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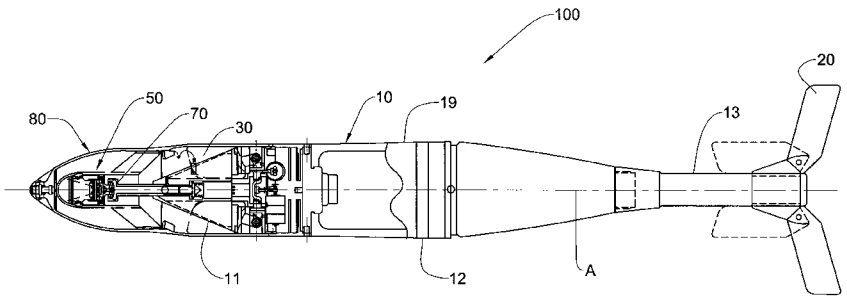


Fig. 1

(57) Abstract: A projectile is provided for operating at least in a launch phase and in a post-launch phase. The projectile includes a projectile body, a projectile head, and a support structure. The projectile head is non-rigidly mounted to the projectile body via a joint structure. The support structure is configured for selectively supporting the projectile head with respect to the projectile body in a load bearing relationship independently of the joint structure during at least a portion of the launch phase, and for selectively terminating the support during at least a portion of the post-launch phase. A method for operating a projectile and a method for retrofitting a projectile are also provided.

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PROJECTILE

FIELD OF THE INVENTION

This invention relates to projectiles, especially shells, in particular for use in mortars or other high launch-acceleration applications.

BACKGROUND OF THE INVENTION

By way of general background, the following publications disclose a variety of projectile or air vehicle configurations: US 4,533,094; US 2010/0057285; US 2008/0276821; US 4,938,434; US 4,541,591.

The contents of these references are incorporated herein in their entirety.

SUMMARY

According to a first aspect of the invention, there is provided an air vehicle, for example in the form of a projectile configured for operating at least in a first traveling phase and in a second traveling phase.

By traveling of the vehicle is meant the motion of the vehicle through a fluid medium or a vacuum, in particular Earth's atmosphere or through space as a free body. By free motion of the vehicle is meant the motion of the vehicle through a fluid medium or a vacuum, in particular Earth's atmosphere or space as a free body, while unsupported on the ground, either directly or indirectly, or unsupported within another vessel that is itself traveling through the fluid medium or vacuum. In at least one example the first traveling phase is a launch phase and the second traveling phase is a post-launch phase, and at least in the post-launch phase the vehicle is in free motion.

The air vehicle or projectile comprises:

a projectile body, a projectile head, and a support structure,

wherein said projectile head is non-rigidly mounted to said projectile body via a joint structure; and

wherein said support structure is configured for selectively supporting said projectile head with respect to said projectile body in a load bearing relationship independently of said joint structure during at least a portion of (or all of) said launch phase (or said first traveling phase), and for selectively terminating said support during at least a portion of said post-launch phase (or said second traveling phase).

In particular, the air vehicle or projectile is configured for selectively terminating said support during said at least a portion of said post-launch phase (or said second traveling phase), wherein the air vehicle or projectile is in free motion.

The air vehicle or projectile can have one or more of the following features, in any desired combination or permutation.

In at least some embodiments, said projectile head is pivotably mounted to said projectile body via said joint structure.

Additionally or alternatively, said projectile head is axially movable with respect to said projectile body via said joint structure at least in when said support is terminated. For example, said projectile head is axially movable with respect to said projectile body via said joint structure in the absence of said support.

Additionally or alternatively, said projectile head is configured for being freely aerodynamically aligned with said velocity vector of the projectile independently of said projectile body (e.g. in the absence of said support structure) when said support is terminated.

Additionally or alternatively, said support structure is configured for preventing at least a majority of loads between said projectile head and said projectile body associated with said launch phase being channeled via (or supported by) said joint structure. For example, said majority of said loads is otherwise damaging if applied to said joint structure. For example, said majority comprises more than 50% of said loads.

Additionally or alternatively, said projectile body comprises a front end, an aft end and a first longitudinal axis extending therebetween, and wherein said projectile head comprises a second longitudinal axis, wherein in said load bearing relationship, said first longitudinal axis is substantially coaligned with said second longitudinal axis. Alternatively, the first longitudinal axis is parallel to but not co-aligned with said

second longitudinal axis. Optionally, the air vehicle or projectile may comprise a plurality of said projectile heads mounted to said projectile body, each via a respective said joint structure.

Additionally or alternatively, in said load bearing relationship, said support structure externally supports said projectile head with respect to said projectile body. For example, said support structure supports said projectile head with respect to said projectile body on an outside of the projectile body.

Additionally or alternatively, in said load bearing relationship, said support structure reversibly interconnects said projectile head with said projectile body and is configured for supporting said loads between said projectile head and said projectile body when thus interconnected.

Additionally or alternatively, said support structure is configured for being removed from said projectile body and said projectile head at least during said portion of said post-launch phase for selectively terminating said support.

Additionally or alternatively, said loads are induced responsive to an acceleration of the projectile during said launch phase (or said first traveling phase). For example, such loads may be in the order of 10^4*W, where W is the mass of the projectile head.

Additionally or alternatively, said support structure is further configured for preventing aerodynamic loads being directly applied to said projectile head during said portion of said launch phase and optionally until the support is terminated. For example, said support structure is configured for shielding the projectile head from aerodynamically-induced loads.

Additionally or alternatively, said support structure comprises a load bearing member, wherein in said load bearing relationship said load bearing member is in load bearing contact with said projectile body and in load bearing contact with an external part of said projectile head.

Additionally or alternatively, said support structure comprises a housing having an open aft end and a cavity in communication therewith, wherein said aft end is configured for reversibly connecting to said projectile body and wherein said cavity is

configured for accommodating said projectile head therein in load bearing contact therewith.

Additionally or alternatively, at least during said portion of said post-launch phase (or of said second traveling phase) said projectile head is freely pivotable with respect to said projectile body in at least one rotational degree of freedom.

Additionally or alternatively, at least during said portion of said post-launch phase (or of said second traveling phase) said projectile head is freely pivotable with respect to said projectile body in at least two rotational degrees of freedom.

Additionally or alternatively, at least during said portion of said post-launch phase said projectile head is freely pivotable with respect to said projectile body in three rotational degrees of freedom.

Additionally or alternatively, said joint structure is configured for permitting relative angular movement between said projectile head and said projectile body, said projectile head being configured for self-alignment with a free stream fluid flow direction, of a fluid through which said projectile is traveling, via said joint structure in said post-launch phase, wherein said projectile head is exposed to the fluid flow.

.Additionally or alternatively, said projectile head is gimbaled freely to said projectile body via said joint structure. Alternatively, said joint structure comprises a flexible hose.

Additionally or alternatively, said projectile head comprises an aft portion comprising an annular tail airfoil, configured for providing said self-alignment.

Additionally or alternatively, said projectile head is configured for homing said projectile to a target.

Additionally or alternatively, said projectile body further comprises a steering arrangement configured for steering the projectile responsive to suitable control input; and said projectile head is further configured for providing said control input at least during said portion of said post-launch phase. The projectile head can comprise a suitable sensor arrangement configured for sensing a control parameter wherein to generate said control input in response thereto. The sensor arrangement can be provided at a forward end of said projectile head. The sensor arrangement can be configured for

sensing a predetermined illuminating electromagnetic radiation wherein to generate said control input in response thereto. The steering arrangement can comprise an aerodynamic control surface arrangement configured for generating aerodynamic moments suitable for steering said projectile, responsive to said control input. The aerodynamic moments can include one or more of pitch, yaw and roll. Optionally, the aerodynamic control surface arrangement can comprise a plurality of canards, said canards being individually controllable to selectively generate said aerodynamic moments. Optionally, the canards can be deployable from a stowed configuration to a deployed configuration, and wherein said canards are in said stowed configuration at least during said portion of said launch phase. Optionally, the canards can be in said deployed configuration at least during said portion of said post-launch phase. Optionally, the sensor arrangement can comprise a plurality of sensors operatively connected to said plurality of canards, each said sensor being configured for generating a control signal for operating a respective said canard.

