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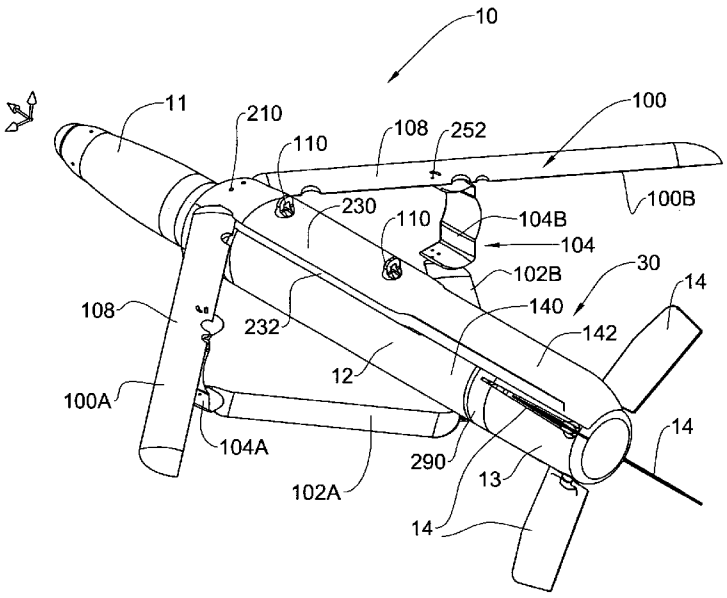
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(54) **Title:** AIR VEHICLE AND DEPLOYABLE WING ARRANGEMENT THEREFOR



(57) **Abstract:** A deployable wing arrangement or kit is provided for use with a longitudinally extending fuselage (20) having an upper portion and a lower portion. The kit includes a first pair of wings (100) pivotably mountable with respect to said upper portion and capable of being deployed from a first retracted position to a first deployed position, and a second pair of wings (102) pivotably mountable with respect to said lower portion and capable of being deployed from a second retracted position to a second deployed position. A strut arrangement, having at least one pair of struts (104), interconnect the first pair of wings (100) with the said second pair of wings (102). An air vehicle having such a kit, and a method for increasing the range of an air vehicle are also provided.

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AIR VEHICLE AND DEPLOYABLE WING ARRANGEMENT THEREFOR

FIELD OF THE INVENTION

This invention relates to air vehicles, specially to controllable air vehicles, and particularly having deployable wings.

BACKGROUND OF THE INVENTION

Controllable air vehicles such as airplanes, projectiles, missiles, and the like are well known. Some examples are included in the following patents.

US 5,615,846 discloses a deployable diamond shaped wing for use in extending range or increasing maneuverability of guided missiles or munitions. A hardback mechanism attaches the wing kit to the top part of an existing guided munition or missile and the forward wing is attached with a forward wing pivot assembly so as to allow the forward wing to rotate in the horizontal plane. The rear wing is comprised in the hardback and is attached to a driveshaft and carriage with a rear wing pivot that allows rear wing rotation in the horizontal plane. The forward wing and rear wing are joined at the wingtips with a wing tip pivot pin and folded laterally along the hardback for storage. A motor is mounted within the hardback and connected to the driveshafts in a manner to cause the carriages to move fore and aft. After launch, the lifting surfaces are extended by powering the driveshaft to move the carriages longitudinally aft with the attached rear wing pivot and to cause the wings to form a diamond shaped lifting surface. The wings can be retracted by reversing the procedure. The entire wing kit assembly is attached to an inventory weapon and launch platform by using the existing suspension points with new hardback lugs.

US 6,845,937 discloses a reusable, mach-velocity mobile platform that includes a generally tubular shaped body having an aft and forward end, and a payload section. An arch wing is supported by the body aft end. The arch wing has an upper and a lower wing joined at distal ends by two curved end plates. A nose assembly is connected at the forward end having an upward directed fixed angle-of-attack to generate forward end lift.

In US 5,899,410 an aerodynamic body, such as an aircraft, includes a lengthwise extending fuselage and a pair of coplanar joined wings extending outwardly from opposed sides of the fuselage. The pair of coplanar joined wings are formed by at least

two forward wings extending laterally outward and rearward from opposite sides of a forward portion of the fuselage, and at least two aft wings extending laterally outward and forward from opposite sides of a rearward portion of the fuselage. Each aft wing is joined to a respective forward wing at a common wingtip to thereby form one of the joined wings. In particular, the aft wing can either be joined to the outermost portion of the respective forward wing or to a medial portion of the respective forward wing such that a portion of the forward wing extends outboard of the common wingtip. In either embodiment, the forward and aft wings of the joined wing aircraft define respective planes which are mutually coplanar.

US 3,942,747 discloses an aircraft of the Canard type in which a first airfoil is attached to an aft fin portion of the fuselage at a higher elevation than a second airfoil which is attached to the fore portion of the fuselage. The second airfoil extends outwardly and rearwardly to meet the first airfoil whereby a triangular configuration is formed in plan view and in front elevation view.

US 4,365,773 discloses an aircraft having a fuselage and a pair of first airfoils in the form of wings extending outwardly from the vertical tail and a pair of second airfoils in the form of wings extending outwardly from the forward portion of the fuselage at a lower elevation than the first airfoils. The second wings extend rearwardly having a positive dihedral so that the tip ends of the second airfoil are located in close proximity to and may overlap the tip ends of the first wings. The pairs of wings along with the fuselage present a double triangle or diamond shape in both front elevational view and top plan view. A winglet structurally connects the tip ends of the corresponding first wings and second wings, and these winglets have airfoil surfaces which extend vertically substantially beyond the tip ends of the first and second wings in order to minimize the effects of induced drag and also to augment directional stability of the aircraft.

US 4,146,199 discloses a fore mounted aft swept and aft mounted forward swept wings extend from either side of a lifting body fuselage. Each lateral pair of the wings is joined at the tops by a wing tip vortex translating device to induce translation of the tip generated vortices along the trailing edge of the aft wings. End plates extend rearwardly from the maximum chord thickness of the fuselage to increase the effective lift of the fuselage.

US 5,141,175 discloses a device having pop-out wings and a guidance and control system is detachably mounted on a munition such as a bomb and is used to extend the range capability of the munition. Prior to launch, the wings are folded together. The control system is contained within a saddle portion of the device, and when the munition is released from the aircraft, the wings are caused to pop out to their flying position. The saddle is secured to the munition through a single bolt. When the target area is reached, the device is jettisoned by detonating a charge which shears the securing bolt, thereby permitting the device to pivot rearwardly and separate from the munition.

US 6,745,979 discloses a spacecraft such as a fly back booster or a reusable launch vehicle, or an aerospace plane, having a fuselage and a set of scissors wings consisting of two main wings. Both of the main wings are rotatably mounted on the fuselage and can be yawed at opposite directions.

SUMMARY OF THE INVENTION

According to one aspect of the invention, a deployable wing arrangement (referred to synonymously as a deployable wing kit) is provided for use with a longitudinally extending fuselage, for example of a projectile, bomb, or other stores, having an upper portion and a lower portion, the kit comprising:

a first pair of wings pivotably mountable with respect to said upper portion and capable of being deployed from a first retracted position to a first deployed position;

a second pair of wings pivotably mountable with respect to said lower portion and capable of being deployed from a second retracted position to a second deployed position;

a strut arrangement comprising at least one pair of struts, wherein one or another strut of said pair of struts respectively interconnect one or another of said first pair of wings with one or another of said second pair of wings.

According to one aspect of the invention, the upper surface and lower surface of the fuselage are spaced, and the first pair of wings is spaced from the second pair of wings at least along a direction generally orthogonal to the longitudinal axis of such a fuselage.

The deployable wing arrangement or kit may further comprise an actuation mechanism adapted for selectively deploying said first and second wings from said first and second retracted positions, respectively, to said first and second deployed positions, respectively. The actuation mechanism may be configured for deploying said first and second wings substantially concurrently one with respect to another.

At least one of said first wings and second wings comprises substantially zero taper (i.e., a taper ratio of unity). The first pair of wings comprises a first port wing and a first starboard wing. Optionally, in said first retracted position, said first pair of wings assume a position generally aligned with said fuselage. The deployable wing arrangement or kit according to the invention may further comprise a suitable housing for stowing at least a part of each said first wing when in the first retracted position. The first wings may be pivotably mounted with respect to said upper portion via a first hinge arrangement. In said first deployed position, said first pair of wings assume a backward swept position with respect to said fuselage, for example having a sweep angle between about 20° and about 30°.

The second pair of wings comprises a second port wing and a second starboard wing. Optionally, in the second retracted position, said second pair of wings may assume a position generally aligned with said fuselage. In the second deployed position, said second pair of wings may assume a forward swept position with respect to said fuselage, for example having a sweep angle between about –30° and about –40°. The second wings may be pivotably mounted with respect to said lower portion via a second hinge arrangement.

Each said strut interconnects a corresponding said first wing with a corresponding said second wing in a manner such as to synchronise said deployment of said first wing with said deployment of said second wing. Each said strut pivotably interconnects a corresponding said first wing with a corresponding said second wing via a third hinge arrangement, for example. Optionally, each said strut may comprise an aerodynamic profile, in particular a symmetric aerofoil, configured to increase lateral maneuverability to said air vehicle at least when said first wings and said second wings are in their respective said first and second deployed positions. Each said strut may comprise a pair of spaced end portions joined by means of a central arched portion, wherein each said end portion is pivotably mounted to one or another corresponding said first and second wings via said third hinge arrangement.

The deployable wing arrangement or kit may comprise a strongback adapted for enabling said wing arrangement to be mounted onto an upper portion of a longitudinally extending fuselage, said strongback comprising said first hinge arrangement. The second hinge mechanism may be axially movable with respect to said first hinge mechanism from a first axial position to a second axial position, an axial position of said first hinge mechanism being substantially fixed with respect to said strongback, such that at said first axial position said second wings and said first wings are at said second and first retracted positions, respectively, and wherein at said second axial position, said second wings and said first wings are at said second and first deployed positions, respectively. Further, said actuating mechanism may be configured for selectively moving said second hinge mechanism from said first axial position to said second axial position such as to cause said second wings to be deployed from said second retracted position to said second deployed position, and so as to cause, via said third hinge arrangement, said first wings to be deployed from said first retracted position to said first deployed position. By way of non-limiting example, the actuator arrangement may comprise any one of or combination of: a mechanical actuator, a pneumatic actuator, a hydraulic actuator, aerodynamic actuator; and electrically-actuable actuator.

