

- 1 -

WING MODULE FOR AIR VEHICLE

TECHNOLOGICAL FIELD

This invention relates to wing systems for an air vehicle, in particular to wing systems having deployable wing elements.

BACKGROUND

Some types of air vehicles, for example some types of unmanned air vehicles (UAVs), are configured as subsonic air vehicles. In some cases, the air vehicle is launched with the lift-generating wings folded in close proximity to the fuselage, and the wings are subsequently deployed to enable aerodynamic flight. In at least some such examples, the air vehicle also has a deployable empennage.

Some examples of existing air vehicles having a deployable appendage include: Lockheed Martin Outrider; Area-I ALTIUS family; Green Dragon (IAI); UVision Hero 120; SkyStriker; VXAerospace Dash X; AeroVironment Switchblade; MBDA Viper Strike.

By way of non-limiting example, on-line publication "<https://iopscience.iop.org/article/10.1088/1742-6596/1005/1/012015/pdf>" discloses a tube Launched UAV with expandable tandem-wing configuration. Folding wing mechanism is used due to the requirements that the UAV should be folded into tubular launcher. This paper focuses on investigating the aerodynamics characteristics because of the effects of folding wing mechanism, tandem wing configuration, and rapid deploying process from tube launcher.

Also by way of non-limiting example, US9108713 discloses a system comprising an aerial vehicle or an unmanned aerial vehicle (UAV) configured to control pitch, roll, and/or yaw via airfoils having resiliently mounted trailing edges opposed by fuselage-house deflecting actuator horns. Embodiments include one or more rudder elements

- 2 -

which may be rotatably attached and actuated by an effector member disposed within the fuselage housing and extendible in part to engage the one or more rudder elements.

Also by way of non-limiting example, on-line publication "<https://journals.sagepub.com/doi/pdf/10.1177/1687814017692290>" discloses a morphing unmanned aerial vehicle with tandem-wing configuration that could fold into a tubular catapult and deploy the four airfoils after launching. Because of the rapid deploying process, the aerodynamic characteristics will become largely different.

Also by way of non-limiting example, CN107380402 discloses an unmanned aerial vehicle with folding wings. The unmanned aerial vehicle with the folding wings comprises a fuselage, the wings, horizontal tails, vertical tails, a folding wing releasing mechanism and a fixing base, and positioning holes are formed in the wings, the horizontal tails and the vertical tails; and positioning clamp columns are arranged on the fixing base, and the positioning clamp columns are matched with the positioning holes.

Also by way of non-limiting example, CN106741847 discloses a launching type unmanned aerial vehicle (UAV) and a system and an implementing method thereof, and relates to the technical field of launched UAVs. The launched UAV is characterized in that the flying states are different in a launching stage and an autonomous flying stage; the flying speed of the UAV can be decreased through an own power and/ or resistance structure so as to enter a flying state of an inverse launching stage from the flying state of the launching stage; after passing through the inverse launching stage, the UAV enters the autonomous flying stage and can enter the flying state that the UAV flies by own power while arriving at or being close to a target place. According to the launching type UAV, the shape and/ or the power is different in different stage, so that the convenience of storing, transporting and launching is ensured, and the convenience of scouting and locating can also be ensured; and the flying, scouting and fighting capacities of the UAV under a complex environment can be improved to a certain extent.

Also by way of non-limiting example, US 2006/163423 discloses a missile having fins that rotate about a single axis to deploy from a stowed position to a deployed position. A foil longitudinal axis of each fin is angled relative to a shaft of the fin, such that a single-axis rotation of the shaft moves the foil from the stowed position to a deployed position. A coil spring may provide both torsion and compression forces to rotate the fin

- 3 -

into the deployed position and lock it into place. Torsion rotates the shaft until it reaches a seat on a bushing that is around the shaft. Then compression forces from the spring engage a keyed protrusion on the shaft with a corresponding keyway in the bushing, locking the shaft in place. There may be an additional lock once the fin is deployed, such as a spring-loaded pin in the missile body that engages a depression in the shaft.

GENERAL DESCRIPTION

According to a first aspect of the presently disclosed subject matter, there is provided a wing system for an air vehicle, the air vehicle having a fuselage including a fuselage section and a fuselage longitudinal axis, the wing system comprising at least one wing deployment module, each wing deployment module comprising:

- a set of wing elements, including at least a first said wing element having a first wing element longitudinal axis, and a second said wing element having a second wing element longitudinal axis;

- each said wing deployment module configured for selectively transitioning between a respective stowed configuration and a respective deployed configuration;

- wherein in the stowed configuration, the first wing element and the second wing element are in overlying relationship such that the first wing element longitudinal axis and the second wing element longitudinal axis are nominally parallel with one another; and

- wherein in the deployed configuration, the first wing element is oriented with respect to the second wing element such that the first wing element longitudinal axis is non-parallel with respect to the second wing element longitudinal axis.

For example, in the stowed configuration, the first wing element and the second wing element are configured in said overlying relationship for being oriented with respect to the fuselage section such that the first wing element longitudinal axis and the second wing element longitudinal axis are each nominally parallel with the fuselage longitudinal axis.

- 4 -

Additionally or alternatively, for example, in the deployed configuration, the first wing element is oriented with respect to the fuselage section such that the first wing element longitudinal axis is non-parallel with respect to the fuselage longitudinal axis.

Additionally or alternatively, for example, in the deployed configuration, the first wing element is oriented with respect to the fuselage section such that the first wing element longitudinal axis is orthogonal with respect to the fuselage longitudinal axis.

Additionally or alternatively, for example, in the deployed configuration, the second wing element is oriented with respect to the fuselage section such that the second wing element longitudinal axis is non-parallel with respect to the fuselage longitudinal axis.

Additionally or alternatively, for example, in the deployed configuration, the second wing element is oriented with respect to the fuselage section such that the second wing element longitudinal axis is orthogonal with respect to the fuselage longitudinal axis.

Additionally or alternatively, for example, in the deployed configuration, the first wing element longitudinal axis is nominally parallel with the pitch axis of the air vehicle.

Additionally or alternatively, for example, each wing deployment module is configured for having the first wing element relatively outboard, and the second wing element relatively inboard, with respect to the fuselage section.

Additionally or alternatively, for example, each wing deployment module in the stowed configuration comprises a first wing root of the first wing element in overlying relationship with respect to a second wing root of the second wing element.

Additionally or alternatively, for example, each wing deployment module comprises a first wing tip and a first root of the first wing element, and a second wing tip and a second wing root of the second wing element, and wherein each wing deployment

- 5 -

module is configured such that in the stowed configuration the first wing tip is forward of the first wing root, and/or the second wing tip is forward of the second wing root, with respect to the air vehicle.

Additionally or alternatively, for example, each wing deployment module in the stowed configuration is configured for providing the first wing element and the second wing element in overlying relationship with respect to the fuselage section.

Additionally or alternatively, for example, for each wing deployment module: each said first wing element is configured for being transitioned between the stowed configuration and the deployed configuration by:

- pivoting said first wing element about a first module pivot axis by a non-zero first module angular displacement, and
- pivoting said first wing element about a first wing element pivot axis by a non-zero first wing element angular displacement;

each said second wing element is configured for being transitioned between the stowed configuration and the deployed configuration by:

- pivoting said second wing element about a second module pivot axis by a non-zero second module angular displacement.

In at least some examples, for each wing deployment module, each said second wing element is further configured for being transitioned between the stowed configuration and the deployed configuration by:

- pivoting said second wing element about a second wing element pivot axis by a non-zero second wing element angular displacement.

Additionally or alternatively, for example, at least one of said first module pivot axis and said second module pivot axis is parallel to a pitch axis of the air vehicle.

Additionally or alternatively, for example, said first wing element pivot axis and said second wing element pivot axis are parallel to one another.

Additionally or alternatively, for example, said first module pivot axis and said second module pivot axis are co-axial.

- 6 -

Additionally or alternatively, for example, at least one of said first wing element pivot axis and said second wing element pivot axis is parallel to a roll axis of the air vehicle.

Additionally or alternatively, for example, said first module angular displacement is between 80° and 100° .

Additionally or alternatively, for example, said first module angular displacement is about 90° .

Additionally or alternatively, for example, said first module angular displacement is such as to enable the first wing element to adopt a non-zero incidence angle in the deployed configuration.

Additionally or alternatively, for example, said second module angular displacement is between 80° and 100° .

Additionally or alternatively, for example, said second module angular displacement is about 90° .

Additionally or alternatively, for example, said first module angular displacement and said second module angular displacement are equal to one another.

Additionally or alternatively, for example, said wing deployment module is configured for pivoting as a unit about at least one of said first module pivot axis and said second module pivot axis.

Additionally or alternatively, for example, said first wing element angular displacement is between 70° and 110° .

Additionally or alternatively, for example, said first wing element angular displacement is about 90° .

Additionally or alternatively, for example, said second wing element angular displacement is between -20° and $+20^{\circ}$.

- 7 -

Additionally or alternatively, for example, in some examples said second wing element angular displacement is about 15° , while in other examples, said second wing element angular displacement is about 0° .

Additionally or alternatively, for example, the wing system in at least a first example is configured for deploying the wing deployment module from the stowed configuration to the deployed configuration by:

- (a) concurrently pivoting the first wing element about the first module pivot axis by said non-zero first module angular displacement and the second wing element about the second module pivot axis by said non-zero second module angular displacement;
- (b) subsequent to step (a), pivoting said first wing element about the first wing element pivot axis by said non-zero first wing element angular displacement.

For example, the wing system is further configured for deploying the wing deployment module from the stowed configuration to the deployed configuration by:

- (c) subsequent to step (a), pivoting said second wing element about the second wing element pivot axis by said non-zero second wing element angular displacement.

Alternatively, for example, the wing system in at least one second example is configured for deploying the wing deployment module from the stowed configuration to the deployed configuration by:

- (a) concurrently pivoting the first wing element about the first module pivot axis to a first partial first module angular displacement, and the second wing element about the second module pivot axis to a first partial second module angular displacement;
- (b) subsequent to step (a), pivoting said first wing element about the first wing element pivot axis by said non-zero first wing element angular displacement, while concurrently pivoting the first wing element about the first module pivot axis to a second partial first module angular displacement, and the

- 8 -

second wing element about the second module pivot axis to a second partial second module angular displacement;

(c) subsequent to step (b), concurrently pivoting the first wing element about the first module pivot axis to said first module angular displacement, and the second wing element about the second module pivot axis to said second module angular displacement;

wherein said second partial first module angular displacement is less than said non-zero first module angular displacement and greater than said first partial first module angular displacement, and

wherein said second partial second module angular displacement is less than said non-zero second module angular displacement and greater than said first partial second module angular displacement.

In alternative variations of this example, said second partial first module angular displacement is equal to said non-zero first module angular displacement, and/or, said second partial second module angular displacement is equal to said non-zero second module angular displacement.

Alternatively, for example, the wing system in at least one third example is configured for deploying the wing deployment module from the stowed configuration to the deployed configuration by:

(a1) pivoting the first wing element about the first module pivot axis to a first partial first module angular displacement;

(b1) subsequent to step (a1), pivoting said first wing element about the first wing element pivot axis by said non-zero first wing element angular displacement, and pivoting the first wing element about the first module pivot axis to a second partial first module angular displacement;

(c1) subsequent to step (b2), respectively pivoting the first wing element about the first module pivot axis to said first module angular displacement;

wherein said second partial first module angular displacement is less than said non-zero first module angular displacement and greater than said first partial first module angular displacement.

- 9 -

Alternatively, for example, the wing system in at least one fourth example is configured for deploying the wing deployment module from the stowed configuration to the deployed configuration by:

(a2) pivoting the second wing element about the second module pivot axis to a first partial second module angular displacement;

(b2) subsequent to step (a2), pivoting the second wing element about the second module pivot axis to a second partial second module angular displacement;

(c2) subsequent to step (b2), pivoting the second wing element about the second module pivot axis to said second module angular displacement;

wherein said second partial second module angular displacement is less than said non-zero second module angular displacement and greater than said first partial second module angular displacement.