Additionally or alternatively, the air vehicle or projectile further comprises a plurality of aft fins for providing longitudinal stability at least during said portion of said post-launch phase. For example, the aft fins can be deployable from a stowed configuration to a deployed configuration, and wherein said aft fins are in said stowed configuration at least during a part of said portion of said launch phase.

Additionally or alternatively, said projectile can be configured for being having a maximum width not greater than a maximum width of said projectile body at least during a part of said portion of said launch phase.

Additionally or alternatively, said support structure comprises a casing having an aerodynamically contoured outer wall, and an internal seat for seating an aft portion of said projectile head in said load bearing relationship. For example, in said load bearing relationship, said projectile head can be immobilized in said casing. Optionally, in said load bearing relationship, the casing substantially prevents axial displacement between said projectile head and said projectile body. Optionally, in said load bearing relationship, said projectile head and said projectile body are longitudinally aligned. Optionally, said casing comprises a first casing half reversibly joined to a second casing half. For example, said support structure is removable from said projectile head and said projectile body by separating said first casing half from said second casing half.

Additionally or alternatively, said support structure is selectively jettisonable from said projectile.

Additionally or alternatively, said projectile is configured as a mortar shell configured to be launched via a mortar.

According to the first aspect of the invention there is also provided a projectile configured for operating at least in a high-g launch phase and a low-g post-launch phase, comprising:

a projectile body, a projectile head, and a selectively removable support structure,

said projectile head being non-rigidly mounted to said projectile body via a joint structure;

said support structure configured for selectively connecting said projectile body and said projectile head in a load bearing relationship independently of said joint structure, when the projectile is subject in operation of said projectile during at least a portion of said launch phase; and

said projectile head being configured for being freely aerodynamically aligned with a velocity vector of the projectile independently of said projectile body (in the absence of said support structure) in operation of said projectile during at least a portion of said post-launch phase wherein said load bearing relationship is terminated.

According to the first aspect of the invention there is also provided a method for operating a projectile, comprising:

(a) providing a projectile or air vehicle as defined above including one or more of the above features in any desired combination or permutation;

(b) operating said projectile or air vehicle during at least said portion of said launch phase (or said first traveling phase) wherein to selectively support said projectile body with respect to said projectile head via said support structure in a load bearing relationship independently of said joint structure;

(c) selectively terminating said load bearing relationship and subsequently operating said projectile or air vehicle during at least said portion of said post-launch phase (or second traveling phase).

In at least some embodiments, step (c) comprises removing said support structure from said projectile head and said projectile body while said projectile is traveling in the atmosphere, and allowing said projectile body to become freely aerodynamically aligned with a velocity vector of the projectile independently of said projectile body.

Additionally or alternatively, the method also comprises homing said projectile to a target. Optionally, the method further comprises illuminating said target with an illuminating radiation, detecting with said projectile head said illuminating radiation reflected from the target, and steering said projectile to said target wherein to maintain said reflected illuminating radiation in the boresight of said projectile head.

According to the first aspect of the invention there is also provided a method for retrofitting a projectile or air vehicle, comprising:

(a) providing the projectile or air vehicle, the projectile or air vehicle comprising a projectile body and a projectile head, wherein the projectile head is non-rigidly mounted to the projectile body via a joint structure; and

(b) providing a selectively removable support structure, wherein said support structure is configured for selectively supporting said projectile head with respect to said projectile body in a load bearing relationship independently of said joint structure during at least a portion of said launch phase, and for selectively terminating said support during at least a portion of said post-launch phase.

Additionally or alternatively, the projectile head, the projectile body, the joint structure and the support structure may be as defined above, *mutatis mutandis*, including one or more of the above features *mutatis mutandis*, in any desired combination or permutation.

For example, said support structure is configured for preventing at least a majority of loads between said projectile head and said projectile body associated with

said launch phase (or said first traveling phase) being channeled via (or supported by) said joint structure, and optionally wherein said majority of said loads is otherwise damaging if applied to said joint structure.

According to a second aspect of the invention there is provided a projectile or air vehicle, comprising:

a projectile body and a projectile head;

wherein said projectile head is non-rigidly mounted to said projectile body via a joint structure at a forward end of the projectile body; and

wherein said projectile is configured for permitting limited relative axial movement between said projectile body and said projectile head via said joint structure.

Additionally or alternatively, the projectile head, the projectile body, and the joint structure may be as defined above for the first aspect of the invention, *mutatis mutandis*, including one or more of the above features for the first aspect of the invention *mutatis mutandis*, in any desired combination or permutation.

Additionally or alternatively, the projectile or air vehicle may further comprise a support structure as defined above for the first aspect of the invention, *mutatis mutandis*, including one or more of the above features for the first aspect of the invention *mutatis mutandis*, in any desired combination or permutation.

Additionally or alternatively, said joint structure comprises a forward portion configured for pivotingly mounting said projectile head thereto, and an aft portion comprising a shaft slidingly mounted to said projectile body. For example, said shaft is axially reciprocably movable with respect to said projectile body within a displacement range. Optionally a resilient member can be provided for biasing said shaft with respect to said projectile body. As in the first aspect of the invention, *mutatis mutandis*, the projectile head can be configured for self-alignment with a free stream fluid flow direction, of a fluid through which the projectile is traveling, via said joint structure, when the projectile head is exposed to the fluid flow. For example, the projectile head can comprise an aft portion comprising an annular tail airfoil, configured for providing said self-alignment.

BRIEF DESCRIPTION OF THE FIGURES

In order to understand the invention and to see how it may be carried out in practice, several embodiments will now be described, by way of non-limiting examples only, with reference to the accompanying drawings, in which:

Fig. 1 is a schematic representation illustrating in side view a projectile according to an embodiment of the invention, including a support structure supporting the projectile head on the projectile body.

Fig. 2 is a detailed view of Fig. 1.

Fig. 3 is a schematic representation illustrating in side view the embodiment of Fig. 1, wherein the support structure is removed.

Fig. 4 is a detailed view of Fig. 3.

Fig. 5 is a schematic representation illustrating an example of operation of the embodiment of Figs. 1 to 4.

DETAILED DESCRIPTION OF THE FIGURES

Referring to Figs. 1 to 4, an air vehicle according to a first embodiment of the invention is generally designated with reference numeral **100** and comprises a body **10** and head **50**, and further comprises a support structure **80**.

In the illustrated example, the air vehicle **100** is particularly configured as a projectile in the form of a mortar round, or the like, for traveling through the atmosphere when launched, though the skilled practitioner appreciates that at least some embodiments of the invention are also applicable, *mutatis mutandis,* to other types of projectiles, including cannon-launched shells, self-propelled missiles, rockets, rocket payloads (e.g. satellites, etc.), non-air vehicles configured for operating in partly or fully in space, for example, and the like, *mutatis mutandis,* having relatively high launch acceleration loads at the launch phase (also referred to herein as the first traveling phase). Accordingly, the term "air vehicle" is taken herein to include any suitable air vehicle that is subjected to relatively high launch acceleration or high acceleration at a first traveling phase, for example (but not limited to) corresponding to projectile launched from cannons, mortars etc, for example (but not limited to) in the order of

10^4*g, where "g" is the acceleration due to gravity, and which also operates by traveling freely, i.e. in free motion, through a fluid medium (such as the Earth's atmosphere, for example) or in space in a post-launch phase (also referred to herein as the second traveling phase) in which it is subject to much lower acceleration loads, or no such loads at all.