Each said strut may be pivotably connected to a corresponding said first wing at a wing tip thereof, or alternatively at a position inboard of a wing tip thereof, or alternatively at a position substantially intermediate a wing tip and a wing root thereof.

Each said strut may be pivotably connected to a corresponding said second wing at a wing tip thereof, or at a position inboard of a wing tip thereof, or at a position substantially intermediate a wing tip and a wing root thereof.

According to another aspect of the invention, an air vehicle is provided, comprising:

a longitudinally extending fuselage having an upper portion and a lower portion; and

a deployable wing arrangement or kit according to the first aspect of the invention.

The air vehicle may comprise a plurality of stabilizing fins mounted to said fuselage. The fins may be deployable from a retracted position substantially

accommodated within said fuselage to a deployed position substantially outside of said fuselage.

The fuselage may comprise at least one of: a guidance system, an electro optics system, a laser system, a radar system, a reconnaissance system, optionally housed in a nose section of the fuselage or elsewhere in the fuselage. The fuselage may comprise at least one of: a payload, a warhead, a reconnaissance system; optionally housed in a center section of the fuselage or elsewhere in the fuselage. The fuselage may comprise a propulsion system, optionally housed in an aft section of the fuselage or elsewhere in the fuselage.

The air vehicle may comprise a deployment mechanism for enabling the air vehicle to be selectively deployed from an attachment station of a carrier air vehicle. The deployment mechanism may comprise at least one suspension lug configured for cooperating with a support hook comprised on said carrier air vehicle.

The present invention also relates to a method for increasing the range of an air vehicle comprising a fuselage, comprising providing a deployable wing arrangement or kit according to the invention, and mounting the same on said vehicle, imparting a forward velocity at a predetermined altitude to the vehicle, and deploying the wings of said wing arrangement. In one embodiment the air vehicle is air launched from a carrier vehicle to impart said forward velocity at a predetermined altitude to the air vehicle. In other embodiments, the air vehicle may be ground launched along a suitable trajectory, for example with the aid of booster rockets.

Some features of at least some embodiments of the invention may include the following:

Large aspect ratio wings provides induced drag reduction, and enables the air vehicle comprising the wing arrangement of the invention to have a larger range than otherwise.

The general diamond configuration for the wing arrangement (in plan view) in the deployed configuration thereof allows the use of high aspect ratio wings, while maintaining static stability margin in pitch of the air vehicle on which the wing arrangement is mounted. In other words, the hinge point of the upper wings may be moved forward, thus allowing the span of the wing to be increased (such that the wing tip, in retracted position, does not significantly extend aft beyond the end of the vehicle).

The sweep angle provided by the wings when in the deployed configuration reduces transonic drag with respect to a similar wing arrangement having zero sweep angle.

The side struts provided between the upper wings and the lower wings allow easy and synchronized deployment of the upper and lower wings, and moreover can increase the skid-to-turn maneuverability by reducing the lateral stability margin of the vehicle and adding vertical surfaces.

The box-like structure formed between the upper wings and lower wings via the side struts provide better aeroelastic properties, and weight advantages than a comparable single wing structure having similar aerodynamic and structural performance.

BRIEF DESCRIPTION OF THE DRAWINGS

In order to understand the invention and to see 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:

Figs. 1a to **1d** illustrate deployment stages of an embodiment of the invention.

Fig. 2 illustrates in top/rear isometric view the embodiment of Figs. 1a-1d in the fully deployed configuration.

Fig. 3 illustrates in bottom/rear isometric view the embodiment of Figs. 1a-1d in the fully deployed configuration.

Fig. 4 illustrates in top/rear isometric view the strut of embodiment of Figs. 1a-1d by itself.

Fig. 5 illustrates in rear view the embodiment of Figs. 1a-1d in the fully retracted configuration.

Fig. 6 illustrates in front view the embodiment of Figs. 1a-1d in the fully deployed configuration.

Figs. 7a to **7c** illustrate alternative embodiments of the invention.

Fig. 8 illustrates in top/rear isometric view the deployable wing kit of the embodiment of Figs. 1a-1d in the fully deployed configuration.

Fig. 9 illustrates in bottom/rear isometric view the deployable wing kit of the embodiment of Figs. 1a-1d in the fully deployed configuration.

DETAILED DESCRIPTION OF EMBODIMENTS

According to one aspect of the present invention, a deployable wing arrangement is provided in kit form for fitting, or retrofitting, to a suitable body such as the fuselage or body of an air vehicle. According to another aspect of the invention, an air vehicle is provided, comprising a deployable wing arrangement of the invention, either integrally or removably fitted with respect to a fuselage or body of the vehicle.

According to an embodiment of the invention, an air vehicle comprising a deployable wing arrangement is illustrated in Figs. 1 to 6, and is generally designated with the numeral **10**. The air vehicle **10**, which may be configured for use as a projectile, for example, such as a guided weapon, for example, comprises an elongate fuselage **20** and a deployable wing arrangement **30**. Optionally, the deployable wing arrangement **30** may be provided in kit form and fitted to the air vehicle body such as the fuselage **20**.

Referring in particular to Figs. 2 and 3, the fuselage **20** comprises a forward or nose section **11** serially connected to, or integrally formed with, a center section **12** and an aft section **13**. The nose section **11** comprises a streamlined fairing and may house, for example, a guidance system and/or a radar system and/or a reconnaissance system and/or an optical system and/or a laser system, and so on. The center section **12** and/or the aft section **13** may accommodate, for example, a payload and/or a warhead and/or a reconnaissance system. Optionally, and in other variations of this embodiment, the center section **12** and/or the aft section **13** may comprise a propulsion system, such as for example a rocket motor, ramjet engine, turbojet engine, and so on, together with a suitable fuel system. Further optionally, other propulsion units may be mounted to the fuselage, for example on the sides thereof at the said aft section **13**. However, in this embodiment, the air vehicle lacks a propulsion system, and the air vehicle **10** is an air launched gliding weapon or the like, propelled by virtue of the momentum imparted thereto by other means, such as a mother or carrier air vehicle e.g., a military aircraft or other weapons platform for example.

The aft section **13** further comprises a plurality of stabilizing and/or control fins **14**, which are deployable from a stowed, folded or retracted position (Fig. 1a), in which the fins **14** are housed in forward facing recesses **35** (Fig. 3) accommodated in the fuselage **20**, to a deployed position (Fig. 1b), in which the fins **14** are radially projecting from the aft section **13** to an outside of the fuselage **20**. Deployment of the fins **14** may

be achieved using any means known in the art, for example by a spring loaded mechanism, pyrotechnic means, and so on. The fins **14** are optionally pivotable in a controlled manner about suitable journals (not shown) aligned with radial axes generally orthogonal with respect to a longitudinal axis **99** of the fuselage **20**, to provide directional control to the air vehicle 10. In the illustrated embodiment, the aft section 13 comprises four fins 14, wherein adjacent fins are angularly spaced one from another with respect to longitudinal axis **99** in a substantially uniform manner. It will be appreciated that in other embodiments, more than four fins **14**, or less than four fins **14**, may be comprised on the air vehicle, typically depending on the specific requirements, mission and so on of the particular air vehicle, for example.

The fuselage **20** is typically of circular cross-section, though may comprise any other suitable cross-section, including, for example oval, polygonal, and so on, and the cross-sectional area thereof gradually increases from the nose section **11** to the center section **12**, and may again diminish at or near the aft section **13**; alternatively the aft section may be blunt-ended. The fuselage **10** comprises an upper portion **140**, and a lower portion **150** diametrically opposed to the upper portion **140** with respect to the centerline or axis **99**.

The wing arrangement **30** comprises a saddle or strongback **142**, which can be further configured as a wing housing, and provides structural support for the rest of the wing arrangement **30**, as well as for the fuselage **20**. The strongback **142** is comprised on the upper portion **140** in the illustrated embodiment, and may be joined thereto, for example when the wing arrangement **30** is provided in kit form, or alternatively may be integrally formed therewith. The wing arrangement **30** is mounted onto the fuselage **20** at a position such that when fully deployed, assures sufficient static margin to the vehicle **10.**

Referring particularly to Figs. 2 and 5, the vehicle optionally comprises a pair of axially spaced suspension lugs **110** which pass through strongback lug pockets **114** in the strongback **142** and are fixedly connected to suitable lug wells **112**, which may constitute standard munitions lug wells when the vehicle **10** is a projectile, for example. The lugs **110** are configured for cooperating with support hooks comprised on a carrier air vehicle, for example, and thus allows the vehicle to be carried by the carrier air vehicle and released when desired. Optionally, the suspension lugs **110** may be configured for locking the strongback **142** with respect to the fuselage **20** by means of

wells **112**, and may thus be longer than standard lugs normally used for the fuselage **20**. For example, the lugs **110** may comprise a flange that abuts the upper portion of the strongback **142** in the vicinity of the pockets **114**. Alternatively, the lugs **110** comprise an external screwthreaded surface that engages a complementary internally threaded surface in the pockets **114** and wells **112**. Other connecting arrangements are also possible.

A number of swaybraces **117**, typically a fore pair of swaybraces and an aft pair of swaybraces, may be provided on the aircraft (or indeed the carrier air vehicle when this is not an aircraft) which abut against swaybrace pads **116** on the housing **142** for providing stability to the vehicle **10** while attached to the carrier air vehicle (not shown).

The deployable wing arrangement **30** comprises a forwardly mounted first pair of wings, collectively designated **100**, an aft mounted second pair of wings, collectively designated **102**, and at least one pair of struts, collectively designated **104**.

