

MODULE FOR PROJECTILE

TECHNOLOGICAL FIELD

The presently disclosed subject matter relates to systems, methods and accessories for launching projectiles, in particular for launching projectiles from a launch tube.

5 BACKGROUND

Vertical launch systems (VLS) for launching missiles are well known in the art. Conventionally, VLS include at least two different categories: hot launches and cold launches.

In a conventional hot launch VLS, the missile propulsion system is ignited in the
10 launch tube at launch, and the missile propels itself out of the cell or firing tube, and thereafter continues along its trajectory still under power from the missile propulsion system for at least a time period after launch.

In cold launch VLS the missile is conventionally ejected from the cell or launch tube via gas produced by a gas generator, which is not necessarily part of the missile.

15 Hot launch VLS are conventionally considered advantageous in that no separate ejection system is required for launch, while a major disadvantage of such systems is that a malfunction in the missile propulsion system can destroy the launch tube and possibly also the immediate area around the launch tube.

On the other hand, cold launch VLS, while conventionally more complex than hot
20 launch VLS, provide greater safety, as a malfunctioning missile is effectively ejected out of the launch tube and the threat of such a missile damaging the launch tube or immediate area is much reduced. Some surface to air missiles (SAM) and ship launched missiles are cold launched.

Many types of missiles are known in the art.

- 2 -

By way of non-limiting example, US 10,378,483 discloses a motor assembly for use with projectiles, such as munitions, having relatively low length to diameter ratios. The motor assembly has an aerospike nozzle and a casing disposed about the aerospike nozzle, where interior aerospike volume contains propellant and where walls of both the
5 cowl of the casing and of the aerospike nozzle jointly define a combustion chamber.

Also by way of non-limiting example, US 9,534,563 discloses a projectile for firing from a launcher, including a propulsion stage having non-axisymmetric boosters arranged about a longitudinal axis of the propulsion stage. The propulsion stage may further include a central booster about which the non-axisymmetric boosters are arranged.

10 Also by way of non-limiting example, US 7,108,223 discloses a jet propulsion outlet device that has a grid plate having a plurality of densely clustered nozzettes, the nozzettes of the grid plate being configured to operably couple to a pressurized gas source to efficiently expand the pressurized gas.

Also by way of non-limiting example, US 5,615,847 discloses a submarine
15 launched unmanned aerial vehicle comprises an elongated generally cylindrically-shaped body. Tail fins are stored in the body and are self-deployable to extend outwardly from the body. A booster motor is fixed to an aft end of the body and is self-releasable from the body. A propeller is disposed at the aft end of the body and is self-deployable to an exposed position at the aft end of the body after release of the booster motor. A propulsion
20 motor is mounted in the body and is operative to drive the propeller. Rotors are stored in the body and are self-deployable to an exposed position wherein the rotors provide lift to the vehicle.

Also by way of non-limiting example, US 4,364,530 discloses a modular, apogee-control package which can be added to existing missiles, and which will limit the apogee
25 of the missile trajectory by implementation of thrust vector control (TVC). The package comprises a boost guidance unit, a solid rocket propellant motor, and jet vane TVC.

- 3 -

GENERAL DESCRIPTION

According to a first aspect of the presently disclosed subject matter there is provided an ejection module for a projectile, in particular for ejecting a projectile, the module comprising:

- 5 - a module forward end comprising a central axis and a module interface, the module interface configured for selectively enabling, in particular for selectively causing the module to be selectively affixed to the projectile in a load-bearing manner, and for selective disconnection between the module and the projectile; and
- 10 - a module aft end comprising a module propulsion system, the module propulsion system comprising a plurality of rocket motors and a source of rocket propellant, wherein:
 - each said rocket motor is laterally spaced with respect to the central axis,
 - each said rocket motor has a respective fixed thrust vector non-parallel
 - 15 with respect to the central axis,
 - each said rocket motor is configured for generating a controllable level of respective thrust along the respective said thrust vector, independently of the respective level of thrust generated by the other said rocket motors along their respective thrust vectors;
- 20 wherein the module propulsion system is configured for enabling independently controlling the respective said level of thrust of each said rocket motor, i.e., wherein the module propulsion system is configured for enabling the independent control of the respective said level of thrust of each said rocket motor.

For example, said source of rocket propellant includes a predetermined quantity
25 of propellant not greater than that required to enable the module to propel the projectile from a launch site to a predetermined range and predetermined altitude with respect to the launch site, wherein said predetermined range and said predetermined altitude correspond to a minimum safe range and a minimum safe altitude with respect to the launch site.

30 For example, said minimum safe range and said minimum safe altitude ensures or minimizes potential damage to the launch site in event of the projectile failing to operate after disconnection from the ejection module and falls back to Earth under gravity.

- 4 -

Additionally or alternatively for example, said predetermined safe range is between 50m and about 70m, and/or the range does not exceed 100m, and/or the range does not exceed 500m.

5 Additionally or alternatively for example, said predetermined safe altitude is between about 30m and about 20m, and/or said predetermined safe does not exceed about 100m.

Additionally or alternatively for example, the ejection module is configured for providing any desired tilt after launch at least between 90° and 0° in elevation, or for example in the range -20° to 80° , or for example from 0° to 40° , or for example from 20° 10 to 30° , for example depending in the specific mission parameters.

Additionally or alternatively for example, the ejection module is configured for providing any desired azimuth after launch at least between 0° and 360° .

Additionally or alternatively for example, each said thrust vector converges towards the central axis at a respective intersection point aft of the module aft end. For 15 example, the respective intersection points of the thrust vectors are the same point.

Additionally or alternatively for example, each said thrust vector lies on a respective plane, and wherein said central axis lies on each said plane. For example, each said thrust vector defines a respective thrust angle on the respective plane with respect to the central axis. For example, the respective thrust angles of said rocket motors are equal 20 in magnitude to one another. Additionally or alternatively for example, each said thrust angle is in the range of between about 10° and about 30° , or for example each said thrust angle is in the range of between about 15° and about 20° , or for example each said thrust angle is about 17° .

25 Additionally or alternatively for example, said rocket motors are configured as liquid fuel rocket motors, and wherein said source of rocket propellant includes at least one liquid fuel tank and at least one oxidizer tank. In at least some other examples the rocket motors can be provided with any suitable propellants that allow for control of the level of respective thrust generated by the rocket motor.

- 5 -

Additionally or alternatively for example, the ejection module is configured for providing a forward velocity to the projectile at least sufficient to enable the projectile to steer, for example to steer aerodynamically, for example via fins, or in any other suitable manner.

- 5 Additionally or alternatively for example, the ejection module is configured for providing a forward velocity to the projectile sufficient to enable the projectile to initiate and maintain flight under its own power.

10 Additionally or alternatively for example, the ejection module is configured for providing a forward velocity to the projectile at least greater than 20 m/s, or at least greater than 20m/s and for example up to 40 m/s, or wherein the forward speed can be in the range 20m/s to 50m/s.