In this example, the projectile does not comprise any propulsion unit or powerplant and receives its forward momentum from a mortar (or in alternative embodiments, from a cannon or the like, i.e., a launch system that is configured to impart to the projectile a forward momentum and acceleration at launch). However, in alternative variations of this embodiment, the projectile **100** may be configured with a propulsion unit or powerplant, such as for example one or more of a rocket motor, ramjet, turbojet and so on, which may be integral for example, for providing propulsion to the projectile **100**, and/or including for example an ejectable rocket propulsion unit, to impart forward acceleration and velocity to the projectile **100**.

Body **10** comprises an elongate fuselage **19** having a longitudinal centerline or axis **A**. The fuselage **19** comprises a nose or front end **11**, middle section **12**, and an aft end **13**, and may comprise a generally circular cross-section along at least a majority of its length along the axis **A**. In alternative variations of this embodiment, the fuselage **19** may comprise a non-circular cross-section, for example oval, polygonal etc., and may optionally comprise a faceted outer surface.

The nose or front end **11** may comprise a relatively pointed or rounded or otherwise aerodynamically contoured profile, and includes a bore **18** aligned with axis A and open at the forward end, the purpose of which shall become clearer below.

Referring in particular to Fig. 3, the middle section **12** comprises a forward portion **12a** of generally constant cross-section, and defining a maximum width or diameter **D**, and a tapering aft portion **12b** that connects to the aft end **13**. The middle section **12** defines a payload chamber **14** that houses an explosive charge as well as at least a part of the mechanism that is used for priming and detonating the explosive charge. In alternative variations of this embodiment, the payload chamber may accommodate other materials, equipment or objects.

Aft end **13** comprises eight fins **20**, radially radiating from the axis **A**, and uniformly spaced with respect to one another. The fins **20** are configured for providing longitudinal and lateral stability, and are pivotably deployable about the respective pivot

axes **22**, from a retracted or stowed configuration marked in phantom lines as **20'**, in which the spans **S** of the fins **20** are generally parallel to axis **A** and the tips of the vanes **20** are forward of the respective pivot axes **22**, to a deployed configuration, in which the spans **S** of the fins **20** are swept back at a modest sweep angle with respect to an imaginary plane that is orthogonal to the axis **A**. In the retracted configuration, the vanes **20** are enclosed within an envelope defined by the aforesaid maximum diameter **D**.

In alternative variations of this embodiment, the aft end **13** may comprise less than eight fins or more than eight fins and/or any other suitable configuration for providing longitudinal and lateral stability.

The projectile **100** further comprises a direction control mechanism **40** comprising four control canards **30**, in cruciform "X" or "+" arrangement, in which the canards **30** are essentially divided into two pairs of canards, wherein in each pair the respective canards **30** are arranged in diametrical opposed relationship with respect to axis A. and are configured for providing steering control of the vehicle **100**, in particular control of one or more of the pitch, yaw and roll of the body **10**, responsive to control inputs generated by the head **50**, as will be disclosed in greater detail below. In alternative variations of this embodiment, the vehicle may comprise less than four or more than four canards, and/or any other suitable configuration for enabling the air vehicle to be steered responsive to said control input or other suitable steering input.

The canards **30** are pivotably deployable about the respective pivot axes **32**, from a retracted or stowed configuration shown in Figs. 1 and 2 (and also marked in phantom lines as **30'** in Figs. 3 and 4), to a deployed configuration illustrated in Figs. 3 and 4. In the stowed configuration, and as best seen in Fig. 4, the spans **Q** of the respective canards **30** are generally parallel to axis **A**, the tips of the canards **30** are forward of the respective pivot axes **32**, and the canards **30** are accommodated in complementary radial slots **34** provided in the front end **11**. In the stowed configuration, the canards **30** are configured to be enclosed within an envelope defined by the aforesaid maximum diameter **D**.

In the deployed configuration, the spans **Q** of the canards **30** are swept back at a modest sweep angle with respect to an imaginary plane that is orthogonal to the axis **A**, and are located close the front end of the middle section **12**. In alternative variations of

this embodiment, other retracted and/or deployed configurations may be provided, or the canards may be permanently deployed.

Pivot axes **32** are orthogonal to and do not intersect the axis **A**, and each pivot axis is generally orthogonal to the span **Q** of the respective canard **30**.

The direction control mechanism **40** further comprises a canard actuation arrangement in the form of a servo assembly **45**. The servo assembly **45** is configured for actuating each opposed pair of canards **30** (responsive to control inputs generated by the head **50**), when the canards **30** are in the deployed configuration, independently of one another, to pivot each canard **30** of the respective pairs in the same or opposite direction to the other canard of the same pair, about the respective actuation axis **B**, radially projecting orthogonally from axis **A**, to provide suitable control moments in one or more of pitch, yaw and roll. The respective actuation axes **B** for a first pair of opposed pair of canards **30** are co-axially aligned, while the respective actuation **axes** B for a second pair of opposed pair of canards **30** are co-axially aligned, but orthogonal to the respective actuation axes **B** of the first pair of opposed pair of canards **30**, and thus the two pairs of axes **B** are thus also in the above mentioned cruciform "X" or "+" arrangement.

In this embodiment, the respective actuation axes **B** for the first pair of opposed pair of canards **30** are aligned with the pitch axis **P** of the vehicle **100**, while the respective actuation axes **B** of the second pair of opposed pair of canards **30** are aligned with the yaw axis **Y** of the air vehicle **100**. In alternative variations of this embodiment, the actuation axes **B** may be inclined at any desired angle with respect to the pitch and yaw axes of the air vehicle, and actuation of each pair of opposed canards **30** provides a component of yaw and/or a component of pitch.

One or both pairs of opposed canards **30** may be actuated to provide roll about axis **A** in one or the other direction.

There are many examples in the art of suitable configurations for servo assembly **45**, and this will not be described in further detail herein.

A suitable thermal battery **49** provides power to the projectile **100**, including head **50** and servo assembly **40**, and is accommodated in an aft part of chamber **79**. The chamber **79** is forward of the payload chamber **14**, and a forward **end** of chamber 79 is open to bore **18**, which is of smaller cross-section than chamber **79**. In alternative variations of this embodiment, other suitable power sources may be provided.

Referring in particular to Fig. 4, the head **50** is configured as a seeker head and comprises a head housing **52** with a forward portion **51** accommodating a sensor arrangement **60**. The aft portion **53** of the head **50** comprises an internal chamber **56** having an aft-open end, and comprises a ring or annular tail airfoil **54**, joined to the external part of aft portion **53** via rigid vanes **55**. The head **50** has a longitudinal axis **a**. The maximum outer diameter of the head **50** (defined at the annular tail airfoil **54**) is less than **D**, and thus the head **50** is within the aforesaid envelope.

The head **50** is non-rigidly, i.e. freely, mounted to body **10** via joint structure 70, at the forward end **71** of connecting shaft **72** that projects forward of the nose section **11** from the bore **18**. The aft end **73** of shaft **72** is accommodated in bore **18**, and has an enlarged aft end **76** axially reciprocably movable within a forward part of chamber **79**, allowing for limited axial movement between shaft **72** and the bore **18** and chamber **79**, and thus allowing for corresponding limited axial movement between head **50** and the projectile body **10**. This axial movement is schematically indicated at "**k**" in Fig. 2.

A biasing resilient member in the form of compression spring **78** is provided between the battery **49** and enlarged end **76**, and provides limited resistance to aft movement of shaft **72** with respect to the body **10**, and the resilience of the spring **78** provides a restoring force in the forward direction.