The first pair of wings **100** comprises a port wing **100A** and a starboard wing **100B**, each pivotably mounted with respect to the upper portion **140** by means of a suitable hinge arrangement **210** for the forward wings. In this embodiment the hinge arrangement **210** is configured for allowing free pivoting of the wings **100** with respect to the fuselage **20**. (In other embodiments of the invention, though, the hinge arrangement may be actuable directly to deploy the first wings **100** – for example the hinge arrangement may comprise a rack and pinion mechanism, wherein the rack is actuated by any suitable powered mechanism, thereby rotating the pinions which in turn rotate the wings **100** to the deployed position. Alternatively, a spring based actuator may use a spring to deploy the wings, for example.) The wings **100** are configured for, and are capable of, being deployed from a first retracted position (Fig. 1a) to a first fully deployed position (Fig. 1d), by pivoting about the hinge arrangement **210**. In this embodiment, the position of hinge arrangement **210** is fixed axially with respect to the fuselage **20**. The wings **100** in this embodiment are shown as having substantially zero taper, but may alternatively comprise any suitable taper ratio, as required for particular applications of the vehicle **10**. In the deployed configuration, the wings **100** are swept back, at a sweep angle which may be, for example, between about 20° and about 30°. In other embodiments, the sweep angle may be zero or negative (swept forward). In the retracted configuration, the wings **100**, or at least the trailing edges thereof, are retracted into axially extending slits **232** comprises on either side of a suitable housing **230**

comprised on said upper portion **140**, which may be integral or separate from the strongback **142**. Thus, in the retracted configuration illustrated in Fig. 1a, the wings **100** assume a position generally aligned with said fuselage **20**.

The second pair of wings **102** comprises a port wing **102A** and a starboard wing **102B**, each pivotably mounted with respect to the lower portion **150** by means of a suitable second hinge arrangement **220** for the aft wings. In this embodiment the hinge arrangement **220** is configured for allowing free pivoting of the wings **102** with respect to the fuselage **20**. The wings **102** are configured for, and are capable of, being deployed from a second retracted position (Fig. 1a) to a second fully deployed position (Fig. 1d), as will become clearer herein. The position of hinge arrangement **220** may be moved from a first, aft axial position **P1** to a second, fore axial position **P2** with respect to the fuselage **20**, and thus the second hinge arrangement comprises a suitable translation mechanism, for example a rail **221** mounted to the underside **150**, and a runner (not shown) on which the hinge arrangement **220** is mounted, the runner being configured for axial movement with respect to the rail. The rail **221** may comprise a suitable base **222** for mounting onto the fuselage, and may be faired for minimizing drag thereof. The base **222** may be held in position on the fuselage by means of a belt **290** that is connected to the strongback **142**. The aft position **P1** is associated with the retracted position of wings **102**, and the fore position **P2** is associated with the deployed position of the wings **102**. The wings **102** in this embodiment are also shown as having substantially zero taper, but may alternatively comprise any suitable taper, as required for particular applications of the vehicle **10**. In the deployed configuration, the wings **102** are swept forward, at a sweep angle which may be, for example, between about -30° and about –40°. In other embodiments, the sweep angle may be zero or positive (swept back). In the retracted configuration, the wings **102** assume a position generally aligned with said fuselage 20.

The wings **100**, **102** are configured for providing desired lift/drag characteristics in the particular flight regime that the vehicle is designed or desired to operate, and for example may be optimized for transonic flight performance. In particular, the wings **100**, **102** may comprise a relatively high aspect ratio, minimizing induced drag.

In the illustrated embodiment, the lower wings **102** comprise a shorter span than the upper wings **100**, but in other embodiments the spans may be about the same, or alternatively the lower wings **102** may be longer than the upper wings **100**. Further, in

the illustrated embodiment, the tip of each wing **102A, 102B** is interconnected with a central portion **108** of the corresponding upper wing **100A, 100B** respectively by means of port strut **104A** and a starboard strut **104B**, collectively referred to as struts **104**, via an upper hinge **252** and a lower hinge **254**. As may be seen in Fig. 4 in particular, each strut **104** comprises a sideways-facing generally U-shaped form, the upper and lower arms **250** thereof being adapted for pivotably mounting the strut **104** to the underside of the corresponding upper wing **100**, and to the upper side of the corresponding lower wing **102**, respectively, by means of hinge arrangements **252, 254**, respectively. The hinge arrangements **252, 254** may comprise, for example, simple pins or journals, comprised in the arms **250** or the corresponding wings, that are receivable in suitable bearings in the wings or arms **250**, respectively. The upper arm **250** that is pivotably mounted to the corresponding upper wing **100** comprises a stop **126** which limits the relative rotation between the wing **100** and the strut **104**, by abutting and locking against the trailing edge of the wing **100**. The base **260** of the strut **104** comprises an arch portion **262** having a concave side **264** that faces the fuselage **20**. As may be best seen in Figs 1a and 5, the fuselage **20** comprises a substantially circular cross-section at least at a fuselage part **20A** thereof axially aligned with the struts when the upper wings **100** and lower wings **102** are at their respective retracted positions. The concave side **264** of the arch portion **262** comprises a concave curvature generally complementary to the convex curvature of the fuselage part **20A**, which enables the struts **104** to be snuggly retained or abutted against the fuselage part **20A** in the retracted configuration illustrated in Fig. 1a. In other embodiments, the fuselage may be non-circular in cross-section, and the corresponding side struts may optionally be formed to conform to the outer shape of the fuselage in an appropriate manner.

The struts **104** act as side force panels, and may comprise a suitable aerodynamic cross-section, typically in the form of a symmetric aerofoil, and are configured to present a substantially zero incidence angle with respect to the fuselage centerline **99** when the wings are fully deployed. This configuration provides the vehicle **10** with the capability of performing skid-to-turn maneuvers, for example when wishing to home onto a target.

Thus, the upper wings **100** are constrained to pivot about a fixed axial position, the struts **104** are constrained to pivot with respect to the wings **100** and with respect to the tip end of the lower wings **102**, while the root ends of the lower wings **102** are

constrained to rotate with respect to the hinge arrangement **220** while translating between positions **P1** and **P2**.

In operation, and referring particularly to Fig. 1a, the vehicle **10** may be released from a carrier aircraft on which it is being carried by disengaging the lugs **110** from the deployment mechanism of the aircraft, the wings **100** and **102** being in the retracted configuration, and the struts **104** being close to the fuselage **20**.

Alternatively, it is possible to launch the vehicle **10**, in the retracted configuration shown in Fig. 1a, by a suitable cannon, or by means of a carrier rocket or the like. (In such cases, it may be that the lugs **110** are not required, and instead the vehicle is equipped with a suitable shell cartridge or rocket propulsion system, etc.) In any case, the air vehicle **10** is imparted with a particular forward momentum and trajectory through the air.

In the next operating stage shown in Fig. 1b, the safe store separation stage of the air launched vehicle, the fins **14** are immediately deployed after the launch in Fig. 1a to provide longitudinal stability to the air vehicle **10**, and prevent collision with the aircraft (or other carrier vehicle).

In Fig. 1c, the wing arrangement **30** begins to deploy, and as the hinge arrangement **220** is moved from the aft position **P1** to the forward position **P2**, the wings **102** are constrained to rotate, deploying in a manner such that the tips thereof with the struts **104** are laterally displaced away from the fuselage, causing the upper wings **100** to also deploy outwards. Deployment of the wing arrangement may occur at a predetermined time after the launch in Fig. 1a, or alternatively according to predetermined conditions, for example. Such predetermined conditions may include, for example, the angle and/or rate of yaw/pitch/roll of the vehicle and/or velocity of the vehicle **10**, as determined via suitable sensors and instrumentation carried on board the vehicle **10** or strongback **142**, for example.

In Fig. 1d, the stop **126** limits the angular deployment of the upper wings **100**, and thus also of the lower wings **102**, locking the wings in a particular diamond-shape configuration in plan view.

The hinge arrangement **220** may be configured to be locked in position **P1** until it is desired to deploy the wing arrangement **30**, using any suitable locking arrangement (not shown), while allowing the hinge arrangement **220** to freely translate between the positions **P1** and **P2** when unlocked, without providing an actuation mechanism.

Optionally, an aerodynamic actuator, for example in the form of an aerodynamic mechanism may be provided for inducing an aerodynamic force applied at a strategic point and in a direction such as to deploy the wings **100**, **102**. For example, the struts **104** may be configured to initially present a positive angle of attack to the incoming airflow such that an aerodynamically induced force having a component in a transverse direction away from the fuselage is created, thereby pulling the struts **104** away from the fuselage, when the hinge arrangement is unlocked, and thus deploying the wings **100** and **102**, until the final locked position shown in Fig 1d. A suitable mechanism may be provided to counter-rotate the struts about a vertical (translating) axis such that when the strut assumes its final position at full deployment of the wings, the struts present a zero incidence angle with respect to the fuselage centerline **99**. Such a suitable mechanism may comprise, for example, a four-bar linkage or the like.

Alternatively, a suitable actuation mechanism may be provided for positively moving the hinge arrangement from position **P1** to position **P2**, thereby deploying the wings **100**, **102**. The actuation mechanism may be mechanical, for example comprising a spring release mechanism, pyrotechnic-based, pneumatic, hydraulic, electrically operated, or any other form, as is known in the art. In the embodiment illustrated in Fig. 3, a power source (not shown) causes a drive shaft **132** of an actuator (not shown) to translate the hinge arrangement **220**.

Alternatively, an aerodynamic actuator in the form of an aerodynamically actuated mechanism may be provided. For example, in embodiments where the pivot axis of the lower wings **102** is axially fixed with respect to the fuselage, and the pivot axis of the upper wings **100** axially translates in an aft direction during deployment of the wings, a relatively small drogue parachute tethered to the axially movable upper wing pivot may be deployed such as to induce a rearward aerodynamic (drag) force component on the upper wings at the pivot, enabling the same to deploy. The drogue parachute may be configured to be discarded when the wings **100**, **102** are fully deployed.