For example, step (a1) can be concurrent with step (a2). Additionally or alternatively, for example, step (b1) can be concurrent with step (b2). Additionally or alternatively, for example, step (c1) can be concurrent with step (c2).

For example, the wing system according to the second, third or fourth example is further configured for deploying the wing deployment module from the stowed configuration to the deployed configuration by further including in step (b), step (b1) or step (b2), respectively:

(d) pivoting said second wing element about the second wing element pivot axis by said non-zero second wing element angular displacement.

Additionally or alternatively, for example, each said wing deployment module is configured for being mounted to a lateral side of the fuselage section.

Additionally or alternatively, for example, each said wing deployment module is configured with a respective maximum width in the stowed configuration correlated with a fuselage height of the fuselage section.

- 10 -

Additionally or alternatively, for example, the wing system comprises two said wing deployment modules, including a first said wing deployment module configured for being mounted to the air vehicle at a port side of the fuselage section, and a second said wing deployment module configured for being mounted to the air vehicle at a starboard side of the fuselage section.

Additionally or alternatively, for example, the wing system is configured as an empennage for the air vehicle. For example, for each said wing deployment module, the first wing element is configured as a horizontal stabilizer, and the second wing element is configured as a vertical stabilizer. For example, for each said wing deployment module, the first wing element comprises an actuable elevator, and the second wing element comprises an actuable rudder. Alternatively, for each said wing deployment module, the first wing element is configured as an actuable monoblock elevator, and the second wing element is configured as an actuable monoblock rudder.

Additionally or alternatively, for example, said fuselage section is an aft fuselage section of the air vehicle.

According to the first aspect of the presently disclosed subject matter, there is also provided a wing system configured as an empennage for an air vehicle, the air vehicle having a fuselage including a fuselage section and a fuselage longitudinal axis, the wing system comprising at least one wing deployment module, each wing deployment module comprising:

- a set of wing elements, including at least a first said wing element configured as a horizontal stabilizer and having a first wing element longitudinal axis, and a second said wing element configured as a vertical stabilizer having a second wing element longitudinal axis;

- each said wing deployment module configured for selectively transitioning between a respective stowed configuration and a respective deployed configuration;

- wherein in the stowed configuration, the first wing element and the second wing element are in overlying relationship such that the first wing element longitudinal axis and the second wing element longitudinal axis are nominally parallel with one another;

- 11 -

wherein in the deployed configuration, the first wing element is oriented with respect to the second wing element such that the first wing element longitudinal axis is non-parallel with respect to the second wing element longitudinal axis;

wherein each said first wing element is configured for being transitioned between the stowed configuration and the deployed configuration by:

- pivoting said first wing element about a module pivot axis by a non-zero module angular displacement, and
- pivoting said first wing element about a first wing element pivot axis by a non-zero first wing element angular displacement; and

wherein each said second wing element is configured for being transitioned between the stowed configuration and the deployed configuration by at least:

- pivoting said second wing element about said module pivot axis by said non-zero module angular displacement.

For example, in the deployed configuration, the first wing element is oriented with respect to the second wing element such that the first wing element can operate as a horizontal stabilizer, and such that the second wing element can operate as a vertical stabilizer.

In at least some examples, for each wing deployment module, each said second wing element is further configured for being transitioned between the stowed configuration and the deployed configuration by:

- pivoting said second wing element about a second wing element pivot axis by a non-zero second wing element angular displacement.

For example, for each said wing deployment module, the first wing element comprises an actuatable elevator, and the second wing element comprises an actuatable rudder. Alternatively, for each said wing deployment module, the first wing element is configured as an actuatable monoblock elevator, and the second wing element is configured as an actuatable monoblock rudder.

Additionally or alternatively, for example, said fuselage section is an aft fuselage section of the air vehicle.

- 12 -

Additionally or alternatively, for example, said module angular displacement is between 80° and 100° .

Additionally or alternatively, for example, said module angular displacement is about 90° .

Additionally or alternatively, for example, said module angular displacement is such as to enable the first wing element to adopt a non-zero incidence angle in the deployed configuration.

Additionally or alternatively, for example, said wing deployment module is configured for pivoting as a unit about at least one of said first module pivot axis and said second module pivot axis.

Additionally or alternatively, for example, said first wing element angular displacement is between 70° and 110° .

Additionally or alternatively, for example, said first wing element angular displacement is about 90° .

Additionally or alternatively, for example, said second wing element angular displacement is between -20° and $+20^{\circ}$.

Additionally or alternatively, for example, in some examples said second wing element angular displacement is about 15° , while in other examples, said second wing element angular displacement is about 0° .

Additionally or alternatively, for example, each said wing deployment module is configured for being mounted to a lateral side of the fuselage section.

According to a second aspect of the presently disclosed subject matter, there is provided an air vehicle comprising a wing system as defined herein regarding the first aspect of the presently disclosed subject matter.

For example, the air vehicle further comprises a deployable wing arrangement, including at least one aerodynamic lift generating wing, deployable from a stowed wing configuration to a deployed wing configuration, wherein said at least one aerodynamic lift generating wing is configured for generating sufficient aerodynamic lift for

- 13 -

aerodynamic flight for the air vehicle, the deployable wing arrangement being mounted in one of above and below with respect to the fuselage section. For example, the deployable wing arrangement is mounted below with respect to the fuselage section, and wherein in the stowed configuration the first wing element and the second wing element of each wing deployment module are configured such as to avoid projecting in a downwardly direction past the wing arrangement.

Additionally or alternatively, for example, the air vehicle is configured for being accommodated in a fairing when the wing system is in the stowed configuration.

According to a second aspect of the presently disclosed subject matter, there is provided a method for providing stability and control for an air vehicle, comprising:

- providing an air vehicle as defined herein regarding the second aspect of the presently disclosed subject matter;
- deploying each said wing deployment module from the stowed configuration to the deployed configuration;
- actuating the first wing element and the second wing element of each wing deployment module to provide control moments to the air vehicle.

According to a third aspect of the presently disclosed subject matter, there is provided a method for operating a wing system for an air vehicle, comprising:

- (A) providing an air vehicle as defined herein regarding the second aspect of the presently disclosed subject matter;
- (B) deploying each said wing deployment module from the stowed configuration to the deployed configuration.

For example, step (B) comprises:

- pivoting said first wing element about a first module pivot axis by a non-zero first module angular displacement,
- pivoting said first wing element about a first wing element pivot axis by a non-zero first wing element angular displacement;
- pivoting said second wing element about a second module pivot axis by a non-zero second module angular displacement.

Optionally, step (B) also comprises:

- 14 -

- pivoting said second wing element about a second wing element pivot axis by a non-zero second wing element angular displacement.

In at least a first example, step (B) comprises:

(a) concurrently pivoting the first wing element about the first module pivot axis by said non-zero first module angular displacement and the second wing element about the second module pivot axis by said non-zero second module angular displacement;

(b) subsequent to step (a), pivoting said first wing element about the first wing element pivot axis by said non-zero first wing element angular displacement.

Optionally, the method of the first example further comprises:

(c) subsequent to step (a), pivoting said second wing element about the second wing element pivot axis by said non-zero second wing element angular displacement.

In at least a second example, step (B) comprises:

(a) concurrently pivoting the first wing element about the first module pivot axis to a first partial first module angular displacement, and the second wing element about the second module pivot axis to a first partial second module angular displacement;

(b) subsequent to step (a), pivoting said first wing element about the first wing element pivot axis by said non-zero first wing element angular displacement, while concurrently pivoting the first wing element about the first module pivot axis to a second partial first module angular displacement, and the second wing element about the second module pivot axis to a second partial second module angular displacement;

(c) subsequent to step (b), concurrently pivoting the first wing element about the first module pivot axis to said first module angular displacement, and the second wing element about the second module pivot axis to said second module angular displacement;

- 15 -

wherein said second partial first module angular displacement is less than said non-zero first module angular displacement and greater than said first partial first module angular displacement, and

wherein said second partial second module angular displacement is less than said non-zero second module angular displacement and greater than said first partial second module angular displacement.

In alternative variations of this example, said second partial first module angular displacement is equal to said non-zero first module angular displacement, and/or, said second partial second module angular displacement is equal to said non-zero second module angular displacement.

In at least a third example, step (B) comprises:

(a1) pivoting the first wing element about the first module pivot axis to a first partial first module angular displacement;

(b1) subsequent to step (a1), pivoting said first wing element about the first wing element pivot axis by said non-zero first wing element angular displacement, and pivoting the first wing element about the first module pivot axis to a second partial first module angular displacement;

(c1) subsequent to step (b2), respectively pivoting the first wing element about the first module pivot axis to said first module angular displacement;

wherein said second partial first module angular displacement is less than said non-zero first module angular displacement and greater than said first partial first module angular displacement.

In at least a fourth example, step (B) comprises:

(a2) pivoting the second wing element about the second module pivot axis to a first partial second module angular displacement;

(b2) subsequent to step (a2), pivoting the second wing element about the second module pivot axis to a second partial second module angular displacement;

(c2) subsequent to step (b2), pivoting the second wing element about the second module pivot axis to said second module angular displacement;

- 16 -

wherein said second partial second module angular displacement is less than said non-zero second module angular displacement and greater than said first partial second module angular displacement.

For example, step (a1) can be concurrent with step (a2). Additionally or alternatively, for example, step (b1) can be concurrent with step (b2). Additionally or alternatively, for example, step (c1) can be concurrent with step (c2).

Optionally, the method according to the second example, the third example or the fourth example further includes in step (b), step (b1), or step (b2), respectively:

(d) pivoting said second wing element about the second wing element pivot axis by said non-zero second wing element angular displacement.

A feature of at least one example of the presently disclosed subject matter is that a wing system is provided for an air vehicle, in which in said stowed configuration, the respective first wing element and second wing element of each wing deployment module is compactly folded onto the fuselage lateral sides without projecting past the vertical location of the wing arrangement, thereby enabling maximizing occupancy of the cross-sectional area of the fairing in which it is desired to accommodate the air vehicle in stowed configuration.

Another feature of at least one example of the presently disclosed subject matter is that a wing system is provided for an air vehicle, in which in the deployed configuration the wing system in the form of an empennage can provide for stability and steering even prior to deployment of the main lift generating wing arrangement of the air vehicle.

Another feature of at least one example of the presently disclosed subject matter is that a wing system is provided for an air vehicle, in which a high degree of flexibility can be applied to the design of each wing deployment module, chord size and distribution, taper, span and width, wherein to enable for efficient lateral packaging with respect to the fuselage, within an envelope provided by a fairing.

BRIEF DESCRIPTION OF THE DRAWINGS

In order to better understand the subject matter that is disclosed herein and to exemplify how it may be carried out in practice, embodiments will now be described, by way of non-limiting example only, with reference to the accompanying drawings, in which:

Fig. 1 shows in isometric partial view, an air vehicle comprising a wing system according to a first example of the presently disclosed subject matter, wherein the wing system is in the stowed configuration.

Fig. 2 shows in isometric partial view, the air vehicle and wing system of the example of Fig. 1, wherein the wing system is in the deployed configuration; **Fig. 2(a)** is a side view of the example of Fig. 2; **Fig. 2(b)** is a top view of the example of Fig. 2; **Fig. 2(c)** is an aft view of the example of Fig. 2; **Fig. 2(d)** is an isometric view of the example of Fig. 2 schematically illustrating displacement angles; **Fig. 2(e)** is a side view of an alternative variation of the example of Fig. 2 having a non-zero incidence angle. **Fig. 3(a)** is a side view of the example of Fig. 1 showing the first wing element in the stowed configuration; **Fig. 3(b)** is a side view of the example of Fig. 3(a) in a partially deployed configuration; **Fig. 3(c)** is a front view of the example of Fig. 3(a) in deployed configuration.