Joint structure **70** (including shaft **72**) is configured to allow free relative pivotal movement between the head **50** and the body **10** in three rotational degrees of freedom and limited movement in one degree of freedom. In particular, the joint structure **70** itself is configured for allowing free relative pivotal movement between the head **50** and the body **10** in two rotational degrees of freedom, while the shaft **72** allows for free relative pivotal movement between the head **50** and the body 10 in a third rotational degree of freedom, and limited translational movement in one degree of freedom. In alternative variations of this embodiment, the joint structure **70** may be rotatably mounted to shaft **72**, and thus allows for free relative pivotal movement between the head **50** and the body **10** in three rotational degrees of freedom, while the shaft **72** provides limited translational movement in one degree of freedom. In yet other alternative variations of this embodiment the free pivotal movement between the head **50** and the body **10** may be in one degree of freedom only, or in two degrees of freedom only.

In other words, while axis **a** of head **50** is nominally coaxially aligned with axis **A** of the body **10**, axis **a** may be freely inclined with respect to axis **A** in one, two or three rotational degrees of freedom. The extent of this relative pivotal movement is limited by collision between the aft end **58** of the annular tail airfoil **54** with the nose section **11**, or collision of the aft edge **57** of housing **52** with shaft **72**, or collision of the aft edge **57** of housing **52** with the nose section **11**.

The joint structure **70** is accommodated in chamber **56**, and is in the form of free gimbals in this embodiment, comprising a set of inner gimbals **74** mounted to the head **50** and defining a first pivoting axis, and orthogonally connected to a set of outer gimbals **75** that are mounted at end **71** and defining a second pivoting axis orthogonal to the first pivoting axis. In alternative variations of this embodiment the joint structure **70** may comprise any other suitable arrangement that permits the aforesaid free pivotal movement between the head **50** and the body **10** in three degrees of freedom, for example via flexible hose.

The head **50** is thus configured for automatic alignment with the velocity vector of the vehicle **100**, due to the aerodynamic forces acting thereon, in particular the annular tail airfoil **54**, when exposed to the freestream of the fluid (typically atmospheric air) in which the projectile **100** is traveling.

In this embodiment, the sensor arrangement **60** is configured for homing onto a target that is illuminated by a laser, typically from another source, and for providing suitable control signals to the direction control mechanism **40** for operation thereof to maintain the vehicle **100** in a suitable trajectory to the target. In this embodiment the sensor arrangement **60** comprises a four quadrant detector, in which four laser detectors are arranged in maltese cross arrangement. Each sensor is operatively connected to a different one of said canards **30** of the direction control mechanism **40**, and thus provides a suitable control signal for controlling operation thereof, and thus operation of the respective canard. In operation of the sensor arrangement **60**, a laser radiation transparent dome **59** focuses laser light, reflected from the illuminated target, onto the sensors. When the head **50** is boresighted on the target, i.e., the axis **a** of the head is pointing directly to the target, the reflected radiation received from the target is uniformly sensed by all four sensors, and each generates a similar control signal to the direction control mechanism **40**, which effects no changes to the positions of the canards **30**, and thus the projectile continues along the same direction. On the other

hand, if the head **50** is off-target, the reflected laser light will be more focused on one or more sensors than on the other sensors, and the unequal distribution of sensed reflected light generates unequal control signals, in a ratio proportional to the off-boresight angle, to the control the direction control mechanism **40**. In other words, a different control signal (also referred to herein as error signal) is generated corresponding to each quadrant, which is fed to each respective canard actuator to control actuation thereof.

In this embodiment, a proportional control loop is used, in which the amount of deflection applied to each respective canard **30** about its respective pivot axis **B**, is proportional to the respective error or control signal generated by the respective sensor, and thus each canard **30** may be controlled to correct the velocity vector of the vehicle **100** to align the head **50** with the target. In alternative variations of this embodiment, a simple non-proportional control loop may be used (often referred to as "bang-bang"), which results in either zero deflection or full deflection of the respective canard.

In alternative variations of this embodiment the sensor arrangement may comprise, additionally or alternatively, other sensors such as radar, other electro-optic sensors, surveillance equipment, communication means and so on, which may be housed in the head **50** and/or body **10**, for example.

The projectile **100** further comprises said support structure **80**, configured for selectively supporting high-g thrust loads (also referred to herein as compressive loads or acceleration loads) between the head **50** and the body **10**, so that none, or at least no significant part, of these loads is effectively resisted or channeled via the joint structure **70** during the high-g launch phase (also referred to herein as the firing phase) of the projectile. The support structure **80** is further configured for selectively disengaging from at least one of the head **50** and body **10** so that at least during part of the post-launch phase when the projectile is in free motion, the head **50** is freely movable with respect to the body **10** and thus the head **50** is mechanically connected to the body 10 only via joint structure **70**, and thus shaft **72**.

These thrust loads are essentially the inertial loads of the head, and are determined from the product M*G, wherein M is the mass of the head **50**, and G is the acceleration of the vehicle **100**.

In other words, during at least a part of the high-g launch phase, the support structure **80** is configured for transferring these nominally axial acceleration loads between the head **50** and body **10**, and thus effectively mechanically isolates the joint

structure **70** from these loads. In other words, the support structure **80** is configured for directing acceleration loads from the head **50** to the body **10** while minimizing or eliminating stress on the joint structure **70** otherwise arising from such loads.

The support structure **80** is positioned on the outside of the body **10** and is mechanically connected to the head **50**. The support structure **80** and the head **50** thus define a load bearing unit that provides a load path to the body **10** that is substantially independent of the joint structure **70**, or indeed of the shaft **72**. This load bearing unit is configured to react the aforesaid acceleration loads such that the support structure **80** accepts the acceleration load provided by the head **50** and carries the acceleration load in compression to the body **10**, and such that the joint structure **70** is substantially isolated from and does not react at all, or to any significant extent to the acceleration loads. By "significant extent" is meant that the joint structure **70** is free or otherwise shielded from any damage arising due to the launch acceleration.

Thus, and referring in particular to Figs. 3 and 4, the support structure **80** in this embodiment is in the form of a fairing **90**, defining an internal cavity **92** and comprising a load-bearing interface **93** configured for connection with the forward end of forward portion **12a** in a load-bearing manner therewith. The fairing **90** comprises an internal shoulder **95** configured for axially supporting the annular tail airfoil **54**, in particular via the aft end **58**, in a load bearing manner, while concurrently aligning axis **a** with axis **A**. The internal cavity **92** also provides a close lateral fit with the annular tail airfoil **54**, and thus the support structure **80** is configured for externally restraining the head **50** and preventing relative moment between the head **50** and the body **10**, while not being mechanically connected to or interacting with joint structure **70**.

The fairing **90** is aerodynamically contoured externally to reduce drag and to isolate the head **50** from aerodynamically induced loads while the fairing is connected to the body **10** and the projectile **100** is in forward flight. Furthermore, while the fairing is connected to the body **10**, acceleration loads on the head 50 are reacted through the fairing **90** (via load-bearing contact between the annular tail airfoil 54 and the internal shoulder **95**), and to the body **10** (via load-bearing contact between interface **93** of fairing **90** and interface **94** of body **10**), and not through the joint structure **70**.