15 Additionally or alternatively for example, the ejection module further comprises a control unit operatively coupled to the module propulsion system, the control unit being configured for enabling independently controlling the respective said level of thrust of each said rocket motor. For example, the control unit is accommodated in the ejection module. Alternatively for example, the control unit is accommodated in the projectile.

Additionally or alternatively for example, said control unit is configured for operating the module to provide sufficient thrust to launch the projectile.

20 Additionally or alternatively for example, said control unit is configured for operating the module propulsion system such that the plurality of said rocket motors provide equal thrust to enable the module to provide a net thrust co-axial with the central axis.

25 Additionally or alternatively for example, said control unit is configured for operating the module propulsion system to provide any desired tilt maneuver. For example, said control unit is configured for operating the module propulsion system such that at least one said rocket motor generates less thrust than at least one other said rocket motor.

Additionally or alternatively for example, said module propulsion system comprises a first said rocket motor, a second said rocket motor and a third said rocket

- 6 -

motor, wherein said first rocket motor, said second rocket motor and said third rocket motor are uniformly spaced circumferentially with respect to the central axis. For example, each said rocket motor comprises a respective exhaust nozzle fixedly mounted to the rocket motor in alignment with the respective said thrust vector. Additionally or
5 alternatively for example, the control unit is configured for operating the module propulsion system such that the first rocket motor generates a first said thrust, the second rocket motor concurrently generates a second said thrust, and the third rocket motor concurrently generates a third said thrust, such that the first thrust, the second thrust and the third thrust together provide a module net thrust and a corresponding module thrust
10 vector.

For example, the ejection module is operable for selectively causing the module to execute a first acceleration maneuver, wherein said first thrust, said second thrust and said third thrust are equal to one another. For example, said control unit is configured for selectively causing the module to execute a first acceleration maneuver, wherein said first
15 thrust, said second thrust and said third thrust are equal to one another.

For example, the ejection module is operable for selectively causing the module to execute a first tilt maneuver, wherein said first thrust is greater than said second thrust or said third thrust, and wherein said second thrust is equal to said third thrust. For example, said control unit is configured for selectively causing the module to execute a
20 first tilt maneuver, wherein said first thrust is greater than said second thrust or said third thrust, and wherein said second thrust is equal to said third thrust.

For example, said first thrust corresponds to a nominal maximum thrust level for the said first rocket motor, and wherein said second thrust and said third thrust are each nominally zero.

25 For example, the ejection module is operable for executing said first tilt maneuver for a first time period, and for subsequently implementing a first righting maneuver for a second time period wherein for said second time period the said first thrust is less than said second thrust or said third thrust, and wherein said second thrust is equal to said third thrust, followed by implementing a second righting maneuver for a third time period,
30 wherein for said third time period said first thrust, said second thrust and said third thrust are equal to one another. For example, the control unit is configured for executing said

- 7 -

first tilt maneuver for a first time period, and for subsequently implementing a first righting maneuver for a second time period wherein for said second time period the said first thrust is less than said second thrust or said third thrust, and wherein said second thrust is equal to said third thrust, followed by implementing a second righting maneuver
5 for a third time period, wherein for said third time period said first thrust, said second thrust and said third thrust are equal to one another.

For example, the ejection module is operable for enabling, in particular for selectively causing the module to execute a second tilt maneuver, wherein said first thrust is less than said second thrust or said third thrust, and wherein said second thrust is equal
10 to said third thrust. For example, the control unit is configured for enabling, in particular for selectively causing the module to execute a second tilt maneuver, wherein said first thrust is less than said second thrust or said third thrust, and wherein said second thrust is equal to said third thrust.

For example, the ejection module is operable for enabling, in particular for
15 selectively causing the module to execute a third tilt maneuver, wherein said first thrust is greater than said second thrust or said third thrust, and wherein said second thrust is greater than said third thrust. For example, said control unit is configured for enabling, in particular for selectively causing the module to execute a third tilt maneuver, wherein said first thrust is greater than said second thrust or said third thrust, and wherein said
20 second thrust is greater than said third thrust.

For example, said first thrust corresponds to a nominal maximum thrust level for the said first rocket motor, and wherein said third thrust is nominally zero, and wherein said second thrust is intermediate in magnitude between said first thrust and said third thrust. Additionally or alternatively for example, the control unit is configured for
25 executing said third tilt maneuver for a first time period, and for subsequently implementing a first righting maneuver for a second time period wherein for said second time period said first thrust, said second thrust and said third thrust are each nominally zero, followed by implementing a second righting maneuver for a third time period, wherein for said third time period said third thrust is greater than said second thrust, and
30 said second thrust is greater than said first thrust, followed by implementing a third

- 8 -

righting maneuver for a fourth time period, wherein for said fourth time period said first thrust, said second thrust and said third thrust are equal to one another.

For example, the ejection module is operable for enabling, in particular for selectively causing the module to execute a third tilt maneuver, wherein said first thrust
5 is greater than said second thrust or said third thrust, and wherein said second thrust is less than said third thrust. For example, the control unit is configured for enabling, in particular for selectively causing the module to execute a third tilt maneuver, wherein said first thrust is greater than said second thrust or said third thrust, and wherein said second thrust is less than said third thrust.

10 Additionally or alternatively for example, said third tilt maneuver is configured to provide a desired change in azimuth during execution of said third tilt maneuver.

According to a second aspect of the presently disclosed subject matter there is provided a projectile assembly, comprising:

- 15 - a projectile having a projectile propulsion system and an aft projectile end, the aft projectile end comprising a projectile interface;
- an ejection module as defined herein regarding the first aspect of the presently disclosed subject matter;

wherein the projectile interface is configured for being selectively and reversibly coupled with respect to the module interface, such that when thus coupled the module is
20 reversibly affixed to the projectile in a load-bearing manner, and such that when the projectile interface is decoupled with respect to the module interface, the module is disconnected from the projectile.

For example, the projectile comprises a plurality of fins. In at least some other examples, the projectile omits fins, and for example can be stabilized in any suitable
25 manner.

According to a third aspect of the presently disclosed subject matter there is provided a launch system comprising:

- 30 - a projectile assembly as defined herein regarding the second aspect of the presently disclosed subject matter;

- 9 -

- a launch tube configured for accommodating the projectile launch assembly therein at least in a launch-ready configuration, and for enabling, in particular for selectively causing selective launch of the projectile launch assembly from the launch tube.

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For example, in at least some examples, said launch tube has a closed bottom end, while in at least some other examples, said launch tube has an open bottom end.

For example, said launch tube has a closed bottom end, and wherein said launch
10 tube includes an excess pressure venting arrangement configured for enabling venting of the launch tube responsive to a pressure within the launch tube exceeding a predetermined threshold pressure.

For example, said launch tube comprises a launch tube casing, the launch tube
15 comprising at least one venting opening, and wherein said excess pressure venting arrangement comprises at least one burst disc provided in each said venting opening, wherein each said disc is configured for bursting when subjected to a pressure exceeding said predetermined threshold pressure.