Fig. 4(a) is a transverse cross-sectional view of the example of Fig. 1 showing the first wing element in the stowed configuration; **Fig. 4(b)** is a transverse cross-sectional view of the example of Fig. 4(a) in a partially deployed configuration; **Fig. 4(c)** is a transverse cross-sectional view of the example of Fig. 4(a) in deployed configuration.

Fig. 5(a) is a side view of the example of Fig. 1 showing the second wing element in the stowed configuration; **Fig. 5(b)** is a side view of the example of Fig. 5(a) in the deployed configuration; **Fig. 5(c)** is a front view of the example of Fig. 5(a).

Fig. 6(a) is a transverse cross-sectional view of the example of Fig. 1 showing the second wing element in the stowed configuration; **Fig. 6(b)** is a transverse cross-sectional view of the example of Fig. 6(a) in a partially deployed configuration; **Fig. 6(c)** is a transverse cross-sectional view of the example of Fig. 6(a) in deployed configuration.

- 18 -

Fig. 7(a) is an aft view of the example of Fig. 1 showing the wing system operating in yaw; **Fig. 7(b)** is an aft view of the example of Fig. 7(a) operating in pitch; **Fig. 7(c)** is an aft view of the example of Fig. 7(a) operating in roll.

Figs. 8(a) to 8(d) schematically illustrate an example of a method for deploying the example of Fig. 1 from the stowed configuration to the deployed configuration.

Fig. 9 schematically illustrates the steps of the method of the example of Figs. 8(a) to 8(d).

Figs. 10(a) to 10(e) schematically illustrate an example of a method for deploying the example of Fig. 1 from the stowed configuration to the deployed configuration.

Fig. 11 schematically illustrates the steps of the method of the example of Figs. 10(a) to 10(e).

Fig. 12(a) shows in isometric partial view, the air vehicle and wing system of the example of Fig. 1, in stowed configuration accommodated in a fairing; **Fig. 12(b)** shows in side view the example of Fig. 12(a); **Fig. 12(c)** shows in transverse cross-sectional view the example of Fig. 12(b), taken along A-A.

DETAILED DESCRIPTION

Referring to Figs. 1, 2, 2(a), 2(b), an air vehicle according to a first example of the presently disclosed subject matter, generally designated **100**, comprises a wing system **200**, which is *per se* novel. The wing system **200** comprises at least one wing deployment module **220**, also referred to herein interchangeably as a wing module.

In at least this example, and referring in particular to Fig. 1, the air vehicle **100** is a powered, fixed-wing type air vehicle, comprising a subsonic or a transonic configuration, comprising a fuselage having a fuselage section, which in this example is an aft fuselage section **110**, a wing arrangement **300** for providing aerodynamic lift to the air vehicle **100**, a suitable propulsion system (not shown), and said wing system **200**. In alternative variations of this example, the air vehicle **100** can be instead configured with a supersonic configuration.

- 19 -

The fuselage, in particular the fuselage section, which in this example is an aft fuselage section **110**, has a fuselage longitudinal axis **LA**.

While the wing system **200** is described in examples below with respect to the aft fuselage section **110**, in alternative variations of such examples, the same teaching can be applied, *mutatis mutandis*, to other fuselage sections of the fuselage, as appropriate.

The wing arrangement **300** can include, at least in this example, a foldable or otherwise deployable wing arrangement, including one, two or more aerodynamic lift generating wings, which are deployable from a stowed wing configuration to a deployed wing configuration. In the stowed wing configuration, the one or more aerodynamic lift generating wings are accommodated above and/or below the fuselage, with the respective span axes generally aligned with the aft fuselage section **110**. In the deployed wing configuration, the one or more aerodynamic lift generating wings are projecting outwardly with respect to the aft fuselage section such that the leading edge of the wings are now facing an airstream **AS**, and enable the wings to generate aerodynamic lift. Such an airstream relative to the wings can be a result of the air vehicle **100** travelling at a significant forward speed in air, for example. The one or more aerodynamic lift generating wing are configured for generating sufficient aerodynamic lift for aerodynamic flight for the air vehicle.

In at least this example, and in other examples, the wing system **200** is configured as a tail configuration or an empennage for the air vehicle **100**. However, in alternative variations of this example, and in other examples, the corresponding wing system can be configured for example as lift-generating wings of the air vehicle, or as other wings for the vehicle.

Furthermore, while the presently disclosed subject matter finds particular application in UAV aircraft, the presently disclosed subject matter can also be applied to manned aircraft, *mutatis mutandis*, in particular to general aviation, subsonic transport, naval aviation, and so on, for example. In alternative variations of this example, and in other examples, the air vehicle **100** can instead be configured as an un-powered, fixed-wing type subsonic or transonic air vehicle, manned or unmanned.

- 20 -

The air vehicle **100** further comprises a control system comprising a controller (not shown) configured for operating the air vehicle **100**, and in particular configured for operating the wing system **200**, at least within the flight envelope thereof.

As will become clearer herein, the wing system **200** has a stowed configuration **SC**, and a deployed configuration **DC**. Furthermore, the wing system **200** is configured for selectively transitioning between stowed configuration **SC**, and the deployed configuration **DC**.

In this example, the wing system **200** comprises two wing deployment modules **220**, in particular a port wing deployment module **220P** and a starboard wing deployment module **220S**. Thus, unless otherwise specified herein, the reference numeral **220** shall also refer to each one of the port wing deployment module **220P** and the starboard wing deployment module **220S**. However, in other alternative variations of this example, the wing system **200** comprises a single wing deployment module **220** – for example in the form of a V-tail. In yet other alternative variations of this example, the wing system **200** can comprise more than two wing deployment modules **220** – for example three or four sets of V-fins arranged around the periphery of the fuselage section.

Each wing deployment module **220** is configured for being mounted to a lateral side of the fuselage section, in particular of the aft fuselage section **110**.

In at least this example, the port wing deployment module **220P** is mounted to a port side **110P** of the aft fuselage section **110**, and the starboard wing deployment module **220S** is mounted to a starboard side **110S** of the aft fuselage section **110**.

The port wing deployment module **220P** and the starboard wing deployment module **220S** are essentially mirror images of one another, and are otherwise substantially identical with one another.

Each wing module **220** comprises a set of wing elements **240** including at least one first wing element **240H**, and at least one second wing element **240V**. In at least this example, each wing module **220** comprises a set of wing elements **240** including a single first wing element **240H** and a single second wing element **240V**.

- 21 -

In alternative variations of this example, each wing module **220** can comprise a set of wing elements **240** including more than one first wing element **240H** and/or more than one second wing element **240V**. For example, in such examples in which the wing module includes two second wing elements, these can be in mutually overlying relationship in the stowed configuration (and also overlying with respect to one or more first wing elements in the stowed configuration), and are deployed in the deployed configuration such that one second wing element is projecting upwardly from the aft fuselage section (as in the illustrated examples), and the other second wing element is projecting in the opposite direction – downwardly from the aft fuselage section. Additionally or alternatively, for example, in such examples in which the wing module includes two first wing elements, these can be in mutually overlying relationship in the stowed configuration (and also overlying with respect to one or more first wing elements in the stowed configuration), and are deployed in the deployed configuration such that one first wing element is inclined upwardly from the aft fuselage section, and the other first wing element is inclined downwardly from the aft fuselage section, for example in "<" formation.

In at least this example, for each wing module **220**, the respective first wing element **240H** is configured as a horizontal stabilizer, also referred to interchangeably herein as a horizontal tail, and the second wing element **240V** is configured as vertical stabilizer, also referred to interchangeably herein as a vertical tail.

The first wing element **240H** in at least this example has a corresponding aerofoil cross-sectional profile **AE_H** with chord **C_H** at transverse sections along the first wing element longitudinal axis **240LA1** thereof, from the first wing element root **242H** to the first wing element tip **244H**. While in this example the aerofoil cross-sectional profiles **AE_H** have zero camber and generate zero aerodynamic force (i.e., have a lift coefficient of zero) corresponding to a zero angle of attack α to an airstream, in alternative variations of this example the aerofoil cross-sectional profiles **AE_H** can have non-zero camber and/or generate an aerodynamic force (i.e., have a non-zero, positive lift coefficient) corresponding to a zero angle of attack α to an airstream.

In at least this example the first wing element **240H** has a leading edge **241H**, a trailing edge **243H**, and a span **S_H**. The first wing element first wing element longitudinal

- 22 -

axis **240LA1** extends along the length of the first wing element **240H** between the first wing element root **242H** and the first wing element tip **244H**.

In at least this example the first wing element **240H** is in plan form generally rectangular, and the aerofoil cross-sectional profile **AE_H** is uniform in size and profile along the respective first wing element first wing element longitudinal axis **240LA1** of the first wing element **240H**. Thus the first wing element **240H** in at least this example the chord **C_H** is uniform (and corresponds to the maximum chord of the first wing element **240H**).

However, in alternative variations of this example the first wing element **240H** can be, for example, in plan form generally trapezoidal (i.e., having a taper) or any other shape, and the aerofoil cross-sectional profile **AE_H** is uniform in profile along the respective first wing element first wing element longitudinal axis **240LA1** of the first wing element **240H**, but the size of the aerofoil cross-sectional profile **AE_H** at each span-wise position along the first wing element first wing element longitudinal axis **240LA1** of the respective first wing element **240H** can change in proportion to the size of the chord **C_H** at the respective span-wise position. In such a case, the chord **C_H** can vary between a maximum chord, and a minimum chord.

However, in yet other alternative variations of this example the first wing element **240H** can be, for example, in plan form generally trapezoidal (i.e., having a taper) or any other shape, and the aerofoil cross-sectional profile **AE_H** is non-uniform in profile along the respective first wing element first wing element longitudinal axis **240LA1** of the first wing element **240H**, and furthermore the size of the aerofoil cross-sectional profile **AE_H** at each span-wise position along the first wing element first wing element longitudinal axis **240LA1** of the respective first wing element **240H** can change in proportion to the size of the chord **C_H** at the respective span-wise position. In such a case, the chord **C_H** can vary between a maximum chord, and a minimum chord.

In at least this example the first wing element **240H** is non-swept, and thus the span **S_H** is parallel to the first wing element first wing element longitudinal axis **240LA1**. However, in alternative variations of this example, the first wing element **240H** can be swept, having for example a positive sweep angle or a negative sweep angle, and thus the span **S_H** is non-parallel to the first wing element longitudinal axis **240LA1**.

- 23 -

In at least one of the above examples the respective thickness to chord ratio along the respective first wing element first wing element longitudinal axis **240LA1** of the first wing element **240H** can be uniform. Alternatively, in at least one variation of the above examples the respective thickness to chord ratio along the respective span of the first wing element **240H** can be non-uniform. For example, respective thickness to chord ratio along the respective first wing element first wing element longitudinal axis **240LA1** can be reduced in a direction from the respective first wing element root **242H** to the first wing element tip **244H**.

It is to be noted that in plan view (for example as seen in Fig. 2(b)), the first wing element **240H** is configured with a maximum width **W_H**, wherein this width is taken orthogonal to the span **S_H**, and/or to the first wing element first wing element longitudinal axis **240LA1** of the first wing element **240H**. Such a maximum width **W_H** is correlated to the height **HF** of the aft fuselage section **110**. For example, such a maximum width **W_H** is about the same dimension as the height **HF** of the aft fuselage section **110**, or within $\pm 10\%$ or within $\pm 20\%$ of the height **HF** of the aft fuselage section **110**.