The limited axial movement **k** between the head **50** and body **10** allows for the fairing **90** to be manufactured without the need for tight tolerances between the actual and relative positions of the interface **93** and internal shoulder **95** on the one hand, and

the actual and relative positions of the interface **94** and the aft end **58** on the other hand. Thus, prior to subjecting the vehicle **100** to any acceleration, there may be a small axial gap between the aft end **58** and internal shoulder **95**, with the interfaces **93** and **94** in contact with one another. However, when subjected to acceleration loads, the head **50** may translate in an aft direction with respect to the body **10** responsive to the acceleration, until there is load bearing contact between the aft end **58** and internal shoulder **95**, the enlarged aft end **76** pressing against and compressing the spring **77**. Once the acceleration loads are removed (as the vehicle decelerates, for example), the head **50** translates back in a forward direction with respect to the body **10** due to the spring **77**.

The fairing **90** is also configured for being selectively disengaged from the body **10** and head **50**. The fairing **90** is formed from two lateral fairing halves, **90A**, **90B**, joined at a plane **W** that is parallel to and intersects the aligned axes **a** and **A**. The fairing halves, **90A**, **90B** are held together during the load-bearing phase via pyrotechnic cable **98** that is provided at the forward end of the fairing **90**, crossing plane **W**. Cable **98** is electrically connected to thermal battery **49** via leads **97** and switch mechanism **48**.

When activated by means of switch mechanism **48**, the cable **98** burns or otherwise breaks, allowing the fairing halves, **90A**, **90B**, to separate at the nose, and allowing full lateral separation of the fairing halves, **90A**, **90B**, by application of aerodynamic forces thereon, induced by the forward motion of the projectile **100**. As the fairing halves, **90A, 9 0B** laterally separate from one another, the fairing **90** automatically disengages from the head **50** and the body **10**, and reaction support previously provided to the head **50** via shoulder **95** is removed, allowing thereafter free relative movement between the head **50** and body **10** via the joint structure **70**.

In this embodiment, the switching mechanism **48** is configured for activating the cable **98** by means of one or more of:

- a timer, so that the cable 98 is activated after a predetermined time has elapsed after launch.
- an accelerometer or other suitable acceleration sensor or load sensor (e.g. strain gauge), so that the cable **98** is activated when acceleration forces acting on the projectile are below a predetermined threshold, for example considered not to

be potentially damaging to the joint structure **70** if the head **50** is connected to body **10** via the joint structure **70**.

- a directional sensor, so that the cable **98** is activated when the projectile is on a trajectory aligned with the target. For example, regarding a ground target and a ground launcher, the cable **98** may be activated when the projectile is on a downward trajectory, such that the velocity vector comprises a downwards components, i.e., in the direction of the earth.

In one form of operation of the projectile **100**, and referring to Fig. 5, the projectile **100** is launched in a conventional manner from a suitable mortar **200**, and follows a nominal parabolic trajectory **T** to a general target zone **Z**. The specific target **X** in zone **Z** is illuminated by an operator **OP** via a laser beam **LB**. At launch, and at least for part of the launch phase (**T1**), in which acceleration loads between the body **10** and head **50** would otherwise potentially damage or destroy the joint structure **70** in the absence of support structure **80**, the fairing **90** provides mechanical support between the body **10** and head **50**, isolating the joint structure **70** from such acceleration loads. The joint structure **70** may generate its own inertial forces due to acceleration, but these are substantially less than any corresponding loads between the head **50** and body **10**, and in any case the joint structure **70** is configured for withstanding its own inertia-induced loads without risk of damage.

Soon after launch, at point **T2**, the vanes **20** are deployed to provide directional stability.

At a predetermined point **T3** in the trajectory **T** after launch, within the post-launch phase, the fairing **90** is disengaged and removed from the body **10** and head **50**, allowing the head to freely align with the velocity vector of the projectile **100**. Soon after removal of the fairing **90**, or alternatively just before or concurrently therewith, the canards **30** are deployed, and the sensor arrangement in the seeker head is operational. Point **T3** is chosen such that the sensor arrangement **60** is pointing in the general direction of the zone **Z** and in particular the target **X**, so that the laser-illuminated target **X** will be in the field of view of at least one of the sensors of sensor arrangement **60**. In this manner, the sensor arrangement **60** will then control the canards **30** (**T4**) to steer the projectile **100** so that this is homed towards the target **X** (**T5**).

Point **T3** can be chosen in a number of different ways. For example, **T3** may be set at a predetermined time after launch, where it is assumed that the projectile **100** has

already passed the high acceleration stage and is now in the descent path (or other corresponding path) towards the target. Alternatively, **T3** may be defined as the point in the trajectory where the acceleration forces are now not potentially dangerous to the joint structure **70**, and thus the fairing **90** may be disengaged, the acceleration forces being monitored by an accelerometer or other suitable sensor. Alternatively, point **T3** may be determined according to the attitude of the projectile – a suitable orientation sensor or accelerometer can determine when the projectile **100** is in the descending part of the trajectory **T** and thus likely to be pointing in the general direction of zone **Z**, after which the faring may be removed.

Alternatively, the point **T3** may be chosen as the point where any two or all three conditions above are met – i.e., (a) not before a predetermined time after launch; and/or (b) when the projectile (in particular the joint structure **70**) is no longer subject to potentially damaging acceleration forces; and/or (c) the projectile is in a descending part of the trajectory (or the corresponding final part of the trajectory where the projectile is nominally aligned with the target).

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

It should be noted that the word "comprising" as used throughout the appended claims is to be interpreted to mean "included but not limited to".

Whilst some particular embodiments have been described and illustrated with reference to some particular drawings, the artisan will appreciate that many variations are possible which do not depart from the general scope of the invention, *mutatis mutandis*.

CLAIMS:

1. A projectile configured for operating at least in a launch phase and in a post-launch phase, comprising:

a projectile body, a projectile head, and a support structure,

wherein said projectile head is non-rigidly mounted to said projectile body via a joint structure; and

wherein said support structure is configured for selectively supporting said projectile head with respect to said projectile body in a load bearing relationship independently of said joint structure during at least a portion of said launch phase, and for selectively terminating said support during at least a portion of said post-launch phase.

2. A projectile according to claim 1, wherein said projectile head is pivotably mounted to said projectile body via said joint structure.

3. A projectile according to any one of claims 1 and 2, wherein said projectile head is axially movable with respect to said projectile body via said joint structure at least in when said support is terminated

4. A projectile according to any one of claims 1 to 3, wherein said projectile head is configured for being freely aerodynamically aligned with said velocity vector of the projectile independently of said projectile body when said support is terminated.

5. A projectile according to any one of claims 1 to 4, wherein said support structure is configured for preventing at least a majority of loads between said projectile head and said projectile body associated with said launch phase being channeled via said joint structure.

6. A projectile according to claim 5, wherein said majority of said loads is otherwise damaging if applied to said joint structure.

7. A projectile according to any one of claims 1 to 6, wherein said projectile body comprises a front end, an aft end and a first longitudinal axis extending therebetween, and wherein said projectile head comprises a second longitudinal

axis, wherein in said load bearing relationship, said first longitudinal axis is substantially coaligned with said second longitudinal axis.

8. A projectile according to any one of claims 1 to 7, wherein in said load bearing relationship, said support structure externally supports said projectile head with respect to said projectile body.

9. A projectile according to any one of claims 1 to 8, wherein in said load bearing relationship, said support structure reversibly interconnects said projectile head with said projectile body and is configured for supporting said loads between said projectile head and said projectile body when thus interconnected.

10. A projectile according to any one of claims 1 to 9, wherein said support structure is configured for being removed from said projectile body and said projectile head at least during said portion of said post-launch phase for selectively terminating said support.

11. A projectile according to any one of claims 1 to 10, wherein said loads are induced responsive to an acceleration of the projectile during said launch phase.

12. A projectile according to any one of claims 1 to 11, wherein said support structure is further configured for preventing aerodynamic loads being directly applied to said projectile head during said portion of said launch phase.