20 According to a third aspect of the presently disclosed subject matter there is provided a method for launching a projectile, comprising;

- (a) providing a launch system as defined herein regarding the third aspect of the presently disclosed subject matter;
- (b) selectively launching the projectile launch assembly from the launch tube by
25 operating the module propulsion system to generate thrust sufficient to at least eject the projectile launch assembly outside of a control zone around the launch tube;
- (c) decoupling the module from the projectile according to predetermined criteria including a first criterion, wherein said first criterion requires the projectile
30 launch assembly to be outside of said control zone.

For example, at least during step (b) the projectile propulsion system is not operated.

Additionally or alternatively, for example, the ejection module is as defined herein regarding the first aspect of the presently disclosed subject matter, and the module propulsion system is operated such that the first rocket motor generates a first said thrust, 5 the second rocket motor concurrently generates a second said thrust, and the third rocket motor concurrently generates a third said thrust, such that the first thrust, the second thrust and the third thrust together provide a module net thrust and a corresponding module thrust vector.

For example, said first thrust, said second thrust and said third thrust are equal to 10 one another.

For example, the module executes a first tilt maneuver, wherein said first thrust is greater than said second thrust or said third thrust, and wherein said second thrust is equal to said third thrust. For example, said first thrust corresponds to a nominal maximum thrust level for the said first rocket motor, and wherein said second thrust and said third 15 thrust are each nominally zero.

For example, said first tilt maneuver is executed for a first time period, and the method further comprises;

(I) subsequently implementing a first righting maneuver for a second time period wherein for said second time period the said first thrust is less than said second 20 thrust or said third thrust, and wherein said second thrust is equal to said third thrust,

(II) subsequent to step (I) implementing a second righting maneuver for a third time period, wherein for said third time period said first thrust, said second thrust and said third thrust are equal to one another.

25 For example, the module executes a second tilt maneuver, wherein said first thrust is less than said second thrust or said third thrust, and wherein said second thrust is equal to said third thrust.

For example, the module executes a third tilt maneuver, wherein said first thrust is greater than said second thrust or said third thrust, and wherein said second thrust is 30 greater than said third thrust. For example, said first thrust corresponds to a nominal

- 11 -

maximum thrust level for the said first rocket motor, and wherein said third thrust is nominally zero, and wherein said second thrust is intermediate in magnitude between said first thrust and said third thrust. Additionally or alternatively, for example, the third tilt maneuver is executed for a first time period, and the method further comprises:

- 5 (i) subsequently implementing a first righting maneuver for a second time period wherein for said second time period said first thrust, said second thrust and said third thrust are each nominally zero,
- (ii) subsequent to step (i), implementing a second righting maneuver for a third time period, wherein for said third time period said third thrust is greater than
10 said second thrust, and said second thrust is greater than said first thrust,
- (iii) subsequent to step (ii), implementing a third righting maneuver for a fourth time period, wherein for said fourth time period said first thrust, said second thrust and said third thrust are equal to one another.

For example, said control unit is configured for enabling, in particular for
15 selectively causing the module to execute a third tilt maneuver, wherein said first thrust is greater than said second thrust or said third thrust, and wherein said second thrust is less than said third thrust.

Additionally or alternatively, for example, said third tilt maneuver is configured to provide a desired change in azimuth during execution of said third tilt maneuver.

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BRIEF DESCRIPTION OF THE DRAWINGS

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

Fig. 1 is an isometric view of an ejector module according to an example of the presently disclosed subject matter.

Fig. 2 is an isometric view of a projectile assembly including the example of the ejector module of Fig. 1, wherein the projectile assembly has just ejected from a launch
10 tube.

Fig. 3 schematically illustrates a control zone associated with the projectile assembly example of Fig. 2.

Fig. 4 is an isometric view of a lower portion of a projectile of the projectile assembly example of Fig. 2.

Fig. 5 is an isometric cross-sectional view of a lower portion of the projectile assembly example of Fig. 2.
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Fig. 6(a) is an isometric view of a lower portion of the projectile assembly example of Fig. 2, prior to separation; **Fig. 6(b)** is an isometric view of the example of Fig. 6(a) during separation; **Fig. 6(c)** is an isometric view of the example of Fig. 6(a) after
20 separation.

Fig. 7 is an isometric exploded view of the example of Fig. 1.

Fig. 8 is a cross-sectional view of a rocket motor of the ejector module example of Fig. 1.

Fig. 9 schematically illustrates an example of a propulsion system of the ejection
25 module example of Fig. 1.

Fig. 10 schematically illustrates geometrical relationships associated with the ejection module example of Fig. 1.

Fig. 11 schematically illustrates azimuth and elevation angles associated with the projectile assembly example of Fig. 2.

Fig. 12 schematically illustrates thrust distributions over time for one example of operation of the ejection module example of Fig. 1.
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Fig. 13(a) schematically illustrates thrust levels associated with an example of operation of the ejection module example of Fig. 1 in which there is no net radial thrust;

- 13 -

Fig. 13(b) schematically illustrates thrust levels associated with an example of operation of the ejection module example of Fig. 1 in which there is a net radial thrust in an upward vertical direction; **Fig. 13(c)** schematically illustrates thrust levels associated with an example of operation of the ejection module example of Fig. 1 in which there is a net radial thrust in a downward vertical direction; **Fig. 13(d)** schematically illustrates thrust levels associated with an example of operation of the ejection module example of Fig. 1 in which there is no net radial thrust.

Fig. 14 schematically illustrates thrust distributions over time for another example of operation of the ejection module example of Fig. 1.

Fig. 15 schematically illustrates thrust distributions over time for another example of operation of the ejection module example of Fig. 1.

Fig. 16(a) schematically illustrates thrust levels associated with an example of operation of the ejection module example of Fig. 1 in which there is a net radial thrust in a general lateral and vertically upward direction; **Fig. 16(b)** schematically illustrates thrust levels associated with an example of operation of the ejection module example of Fig. 1 in which there is no net radial thrust; **Fig. 16(c)** schematically illustrates thrust levels associated with an example of operation of the ejection module example of Fig. 1 in which there is a net radial thrust in a general lateral and vertically downward direction; **Fig. 16(d)** schematically illustrates thrust levels associated with an example of operation of the ejection module example of Fig. 1 in which there is no net radial thrust.

Fig. 17 is a cross-sectional side view of a bottom portion of the projectile assembly example of Fig. 2 when accommodated in the launch tube.

Fig. 18 is a cross-sectional isometric view of a bottom portion of an alternative variation of the projectile assembly example of Fig. 2 when accommodated in the launch tube.

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DETAILED DESCRIPTION

Referring to Fig. 1, an ejection module (also interchangeably referred to herein as a module) according to a first example of the presently disclosed subject matter, generally designated with reference numeral **500**, comprises a module forward end **510**, and a module
5 aft end **520**.

Referring to Fig. 2 and Fig. 3, the module **500** is configured for ejecting a projectile **100** out of a launch tube **700** or the like, and for propelling the projectile **100** at least out of a control zone **CZ** associated with the launch tube **700**. The control zone **CZ** is defined by a control zone altitude **AT** and a control range **RA** from the launch tube **700** at launch site
10 **LS**.