In at least this example the first wing element **240H** comprises at least one control surface, in the form of elevator **245H**, which can be controllably operated by pivoting about a pivot axis to provide selectively positive elevator deflections or negative elevator deflections to thereby enable control moments in pitch, yaw and roll to be generated, as will become clearer herein. In alternative variations of this example, the first wing element **240H** itself is configured as an actuable monoblock elevator, which can be controllably operated to pivot about a suitable first wing element pivot axis to provide selectively positive elevator deflections or elevator rudder deflections to thereby enable control moments in pitch, yaw and roll to be generated.

In at least this example, a suitable actuator system (not shown) is operatively coupled to the of elevator **245H** as well as to the controller to control and carry out changes in elevator deflection angle. For example, such an actuator system can be embedded within the first wing element **240H** itself, for example inside of the main body of the first wing element **240H**. By way of non-limiting example, such an actuator system can include one or more of the Volz DA-30 or the Volz DA-15 servos, by Volz Servos GmbH & Co. KG, Germany.

- 24 -

Referring to Fig. 2(c), in at least this example, in the deployed configuration **DC**, the first wing element **240H** is oriented with respect to the aft fuselage section **110** at nominally zero dihedral angle, in other words, the respective first wing element longitudinal axes **240LA1** of the port and starboard first wing elements **240H** are parallel to one another, in particular co-axial with one another. Thus, the pivot axis of the elevator **245H** is essentially parallel to the pitch axis of the air vehicle **100**. Furthermore, in the deployed configuration **DC**, the first wing element **240H** is projecting outwardly and laterally from the aft fuselage section **110** such that the first wing element tip **244H** is at a greater spacing from the aft fuselage section **110** than first wing element root **242H**.

Referring again to Fig. 1, in the stowed configuration **SC**, the first wing element **240H** and the second wing element **240V** are in overlying relationship such that the first wing element longitudinal axis **240LA1** and the second wing element longitudinal axis **240LA2** are nominally parallel with one another. Each wing deployment module **220** in the stowed configuration **SC** is configured for providing the first wing element **240H** and the second wing element **240V** in overlying relationship with respect to the fuselage section **110**.

As will become clearer herein, in the stowed configuration **SC**, the first wing element **240H** and the second wing element **240V** are configured in the aforesaid overlying relationship for being oriented with respect to the fuselage section **110** such that the first wing element longitudinal axis **240LA1** and the second wing element longitudinal axis **240LA2** are each nominally parallel with the fuselage longitudinal axis **LA**.

Referring again to Fig. 2, in the deployed configuration **DC**, the first wing element **240H** is oriented with respect to the second wing element **240V** such that the first wing element longitudinal axis **240LA1** is non-parallel with respect to the second wing element longitudinal axis **240LA2**.

Also as will become clearer herein, in the deployed configuration **DC**, the first wing element **240H** is oriented with respect to the fuselage section **110** such that the first wing element longitudinal axis **240LA1** is non-parallel, for example orthogonal, with respect to the fuselage longitudinal axis **LA**. Furthermore, in the deployed configuration **DC**, the second wing element **240V** is oriented with respect to the fuselage section **110**.

- 25 -

such that the second wing element longitudinal axis **240LA2** is non-parallel, for example orthogonal, with respect to the fuselage longitudinal axis **LA**.

For example, and referring again to Fig. 1, in the stowed configuration **SC**, the first wing element **240H** is oriented with respect to the aft fuselage section **110** such that the first wing element longitudinal axis **240LA1** of the first wing element **240H** is nominally parallel with the longitudinal axis **LA** of the fuselage, in particular of the aft fuselage section **110**.

Referring again to Figs. 2, 2(a), 2(b), 2(c), in the deployed configuration **DC**, the first wing element **240H** is oriented with respect to the aft fuselage section **110** such that the first wing element longitudinal axis **240LA1** of the first wing element **240H** is non-parallel with respect to the longitudinal axis **LA**. In at least this example, in the deployed configuration, the first wing element longitudinal axis **240LA1** is nominally orthogonal with the longitudinal axis **LA** of the fuselage, in particular of the aft fuselage section **110**. In at least this example, in the deployed configuration, the first wing element longitudinal axis **240LA1** is nominally parallel with the pitch axis **P** of the air vehicle **100**.

Referring in particular to Fig. 2(c), the wing system **200** further comprises a deployment system **400** configured for transitioning the wing system **200**, in particular each wing module **240**, from the stowed configuration **SC** to the deployed configuration **DC**.

In at least this example, and referring in particular to Figs. 3(a), 3(b), 3(c), the deployment system **400** configured for deploying each first wing element **240H** from the stowed configuration **SC** to the deployed configuration **DC** by:

- pivoting the respective first wing element **240H** about a respective first module pivot axis **MPA1** by a non-zero module angular displacement θ_{M1} , and
- pivoting the first wing element **240H** about a respective first wing element pivot axis **WPAH** by a non-zero wing element angular displacement θ_H .

It is to be noted that pivoting the first wing element **240H** about respective first module pivot axis **MPA1** essentially rotates the first wing element **240H** along or generally parallel to the surface of the aft fuselage section **110**, thereby orienting the

- 26 -

leading edge **241H** towards the forward end of the air vehicle **100** and the trailing edge **243H** towards the aft end of the air vehicle **100**, and concurrently essentially increases the spacing of the first wing element tip **244H** with respect to the aft fuselage section **110**, while concurrently the spacing of the first wing element root **242H** with respect to the aft fuselage section **110** can remain unchanged, or changed by a much smaller amount. Such a rotation about respective first module pivot axis **MPA1** is nominally over a vertical plane, at least in this example.

On the other hand, pivoting the first wing element **240H** about the first wing element pivot axis **WPAH** orients the first wing element **240H** in which leading edge **241H** remains facing towards the forward end of the air vehicle **100**, the trailing edge **243H** remains facing towards the aft end of the air vehicle **100**, and the first wing element tip **244H** remains spaced with respect to the aft fuselage section **110** at a larger spacing than the spacing of the first wing element root **242H** with respect to the aft fuselage section **110**, but first wing element **240H** is now in a general horizontal direction corresponding to the deployed configuration **DC**, at least in this example.

In at least this example, the first module pivot axis **MPA1** is orthogonal with respect to the first wing element pivot axis **WPAH**. In alternative variations of this example, for example, the first module pivot axis **MPA1** is at a non-zero angle with respect to the first wing element pivot axis **WPAH**, different from 90°.

In at least this example, the first module pivot axis **MPA1** is parallel to a pitch axis **P** of the air vehicle **100**. In alternative variations of this example, for example, the first module pivot axis **MPA1** can be at a non-zero angle with respect to the pitch axis **P**, and can be at a non-zero angle, different from 90°, from the roll axis **R**.

In at least this example, the first wing element pivot axis **WPAH** is parallel to a roll axis **R** of the air vehicle **100**. In alternative variations of this example, for example, the first wing element pivot axis **WPAH** is at a non-zero angle with respect to the roll axis **R**.

In at least this example, the first wing element pivot axis **WPAH** is parallel to a longitudinal axis **LA** of the air vehicle **100**. In alternative variations of this example, for

- 27 -

example, the first wing element pivot axis **WPA_H** is at a non-zero angle with respect to the longitudinal axis **LA**.

In at least this example, the first wing element pivot axis **WPA_H** is parallel to a chordline **CL_H** of the first wing element **240H**.

For example, and referring to Figs. 4(a), 4(b) and 4(c), the deployment system **400** comprises a shaft or journal **250H** pivotably or rotatably mounted with respect to the aft fuselage section **110** in a manner enabling the wing module **220**, or at least the respective first wing element **240H** thereof, to pivot about the first module pivot axis **MPA1**, at least from the position at the stowed configuration **SC** (Fig. 4(a)) to an intermediate position (Fig. 4(b)) following the non-zero module angular displacement θ_{M1} .

Furthermore, the respective first wing element **240H** is pivotably mounted to journal **250H**, for example to a free end of the journal **250H** outside of the aft fuselage section **110**, via pin **254H** and bracket **252H**, such as to enable the first wing element **240H** to pivot about the first wing element pivot axis **WPA_H** with respect to journal **250H** by non-zero wing element angular displacement θ_H , from the intermediate position to the position corresponding to the deployed configuration **DC** (Fig. 4(c)).

The first module pivot axis **MPA1** is located at a chordwise position **X_{HA}** along the chord **C_H** at the first wing element root **242H**, from the leading edge thereof. For example the chordwise position **X_{HA}** can be about 25% of the chord **C_H** and/or about 1% to 2% of the chord **C_H** forward of the aerodynamic center of the first wing element **240H** (for example about 1% to 2% of the chord **C_H** forward of the aerodynamic center of the first wing element root **242H**).

Referring again to Fig. 1, the second wing element **240V** in at least this example has a corresponding aerofoil cross-sectional profile **AE_v** with chord **C_v** at transverse sections along the second wing element second wing element longitudinal axis **240LA2** thereof, from the second wing element root **242V** to the second wing element tip **244V**. In this example the aerofoil cross-sectional profiles **AE_v** have zero camber and generate zero aerodynamic force (i.e., have a lift coefficient of zero) corresponding to a zero angle of attack α to an airstream.

- 28 -

In at least this example, and referring also to Fig. 2(a), the second wing element **240V** has a leading edge **241V**, a trailing edge **243V**, and a span **S_v**. The second wing element second wing element longitudinal axis **240LA2** extends along the length of the second wing element **240V** between the second wing element root **242V** and the second wing element tip **244V**.

In at least this example the second wing element **240V** is in plan form generally rectangular, and the aerofoil cross-sectional profile **AE_v** is uniform in size and profile along the respective second wing element longitudinal axis **240LA2** of the second wing element **240V**. Thus the second wing element **240V** in at least this example the chord **C_v** is uniform (and corresponds to the maximum chord of the second wing element **240V**).

However, in alternative variations of this example the second wing element **240V** can be, for example, in plan form generally trapezoidal (i.e., having a taper) or any other shape, and the aerofoil cross-sectional profile **AE_v** is uniform in profile along the respective second wing element second wing element longitudinal axis **240LA2** of the second wing element **240V**, but the size of the aerofoil cross-sectional profile **AE_v** at each span-wise position along the second wing element longitudinal axis **240LA2** of the respective second wing element **240V** can change in proportion to the size of the chord **C_v** at the respective span-wise position. In such a case, the chord **C_v** can vary between a maximum chord, and a minimum chord.

However, in yet other alternative variations of this example the second wing element **240V** can be, for example, in plan form generally trapezoidal (i.e., having a taper) or any other shape, and the aerofoil cross-sectional profile **AE_v** is non-uniform in profile along the respective second wing element second wing element longitudinal axis **240LA2** of the second wing element **240V**, and furthermore the size of the aerofoil cross-sectional profile **AE_v** at each span-wise position along the second wing element longitudinal axis **240LA2** of the respective second wing element **240V** can change in proportion to the size of the chord **C_v** at the respective span-wise position. In such a case, the chord **C_v** can vary between a maximum chord, and a minimum chord.

In at least this example the second wing element **240V** is non-swept, and thus the span **S_v** is parallel to the second wing element longitudinal axis **240LA2**. However, in alternative variations of this example, the second wing element **240V** is swept, having for

- 29 -

example a positive sweep angle or a negative sweep angle, and thus the span **S_v** is non-parallel to the second wing element longitudinal axis **240LA2**.

In at least one of the above examples the respective thickness to chord ratio along the respective second wing element longitudinal axis **240LA2** of the second wing element **240V** can be uniform. Alternatively, in at least one variation of the above examples the respective thickness to chord ratio along the respective span of the second wing element **240V** can be non-uniform. For example, respective thickness to chord ratio along the respective second wing element longitudinal axis **240LA2** can be reduced in a direction from the respective second wing element root **242V** to the second wing element tip **244V**.

