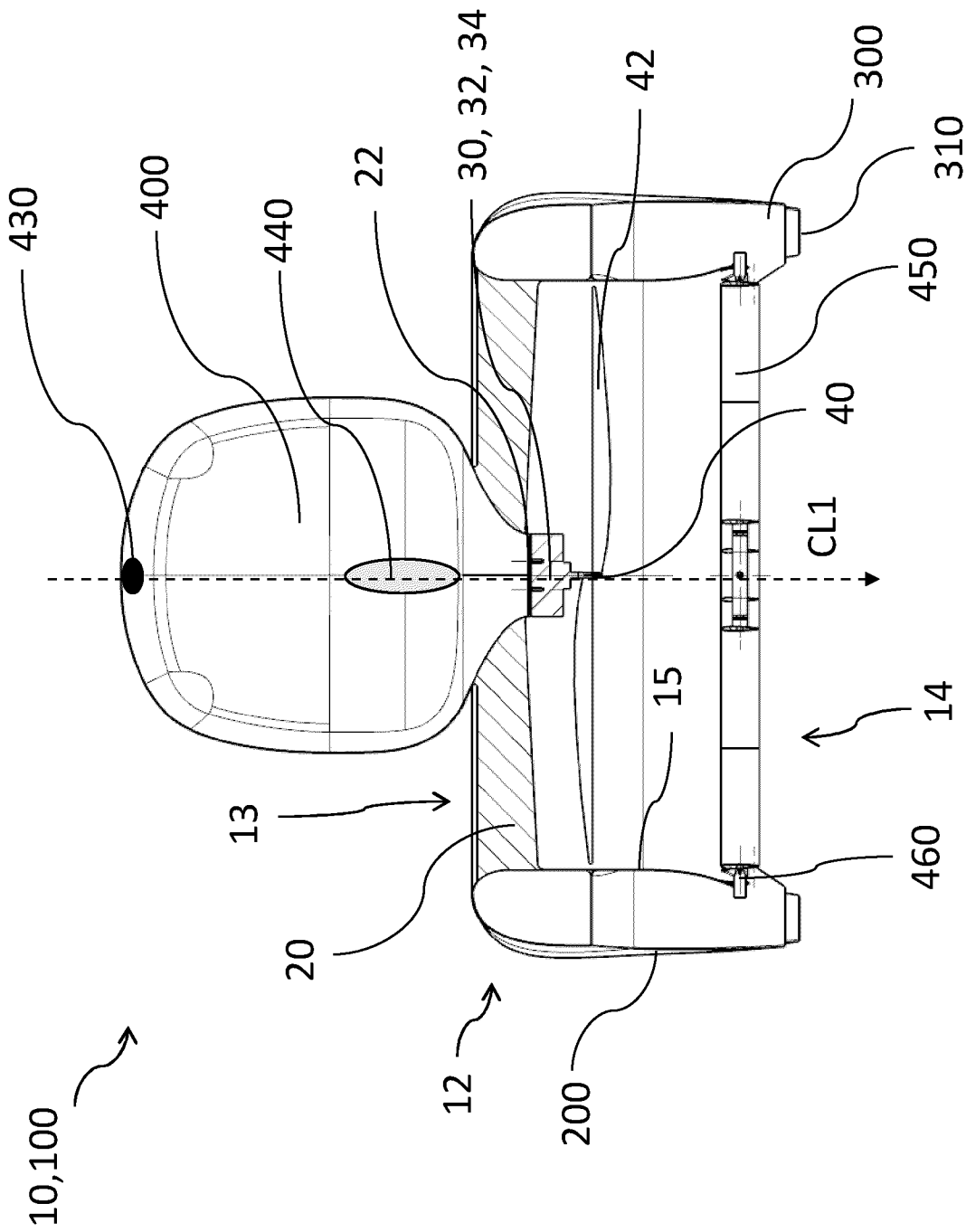


Figure 4

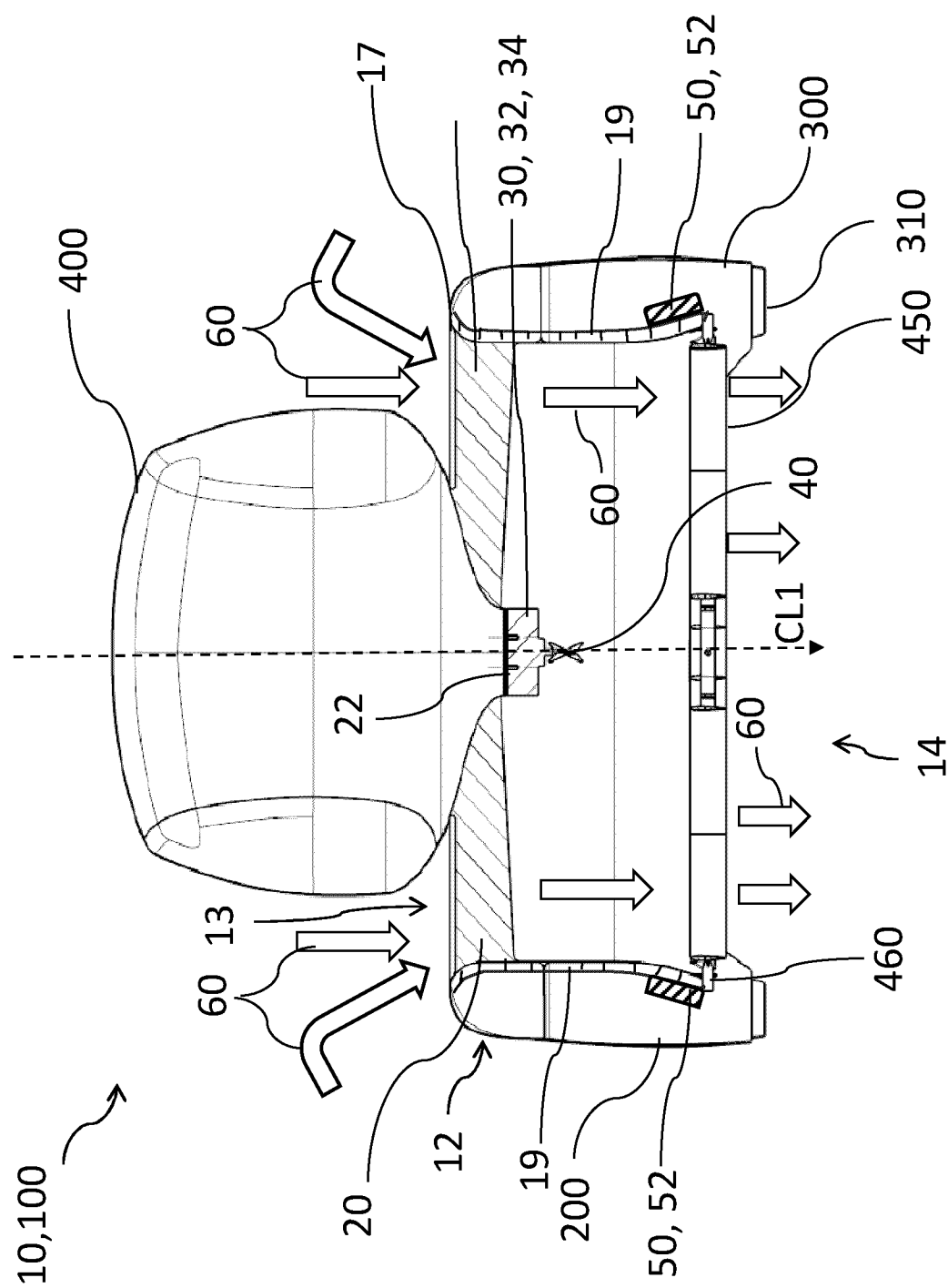


Figure 5

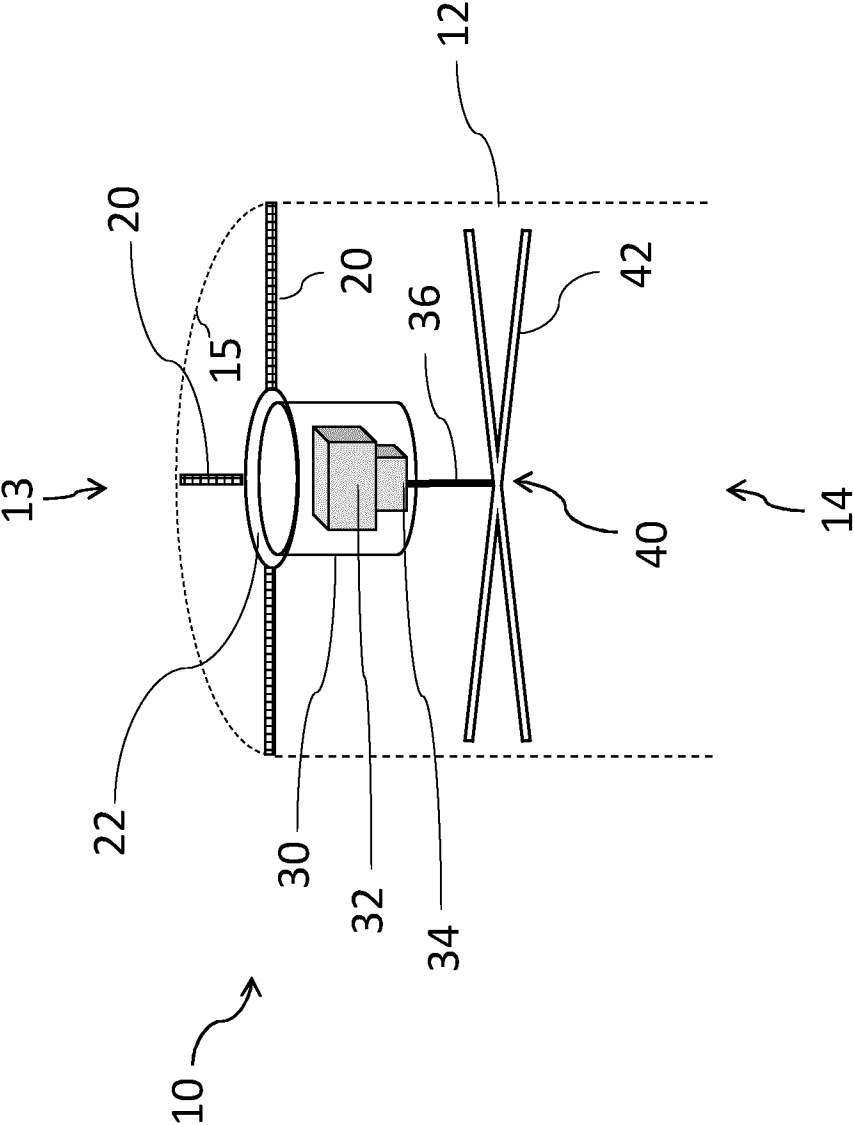


Figure 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2024/066640

A. CLASSIFICATION OF SUBJECT MATTER		
INV.	B64U30/26	B64C11/00
	B64D27/24	B64D35/08
	B64U50/19	B64U10/10
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)		
B64U 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		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2022/274715 A1 (BEALL GRANT [US] ET AL) 1 September 2022 (2022-09-01) paragraph [0002] paragraphs [0020] - [0033] claims 1,2 figures	1-6,9-17
X	US 2017/217600 A1 (REGEV EYAL [IL]) 3 August 2017 (2017-08-03)	1,5,9, 10,12-16
Y	paragraph [0002] paragraphs [0107] - [0128] claims 1,15 figures	7,8
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☒ See patent family annex.		
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Date of the actual completion of the international search		Date of mailing of the international search report
12 July 2024		30/07/2024
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Weber, Carlos

INTERNATIONAL SEARCH REPORT

International application No

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X	US 2020/407052 A1 (PREISSER GERO [DE]) 31 December 2020 (2020-12-31) paragraph [0002] paragraphs [0063] - [0097] figures -----	1, 5, 9, 12-17
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