In particular, the module **500** is configured for enabling the ejection of a projectile **100** out of a launch tube **700** and to bring the projectile **100** to a specific position and orientation outside the launcher according to mission and safety requirements.

As will become clearer herein, when coupled together the module **500** and the
15 projectile **100** provide a projectile assembly **900**.

Also as will become clearer herein, a launch system **990** according a first example comprises at least one projectile assembly **900** and at least one launch tube **700**. The launch tube **700** is configured for accommodating the projectile assembly **900** therein at least in a launch-ready configuration, and for enabling selective launch of the projectile assembly **900**
20 from the launch tube **700**.

The size of the control zone **CZ**, in particular the magnitude of the altitude **AT** and the magnitude of the range **RA**, correspond to, and represent, a minimum safety altitude and range, respectively, for the projectile **100** to reach, such that, in case the projectile malfunctions, there is minimal risk of damage and/or injury within the control zone **CZ**
25 resulting from such malfunction.

For example, the altitude **AT** can be between about 30m and about 20m, and the range **RA** can be between about 50m and about 70m. In at least some examples, the altitude **AT** does not exceed about 100m, and/or the range **RA** does not exceed about 100m. In at least some examples, the range **RA** does not exceed about 500m.

- 15 -

Referring also to Fig. 4 and Fig. 5, the projectile **100** can be any suitable missile or rocket, and comprises a projectile aft end **150** and a projectile propulsion system. While in at least this example the propulsion system includes one projectile rocket motor **125**, in alternative variations of this example the respective propulsion system can include a plurality
5 of projectile rocket motors. In any case the one or more projectile rocket motors can be provided with any suitable propellants.

The projectile **100** can also include a suitable payload, typically at the front end thereof, for example a warhead.

In at least this example, the projectile **100** further comprises a plurality of fins **130**,
10 which in at least this example are deployable between a stowed configuration and a deployed configuration. In the stowed configuration, the fins **130** are pivoted to a position overlying the casing of the projectile **100**, as illustrated in Fig. 1, and provide a compact configuration suitable for the launch tube **700**. In the deployed configuration, which does not occur until at least after the projectile **100** has fully exited the launch tube **700**, the fins **130** project for
15 example radially with respect to the projectile casing, and provide stability to the projectile in flight.

The module **500** is configured for being reversibly coupled to the projectile to form a projectile assembly **900**.

Referring again to Fig. 2, the module **500** defines a central axis **CA**, which at least
20 in this example is parallel to and co-axial with the longitudinal axis **LA** of the projectile **100**, when the module **500** is coupled to the projectile **100** in the projectile assembly **900**.

Referring also to Fig. 6(a), Fig. 6(b), and Fig. 6(c), the module forward end **510** comprises a module interface **580**.

The module interface **580** is configured for selectively enabling the module **500** to
25 be selectively affixed to the projectile **100** in a load-bearing manner, and for enabling selective disconnection between the module **500** and the projectile **100**.

For example, the projectile aft end **150** comprises a projectile interface **155**. The projectile interface **155** is configured for being selectively and reversibly coupled with respect to the module interface **580**, such that when thus coupled the module **500** is

- 16 -

reversibly affixed to the projectile **100** in a load-bearing manner, and such that when the projectile interface **155** is decoupled with respect to the module interface **580**, the module **500** is disconnected from the projectile **100**.

In at least this example, the projectile interface **155** comprises a projecting end **156**
5 having first cross-sectional shape **CS1**, which is uniform for an axial length **AX1** of the projecting end **156**.

Referring again to Fig. 5, in at least this example, the module interface **580** comprises a forward facing well **585** having an inlet end **586** having an opening defining a second cross-sectional shape **CS2** which can be essentially complementary to the first cross-sectional shape **CS1**, wherein the first cross-sectional shape **CS1** is peripherally spaced by
10 a suitable tolerance gap **GP** with respect to the second cross-sectional shape **CS2**. The well **585** also has a suitable depth **DP**, at least not less than the axial length **AX1**, such as to enable the projectile aft end **150** to be received and accommodated within the well **585** via the inlet end **586**.

In at least this example, the projectile **100** and module **500** are releasably locked in the projectile assembly **900** via a plurality of explosive bolts **587**, which can be selectively actuated to fracture, thereby enabling decoupling of the projectile **100** with respect to the module **500**. However, in at least some alternative variations of this example, any other suitable release mechanism as known in the art can be used instead of or in addition to
20 explosive bolts.

Referring in particular to Fig. 7, the module aft end **520** comprises a module propulsion system **600**.

The module propulsion system **600** comprises a plurality of rocket motors **620** and a source of rocket propellant **650** operatively coupled to the rocket motors **620**.

25 While in at least this example, the module propulsion system **600** comprises three rocket motors **620**, in at least some alternative variations of this example, the respective module propulsion system can comprise two, or more than three, for example four, five, six or more than six, respective rocket motors.

- 17 -

Referring also to Fig. 8, each rocket motor **620** comprises a respective combustion chamber **627** and a respective exhaust nozzle **628**.

For each rocket motor **620**, the respective exhaust nozzle **628** is fixedly mounted to the rocket motor **620** in alignment with the respective thrust vector **TV**.

5 Thus the direction of each thrust vector **TV** with respect to the module **500** is fixed.

The module **500** comprises a module casing **580**, including a cylindrical wall **582** joined to bottom wall **584**. The upper end of the module casing **580** is joined to the module interface **580**, in particular to the inlet end **586**.

The ejection module **500** further comprises, or is operatively coupled to a control
10 unit **590**.

In at least this example, the module casing **580** accommodates the module propulsion system **600** and the functions of the control unit **590** can be provided in the projectile **100**, for example by the flight computer of the projectile. Thus, in at least this example, the control unit **590** is not part of the ejection module **500** per se, but rather the
15 control unit **590** is operatively coupled to the ejection module **500**. However, in at least some alternative variations of this example, the respective module casing **580** accommodates the module propulsion system **600** and the control unit **590**, and in such examples, the respective ejection module **500** comprises the respective control unit **590**.

In at least this example, the rocket motors **620** are configured as liquid fuel rocket
20 motors, for example bi-propellant rocket motors, and operate to generate thrust by the combustion of propellants, the propellants including a fuel and an oxidizer.

Referring in particular to Fig. 7 and Fig. 9, in at least this example, the rocket propellant source **650** of module propulsion system **600** comprises a fuel tank **652**, an oxidizer tank **654**, and a pressurized gas tank **656**.

25 Suitable fuel conduits **653** interconnect the fuel tank **652** to each of the rocket motors **620** via manifold **653A**.

Suitable oxidizer conduits **655** interconnect the oxidizer tank **654** to each of the rocket motors **620** via manifold **655A** (Fig. 9).

Suitable pressurized gas conduits **657**, **658** interconnect the pressurized gas tank **656** to the fuel tank **652** and the oxidizer tank **654**, respectively, via manifold **659** (Fig. 9).