It is to be noted that in plan view, and referring to Fig. 5(a), the second wing element **240V** is configured with a maximum width **W_v**, wherein this width is taken orthogonal to the span **S_v**, and/or to the second wing element longitudinal axis **240LA2** of the second wing element **240V**. Such a maximum width **W_v** is correlated to the height **HF** of the aft fuselage section **110**. For example, such a maximum width **W_v** is about the same dimension as the height **HF** of the aft fuselage section **110**, or within $\pm 10\%$ or within $\pm 20\%$ of the height **HF** of the aft fuselage section **110**.

In at least this example the second wing element **240V** comprises at least one control surface in the form of rudder **245V**, which can be controllably operated to pivot about a pivot axis to provide selectively positive rudder deflections or negative rudder deflections to thereby enable control moments in yaw and roll to be generated, as will become clearer herein. In alternative variations of this example, the second wing element **240V** itself is configured as an actuable monoblock rudder, which can be controllably operated to pivot about a suitable second wing element pivot axis to provide selectively positive rudder deflections or negative rudder deflections to thereby enable control moments in yaw and roll to be generated.

In at least this example, a suitable actuator system (not shown) is operatively coupled to the of rudder **245V** as well as to the controller to control and carry out changes in rudder deflection angle. For example, such an actuator system can be embedded within the second wing element **240V** itself, for example inside of the main body of the second wing element **240V**. By way of non-limiting example, such an actuator system can

- 30 -

include one or more of the Volz DA-30 or the Volz DA-15 servos, by Volz Servos GmbH & Co. KG, Germany.

Referring in particular to Fig. 2(d) and Fig. 5(c), in at least this example, in the deployed configuration **DC**, the second wing element **240V** is oriented with respect to the aft fuselage section **110** at a desired cant angle ϕ from the horizontal, and the pivot axis of the rudder **245V** is essentially parallel to the yaw axis **Y** of the air vehicle **100**, or can be inclined to the second wing element longitudinal axis **240LA2**. Furthermore, in the deployed configuration **DC**, the second wing element **240V** is projecting outwardly and upwardly from the aft fuselage section **110** such that the second wing element tip **244V** is at a greater spacing from the aft fuselage section **110** than second wing element root **242V**. In at least some examples, providing a cant angle ϕ less than 90° , to thereby provide a divergent configuration of the two second wing element **240V** of the wing system **200** with respect to the aft fuselage body **110**, can minimize aerodynamic interference between the two second wing elements **240V**.

Referring again to Fig. 1, in the stowed configuration **SC**, second wing element **240V** is oriented with respect to the aft fuselage section **110** such that the second wing element longitudinal axis **240LA2** of the second wing element **240V** is nominally parallel with the longitudinal axis **LA** of the fuselage, in particular of the aft fuselage section **110**.

Referring again to Figs. 2, 2(a), 2(b), 2(c), in the deployed configuration **DC**, the second wing element **240V** is oriented with respect to the aft fuselage section **110** such that the second wing element longitudinal axis **240LA2** of the second wing element **240V** is non-parallel with respect to the longitudinal axis **LA**. In at least this example, in the deployed configuration **DC**, the second wing element longitudinal axis **240LA2** is nominally orthogonal with the longitudinal axis **LA** of the fuselage, in particular of the aft fuselage section **110**. In at least this example, in the deployed configuration **DC**, the second wing element longitudinal axis **240LA2** is lies on a pitch-yaw plane and inclined between with the pitch axis **P** and the yaw axis **Y** of the air vehicle **100**.

Referring in particular to Fig. 2(c), the wing system **200** the deployment system **400** is further configured for transitioning the wing system **200**, in particular each wing module **240**, from the stowed configuration **SC** to the deployed configuration **DC** also with respect to the second wing elements **240V**.

- 31 -

In at least this example, each wing deployment module **220** in the stowed configuration comprises a first wing root **242H** of the first wing element **240H** in overlying relationship with respect to a second wing root **242V** of the second wing element **240V**.

In at least this example, and referring in particular to Figs. 5(a), 5(b), 5(c), the deployment system **400** is also configured for deploying or otherwise transitioning each second wing element **240V** from the stowed configuration **SC** to the deployed configuration **DC** by:

- pivoting the respective second wing element **240V** about a respective second module pivot axis **MPA2** by a non-zero module angular displacement θ_{M2} ; and optionally
- pivoting the second wing element **240V** about a respective second wing element pivot axis **WPA_v** by a non-zero wing element angular displacement θ_v .

It is to be noted that for implementations of this and other examples in which the cant angle ϕ is set at 90° , while second wing element **240V** is pivoted about a respective second module pivot axis **MPA2** by a non-zero module angular displacement θ_{M2} , when transitioning from the stowed configuration **SC** to the deployed configuration **DC**, no further transitioning is required. In other words, the step of pivoting the second wing element **240V** about a respective second wing element pivot axis **WPA_v** by a non-zero wing element angular displacement θ_v , is omitted.

It is also to be noted that for implementations of this and other examples in which the cant angle ϕ is set at less 90° , while second wing element **240V** is pivoted about a respective second module pivot axis **MPA2** by a non-zero module angular displacement θ_{M2} , when transitioning from the stowed configuration **SC** to the deployed configuration **DC**, no further transitioning is required. In other words, the step of pivoting the second wing element **240V** about a respective second wing element pivot axis **WPA_v** by a non-zero wing element angular displacement θ_v , is omitted. In such cases the respective second module pivot axis **MPA2** can be set at a corresponding angle to the pitch axis **P** and to the roll axis **R**, so that while in the stowed configuration **SC** the second wing element longitudinal axis **240LA2** of the second wing element **240V** is parallel with

- 32 -

respect to the longitudinal axis **LA**, in the deployed configuration **DC** the second wing element **240V** is pivoted about the respective second module pivot axis **MPA2** automatically providing the required cant angle.

It is to be noted that pivoting the second wing element **240V** about respective second module pivot axis **MPA2** essentially rotates the second wing element **240V** along or generally parallel to the surface of the aft fuselage section **110**, thereby orienting the leading edge **241V** towards the forward end of the air vehicle **100** and the trailing edge **243V** towards the aft end of the air vehicle **100**, and concurrently essentially increases the spacing of the second wing element tip **244V** with respect to the aft fuselage section **110**, while concurrently the spacing of the second wing element root **242V** with respect to the aft fuselage section **110** can remain unchanged, or changed by a much smaller amount. Such a rotation about respective second module pivot axis **MPA2** is nominally over a vertical plane, at least in this example. In alternative variations of this example in which the cant angle ϕ is set at 90° , such a rotation about respective second module pivot axis **MPA2** of module angular displacement θ_{M2} brings the second wing element **240V** to its position corresponding to the deployed configuration **DC**.

On the other hand, in for example this example in which the cant angle ϕ is set at less than 90° , pivoting second wing element **240V** about the second wing element pivot axis **WPAv** orients the second wing element **240V** in which leading edge **241V** remains facing towards the forward end of the air vehicle **100**, the trailing edge **243V** remains facing towards the aft end of the air vehicle **100**, and the second wing element tip **244V** remains spaced with respect to the aft fuselage section **110** at a larger spacing than the spacing of the second wing element root **242V** with respect to the aft fuselage section **110**, but second wing element **240V** is now inclined to a vertical plane at wing element angular displacement θ_v , corresponding to the deployed configuration **DC**. In the illustrated example, the second wing element **240V** is at a cant angle ϕ of less than 90° , for example 75° . Thus in addition to the aforementioned pivoting the second wing element **240V** about the first module pivot axis **MPA2** by non-zero module angular displacement θ_{M2} , the second wing element **240V** is further pivoted about a respective second wing element pivot axis **WPAv** by a non-zero second wing element angular displacement θ_v .

- 33 -

Thus, in at least this example, the second wing element angular displacement θ_v is related to cant angle φ by the expression:

$$\theta_v = 90^\circ - \varphi$$

In at least this example, the second module pivot axis **MPA2** is orthogonal with respect to the second wing element pivot axis **WPA_v**. In alternative variations of this example, for example, the second module pivot axis **MPA2** is at a non-zero angle with respect to the second wing element pivot axis **WPA_v**, different from 90° .

In at least this example, the second module pivot axis **MPA2** is parallel to a pitch axis **P** of the air vehicle **100**. In alternative variations of this example, for example, the second module pivot axis **MPA2** is at a non-zero angle with respect to the pitch axis **P**, and can be at a non-zero angle, different from 90° , from the roll axis **R**.

In at least this example, the second wing element pivot axis **WPA_v** is parallel to a roll axis **R** of the air vehicle **100**. In alternative variations of this example, for example, the second wing element pivot axis **WPA_v** is at a non-zero angle with respect to the roll axis **R**.

In at least this example, the second wing element pivot axis **WPA_v** is parallel to a longitudinal axis **LA** of the air vehicle **100**. In alternative variations of this example, for example, the second wing element pivot axis **WPA_v** is at a non-zero angle with respect to the longitudinal axis **LA**.

In at least this example, the second wing element pivot axis **WPA_v** is parallel to a chordline **CL_v** of the second wing element **240V**.

For example, and referring to Figs. 6(a), 6(b) and 6(c), the deployment system **400** comprises a shaft or journal **250V** pivotably or rotatably mounted with respect to the aft fuselage section **110** in a manner enabling at least the respective second wing element **240V** of the wing module **220**, to pivot about the second module pivot axis **MPA2**, at least from the position at the stowed configuration **SC** (Fig. 6(a)) to an intermediate position (Fig. 6(b)) following the non-zero module angular displacement θ_{M2} .

Furthermore, the respective second wing element **240V** is pivotably mounted to journal **250V**, for example to a free end of the journal **250V** outside of the aft fuselage

- 34 -

section **110**, via pin **254V** and bracket **252V**, such as to enable the second wing element **240V** to pivot about the second wing element pivot axis **WPA_v** with respect to journal **250V** by non-zero wing element angular displacement θ_v , from the intermediate position to the position corresponding to the deployed configuration **DC** (Fig. 6(c)).

The second module pivot axis **MPA2** is located at a chordwise position **X_{VA}** along the chord **C_v** at the second wing element root **242V**, from the leading edge thereof. For example the chordwise position **X_{VA}** can be about 25% of the chord **C_v** and/or about 1% to 2% of the chord **C_v** forward of the aerodynamic center of the second wing element **240V** (for example about 1% to 2% of the chord **C_v** forward of the aerodynamic center of the second wing element root **242V**).

In at least this example, the first module pivot axis **MPA1** is parallel to second module pivot axis **MPA2**. Furthermore, in at least this example, the first module pivot axis **MPA1** is co-axial with second module pivot axis **MPA2**.

According to some examples, at least one of the first module pivot axis **MPA1** and the second module pivot axis **MPA2** is parallel to a pitch axis **P** of the air vehicle **100**. However, in at least the illustrated example, the first module pivot axis **MPA1** and the second module pivot axis **MPA2** are both parallel to a pitch axis **P** of the air vehicle **100**.

In at least this example, the first wing element pivot axis **WPA_H** and said second wing element pivot axis **WPA_v** are parallel to one another.

According to an aspect of the presently disclosed subject matter, at least one of said first wing element pivot axis **WPA_H** and said second wing element pivot axis **WPA_v** is parallel to a roll axis **R** of the air vehicle **100**. In at least this example, the first wing element pivot axis **WPA_H** and the second wing element pivot axis **WPA_v** are parallel to a roll axis **R** of the air vehicle **100**.

In at least this example, the first journal **250H** is parallel to second journal **250V**. Furthermore, in at least this example, the first journal **250H** is co-axial with second journal **250V**. Furthermore, in at least this example, the first journal **250H** and the second journal **250V** constitute a single integrated journal, i.e., the first journal **250H** and the second journal **250V** are one and the same journal. Furthermore, in at least this example,

- 35 -

the first module pivot axis **MPA1** and the second module pivot axis **MPA2** are the same axis, and can be referred to as the module pivot axis **MPA**. Similarly, in at least this example, the first non-zero module angular displacement θ_{M1} and the second non-zero module angular displacement θ_{M2} refer to the same angular displacement, since the wing module **220** pivots about the module pivot axis **MPA** as a unit, and can be referred to as the module angular displacement θ_M .