13. A projectile according to any one of claims 1 to 12, wherein said support structure comprises a load bearing member, wherein in said load bearing relationship said load bearing member is in load bearing contact with said projectile body and in load bearing contact with an external part of said projectile head.

14. A projectile according to any one of claims 1 to 13, wherein said support structure comprises a housing having an open aft end and a cavity in communication therewith, wherein said aft end is configured for reversibly connecting to said projectile body and wherein said cavity is configured for accommodating said projectile head therein in load bearing contact therewith.

15. A projectile according to any one of claims 1 to 14, wherein at least during said portion of said post-launch phase said projectile head is freely pivotable with

respect to said projectile body in at least one rotational degree of freedom, or in at least two rotational degrees of freedom, or in three rotational degrees of freedom.

16. A projectile according to any one of claims 1 to 15, wherein said joint structure is configured for permitting relative angular movement between said projectile head and said projectile body, said projectile head being configured for self-alignment with a free stream fluid flow direction, of a fluid through which said projectile is traveling, via said joint structure in said post-launch phase wherein said projectile head is exposed to the fluid flow.

17. A projectile according to any one of claims 1 to 16, wherein said projectile head is gimbaled freely to said projectile body via said joint structure or wherein said joint structure comprises a flexible hose.

18. A projectile according to any one of claims 1 to 17, wherein said projectile head comprises an aft portion comprising an annular tail airfoil configured for providing said self-alignment.

19. A projectile according to any one of claims 1 to 18, wherein said projectile head is configured for homing said projectile to a target.

20. A projectile according to any one of claims 1 to 19, wherein:

said projectile body further comprises a steering arrangement configured for steering the projectile responsive to suitable control input; and

said projectile head is further configured for providing said control input at least during said portion of said post launch phase.

21. A projectile according to claim 20, wherein said projectile head comprises a suitable sensor arrangement configured for sensing a control parameter wherein to generate said control input in response thereto.

22. A projectile according to claim 21, wherein said sensor arrangement is provided at a forward end of said projectile head.

23. A projectile according to any one of claims 21 to 22, wherein said sensor arrangement is configured for sensing a predetermined illuminating

electromagnetic radiation wherein to generate said control input in response thereto.

24. A projectile according to any one of claims 20 to 23, wherein said steering arrangement comprises an aerodynamic control surface arrangement configured for generating aerodynamic moments suitable for steering said projectile, responsive to said control input.

25. A projectile according to claim 24, wherein said aerodynamic control surface arrangement comprises a plurality of canards, said canards being individually controllable to selectively generate said aerodynamic moments.

26. A projectile according to claim 25, wherein said sensor arrangement comprises a plurality of sensors operatively connected to said plurality of canards, each said sensor being configured for generating a control signal for operating a respective said canard.

27. A projectile according to any one of claims 1 to 26, wherein said support structure comprises a casing having an aerodynamically contoured outer wall, and an internal seat for seating an aft portion of said projectile head in said load bearing relationship.

28. A projectile according to claim 27, wherein in said load bearing relationship, said projectile head is immobilized in said casing.

29. A projectile according to any one of claims 27 to 28, wherein in said load bearing relationship, said casing prevents axial displacement between said projectile head and said projectile body and/or wherein in said load bearing relationship, said projectile head and said projectile body are longitudinally aligned.

30. A projectile according to any one of claims 27 to 29, wherein said casing comprises a first casing half reversibly joined to a second casing half.

31. A projectile according to claim 30, wherein said support structure is removable from said projectile head and said projectile body by separating said first casing half from said second casing half.

32. A projectile according to any one of claims 1 to 31, wherein said support structure is selectively jettisonable from said projectile.

33. A projectile according to any one of claims 1 to 32, wherein said projectile is configured as a mortar shell configured to be launched via a mortar.

34. A method for operating a projectile, comprising:

(a) providing a projectile as defined in any one of claims 1 to 33;

(b) operating said projectile during at least said portion of said launch phase wherein to selectively support said projectile body with respect to said projectile head via said support structure in a load bearing relationship independently of said joint structure;

(c) selectively terminating said load bearing relationship and subsequently operating said projectile during at least said portion of said post-launch phase.

35. A method according to claim 34, wherein step (c) comprises removing said support structure from said projectile head and said projectile body while said projectile is traveling in the atmosphere, and allowing said projectile body to become freely aerodynamically aligned with a velocity vector of the projectile independently of said projectile body.

36. A method according to claim 34 or claim 35, further comprising homing said projectile to a target.

37. A method according to claim 36, further comprising illuminating said target with an illuminating radiation, detecting with said projectile head said illuminating radiation reflected from the target, and steering said projectile to said target wherein to maintain said reflected illuminating radiation in the boresight of said projectile head.

38. A method for retrofitting a projectile, comprising:

(a) providing the projectile, the projectile comprising a projectile body and a projectile head, wherein the projectile head is non-rigidly mounted to the projectile body via a joint structure; and

(b) providing a selectively removable support structure, wherein said support structure is configured for selectively supporting said projectile head with respect to said projectile body in a load bearing relationship independently of said joint structure during at least a portion of said launch phase, and for selectively terminating said support during at least a portion of said post-launch phase.

39. A method according to claim 38, wherein said support structure is configured for preventing at least a majority of loads between said projectile head and said projectile body associated with said launch phase being channeled via (or supported by) said joint structure, and optionally wherein said majority of said loads is otherwise damaging if applied to said joint structure.

40. A projectile, comprising:

a projectile body and a projectile head;

wherein said projectile head is non-rigidly mounted to said projectile body via a joint structure at a forward end of the projectile body; and

wherein said projectile is configured for permitting limited relative axial movement between said projectile body and said projectile head via said joint structure.

41. A projectile according to claim 40, wherein said joint structure comprises a forward portion configured for pivotingly mounting said projectile head thereto, and an aft portion comprising a shaft slidingly mounted to said projectile body.

42. A projectile according to claim 41, wherein said shaft is axially reciprocably movable with respect to said projectile body within a displacement range, and wherein optionally a resilient member may be provided for biasing said shaft with respect to said projectile body.