In at least this example, the fuel and oxidizer are hypergolic, and thus ignite on contact with one another within the respective combustion chamber **627** of the respective rocket motor **620**. However, in at least some alternative variations of this example, the fuel and oxidizer are not hypergolic, and thus an ignitor is provided to ignite the fuel and oxidizer within the respective combustion chamber **627** of the respective rocket motor **620**.

In at least this example, the fuel provided in the fuel tank **652** can be any one of kerosene, hydrazine and its derivatives, liquid hydrogen and so on, for example, the oxidizer provided in the oxidizer tank **654** is hydrogen peroxide, and the gas provided in the pressurized gas tank **656** is nitrogen. However, in alternative variations of this example, any suitable combination of fuel, oxidizer and gas can be used, for example any one of nitric acid, nitrogen tetroxide, liquid oxygen, liquid fluorine, and so on.

In at least this example, and referring to Fig. 9, the fuel tank **652** and oxidizer tank **654** are pressurized via the pressurized gas tank **656**, thereby increasing the fuel pressure within the fuel tank **652** and the oxidizer pressure within the oxidizer tank **654**. High pressure fuel and oxidizer flows enter the combustion chambers **627** through the control valves **621** **622** which are controlled via suitable command signals from the control unit **590**.

For example, the fuel tank **652** comprises a first rupture disc **672** selectively preventing fluid communication between the fuel tank **652** and the fuel conduits **653**. The first rupture disc **672** is configured for rupturing and thereby establishing fluid communication between the fuel tank **652** and the fuel conduits **653**, and thus establishing fluid communication between the fuel tank **652** and the rocket motors **620**, when the pressure difference across the first rupture disc **672** exceeds a first predetermined threshold pressure. Furthermore, the fuel tank **652** comprises a first internal piston **652P** separating the respective pressurized gas conduit **657** from the liquid fuel contents **FC** of the fuel tank **652**. The first internal piston **652P** is movable within the fuel tank **652** towards the first rupture disc **672** when subjected to gas pressure from the pressurized gas tank **656**, thereby increasing the fuel pressure within the fuel tank **652**. When the pressure in the fuel tank **652** exceeds the first predetermined pressure, the first rupture disc **672** ruptures, and fuel is delivered to the rocket motors **620** via the fuel conduits **653**. Fluid communication between

- 19 -

the pressurized gas tank **656** and the fuel tank **652** is controlled by valve **673**, which is in turn controlled by the control unit **590**. Valve **673** is normally closed, preventing fluid communication between the pressurized gas tank **656** and the fuel tank **652**, and the valve **673** is selectively opened (via suitable command signals from the control unit **590**) to
5 establish fluid communication between pressurized gas tank **656** and the fuel tank **652**, thus enabling the gas pressure of the pressurized gas tank **656** to be applied to the fuel tank **652** via the first piston.

Similarly, in at least this example, the oxidizer tank **654** comprises a second rupture disc **674** selectively preventing fluid communication between the oxidizer tank **654** and the
10 oxidizer conduits **655**. The second rupture disc **674** is configured for rupturing and thereby establishing fluid communication between the oxidizer tank **654** and the oxidizer conduits **655**, and thus establishing fluid communication between the oxidizer tank **654** and the rocket motors **620**, when the pressure difference across the second rupture disc **674** exceeds a second predetermined threshold pressure. Furthermore, the oxidizer tank **654** comprises a
15 second internal piston **654P** separating the respective pressurized gas conduit **658** from the liquid oxidizer contents **LO** of the oxidizer tank **654**. The second internal piston **654P** is movable within the oxidizer tank **654** towards the second rupture disc **674** when subjected to gas pressure from the pressurized gas tank **656**, thereby increasing the fuel pressure within the oxidizer tank **654**. When the pressure in the oxidizer tank **654** exceeds the second
20 predetermined pressure, the second rupture disc **674** ruptures, and oxidizer is delivered to the rocket motors **620** via the oxidizer conduits **655**. Fluid communication between the pressurized gas tank **656** and the oxidizer tank **654** is also controlled by valve **673**, which is in turn controlled by the control unit **590**. Valve **673** is normally closed, preventing fluid communication between the pressurized gas tank **656** and the oxidizer tank **654**, and the
25 valve **673** is selectively opened (via suitable command signals from the control unit **590**) to establish fluid communication between pressurized gas tank **656** and the oxidizer tank **654**, thus enabling the gas pressure of the pressurized gas tank **656** to be applied to the oxidizer tank **654** via the second piston.

Referring in particular to Fig. 9, each rocket motor **620** is coupled to the fuel tank
30 **652** and to the oxidizer tank via respective fuel conduit **653** and respective oxidizer conduit **655**.

- 20 -

In at least this example, the rocket propellant source **650** includes a predetermined quantity of propellant not greater than that required to enable the module **500** to propel the projectile **100** from the launch site to the control zone altitude **AT** and a control range **RA** with respect to the launch site. In particular, in at least this example, fuel tank **652** and the
5 oxidizer tank **654** each includes a predetermined quantity of fuel and oxidizer, respectively, not greater than that required to enable the module **500** to propel the projectile **100** from the launch site to the control zone altitude **AT** and a control range **RA** with respect to the launch site.

Referring again to Fig. 8, each rocket motor **620** has a respective fixed thrust vector
10 **TV** (generally co-axial with the centerline of the exhaust nozzle **628**) that is non-parallel with respect to the central axis **CA**.

Each rocket motor **620** is configured for generating a controllable level of respective thrust **T** along the respective thrust vector **TV**, independently of the respective level of thrust generated by the other rocket motors **620** along their respective thrust vector **TV**.

15 In at least this example, and referring again to Fig. 9, each rocket motor **620** comprises respective solenoid valves **621**, **622** provided in the respective fuel conduit **653** and oxidizer conduit **655**, respectively. Each pair of solenoid valves **621**, **622** is configured for controlling flow of fuel and oxidizer, respectively, to the respective rocket motor **620**, and each pair of solenoid valves **621**, **622** is operatively coupled to the control unit **590**.

20 In each pair of solenoid valves **621**, **622**, the respective solenoid valves **621**, **622** have a fully closed configuration **C1**, a fully open configuration **C3**, and a plurality of intermediate partially open configurations **C2**.

In the fully closed configuration **C1**, the respective pair of solenoid valves **621**, **622** are fully closed, thereby preventing flow of fuel and oxidizer, respectively, to the respective
25 rocket motor **620**, and the respective rocket motor **620** generates zero thrust **T₁**.

In the fully open configuration **C3**, the respective pair of solenoid valves **621**, **622** are fully open, thereby providing maximum flow communication and enabling providing maximum flow of fuel and oxidizer, respectively, to the respective rocket motor **620**, and the respective rocket motor **620** generates maximum thrust **T₃**.

In the partially open configuration **C2**, the respective pair of solenoid valves **621**, **622** are partially open, thereby providing partial flow communication and enabling providing partial flow of fuel and oxidizer, respectively, to the respective rocket motor **620**, and the respective rocket motor **620** generates intermediate thrust **T₂**.