In at least some other alternative variations of this example, the first journal **250H** is co-axial with second journal **250V** but the first journal **250H** and the second journal **250V** are different from one another. For example, the first journal **250H** is accommodated within a lumen provided in the second journal **250V**.

It is to be noted that in at least some other alternative variations of this example, the first module pivot axis **MPA1** is parallel and spaced from second module pivot axis **MPA2**. For example, the first journal **250H** is parallel and spaced from second journal **250V**. In other words, the first journal **250H** is not co-axial with, and is different from, the second journal **250V**.

In at least this example, in the stowed configuration **SC**, the first wing element **240H** and the second wing element **240V** are in overlying spatial relationship, in which one aerofoil surface of the first wing element **240H** is facing one of the two aerofoil surface of the second wing element **240V**.

In at least this example, and referring to Fig. 1, in the aforesaid overlying spatial relationship, the first wing element root **242H** is in close proximity to the second wing element root **242V**. For example, the first wing element root **242H** is overlying the second wing element root **242V**.

In particular, in at least this example, in the stowed configuration **SC** the first wing element **240H** and the second wing element **240V** are in overlying spatial relationship, in which the first wing element longitudinal axis **240LA1** is parallel to the second wing element longitudinal axis **240LA2**, with respect to the aft fuselage section **110**.

Furthermore, at least this example, in the aforesaid lateral superposed spatial relationship, the first wing element **240H** is outboard of the second wing element **240V**, with respect to the aft fuselage section **110**. Said differently, in the aforesaid lateral

- 36 -

superposed spatial relationship, the second wing element **240V** is inboard of the first wing element **240H**, with respect to the aft fuselage section **110**.

Furthermore in at least this example, the first wing element **240H** and the second wing element **240V** are similar or identical in size. For example the first wing element span **S_H** is similar or identical to the second wing element span **S_V**. Similarly, the first wing element chords **C_H** are similar or identical to the second wing element chords **C_V**.

In at least some variations of this example, the first wing element **240H** and the second wing element **240V** are not similar in size. For example the first wing element span **S_H** is different in magnitude with respect to the second wing element span **S_V**, and/or, the first wing element chords **C_H** are different in magnitude with respect to the second wing element chords **C_V**.

In at least this example, the first wing element **240H** and the second wing element **240V** are configured for pivoting together as a unit, and in the same rotational direction, when pivoting about the respective first module pivot axis **MPA1** and second module pivot axis **MPA2**. Thus, the first module angular displacement θ_{M1} and the second module angular displacement θ_{M2} are nominally equal to one another. Thus, in at least this example, in the stowed configuration **SC** the first wing element **240H** and the second wing element **240V** are in the aforesaid overlying spatial relationship, and in which the first wing element leading edge **241H** is generally overlying the second wing element leading edge **241V**, and the first wing element trailing edge **243H** is generally overlying the second wing element trailing edge **243V**.

In at least this example, the first wing element **240H** and the second wing element **240V** are pivoted by the first module angular displacement θ_{M1} and the second module angular displacement θ_{M2} , respectively, which are nominally equal to one another, and which result in the chord **C_H** of the first wing element **240H** being generally parallel with the longitudinal axis **LA** of the aft fuselage section **110** or of the air vehicle **100**. This provides a zero incidence angle for the first wing elements **240H**.

However, and referring to Fig. 2(e), in at least one alternative variation of this example, the first wing element **240H** and the second wing element **240V** are pivoted by the first module angular displacement θ_{M1} and the second module angular displacement

- 37 -

θ_{M2} , respectively, which are nominally equal to one another, and which result in the chord C_H of the first wing element **240H** being generally non-parallel with the longitudinal axis **LA** of the aft fuselage section **110** or of the air vehicle **100**. This provides a non-zero incidence angle η for the first wing elements **240H**.

In at least some alternative variations of this example, the first wing element **240H** and the second wing element **240V** are configured for pivoting concurrently, either in the same rotational direction or in opposite rotational directions one from the other, when pivoting about the respective first module pivot axis **MPA1** and second module pivot axis **MPA2**. The respective first module angular displacement θ_{M1} and second module angular displacement θ_{M2} can be nominally equal to one another, or different from one another, in such examples. In examples in which the first wing element **240H** and the second wing element **240V** are not pivoting together relative to the respective first module pivot axis **MPA1** and second module pivot axis **MPA2**, the movement can be coordinated by a suitable gear system, for example, to ensure timing, and also to better utilize the aerodynamic loads to alleviate the actuator loading during deployment, at wide range of flight conditions.

In at least some alternative variations of this example, the first wing element **240H** and the second wing element **240V** are configured for pivoting sequentially, when respectively pivoting about the respective first module pivot axis **MPA1** and second module pivot axis **MPA2**. In such examples, the first module angular displacement θ_{M1} and the second module angular displacement θ_{M2} can be nominally equal to one another, or different from one another. Furthermore in such examples the first wing element **240H** and the second wing element **240V** can be configured for pivoting in the same rotational direction, or can be configured for pivoting in opposite rotational directions. The respective first module angular displacement θ_{M1} and second module angular displacement θ_{M2} can be nominally equal to one another, or different from one another, in such examples.

In examples in which the respective first wing element **240H** and the respective second wing element **240V** are configured for pivoting (concurrently or sequentially) in the same rotational direction, in the respective stowed configuration **SC** the respective first wing element **240H** and the respective second wing element **240V** are in the

- 38 -

aforesaid overlying spatial relationship, and in which the respective first wing element leading edge **241H** is generally overlying the respective second wing element leading edge **241V**, and the respective first wing element trailing edge **243H** is generally overlying the respective second wing element trailing edge **243V**.

In examples in which the respective first wing element **240H** and the respective second wing element **240V** are configured for pivoting (concurrently or sequentially) in the opposite rotational directions, in the respective stowed configuration **SC** the respective first wing element **240H** and the respective second wing element **240V** are in the aforesaid overlying spatial relationship, and in which the respective first wing element leading edge **241H** is generally overlying the respective second wing element trailing edge **243V**, and the respective first wing element trailing edge **243H** is generally overlying the respective second wing element leading edge **241V**.

It is to be noted that once each of the respective first wing element **240H** and the respective second wing element **240V** reaches the respective deployed position corresponding to the deployed configuration **DC**, the respective first wing element **240H** and the respective second wing element **240V** are locked in position, for example via any suitable mechanical lock. For example, such a mechanical lock can be provided using a suitable pin and lug system, as are known in the art for example. Alternatively, such a mechanical lock can be in the form of spring loaded wedge element, for example.

Suitable actuators (not shown) are provided for actuating the first wing element **240H** and the respective second wing element **240V** of each module **220**, to cause the first wing element **240H** and the respective second wing element **240V** to rotate as required about the respective first module pivot axis **MPA1** and second module pivot axis **MPA2**, to provide the first module angular displacement θ_{M1} and second module angular displacement θ_{M2} , and to cause the first wing element **240H** and the respective second wing element **240V** to rotate as required about the respective first wing element pivot axis **WPAH** and second wing element pivot axis **WPAV**, through respective first wing element angular displacement θ_H and second wing element angular displacement θ_V , as required by the respective deployment method. Such actuators can comprise, for example, suitable prestressed springs that provide a torque when selectively released, corresponding to actuation of the actuator. For example, a coil spring can be configured to provide both

- 39 -

torsion and compression forces to rotate each one of the first wing element **240H** and the respective second wing element **240V** about the respective first module pivot axis **MPA1** and second module pivot axis **MPA2**, and lock it into place.

Suitable dampers (not shown) can be provided for dampening the rotation of the first wing element **240H** and the respective second wing element **240V** about the respective first module pivot axis **MPA1** and second module pivot axis **MPA2**. Such dampers can be configured for limiting the rate of rotation and limiting transmission of loads to the air vehicle. Suitable dampers (not shown) can also be provided for dampening the rotation of the first wing element **240H** and the respective second wing element **240V** about the respective first wing element pivot axis **WPAH** and second wing element pivot axis **WPAV**.

Such dampers can be configured for limiting the rate of rotation and limiting transmission of loads to the air vehicle. For example, such dampers can include linear oil dampers, which are well known in the art.

In at least this example, the first module angular displacement θ_{M1} is between 80° and 100° ; for example the first module angular displacement θ_{M1} is about 90° . For example, the first module angular displacement θ_{M1} is such as to enable the first wing element **240H** to adopt a zero incidence angle, or alternatively a non-zero incidence angle in the deployed configuration **DC**.

In at least this example, the second module angular displacement θ_{M2} is between 80° and 100° ; for example the second module angular displacement θ_{M2} is about 90° .

In at least this example, the first module angular displacement θ_{M1} and the second module angular displacement θ_{M2} are equal to one another. Furthermore, the wing deployment module **220** is configured for pivoting as a unit about at least one of first module pivot axis **MPA1** and the second module pivot axis **MPA2**.

In at least this example, the first wing element angular displacement θ_H is between 70° and 110° ; for example the first wing element angular displacement θ_H is about 90° .

In at least some examples, the second wing element angular displacement θ_V is between -20° and $+20^\circ$. For positive second wing element angular displacement θ_V , the

- 40 -

respective second wing elements **240V** of the port wing module **220P** and of the starboard wing module **220S** are in diverging relationship with respect to the fuselage aft section **110**. For negative second wing element angular displacement θ_v , the second wing elements **240V** of the port wing module **220P** and of the starboard wing module **220S** are in converging relationship with respect to the fuselage aft section **110**.

In at least this example, the second wing element angular displacement θ_v is about 15° , or can be in any suitable angle in the range between 0° and 15° . In at least one alternative variation of this example, the second wing element angular displacement θ_v is about 0° .

Two examples of such a deployment method are now disclosed.

First Example of Deployment Method

Referring to Figs. 8(a), 8(b), 8(c), 8(d), and to Fig. 9, a first deployment method **1000** is illustrated for the wing system **200**.

As will become clearer herein, according to method **1000**, the wing system **200** is configured for deploying each wing deployment module **220** from the stowed configuration **SC** to the deployed configuration **DC** by:

- (a) pivoting the first wing element **240H** about the first module pivot axis **MPA1** by said non-zero first module angular displacement θ_{M1} and pivoting the second wing element **240V** about the second module pivot axis **MPA2** by said non-zero second module angular displacement θ_{M2} ; and
- (b) pivoting said first wing element **240H** about the first wing element pivot axis **WPAH** by said non-zero first wing element angular displacement θ_H .

In particular, according to method **1000**, the wing system **200** is configured for deploying each wing deployment module **220** from the stowed configuration **SC** to the deployed configuration **DC** by:

- (a) concurrently pivoting the first wing element **240H** about the first module pivot axis **MPA1** by said non-zero first module angular displacement θ_{M1} and

- 41 -

the second wing element **240V** about the second module pivot axis **MPA2** by said non-zero second module angular displacement θ_{M2} ;

(b) subsequent to step (a), pivoting said first wing element **240H** about the first wing element pivot axis **WPAH** by said non-zero first wing element angular displacement θ_H .

Furthermore, in the method **1000** for examples in which second wing element angular displacement is non-zero, the wing system **200** is configured for deploying each wing deployment module **220** from the stowed configuration **SC** to the deployed configuration **DC** by:

(c) subsequent to step (a), pivoting said second wing element **240V** about the second wing element pivot axis **WPAv** by said non-zero second wing element angular displacement θ_V .

Thus, this method **1000** can be considered to be characterized in that, for each module **220**, the respective first wing element **240H** and the respective second wing element **240V** are sequentially deployed from the stowed configuration **SC** to the deployed configuration **DC**.