Alternatively, an actuation mechanism may be provided in strongback **142** and configured for directly deploying the upper wings **100** by rotating the same about their hinge arrangement **210**, which in turn causes the deployment of the lower wings **102** via struts **104**.

In any case, in the fully deployed configuration illustrated in Figs. 1d, 2 and 3, and particularly in Fig. 6, the upper wings **100** are maintained at a vertical spacing from the lower wings **102** by means of the struts **104**, which provide a structural-box-like configuration, which increases the overall effective stiffness of the wings themselves, while potentially providing weight and/or aeroelastic advantages. Further, while the embodiment illustrated in Fig. 6 comprises upper and lower wings with essentially zero dihedral, one or both sets of wings may comprise any desired dihedral angle, so long as the wings may be deployed from a retracted to a fully deployed configuration.

Once the wing arrangement **30** is fully deployed from the compact storage or retracted configuration, the air vehicle **10** is able to glide and maneuver in a more controlled manner than in the absence of the wing arrangement **30**, or when the wing arrangement is not deployed, and moreover the deployed wing arrangement 30 increases the endurance or range of the vehicle 10. In particular, there is a considerable induced drag reduction due to the relatively high aspect ratio of the wings, which provide good lift-to-drag performance.

In the embodiments illustrated in Figs. 1 to 6, the wings **100** are longer than wings **102**, which deploy to a diamond-shaped configuration, the wings **100** being arranged at a fixed position on the upper part of the fuselage, while the wings **102** are axially movably mounted to a lower part of the fuselage. However, many other variations of the embodiment are possible, for example as follows.

In the embodiment illustrated in Fig. 7a, the lower wings are longer than the upper wing and comprise wing tips that project forward of the struts **104**. In the embodiment illustrated in Fig. 7b, the upper and lower wings have approximately the same span, and the struts **104** are located at the tips of the wings. In the embodiment illustrated in Fig. 7c, the upper and lower wings have approximately the same span, but the struts 104 are located at a position intermediate between the tips and roots of the wings, so that the tips of the bottom wings are forward of the struts **104**, while the tips of the upper wings are aft of the struts **104**. In the embodiments of Figs. 7a and 7c, the tips of the lower wings need to be sufficiently stiff to withstand the severe bending moments induced by the airflow.

In yet other embodiments of the invention, rather than presenting a diamond shape plan configuration for the wings when deployed, the upper and lower wings may be hinged in order to both deploy in a rear swept, or indeed forward swept, manner,

with the same or different sweep between the upper and lower wings, and a suitable hinge and optionally actuation mechanism allows deployment of the wings in a similar manner to that described for the embodiment of Figs 1 to 6, *mutatis mutandis*.

In yet other embodiments of the invention, the translation mechanism for the hinge arrangement **220** together with wings **102** may be mounted to the upper part **140** of the vehicle **10**, while the wing **100** and housing **142** is mounted to the lower part **150** of the vehicle, the lugs **110** still being in the upper part of the fuselage **20**.

In yet other embodiments of the invention, the forward wings **100**, whether on the upper or lower part of the fuselage, are pivotably mounted thereto via a translation mechanism, while the rear wings **102** are pivotably mounted, to the lower or upper part of the fuselage, respectively, at a fixed position.

Many other variations of the above embodiments according to the invention are also possible.

According to another aspect of the invention, and referring to Figs. 8, 9, the wing arrangement **30** may be provided in kit form, comprising upper wings **100**, lower wings **102**, side struts **104**, strongback **142** and lower hinge arrangement **222**, substantially as described with respect to Figs. 1 to 6, *mutatis mutandis*. The wing arrangement **30** may be mounted onto any suitable body or fuselage, for example fuselage **20** of Figs. 1 to 6, *mutatis mutandis*, for example by means of lugs **110**, as described above, *mutatis mutandis*. A brace, clamp, or belt **290** may be used for holding together the second hinge arrangement **220** with the strongback **142**, particularly when mounted onto a fuselage as described above, *mutatis mutandis*.

Many other variations of the above embodiments according to the invention are also possible.

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 example embodiments in accordance with the invention, it will be appreciated that many changes may be made therein without departing from the invention.

CLAIMS:

1. A deployable wing arrangement or kit for use with a longitudinally extending fuselage having an upper portion and a lower portion, the kit comprising

a first pair of wings pivotably mountable with respect to said upper portion and capable of being deployed from a first retracted position to a first deployed position;

a second pair of wings pivotably mountable with respect to said lower portion and capable of being deployed from a second retracted position to a second deployed position;

a strut arrangement comprising at least one pair of struts, wherein one or another strut of said pair of struts respectively interconnect one or another of said first pair of wings with one or another of said second pair of wings.

2. A deployable wing arrangement or kit according to claim 1, further comprising an actuation mechanism adapted for selectively deploying said first and second wings from said first and second retracted positions, respectively, to said first and second deployed positions, respectively.

3. A deployable wing arrangement or kit according to claim 2, wherein said actuation mechanism is configured for deploying said first and second wings substantially concurrently one with respect to another.

4. A deployable wing arrangement or kit according to any one of claims 1 to 3, wherein at least one of said first wings and second wings comprises substantially zero taper.

5. A deployable wing arrangement or kit according to any one of claims 1 to 4, wherein said first pair of wings comprises a first port wing and a first starboard wing.

6. A deployable wing arrangement or kit according to any one of claims 1 to 5, wherein in said first retracted position, said first pair of wings assumes a position generally aligned with said fuselage.

7. A deployable wing arrangement or kit according to claim 6, further comprising a suitable housing for stowing at least a part of each said first wing when in the first retracted position.

8. A deployable wing arrangement or kit according to any one of claims 1 to 7, wherein said first wings are pivotably mounted with respect to said upper portion via a first hinge arrangement.

9. A deployable wing arrangement or kit according to any one of claims 1 to 8, wherein in said first deployed position, said first pair of wings assume a backward swept position with respect to said fuselage.

10. A deployable wing arrangement or kit according to claim 9 wherein said first pair of wings assume a position having a sweep angle between about 20° and about 30°.

11. A deployable wing arrangement or kit according to any one of claims 1 to 10, wherein said second pair of wings comprises a second port wing and a second starboard wing.

12. A deployable wing arrangement or kit according to any one of claims 1 to 11, wherein in said second retracted position, said second pair of wings assumes a position generally aligned with said fuselage.

13. A deployable wing arrangement or kit according to any one of claims 1 to 12, wherein in said second deployed position, said second pair of wings assumes a forward swept position with respect to said fuselage.

14. A deployable wing arrangement or kit according to claim 13 wherein said second pair of wings assumes a position having a sweep angle between about –30° and about –40°.

15. A deployable wing arrangement or kit according to any one of claims 1 to 14, wherein said second wings are pivotably mounted with respect to said lower portion via a second hinge arrangement.

16. A deployable wing arrangement or kit according to any one of claims 1 to 15, wherein each said strut interconnects a corresponding said first wing with a corresponding said second wing in a manner such as to synchronise said deployment of said first wing with said deployment of said second wing.

17. A deployable wing arrangement or kit according to claim 16, wherein each said strut pivotably interconnects a corresponding said first wing with a corresponding said second wing via a third hinge arrangement.

18. A deployable wing arrangement or kit according to claim 17, wherein each said strut comprises an aerodynamic profile configured to increase lateral

maneuverability to said air vehicle at least when said first wings and said second wings are in their respective said first and second deployed positions.

19. A deployable wing arrangement or kit according to any one of claims 17 to 18, wherein each said strut comprises a pair of spaced end portions joined by means of a central arched portion, wherein each said end portion is pivotably mounted to one or another corresponding said first and second wings via said third hinge arrangement.

20. A deployable wing arrangement or kit according to any one of claims 1 to 19, comprising a strongback adapted for enabling said wing arrangement to be mounted onto an upper portion of a longitudinally extending fuselage, said strongback comprising said first hinge arrangement.

21. A deployable wing arrangement or kit according to claim 20, said second hinge mechanism being axially movable with respect to said first hinge mechanism from a first axial position to a second axial position, an axial position of said first hinge mechanism being substantially fixed with respect to said strongback, such that at said first axial position said second wings and said first wings are at said second and first retracted positions, respectively, and wherein at said second axial position, said second wings and said first wings are at said second and first deployed positions, respectively.

22. A deployable wing arrangement or kit according to claim 21, further comprising an actuating mechanism configured for selectively moving said second hinge mechanism from said first axial position to said second axial position such as to cause said second wings to be deployed from said second retracted position to said second deployed position, and so as to cause, via said third hinge arrangement, said first wings to be deployed from said first retracted position to said first deployed position.

23. A deployable wing arrangement or kit according to claim 22, wherein said actuating mechanism comprises any one of or combination of: a mechanical actuator, a pneumatic actuator, a hydraulic actuator, an aerodynamic actuator, and an electrically-actuable actuator.

24. A deployable wing arrangement or kit according to any one of claims 17 to 23, wherein each said strut is pivotably connected to a corresponding said first wing at a wing tip thereof.

25. A deployable wing arrangement or kit according to any one of claims 17 to 23, wherein each said strut is pivotably connected to a corresponding said first wing at a position inboard of a wing tip thereof.

26. A deployable wing arrangement or kit according to any one of claims 17 to 23, wherein each said strut is pivotably connected to a corresponding said first wing at a position substantially intermediate a wing tip and a wing root thereof.

27. A deployable wing arrangement or kit according to any one of claims 17 to 26, wherein each said strut is pivotably connected to a corresponding said second wing at a wing tip thereof.

28. A deployable wing arrangement or kit according to any one of claims 17 to 26, wherein each said strut is pivotably connected to a corresponding said second wing at a position inboard of a wing tip thereof.

29. A deployable wing arrangement or kit according to any one of claims 17 to 26, wherein each said strut is pivotably connected to a corresponding said second wing at a position substantially intermediate a wing tip and a wing root thereof.

30. An air vehicle comprising:

a longitudinally extending fuselage having an upper portion and a lower portion; and

a deployable wing arrangement or kit according to any one of claims 1 to 29.