- 5 The intermediate thrust **T₂** is thus less than the maximum thrust **T₃** and greater than the zero thrust **T₁**.

Thus, the control unit **590** is capable of controlling the level of thrust generated by each of the rocket engines **620**, independently of one another, via control of the respective pairs of solenoid valves **621**, **622**.

- 10 Referring again to Fig. 8, each rocket motor **620** is laterally (for example, radially) spaced with respect to the central axis **CA** by lateral spacing **LS**.

In at least this example, and as disclosed above, the module propulsion system **600** comprises three rocket motors **620**, which are uniformly spaced circumferentially with respect to the central axis **CA**, at 120° angular spacings with respect to the central axis **CA**.

- 15 Referring for example to Fig. 9, where necessary to differentiate herein the rocket motors **620** one from the other, the first rocket motor is further designated with alphanumeric reference **620A**, the second rocket motor is further designated with alphanumeric reference **620B**, and the third rocket motor is further designated with alphanumeric reference **620C**. Otherwise, each rocket motor is interchangeably referred to herein with alphanumeric
20 reference **620**.

- Similarly, where necessary to differentiate the thrust **T** of the rocket motors **620A**, **620B**, **620C** one from the other, the first thrust generated by the first rocket motor **620A** is further designated with alphanumeric reference **T_A**, the second thrust generated by the second rocket motor **620B** is further designated with alphanumeric reference **T_B**, and the
25 third thrust generated by the third rocket motor **620C** is further designated with alphanumeric reference **T_C**. Otherwise, the thrust generated by each rocket motor **620** is interchangeably referred to herein with alphanumeric reference **T**.

Similarly, where necessary to differentiate the thrust vectors **TV** of the rocket motors **620A**, **620B**, **620C** one from the other, the first thrust vector of the first rocket motor **620A**

- 22 -

is further designated with alphanumeric reference **TV_A**, the second thrust vector of the second rocket motor **620B** is further designated with alphanumeric reference **TV_B**, and the third thrust vector of the third rocket motor **620C** is further designated with alphanumeric reference **TV_C**. Otherwise, each thrust vector is interchangeably referred to herein with
5 alphanumeric reference **TV**.

Referring to Fig. 8 and Fig. 10, each thrust vector **TV** lies on a respective reference plane **PL**, and the central axis **CA** also lies on each such reference plane **PL**. Each thrust vector **TV** defines a respective thrust angle θ on the respective reference plane **PL** with respect to the central axis **CA**.

10 In at least this example, the respective thrust angles θ of the rocket motors **620** are equal in magnitude to one another. However, in at least some alternative variations of this example, the respective thrust angles θ of the rocket motors **620** can be different in magnitude to one another.

In at least this example, each respective thrust angle θ is about 17°. However, in
15 at least some alternative variations of this example, each thrust angle θ can have any suitable magnitude, for example in the range of between about 10° and about 30°, or in the range of between about 15° and about 20°.

In at least this example, the plurality of rocket motors **620** are arranged with respect to the central axis **CA**, such that the respective thrust vectors **TV** converge
20 towards one another aft of the module **500**.

In particular, in at least this example the plurality of rocket motors **620** are arranged with respect to the central axis **CA**, such that each respective thrust vector **TV** intersects the central axis **CA** at a respective intersection point **IP** aft of the module aft end **520**, and furthermore, that the respective intersection points of the thrust vectors **TV**
25 are the same point **IP**. In other words, in at least this example the plurality of rocket motors **620** are arranged with respect to the central axis **CA**, such that all the respective thrust vectors **TV** intersect the central axis at the same intersection point **IP** aft of the module aft end **520**.

Referring to Fig. 8, each thrust vector **TV** is angled to the central axis by angle θ ,
30 such that the axial thrust **AT** generated by each rocket motor is provided via the expression:

- 23 -

$$\mathbf{AT} = \mathbf{T} * \cos(\theta)$$

Concurrently, the thrust vector **TV** of each respective each rocket motor **620**, by being angled to the central axis by angle θ , also provides a radial thrust **RT**, orthogonal to the central axis **CA** and along the respective reference plane **PL**, and the respective radial thrust **RT** by is provided via the expression:

$$\mathbf{RT} = \mathbf{T} * \sin(\theta)$$

Thus, in at least this example, with angle θ being about 17° , the corresponding axial **AT** is about 95.63% of the respective thrust **T**, while the corresponding radial thrust **RT** is about 29.23% of the respective thrust **T**.

However, it can be appreciated that angle θ can have any suitable value such as to enable providing a suitable axial thrust as well as a suitable radial thrust.

The control unit **590** is configured, in operation of the module **500**, for operating the module propulsion system **600** such that the first rocket motor **620A** generates a first thrust **TA**, the second rocket motor **620B** concurrently generates a second thrust **TB**, and the third rocket motor **620C** concurrently generates a third thrust **TC**, such that the first thrust **TA**, the second thrust **TB**, and the third thrust **TC** together provide a module net thrust **MNT** and a corresponding module net thrust vector **MNV**.

The module **500** is configured for operating in a plurality of operational modes.

For example, in a rectilinear acceleration operational mode, the control unit **590** is configured for enabling, in particular for causing, the module **500** to execute a first acceleration maneuver **AM1**, wherein the first thrust **TA**, the second thrust **TB**, and the third thrust **TC** are equal to one another.

Furthermore, the control unit **590** is configured for operating the module **500** to provide sufficient module net thrust **MNT** to launch the projectile **100** from the launch site. For this purpose, the control unit **590** operates the module propulsion system **600** such that the plurality of rocket motors **620** all provide equal thrust **T** to one another, enabling the module **500** to provide a module net thrust **MNT** co-axial with the central axis **CA**, and thus the corresponding module net thrust vector **MNV** is co-axial with the central axis **CA**.

In at least some examples, the control unit **590** is configured for operating the module **500** in an autonomous manner, i.e., in which the controller **590** controls the module **600** in a predefined manner and without any interference from the controller of the projectile **100**.

In at least this example, for takeoff from the launch area (typically the launch tube **700**), the thrusts **T_A**, **T_B**, **T_C** generated by the rocket motors **620** each corresponds to the respective maximum thrust **T₃** of each rocket motor **620**, to thereby provide maximum acceleration to the projectile assembly **900**, and thus to the projectile **100**. However, the control unit **590** can instead be operated such that the thrusts **T_A**, **T_B**, **T_C** generated by the rocket motors **620**, while being equal to one another, each corresponds to a respective desired intermediate thrust **T₂**, to thereby provide a corresponding desired acceleration to the projectile assembly **900**, and thus to the projectile **100**.

In such a case, and in view of the three rocket motors **620** being equi-spaced from one another circumferentially and radially with respect to the central axis **CA**, the radial thrusts **RT** generated by the three rocket motors **620** are equal to one another and essentially balance each other out, so that there is zero net radial thrust **RT** generated by the module propulsion system **500**.