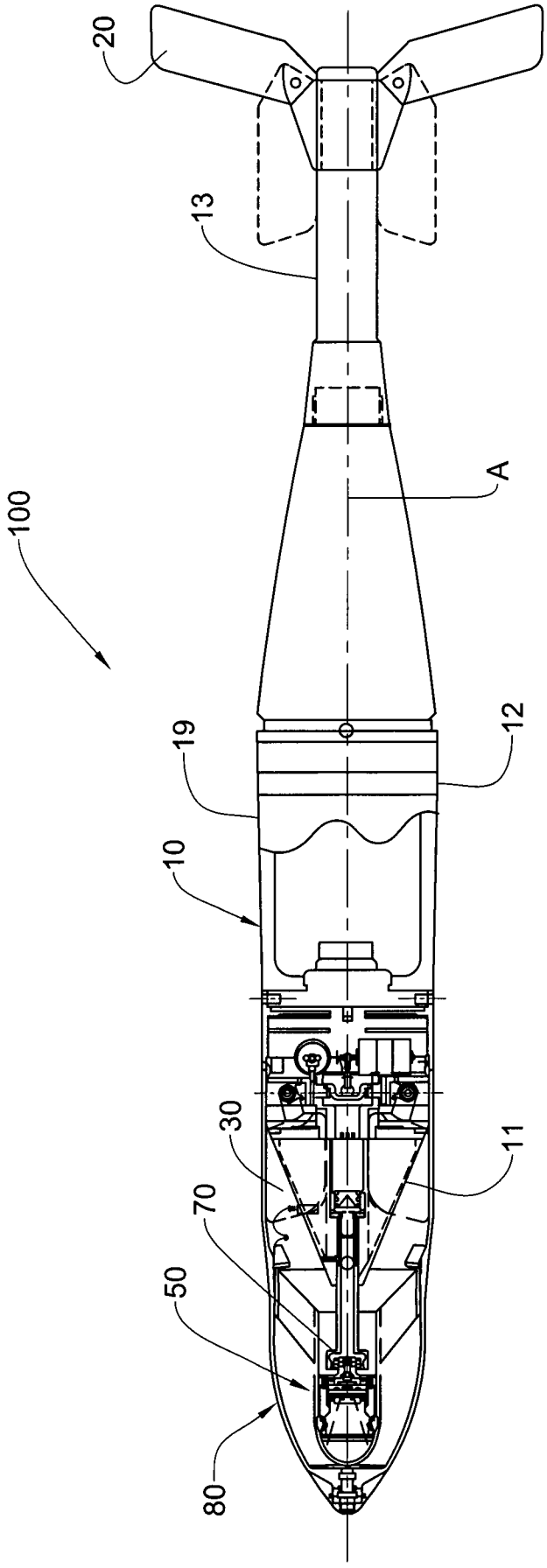


Fig. 1

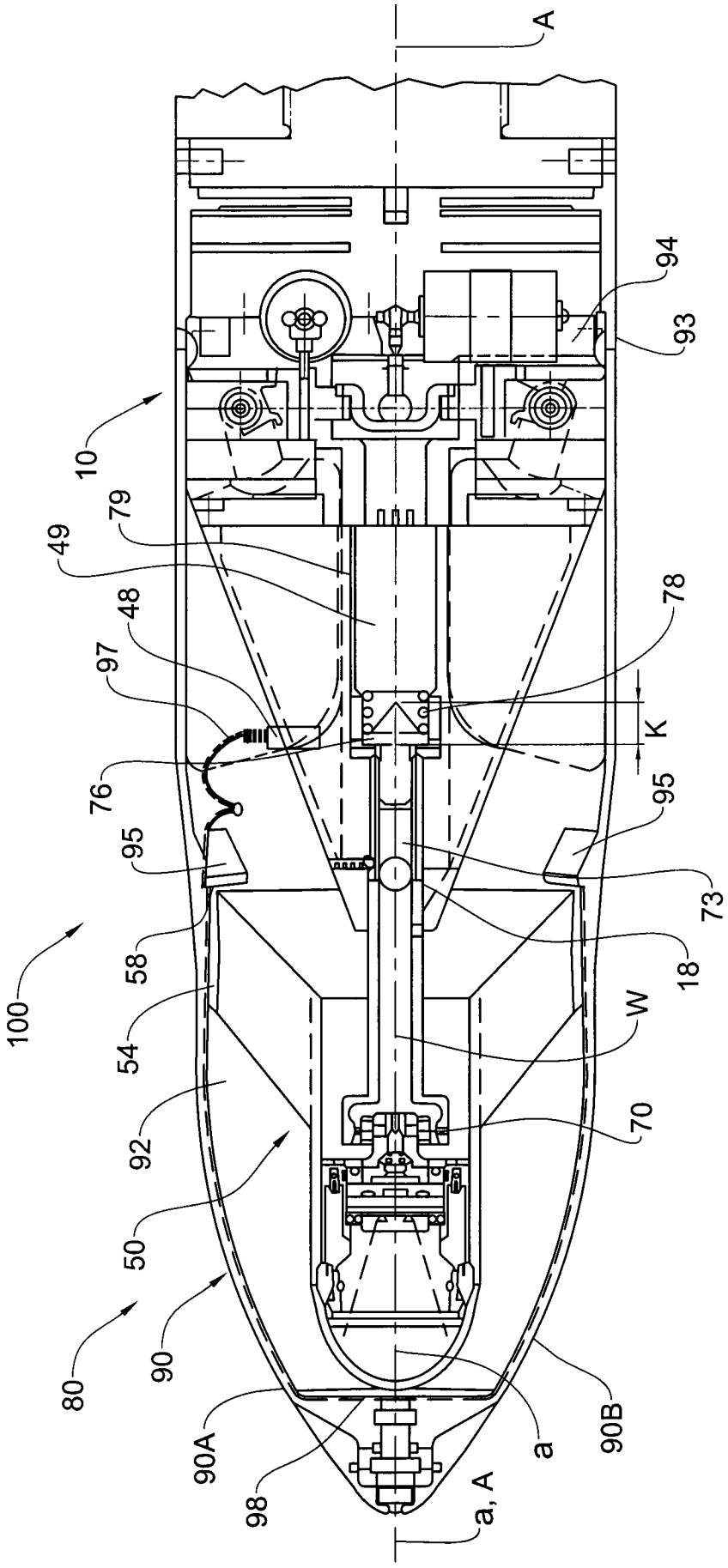

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Fig. 2

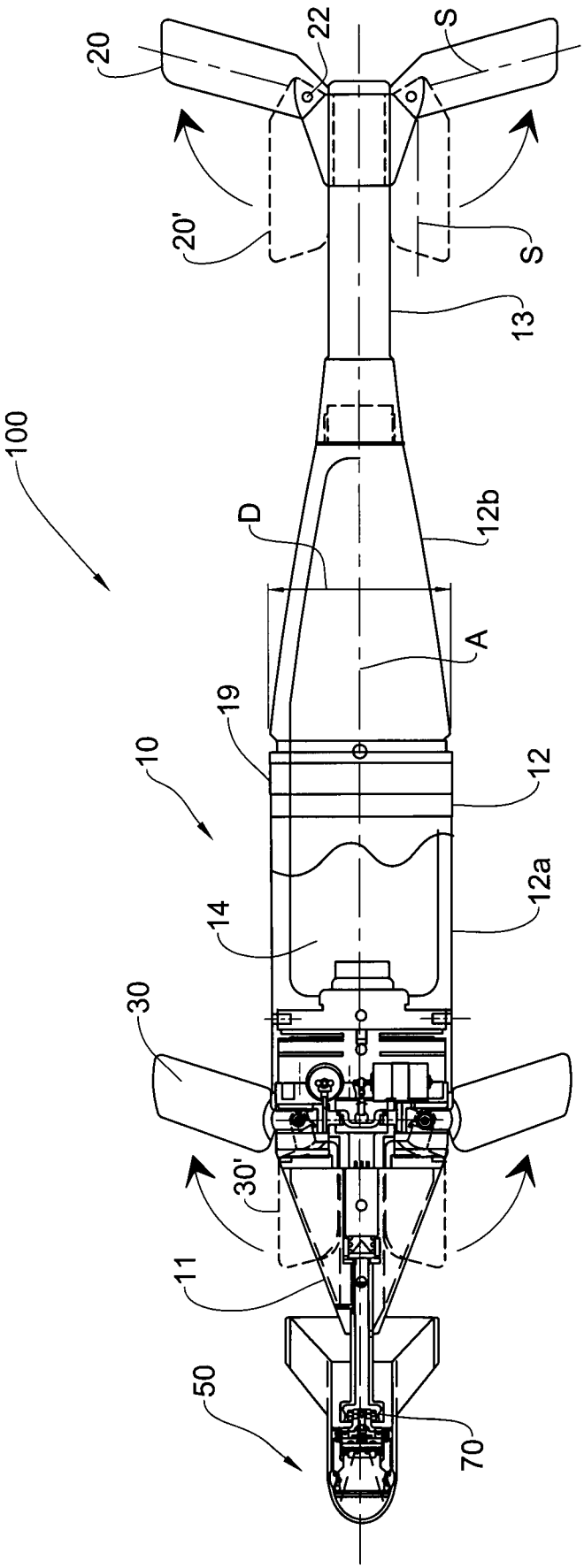