31. An air vehicle according to claim 30, further comprising a plurality of stabilizing fins mounted to said fuselage.

32. An air vehicle according to claim 31, wherein said fins are deployable from a retracted position substantially accommodated within said fuselage to a deployed position substantially outside of said fuselage.

33. An air vehicle according to any one of claims 30 to 32, wherein said fuselage comprises at least one of: a guidance system, a radar system, an electro optics system, a laser system, a reconnaissance system.

34. An air vehicle according to any one of claims 30 to 33, wherein said fuselage comprises at least one of: a payload, a warhead, a reconnaissance system.

35. An air vehicle according to any one of claims 30 to 34, wherein said fuselage comprises a propulsion system.

36. An air vehicle according to any one of claims 30 to 35, further comprising a deployment mechanism for enabling the air vehicle to be selectively deployed from an attachment station of a carrier air vehicle.

37. An air vehicle according to claim 36, wherein said deployment mechanism comprises at least one suspension lug configured for cooperating with a support hook comprised on said carrier air vehicle.

38. An air vehicle comprising:

a longitudinally extending fuselage having an upper portion and a lower portion; and

a deployable wing arrangement comprising

a first pair of first wings pivotably mounted with respect to said upper portion and capable of being deployed from a first retracted position to a first deployed position;

a second pair of second wings pivotably mounted with respect to said lower portion and capable of being deployed from a second retracted position to a second deployed position;

a strut arrangement comprising at least one pair of struts, wherein for the or each pair of struts one said strut interconnects a said first wing with a said second wing and the other said strut interconnects the other said first wing with the other said second wing in a manner allowing said first and second wings to be at least deployed to respective said first and second deployed positions from respective said first and second retracted positions.

39. A method for increasing the range of an air vehicle comprising a fuselage, comprising

(a) providing a deployable wing arrangement or kit according to any one of claims 1 to 29 and mounting the same on said air vehicle,

(b) imparting a forward velocity at a predetermined altitude to the vehicle, and

(c) deploying the wings of said wing arrangement.

40. A method according to claim 39, wherein said air vehicle is air launched from a carrier vehicle to impart said forward velocity at a predetermined altitude to the air vehicle.