Typically, the module net thrust **MNT** (when accompanied by zero net radial thrust **RT**) generated by the module propulsion system **600**, is sufficient for the projectile assembly **900** to reach the boundary of the control zone **CZ**, while imparting sufficient forward velocity to the projectile **100** to enable the fins to provide aerodynamic steering and/or longitudinal stability. Furthermore, this allows for safe separation of the projectile **100** from the module **600** and activation of the propulsion system of the projectile **100**. For example, in at least this example, such a forward speed is at least greater than 20m/s, and for example up to 40 m/s. In at least some examples, the forward speed can be in the range 20m/s to 50m/s.

In another operational mode, the module **500** is configured for providing a turning maneuver to the projectile assembly **900**. Thus, for example, in a turning operational mode, the control unit **590** is further configured for independently controlling the respective level of thrust **T** of each rocket motor **620** to thereby execute any desired turning maneuver in elevation μ and/or azimuth ϕ , prior to the module **500** being disconnected from the projectile **100**, and thereby providing the desired elevation and/or azimuth to the projectile **100**.

- 25 -

In at least this example, and referring to Fig. 11, the control unit **590** can operate to provide any desired tilt angle after launch, at least in the range between 0° and 90° in elevation μ . Furthermore, in at least this example, the control unit **590** can operate to provide, additionally or alternatively, any desired azimuth angle ϕ after launch, at least in the range
 5 between 0° and 360° .

In such turning maneuvers, the control unit **590** is configured for operating the module propulsion system such that at least one rocket motor **620** generates less thrust **T** than at least one other rocket motor **620**.

For example, and referring to Fig. 12, in one such turning operational mode, the
 10 control unit **590** is configured for enabling, in particular for causing, the module **500** to execute a first turning maneuver **TM1**, in which the projectile assembly **900** is to be tilted along one of the three reference planes **PL** associated with the module **500**. This is preceded by an acceleration phase **AM1**.

During the acceleration phase **AM1**, and referring also to Fig. 13(a), the three
 15 rocket motors **620A**, **620B** and **620C** each generate the same thrust, for example the respective maximum thrust **T₃**, and the projectile assembly accelerates vertically upwards, i.e., there is no net radial thrust **RT**.

Taking the reference plane **PL** of the first rocket motor **620A** as an example for such a first turning maneuver **TM1**, and referring also to Fig. 13(b), the first rocket motor
 20 **620A** generates a thrust **T_A** greater than the second thrust **T_B** and the third thrust **T_C**, generated by the second rocket motor **620B** or third rocket motor **620C**, respectively. Thus, there is a net radial thrust **RT** in the direction of the first radial thrust **RT_A**. Concurrently, since the second thrust **T_B** is equal to the third thrust **T_C**, so too is the second radial thrusts **RT_B** equal to the third radial thrust **RT_C**, and thus there is no net radial
 25 thrust in the direction of the second radial thrusts **RT_B** or of the third radial thrust **RT_C**. Thus, the corresponding module net thrust vector **MNV** is on the respective plane **PL** of the first rocket motor **620A** and in the direction of the radial thrust **RT_A**.

The net radial thrust **RT** in the direction of the first radial thrust **RT_A** provides a turning moment to the projectile assembly **900** about the center of gravity of the projectile
 30 assembly **900**, and along the respective plane **PL**. The projectile assembly **900** thus begins

to rotate about an axis orthogonal to this reference plane **PL**, thereby decreasing the elevation of the projectile assembly **900** from nominally 90° at launch.

In at least one example, and referring again to Fig. 12, in the first tilt maneuver **TM1** the first thrust **T_A** corresponds to a nominal maximum thrust level **T₃** for the first
5 rocket motor **620A**, while concurrently the second thrust **T_B** and the third thrust **T_C** are each nominally zero.

The control unit **590** is configured for executing the first tilt maneuver for a first time period **TP1**, such as to provide a desired elevation angle, for example 1 second or less.

10 Thereafter, the control unit **590** operates to halt further turning to maintain a desired elevation angle, and subsequently implements a first righting maneuver **RM1** for a second time period **TP2**. During the second time period **TP2**, and referring also to Fig. 13(c), first thrust **T_A** is reduced and the second thrust **T_B** and third thrust **T_C** are each increased such that the first thrust **T_A** is less than the second thrust **T_B** or the third thrust
15 **T_C**. Concurrently, the second thrust **T_B** is maintained equal to the third thrust **T_C**. For example, the first thrust **T_A** is reduced to the respective zero minimum thrusts **T₁**, and each of the second thrust **T_B**, and the third thrust **T_C** are increased to the respective maximum thrust levels **T₃**.

Referring also to Fig. 13(d), this is then followed by implementing a second
20 righting maneuver **RM2** for a third time period **TP3**, in which for the duration of the third time period the first thrust **T_A**, the second thrust **T_B**, and the third thrust **T_C** are equal to one another. For example, the three rocket motors **620A**, **620B** and **620C** each generate the same thrust, for example the respective maximum thrust **T₃**.

Thereafter, the first thrust **T_A**, the second thrust **T_B**, and the third thrust **T_C** are
25 reduced concurrently to the respective zero minimum thrusts **T₁**.

To provide a second tilt maneuver **TM2** in the opposite direction to first radial thrust **RT_A**, and referring to Fig. 14, instead of providing a first thrust **T_A** that is greater than the second thrust **T_B** or the third thrust **T_C**, the control unit **590** operates to provide the second thrust **T_B** and the third thrust **T_C** greater than the first thrust **T_A**, while
30 maintaining the second thrust **T_B** equal to the third thrust **T_C**

A similar tilt maneuver can instead be provided about the reference plane **PL** corresponding to the second motor **620B** or corresponding to the third motor **620C**, in a similar manner to the above relating to the first motor **620A**, *mutatis mutandis*.

For example, and referring to Fig. 15, in another such turning operational mode,
5 the control unit **590** is configured for enabling, in particular for causing, the module **500** to execute a second turning maneuver, in which the projectile assembly **900** is to be tilted along a plane **PI** intermediate to two of the three reference planes **PL** associated with the module **500**, thereby providing a desired change in azimuth as well as elevation.

This is preceded by an acceleration phase **AM1**, and referring again to Fig. 13(a),
10 the three rocket motors **620A**, **620B** and **620C** each generate the same thrust, for example the respective maximum thrust **T₃**, and the projectile assembly accelerates vertically upwards, i.e., there is no net radial thrust **RT**, in a similar manner to prior to the first turning maneuver **TM1**, *mutatis mutandis*.

Taking an intermediate plane **PI** intermediate the reference planes **PL** of the first
15 rocket motor **620A** and of the second rocket motor **620B** as an example for such a second maneuver, and referring also to Fig. 16(a), the control unit **590** is configured for enabling the module **500** to execute a third tilt maneuver **TM3**, wherein the first thrust **T_A** by the first rocket motor **620A** is greater than the second thrust **T_B** generated by the second rocket motor **620B** or the third thrust **T_C** generated by the third rocket motor **620C**, and
20 wherein concurrently the second thrust **T_B** is greater than the third thrust **T_C**. The vector difference between the second thrust **T_B** and the third thrust **T_C** provides the desired azimuth, while the vector difference between the first thrust **T_A** and the combination of the second thrust **T_B** and the third thrust **T_C** provides the desired elevation.