Referring in particular to Fig. 8(a), in step **1100** the respective first wing element **240H** and the respective second wing element **240V** of each module **220** are in the stowed configuration **SC**, in the aforementioned overlying relationship.

In the first deployment step **1200**, and referring in particular to Fig. 8(b), the respective first wing element **240H** and the respective second wing element **240V** of each module **220** are concurrently rotated about respective first module pivot axis **MPA1** and second module pivot axis **MPA2**, through respective first module angular displacement θ_{M1} and second module angular displacement θ_{M2} . In this example, the first module pivot axis **MPA1** and second module pivot axis **MPA2** are coaxial, and the first module angular displacement θ_{M1} and second module angular displacement θ_{M2} are equal to one another. For example, first module angular displacement θ_{M1} and second module angular displacement θ_{M2} are each about 90° . The respective first wing element **240H** and the respective second wing element **240V** of each module **220** are then locked in place in terms of preventing further pivoting about the respective first module pivot axis **MPA1**

- 42 -

and second module pivot axis **MPA2**. In step **1200** there is no rotation of the respective module **220** about the respective first wing element pivot axis **WPA_H** and second wing element pivot axis **WPA_V**.

In the second deployment step **1300**, and referring in particular to Fig. 8(c), the respective first wing element **240H** and the respective second wing element **240V** of each module **220** are rotated about respective first wing element pivot axis **WPA_H** and second wing element pivot axis **WPA_V**, through respective first wing element angular displacement θ_H and second wing element angular displacement θ_V . In this example, the first wing element pivot axis **WPA_H** and second wing element pivot axis **WPA_V** are nominally parallel. For example, first wing element angular displacement θ_H is about 90° , while second wing element angular displacement θ_V is about 15° . In at least some alternative variations of this example, second wing element angular displacement θ_V is zero, and thus in respective the second deployment step **1300**, while the respective first wing element **240H** of each module **220** is rotated about respective first wing element pivot axis **WPA_H** through respective first wing element angular displacement θ_H , the respective second wing element **240V** is not pivoted about the second wing element pivot axis **WPA_V**.

In the illustrated example, the respective first wing element **240H** and the respective second wing element **240V** of each module **220** can be concurrently rotated about respective first wing element pivot axis **WPA_H** and second wing element pivot axis **WPA_V**, until the respective second wing element **240V** reaches its respective second wing element angular displacement θ_V , and thereafter the respective first wing element **240H** continues to pivot about respective first wing element pivot axis **WPA_H** until it reaches its respective first wing element angular displacement θ_H . Alternatively, the respective first wing element **240H** is first rotated about respective first wing element pivot axis **WPA_H** until the respective first wing element **240H** reaches its respective first wing element angular displacement θ_H , and thereafter the respective second wing element **240V** is rotated about respective second wing element pivot axis **WPA_V** to pivot about respective second wing element pivot axis **WPA_V** until it reaches its respective second wing element angular displacement θ_V .

- 43 -

In the final deployment step **1500**, and referring in particular to Fig. 8(d), once the respective first wing element **240H** and the respective second wing element **240V** of each module **220** reach their respective first wing element angular displacement θ_H and respective second wing element angular displacement θ_V , the respective first wing element **240H** and the respective second wing element **240V** of each module **220** are then locked in place in terms of preventing further pivoting about the respective first wing element pivot axis **WPA_H** and second wing element pivot axis **WPA_V**, to provide the deployed configuration **DC**.

Without being bound by theory, inventors consider that a positive deployment moment is to be expected along most of first deployment step **1200**, at all relevant flight conditions, alleviating actuation requirements for rotating the respective first wing element **240H** and the respective second wing element **240V** of each module **220** about respective first module pivot axis **MPA1** and second module pivot axis **MPA2**.

However, and again without being bound by theory, inventors consider that an initial small negative deployment moment could exist at the beginning of the first deployment step **1200**, particular at negative angles of attack.

Second Example of Deployment Method

Referring to Figs. 10(a), 10(b), 10(c), 10(d), and to Fig. 11, a second deployment method **2000** is illustrated for the wing system **200**.

As will become clearer herein, according to method **2000**, the wing system **200** is configured for deploying each wing deployment module **220** from the stowed configuration **SC** to the deployed configuration **DC** by:

- (a) pivoting the first wing element **240H** about the first module pivot axis **MPA1** by said non-zero first module angular displacement θ_{M1} and pivoting the second wing element **240V** about the second module pivot axis **MPA2** by said non-zero second module angular displacement θ_{M2} ; and
- (b) pivoting said first wing element **240H** about the first wing element pivot axis **WPA_H** by said non-zero first wing element angular displacement θ_H .

- 44 -

In particular, according to method **2000**, the wing system **200** is configured for deploying each wing deployment module **220** from the stowed configuration **SC** to the deployed configuration **DC** by:

(a') concurrently pivoting the first wing element **240H** about the first module pivot axis **MPA1** to a first partial first module angular displacement θ_{M1}' , and the second wing element **240V** about the second module pivot axis **MPA2** to a first partial second module angular displacement θ_{M2}' ;

(b') subsequent to step (a'), pivoting said first wing element **240H** about the first wing element pivot axis **WPAH** by said non-zero first wing element angular displacement θ_H , while concurrently pivoting the first wing element **240H** about the first module pivot axis **MPA1** to a second partial first module angular displacement θ_{M1}'' , and the second wing element **240V** about the second module pivot axis **MPA2** to a second partial second module angular displacement θ_{M2}'' ;

(c') subsequent to step (b'), concurrently pivoting the first wing element **240H** about the first module pivot axis **MPA1** to said first module angular displacement θ_{M1} , and the second wing element **240V** about the second module pivot axis **MPA1** to said second module angular displacement θ_{M2} ;

In such cases:

- the second partial first module angular displacement θ_{M1}'' is less than said non-zero first module angular displacement θ_{M1} and greater than said first partial first module angular displacement θ_{M1}' , and
- the second partial second module angular displacement θ_{M2}'' is less than said non-zero second module angular displacement θ_{M2} and greater than said second partial second module angular displacement θ_{M2}' .

Furthermore, in the method **2000**, for examples in which second wing element angular displacement is non-zero, the wing system **200** is configured for deploying each wing deployment module **220** from the stowed configuration **SC** to the deployed configuration **DC** by including in step (b'):

- 45 -

(d') pivoting said second wing element **240V** about the second wing element pivot axis **WPA_v** by said non-zero second wing element angular displacement θ_v .

Thus, this method **2000** can be considered to be characterized in that, for each module **220**, the respective first wing element **240H** and the respective second wing element **240V** are for at least a part of the deployment process between the stowed configuration **SC** to the deployed configuration **DC**, are concurrently deployed.

Referring in particular to Fig. 10(a), in step **2100** the respective first wing element **240H** and the respective second wing element **240V** of each module **220** are in the stowed configuration **SC**, in the aforementioned overlying relationship.

In the first deployment step **2200**, and referring in particular to Fig. 10(b), the respective first wing element **240H** and the respective second wing element **240V** of each module **220** begin to be concurrently rotated about respective first module pivot axis **MPA1** and second module pivot axis **MPA2**, and are rotated through a first part of the respective first module angular displacement θ_{M1} and second module angular displacement θ_{M2} , i.e., until a respective first partial first module angular displacement θ_{M1}' and first partial second module angular displacement θ_{M2}' is reached. In this example, the first module pivot axis **MPA1** and second module pivot axis **MPA2** are coaxial, and the first partial first module angular displacement θ_{M1}' and the first partial second module angular displacement θ_{M2}' are equal to one another. For example, first partial first module angular displacement θ_{M1}' and the first partial second module angular displacement θ_{M2}' are each about 45° for example, or can be any suitable angle between about 0° and about 45° for example, or can be any suitable angle between about 0° and about 55° for example. In step **2200** there is no rotation of the respective module **220** about the respective first wing element pivot axis **WPA_H** and second wing element pivot axis **WPA_v**.

In the second deployment step **2300**, and referring in particular to Fig. 10(c), the respective first wing element **240H** and the respective second wing element **240V** of each module **220** are rotated about respective first wing element pivot axis **WPA_H** and second wing element pivot axis **WPA_v**, through respective first wing element angular displacement θ_H and second wing element angular displacement θ_v . In this example, the respective first wing element pivot axis **WPA_H** and second wing element pivot axis

- 46 -

WPA_v are nominally parallel. For example, first wing element angular displacement θ_H is about 90° , while second wing element angular displacement θ_v is about 15° . The respective first wing element **240H** and the respective second wing element **240V** of each module **220** can be concurrently rotated about respective first wing element pivot axis **WPA_H** and second wing element pivot axis **WPA_v**, until the respective second wing element **240V** reaches its respective second wing element angular displacement θ_v , and thereafter the respective first wing element **240H** continues to pivot about respective first wing element pivot axis **WPA_H** until it reaches its respective first wing element angular displacement θ_H . Alternatively, the respective first wing element **240H** is first rotated about respective first wing element pivot axis **WPA_H** until the respective first wing element **240H** reaches its respective first wing element angular displacement θ_H , and thereafter the respective second wing element **240V** is rotated about respective second wing element pivot axis **WPA_v** to pivot about respective second wing element pivot axis **WPA_v** until it reaches its respective second wing element angular displacement θ_v . In any case, in this step the respective first wing element **240H** and the respective second wing element **240V** of each module **220** are rotated rapidly about respective first wing element pivot axis **WPA_H** and second wing element pivot axis **WPA_v**, through respective first wing element angular displacement θ_H and second wing element angular displacement θ_v , while the respective first wing element **240H** and the respective second wing element **240V** of each module **220** continue to be concurrently rotated about respective first module pivot axis **MPA1** and second module pivot axis **MPA2**. At the end of step **2300** the respective first wing element **240H** and the respective second wing element **240V** of each module **220** are rotated about respective first module pivot axis **MPA1** and second module pivot axis **MPA2** through a second part of the respective first module angular displacement θ_{M1} and second module angular displacement θ_{M2} , i.e., until a respective second partial first module angular displacement θ_{M1}'' and second partial second module angular displacement θ_{M2}'' is reached. At this point, after the respective first wing element **240H** and the respective second wing element **240V** of each module **220** have been fully rotated about respective first wing element pivot axis **WPA_H** and second wing element pivot axis **WPA_v**, through respective first wing element angular displacement θ_H and second wing element angular displacement θ_v , the respective first wing element **240H** and the respective second wing element **240V** of each module **220**

- 47 -

are then locked in place in terms of preventing further pivoting about the respective first wing element pivot axis **WPA_H** and second wing element pivot axis **WPA_V**. For example, the second partial first module angular displacement θ_{M1} and the second partial second module angular displacement θ_{M2} are equal to one another. For example, second partial first module angular displacement θ_{M1} and the second partial second module angular displacement θ_{M2} are each about 75° for example, or can be any suitable angle between about 45° and about 75° for example, or can be any suitable angle between about 45° and about 80° for example.

In at least some alternative variations of this example, second wing element angular displacement θ_V is zero, and thus in respective the second deployment step **2300**, while the respective first wing element **240H** of each module **220** is rotated about respective first wing element pivot axis **WPA_H** through respective first wing element angular displacement θ_H , the respective second wing element **240V** is not pivoted about the second wing element pivot axis **WPA_V**.

In the third deployment step **2400**, and referring in particular to Fig. 10(d), with the respective first wing element **240H** and the respective second wing element **240V** of each module **220** locked in terms of preventing further pivoting about the respective first wing element pivot axis **WPA_H** and second wing element pivot axis **WPA_V**, the respective first wing element **240H** and the respective second wing element **240V** of each module **220** continue to be concurrently rotated about respective first module pivot axis **MPA1** and second module pivot axis **MPA2**. At the end of step **3400** the respective first wing element **240H** and the respective second wing element **240V** of each module **220** are now fully rotated about respective first module pivot axis **MPA1** and second module pivot axis **MPA2** through the full first module angular displacement θ_{M1} and second module angular displacement θ_{M2} . For example, the first module angular displacement θ_{M1} and the second module angular displacement θ_{M2} are each about 90°, or can be any suitable angle between about 75° and about 90°. In other examples, for example where it is desired to provide a non-zero incidence angle for the first wing element **240H** in the deployed configuration **DC**, the first module angular displacement θ_{M1} and the second module angular displacement θ_{M2} can be greater than about 90°.