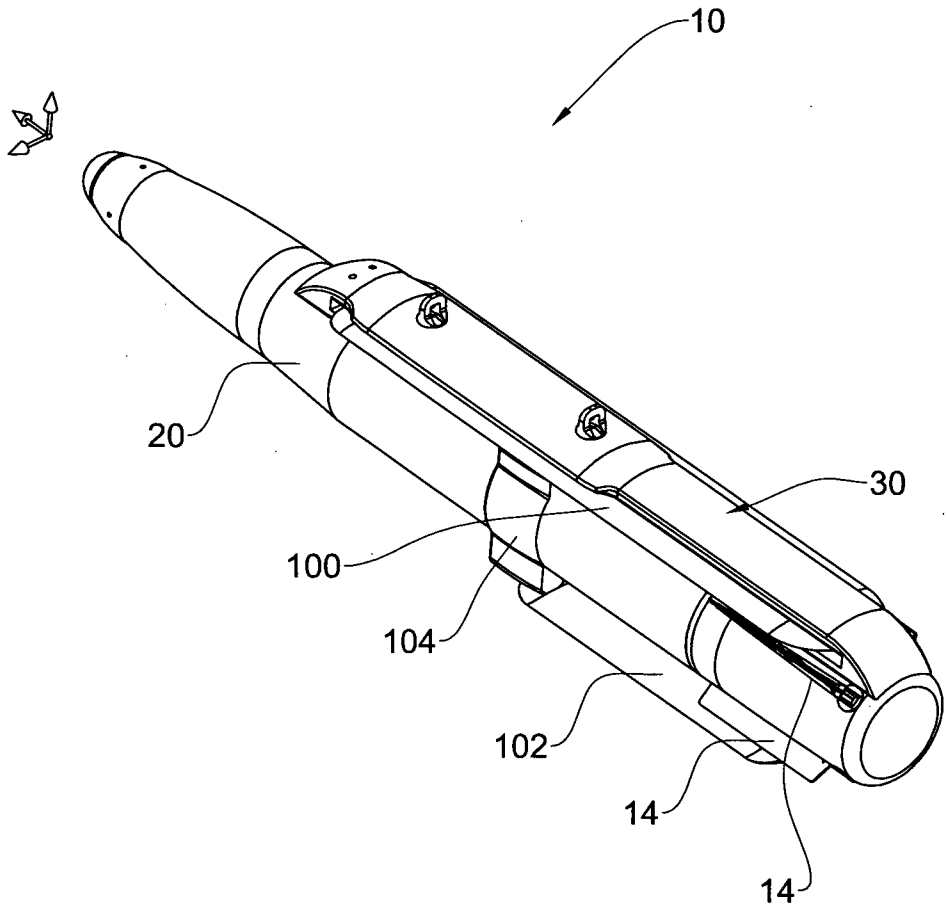


FIG. 1a

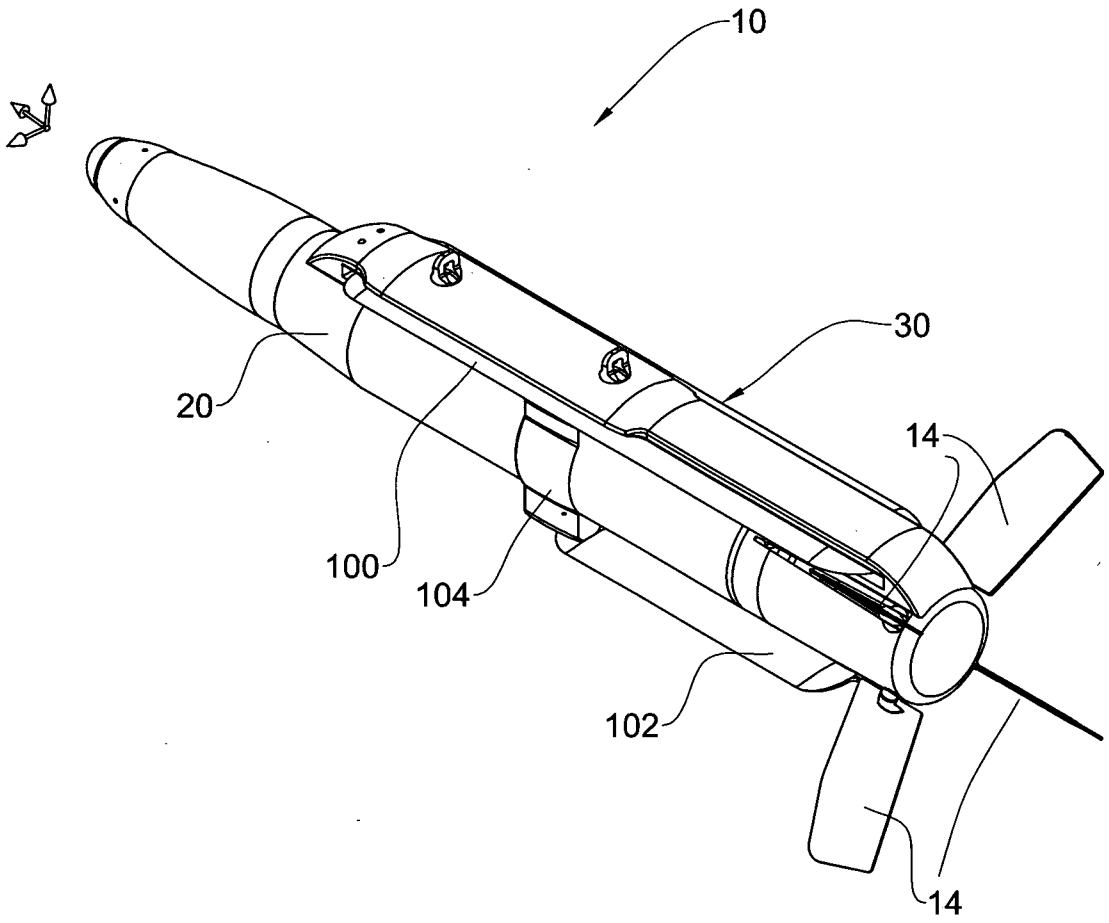


FIG. 1b

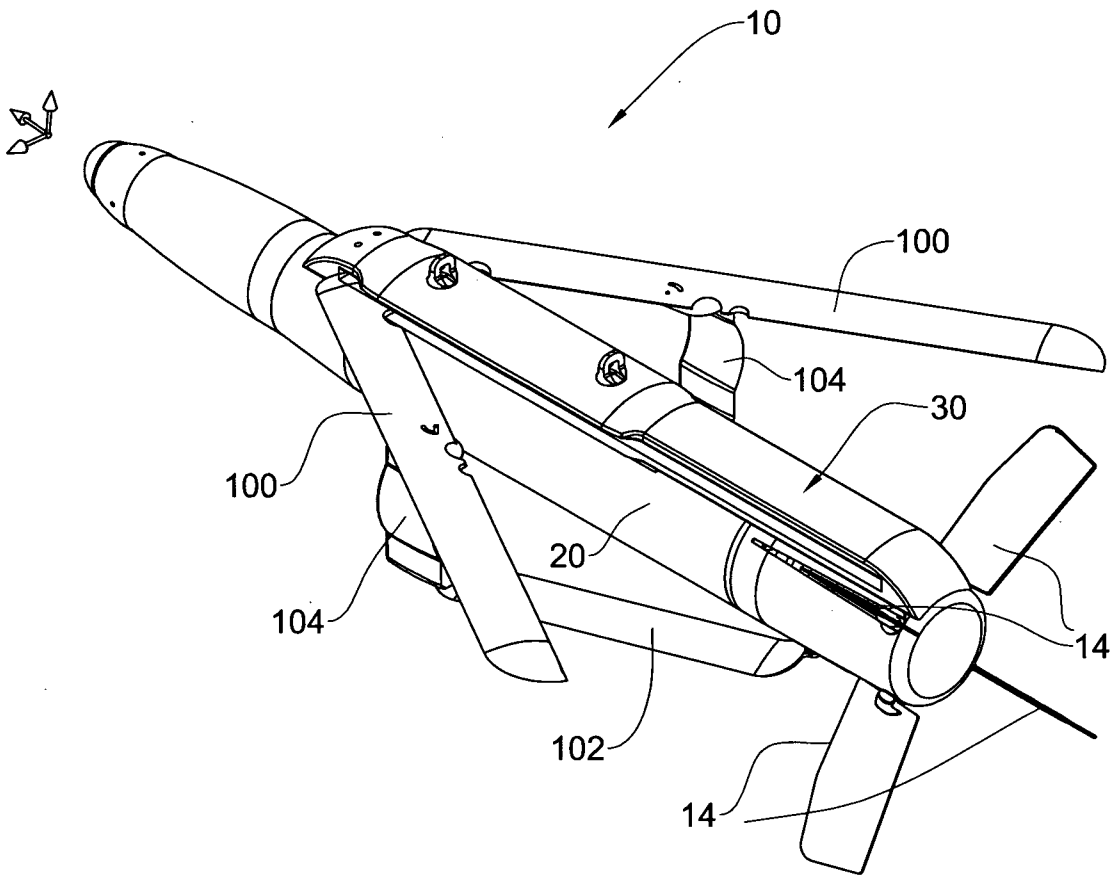


FIG. 1c

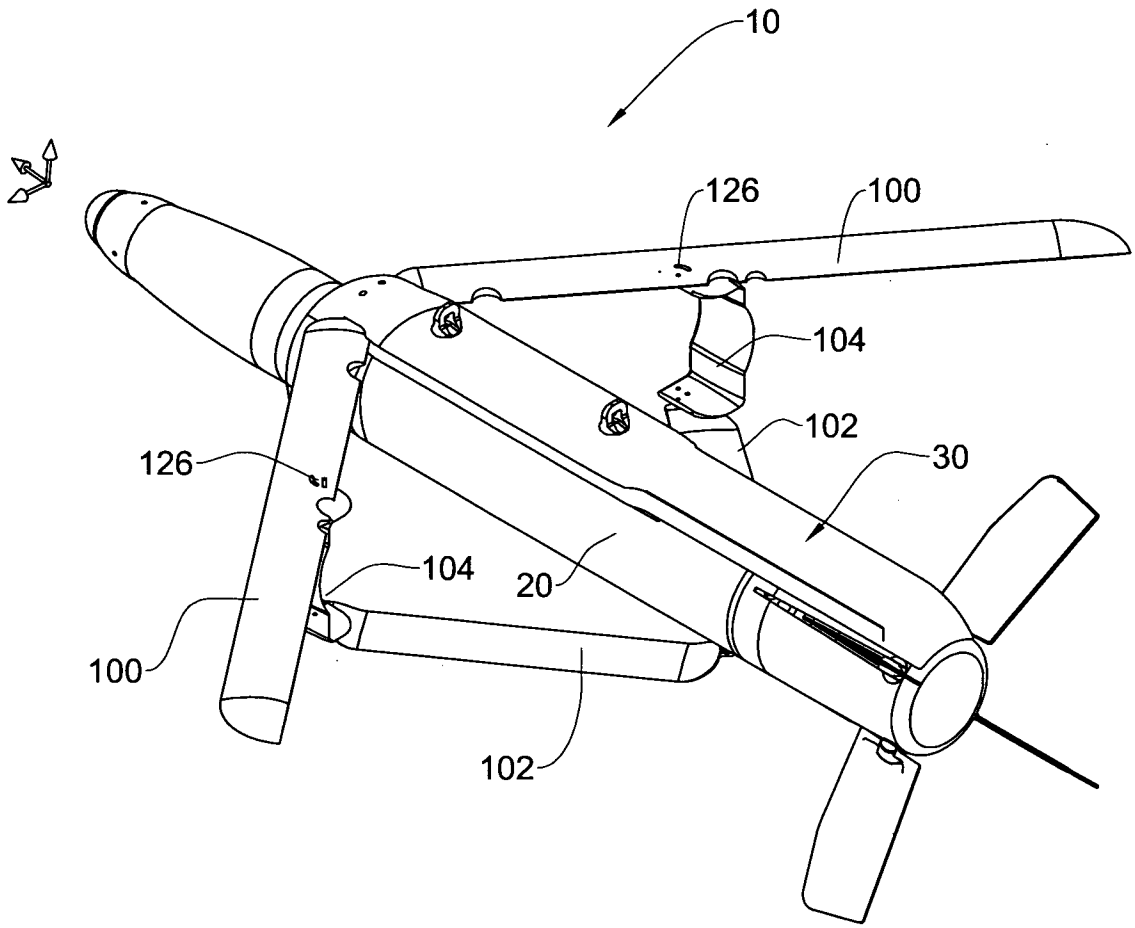


FIG. 1d

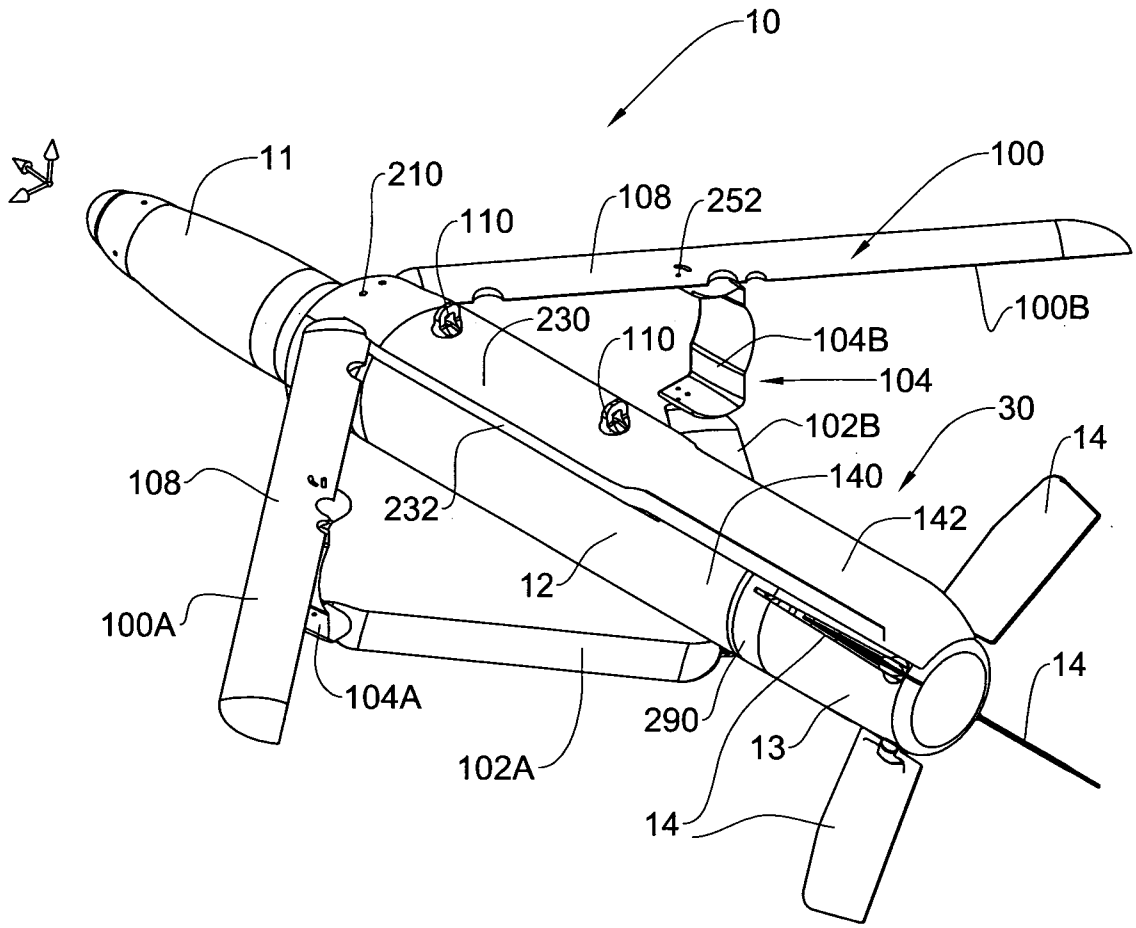

10
11
210
110
108
252
100
100B
230
110
104B
104
102B
30
14
108