Fig. 3

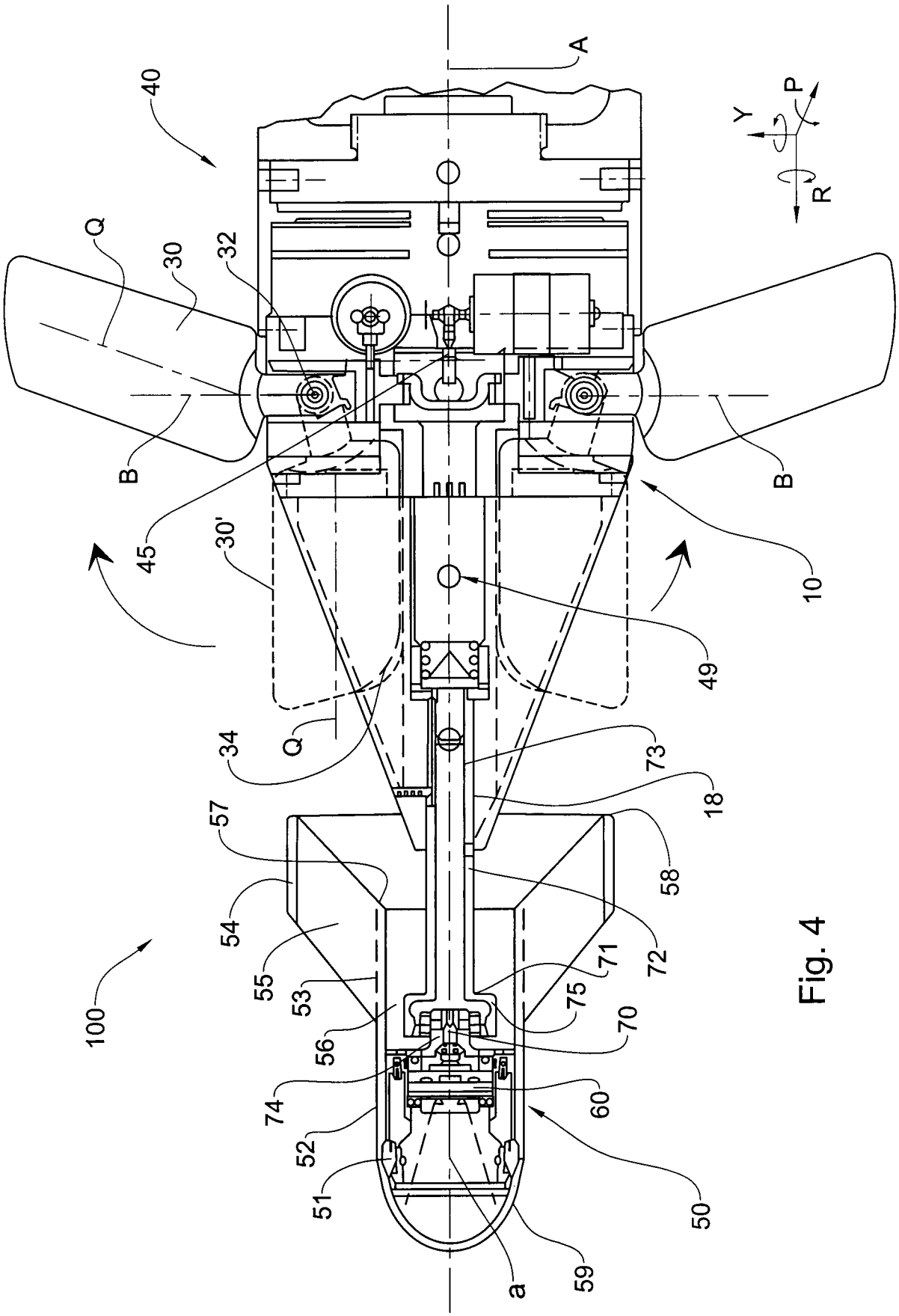

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Fig. 4

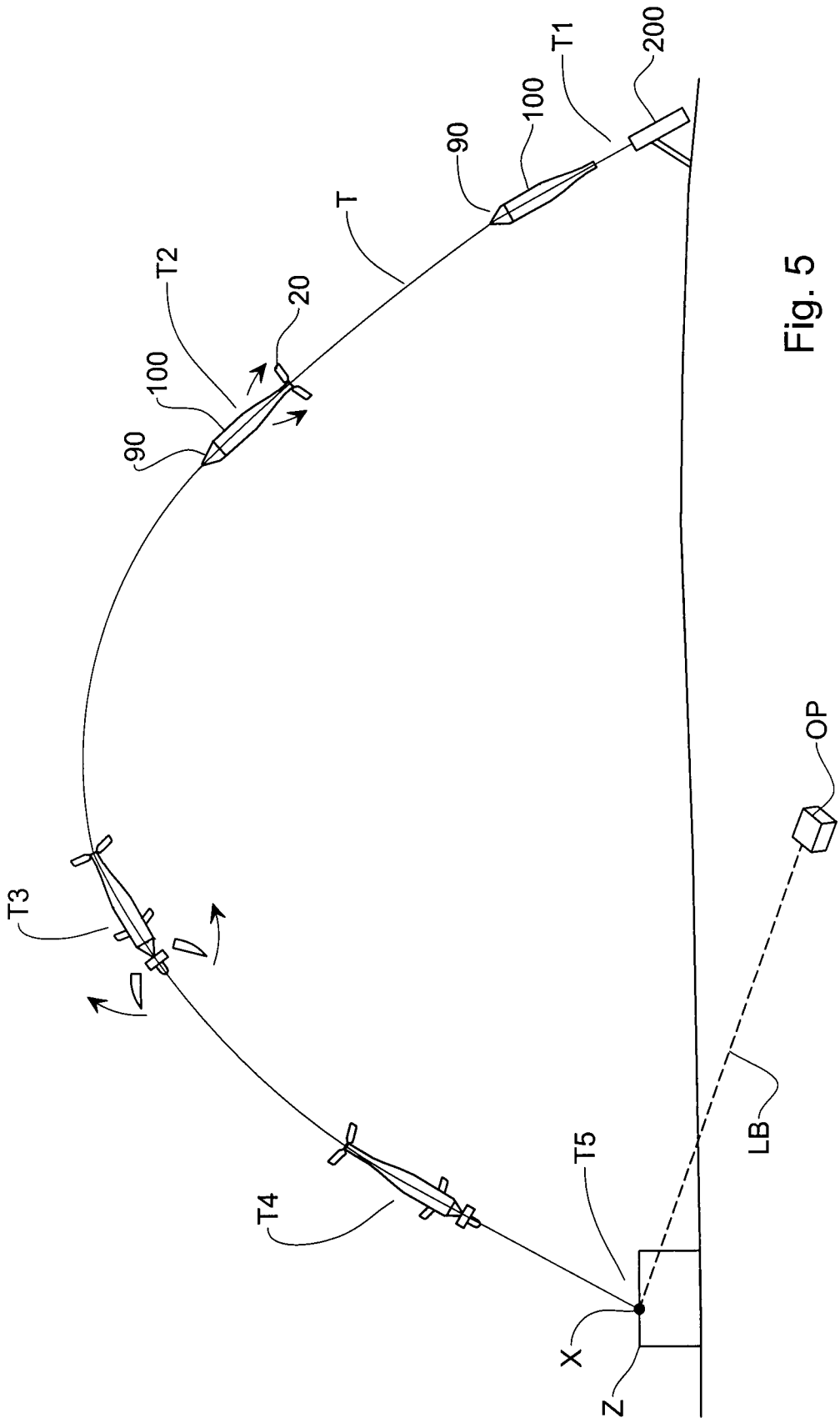


Fig. 5