- 48 -

In the final deployment step **2500**, and referring in particular to Fig. 10(e), once the respective first wing element **240H** and the respective second wing element **240V** of each module **220** reach their respective the first module angular displacement θ_{M1} and the second module angular displacement θ_{M2} , the respective first wing element **240H** and the respective second wing element **240V** of each module **220** are then locked in place in terms of preventing further pivoting about the respective first module pivot axis **MPA1** and second module pivot axis **MPA2**, to provide the deployed configuration **DC**.

Without being bound by theory, inventors consider that method **2000** can provide a faster deployment time, for example as compared with method **1000**, or, that method **2000** can provide a reduction of acceleration, for example as compared with the deployment time in method **1000**.

Without being bound by theory, inventors consider that method **2000** can make use of aerodynamic loads on the wing system **200** during deployment, such as to alleviate deployment actuation requirements.

For example, and again without being bound by theory, inventors consider that a positive deployment moment is to be expected along most of first deployment step **2200**, second deployment step **2300**, and third deployment step **2400**, at all relevant angle of attack conditions, alleviating actuation requirements for rotating the respective first wing element **240H** and the respective second wing element **240V** of each module **220** about respective first module pivot axis **MPA1** and second module pivot axis **MPA2**. However, and again without being bound by theory, inventors consider that an initial small negative deployment moment could exist at the beginning of the first deployment step **1200**, particular at negative angles of attack.

For example, and again without being bound by theory, inventors consider that initiating rotation of the respective first wing element **240H** and the respective second wing element **240V** of each module **220** about respective first wing element pivot axis **WPAH** and second wing element pivot axis **WPAV**, after partial pivoting of the first wing element **240H** and the respective second wing element **240V** of each module **220** about respective first module pivot axis **MPA1** and second module pivot axis **MPA2** about the first partial first module angular displacement θ_{M1}' and the first partial second module angular displacement θ_{M2}' (for example of 45°), can help prevent excessive aerodynamic

- 49 -

loads on the respective first module pivot axis **MPA1** and second module pivot axis **MPA2**, due to a reduced normal velocity component.

Furthermore, and again without being bound by theory, inventors consider that terminating rotation of the respective first wing element **240H** and the respective second wing element **240V** of each module **220** about respective first wing element pivot axis **WPAH** and second wing element pivot axis **WPAv**, before full pivoting of the first wing element **240H** and the respective second wing element **240V** of each module **220** about respective first module pivot axis **MPA1** and second module pivot axis **MPA2**, i.e., at the second partial first module angular displacement θ_{M1} " and the second partial second module angular displacement θ_{M2} " (for example of 75°), can help guarantee a positive deployment moment throughout the rotations about the respective first wing element pivot axis **WPAH** and second wing element pivot axis **WPAv**, alleviating actuator requirements.

By having, in the stowed configuration **SC**, the wing tip **244H** and the wing tip **244V** of the overlying the first wing element **240H** and the second wing element **240V**, respectively, facing in the forward direction with respect to the aft fuselage section **110**, and the wing root **242H** and the wing root **242V** facing in the aft direction with respect to the aft fuselage section **110**, it is possible to maximize the moment arm of first wing element **240H** and the second wing element **240V** for providing control moments in pitch, yaw and roll in the deployed configuration **DC**. Furthermore this arrangement in which the respective wing root **242H** and the wing root **242V** are aft of the respective wing tip **244H** and the wing tip **244V**, allows the aerodynamic loads acting on the each of the wing elements **240H**, **240V** will be in the direction of deployment.

Without being bound to theory, inventors consider that the wing system **200** in the deployed configuration **DC** allows for rapid stabilization, as well as uncoupled all-axis control for the air vehicle **100**, even prior to deployment of the wing arrangement **300** for the generation of aerodynamic lift. The two-wing element structure of the wing deployment modules **220**, to provide separate vertical stabilizer and horizontal stabilizers, provides uncoupled, all-axes control capability. In other words, the wing system **200** in the deployed configuration **DC** allows for steering of the air vehicle **100** even before the wing arrangement **300** is deployed.

- 50 -

Thus, according to an aspect of the presently disclosed subject matter there is provided a method for providing stability and control for an air vehicle, comprising:

- deploying each wing deployment module **220** from the stowed configuration **SC** to the deployed configuration **DC**; and
- operating the first wing element **240H** and the second wing element **240V** of each wing deployment module **220** to provide control moments to the air vehicle **100**.

For example, and referring to Fig. 7(a), uncoupled yaw control can be provided by actuating the rudders **245V** to pivot in the same, desired, direction, which results in a desired yaw moment **Y1** and in an undesired roll moment **R1**. Concurrent with actuation of the rudders **245V**, the elevators **245H** are actuated to pivot in opposite directions to generate forces **F1**, **F2** in opposite directions to thereby provide a roll **-R1** that is opposite in direction and equal in magnitude to the undesired roll moment **R1** that is generated by the deflection of the rudders **245V**. This results in zero roll moment, allowing the air vehicle to be subjected to the uncoupled yaw moment **Y1**.

For example, and referring to Fig. 7(b), uncoupled pitch control can be provided by actuating the elevators **245H** to pivot in the same direction to generate forces **F1**, **F2** in the same direction.

For example, and referring to Fig. 7(c), uncoupled roll control can be provided by actuating the elevators **245H** to pivot in opposite directions to generate forces **F1**, **F2** in opposite directions.

Referring to Fig. 12(a), Fig. 12(b) and Fig. 12(c), in at least this example, the air vehicle **100** is configured for being accommodated in a fairing **800**, while the wing system **200** is in the stowed configuration **SC**, and in which the wing arrangement **300** is in its respective stowed wing configuration. For example, such a fairing **800** enables the air vehicle **100** to be isolated from aerodynamic forces as the air vehicle **100** is accelerated to required speed and altitude, and/or such a fairing can protect the air vehicle while in storage or while being transported. For example the air vehicle **100** can be accelerated to required speed and altitude via an external launch system, for example a launch barrel, or for example via a booster rocket (as a payload thereof for example), or for example can be delivered to required altitude and required speed via a carrier air vehicle.

- 51 -

The fairing **800** has an internal profile and fairing cross-sectional areas at transverse planes orthogonal to the longitudinal axis **LAF** of the fairing such as to enable the respective transverse cross-sections of the air vehicle **100** (i.e., the respective external profiles and transverse cross-sectional areas of the air vehicle **100**) to be accommodated therein. In at least this example, fairing **800** has a substantially uniform internal profile and a substantially uniform cross-sectional area at transverse planes orthogonal to the longitudinal axis **LAF** for at least cross-sections of the air vehicle which include the wings **220** in the stowed configuration **SC**. The longitudinal axis **LAF** of the fairing is generally defined at the centerline of the fairing.

It is to be noted that at least for some implementations of this example in which the acceleration of the air vehicle **100** (while accommodated in the fairing **800** in a respective assembly) is achieved by applying a force to the assembly (for example a thrust force via a booster rocket, or as a result of being fired from a launch barrel), there can be advantages in having such a force aligned with the fairing longitudinal axis **LAF**, in particular the centerline of the fairing. In at least such cases there can also be corresponding advantages in having the center of gravity **CG** of the air vehicle **100** also lying on the fairing longitudinal axis **LAF**, in particular on the centerline of the fairing. For example, such an arrangement can minimize or eliminate risk of nutation.

In at least some such cases, the air vehicle **100** can be configured such that the chord and size of the wing arrangement **300** is maximized, while the wing arrangement is located either at the bottom of the fuselage (as in the illustrated example) or above the fuselage, in particular the fuselage section **110**.

Thus, in at least the example of Fig. 12(a), Fig. 12(b) and Fig. 12(c), the wing arrangement **300** is below the aft fuselage section **110**, that is, the wing arrangement **300** is facing a lower portion **116** of the aft fuselage section **110**. However, in at least one alternative variation of the example of Fig. 1, the wing arrangement **300** can be above the fuselage, that is, the wing arrangement **300** is facing an upper portion of the fuselage, for example of the aft fuselage section **110**.

To maximize potential usage of the faring internal volume for the wing arrangement **300**, and according to an aspect of the presently disclosed subject matter, the wing system **200** provides modules **220**, in which the respective first wing element **240H**

- 52 -

and the second wing element **240V** are in the aforesaid overlying relationship, and in which the respective chords **C_H** and **C_V**, and in particular in which the respective widths **W_H** and **W_V**, allow to maximize utilization of the lateral spaces **LS** between the aft fuselage section **110** and the internal wall of the fairing **800**, without projecting downwards (or in other example, upwards) past where the wing arrangement **300** is to be accommodated. For example, the respective chords **C_H** and **C_V**, and in particular the respective widths **W_H** and **W_V**, can be maximized to fit within the lateral spaces **LS** while not extending beyond the cross-section of the fuselage aft section **110**. This feature enables the wing system **200** to be used with a variety of different types of wing arrangements **300**, and allows for the span of the wing arrangements to be maximized to extend to the aft end **810** of the fairing **800**. For example, for each wing module **220**, the respective first wing element **240H** and the second wing element **240V** have respective chords **C_H** and **C_V**, and in particular have respective widths **W_H** and **W_V**, about the height **HF** of the aft fuselage section **110**.

According to this aspect of the presently disclosed subject matter, great flexibility can be exercised in the design of the wing modules **220** of the wing system **200**. For example, the respective first wing element **240H** and the second wing element **240V** can be designed with relatively large spans **S_H** and **S_V**, since they can be accommodated along the correspondingly long sides of the fuselage aft section **110**. Furthermore, for example, the respective first wing element **240H** and the second wing element **240V** can be designed with similar spans **S_H** and **S_V**, or with unequal spans **S_H** and **S_V**, which can facilitate further maximization of the available volume in the lateral spaces **LS**. Furthermore, for example, the respective first wing element **240H** and the second wing element **240V** can be designed with similar chords **C_H** and **C_V**, and in particular having similar widths **W_H** and **W_V**, or with unequal chords **C_H** and **C_V**, and in particular having non-similar widths **W_H** and **W_V** which can facilitate further maximization of the available volume in the lateral spaces **LS**. Furthermore, for example, the respective first wing element **240H** and the second wing element **240V** can be designed with tapered planforms, which can facilitate further maximization of the available volume in the lateral spaces **LS**. For example, the respective first wing element **240H** and the second wing element **240V** can be designed with desired spans **S_H** and **S_V**, and desired chords **C_H** and **C_V**, and in particular having corresponding widths **W_H** and **W_V**, such as to provide desired

- 53 -

mechanical and aerodynamic performance in the deployed configuration **DC**, while enabling compact storage in the stowed configuration **SC**.

It is to be noted that while in at least this example, the wing system **200** is configured as an empennage for the air vehicle **100**, in other alternative variations of this example, the wing system, or at least a part of the wing system, according to another aspect of the presently disclosed subject matter, can be configured as the main aerodynamic lift generating wings for the air vehicle **100**.

In the method claims that follow, alphanumeric characters and Roman numerals used to designate claim steps are provided for convenience only and do not imply any particular order of performing the steps.

Finally, it should be noted that the word “comprising” as used throughout the appended claims is to be interpreted to mean “including but not limited to”.

While there has been shown and disclosed examples in accordance with the presently disclosed subject matter, it will be appreciated that many changes may be made therein without departing from the scope of the presently disclosed subject matter as set out in the claims.