232
140
142
12
100A
104A
290
13
14
102A
14

FIG. 2

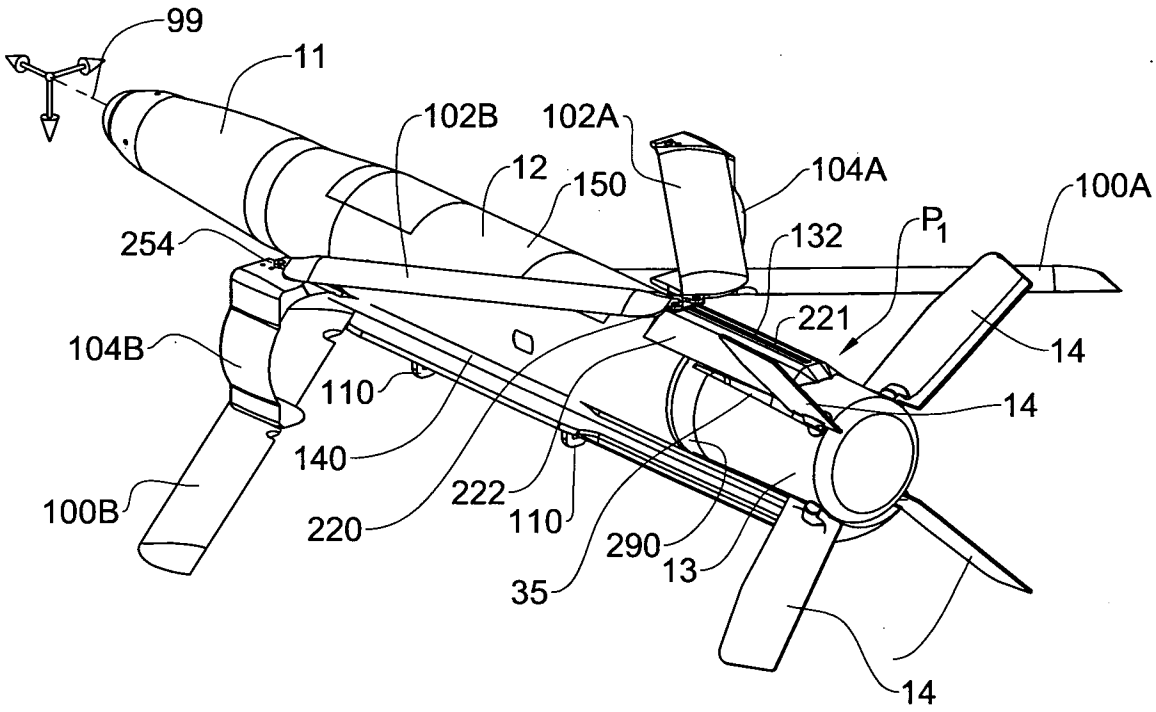

99
11
102B
102A
12
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104A
100A
254
132
P_1
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104B
14
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13
35
14

FIG. 3

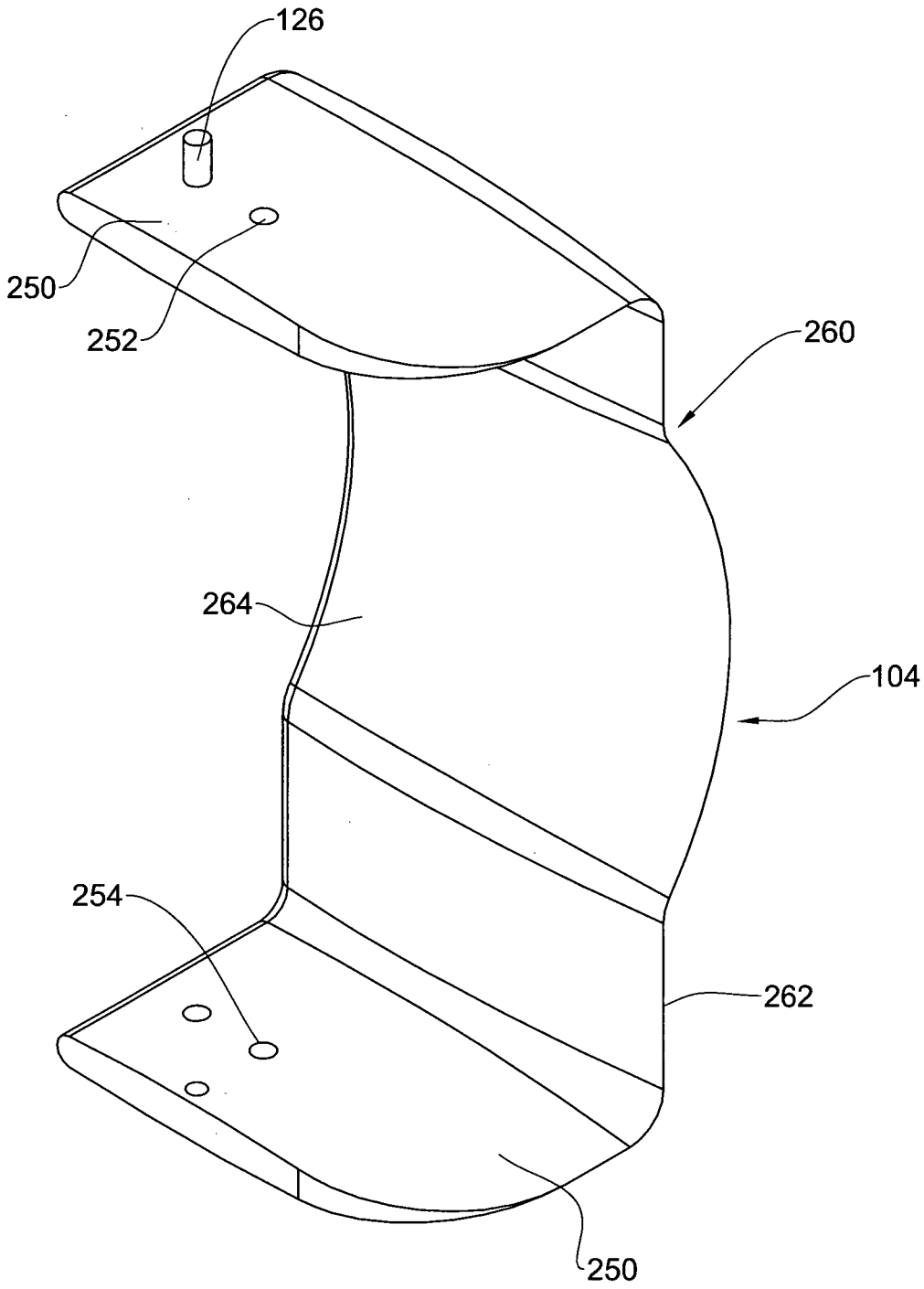


FIG. 4

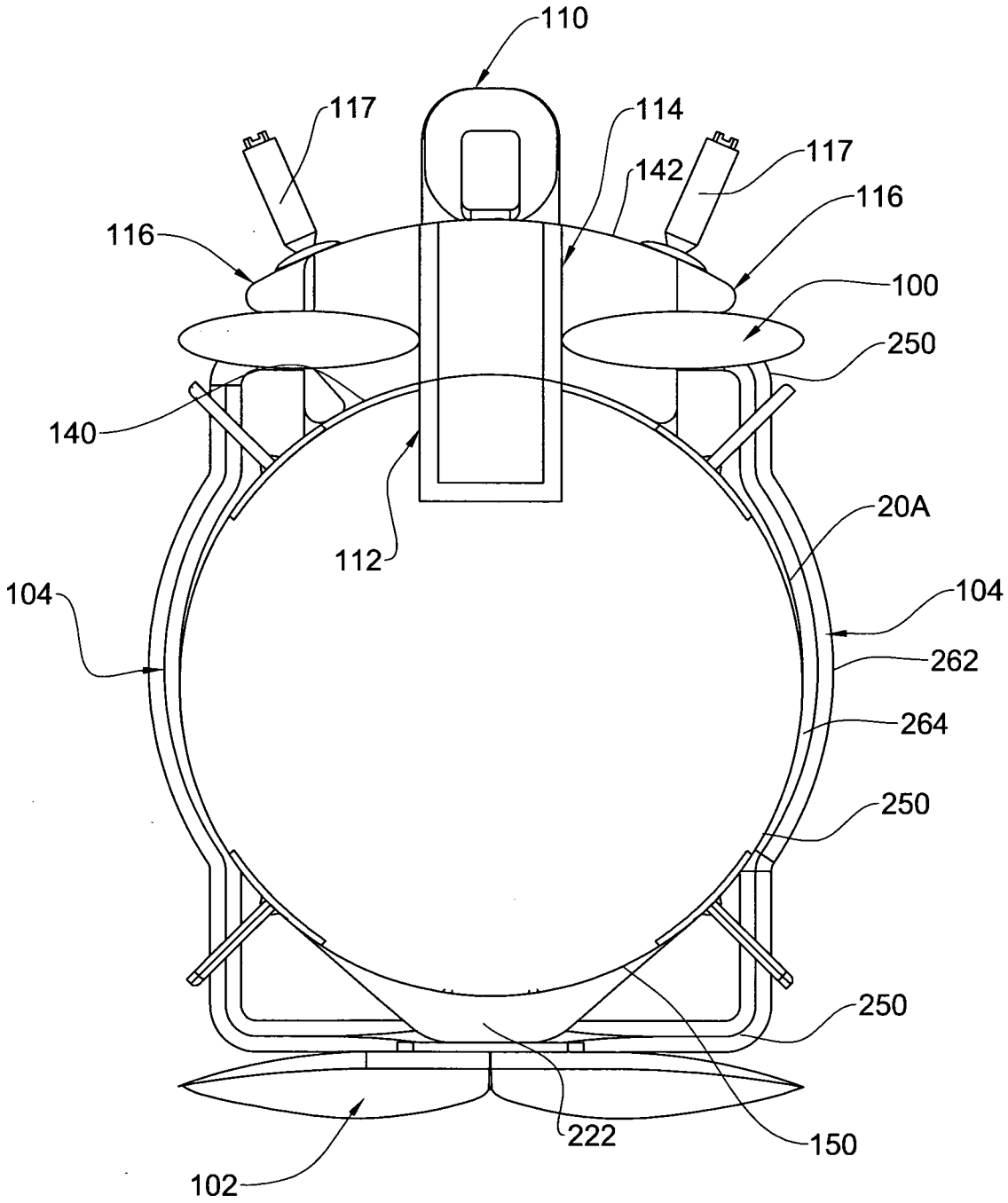

110
117
114
142
117
116
116
100
250
140
112
20A
104
104
262
264
250
250
222
150
102

FIG. 5

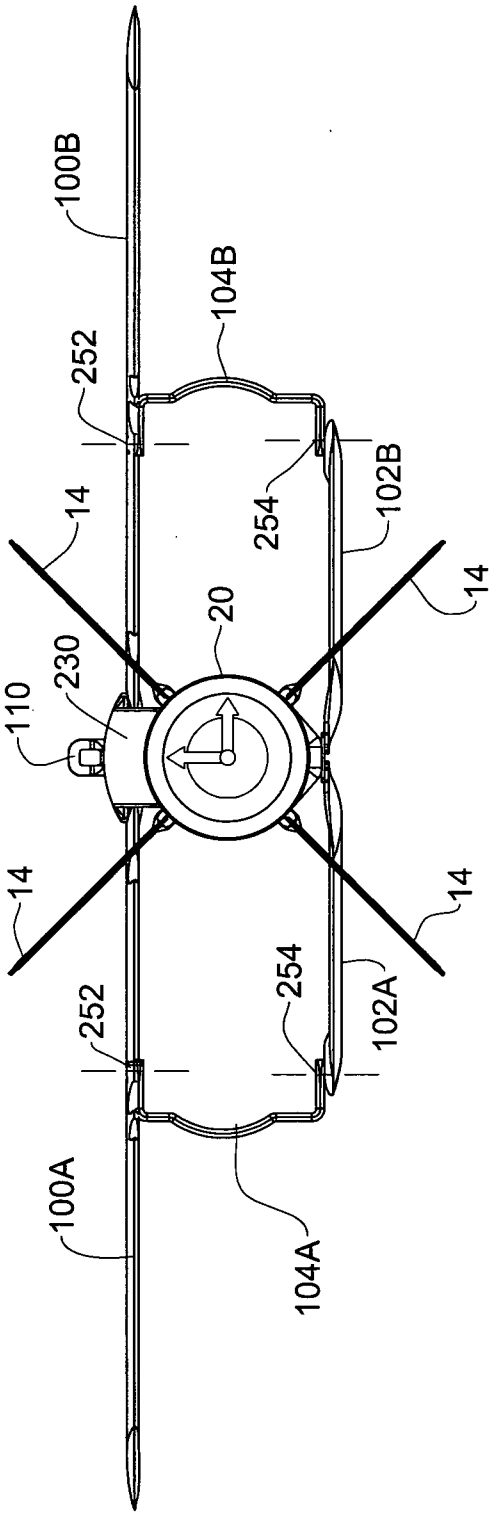

100B
104B
252
254
102B
14
20
230
110
14
14
254
252
102A
100A
104A

FIG. 6

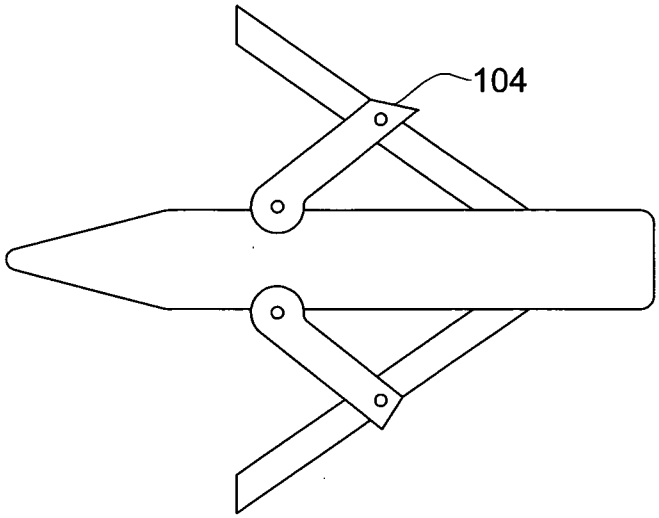


FIG. 7a

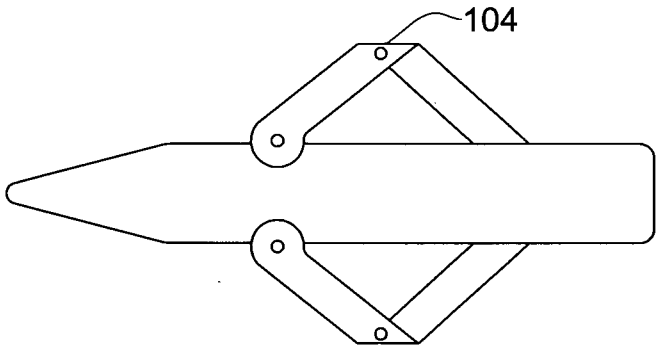


FIG. 7b

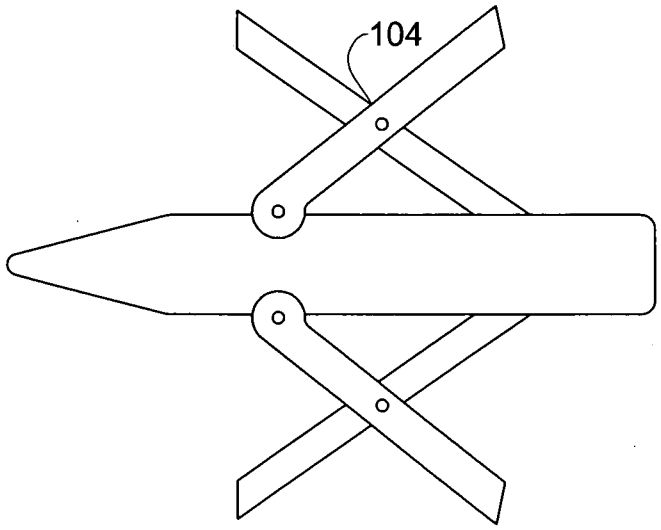


FIG. 7c

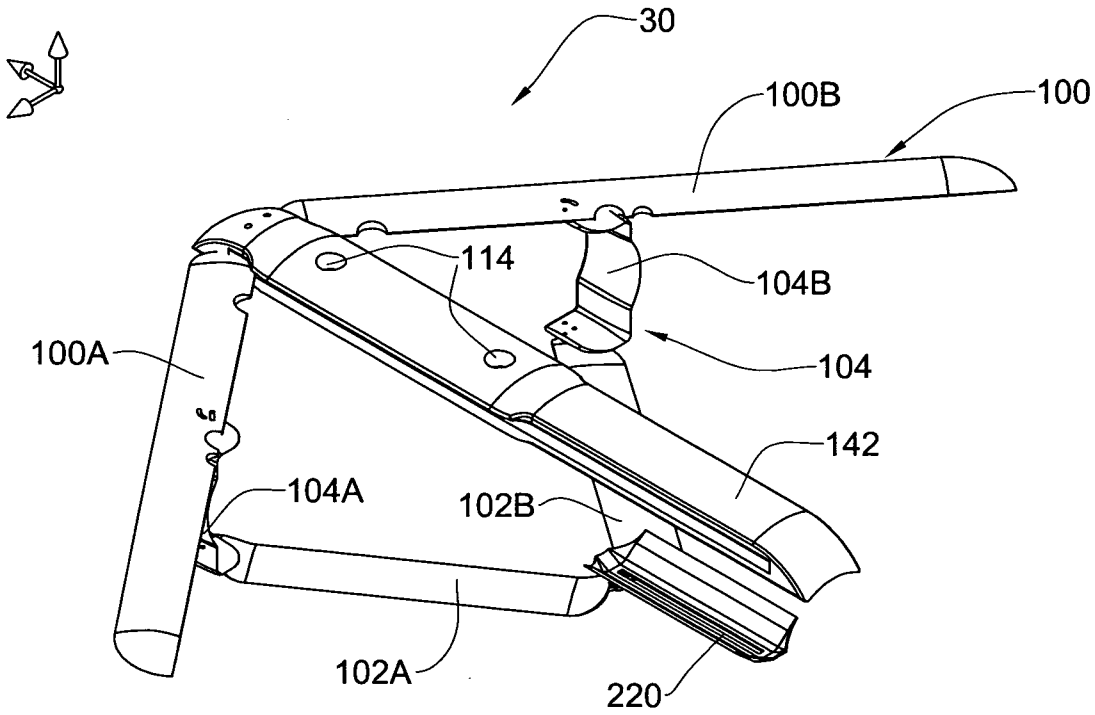


FIG. 8

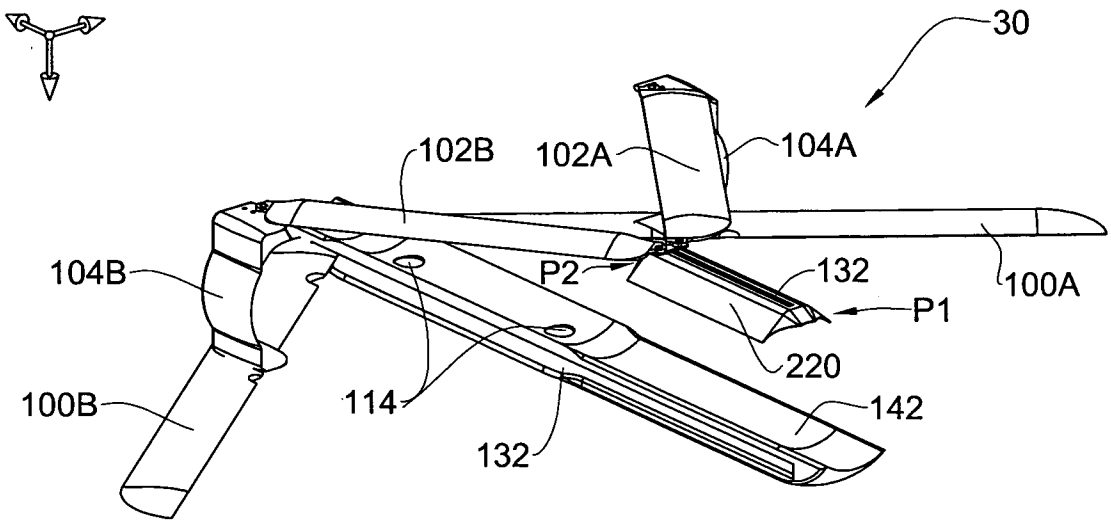


FIG. 9

INTERNATIONAL SEARCH REPORT

International application No
PCT/IL2007/000916

A. CLASSIFICATION OF SUBJECT MATTER
INV. F42B10/18 F42B10/20 F42B10/38 F42B10/62 B64C19/02
B64C39/00 B64C39/08

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F42B B64C

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

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5 615 846 A (SHMOLDAS JOHN D [US] ET AL) 1 April 1997 (1997-04-01) cited in the application the whole document	1-40
Y	DE 40 21 633 A1 (ISRAEL AIRCRAFT IND LTD [IL]) 28 February 1991 (1991-02-28) column 2, line 13 - column 3, line 32 figures	1-40
A	EP 0 716 978 A (FREDIANI ALDO [IT]) 19 June 1996 (1996-06-19) column 4, line 39 - column 6, line 18 figures	24-29
A	US 5 141 175 A (HARRIS GORDON L) 25 August 1992 (1992-08-25) cited in the application the whole document	1-40

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

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

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
27 November 2007	07/12/2007

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	GEX-COLLET, A

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IL2007/000916

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