In such a case, a first radial thrust **RT_A** corresponding to the first thrust **T_A** is
25 greater than the sum of the radial thrusts **RT_B** and **RT_C** corresponding to the second thrust **T_B** and the third thrust **T_C**, respectively. Thus, there is a net radial thrust **RT** in the direction of the first radial thrust **RT_A**, which provides a turning moment about the center of gravity of the projectile assembly **900**, thereby decreasing the elevation of the projectile assembly **900** from nominally 90° at launch.

- 28 -

Concurrently, since the second thrust T_B is greater than the third thrust T_C , there is also a net radial thrust RT in the direction of the second radial thrusts RT_B , which provides a turning moment about the center of gravity of the projectile assembly 900 thereby providing a change in azimuth.

5 In cases where the third thrust T_C is greater than the second thrust T_B , then there is instead a radial thrust RT in the direction of the third thrust T_C , which provides a turning moment about the center of gravity of the projectile assembly 900 in azimuth in the opposite direction.

In any case, the net effect is that the projectile assembly 900 follows a turning
10 trajectory along the intermediate plane PI , which is inclined to the reference plane PL associated with the first rocket motor 620A by a displacement angle β provided by the vector sum of the net radial thrust RT in the direction of the first radial thrust RT_A , and the net radial thrust RT in the direction of the second radial thrusts RT_B or of the third thrust T_C (depending on whether the second thrust T_B is greater than or less than,
15 respectively, the third thrust T_C).

The displacement angle β (and thus the azimuth) can be controlled by suitably controlling the ratio of the second thrust T_B with respect to the third thrust T_C .

The vector combination of the first radial thrust RT_A , the second radial thrust RT_B , and the third radial thrust RT_C provides a net radial thrust NRT , and thus a turning
20 moment to the projectile assembly 900, along the respective intermediate plane PI , and the projectile assembly 900 begins to rotate about an axis orthogonal to this intermediate plane PI , thereby decreasing the elevation of the projectile assembly 900 from nominally 90° at launch and concurrently changing the azimuth as well.

In at least one example, and referring again to Fig. 15, in the third tilt maneuver
25 **TM3** the first thrust T_A corresponds to a nominal maximum thrust level T_3 for the first rocket motor 620A, while concurrently the third thrust T_C is the respective zero minimum thrusts T_1 , and the second thrust T_B has a respective intermediate thrust T_2 , the magnitude of which is intermediate the first thrust T_A and the third thrust T_C .

- 29 -

The control unit **590** is configured for executing the third tilt maneuver **TM3** for a first time period **TP1'**, such as to provide a desired elevation angle and a desired azimuth angle, for example 1 second or less.

Thereafter, and referring also to Fig. 16(b), the control unit **590** operates to halt
5 further turning to maintain a desired elevation angle and a desired azimuth angle, and subsequently implements a first righting maneuver **RM1'** for a second time period **TP2'**. During the second time period **TP2'**, the first thrust **T_A**, the second thrust **T_B**, and the third thrust **T_C** are each decreased to the respective zero minimum thrusts **T₁**.

Referring also to Fig. 16(c), this is then followed by implementing a second
10 righting maneuver **RM2'** for a third time period **TP3'**, in which for the duration of the third time period the third thrust **T_C** is increased and the second thrust **T_B** is increased such that the third thrust **T_C** is greater than the second thrust **T_B**, which is greater than the first thrust **T_A**.

Referring also to Fig. 16(d), this is then followed by implementing a third righting
15 maneuver **RM3'** for a fourth time period **TP4'**, in which for the duration of the fourth time period the first thrust **T_A**, the second thrust **T_B**, and the third thrust **T_C** are equal to one another, and each is at the respective maximum thrust **T₃**.

Thereafter, the first thrust **T_A**, the second thrust **T_B**, and the third thrust **T_C** are reduced concurrently to the respective zero minimum thrusts **T₁**.

20 To provide a tilt maneuver along any other desired plane **PI**, the control unit **590** operates to provide the appropriate ratio between the first thrust **T_A**, the second thrust **T_B** and the third thrust **T_C**.

It is to be noted that the desired intermediate plane **PI**, or the desired reference plane **PL**, along which the projectile assembly **900** is to follow an initial trajectory, can be chosen
25 such as to essentially point the projectile in the corresponding azimuth to the intended target, concurrently changing the elevation of the projectile assembly **900** to any desired elevation, prior to the module **500** being ejected and at a relatively low altitude, so that the projectile **100** can then continue under its own power to the target. For example, the desired elevation can be in the range -20° to 80°, or for example from 0° to 40°, or for example from 20° to
30 30°, depending in the specific mission parameters, for example.

It is also to be noted that the desired intermediate plane **PI**, or the desired reference plane **PL**, along which the projectile assembly **900** is to follow an initial trajectory, can take into account side winds that could otherwise deviate the projectile assembly **900**, and the projectile **100** once the module **500** is ejected, from the desired trajectory to the target.

5 In at least this example, the control unit **590** can further operate to control the trajectory of the projectile assembly **900** to correct for disturbances that can be caused by external forces, including for example wind, turbulence, movements induced to the launch tube (for example in examples where the launch tube is fixed to a ship), and so on.

10 In at least this example, the projectile assembly **900** (for example the projectile **100** or the module **500**) can comprise an inertial measurement unit (IMU), which can operate to monitor, for example on a continuous basis, the behavior of the projectile assembly **900** in three-dimensional space, and which can provide input to the control unit **590** to correct for any deviation from the required trajectory.

15 Referring to Fig. 17, in at least this example, the launch tube **700** has a closed bottom end **710**. The inside diameter of the launch tube **700** is greater than the effective external diameter of the projectile assembly **900** by a radial gap **RGP**.

20 In at least this example, the launch tube **700** includes an excess pressure venting arrangement **720** configured for enabling venting of the launch tube **700** responsive to a pressure within the launch tube **700** exceeding a predetermined threshold pressure **PB**. Such a buildup of pressure can occur for example in a case of malfunction when the projectile is stuck in the launch tube for any reason. In such a case, the pressure relief valve will enable releasing the pressure, preventing the launch tube from bursting.

25 In at least this example, the launch tube **700** comprises a launch tube casing **730**, and at least one venting opening **735**, and the excess pressure venting arrangement **720** comprises a burst disc **725** provided in the respective venting opening **725**. The burst disc **725** is configured for bursting when subjected to a pressure exceeding the predetermined threshold pressure **PB**.

Additionally or alternatively, and referring to Fig. 18, the excess pressure venting arrangement **720** comprises a plurality of vent tubes **740** provided in the module **500**.

Each vent tube **740** comprises an open inlet end **744** at the bottom wall **584**, and an open outlet end **742** provided in the cylindrical wall **582**.

Thus, exhaust gasses accumulating aft of the module **500** can be vented to the radial gap **RGP** via the vent tubes **740**.

- 5 In at least some alternative variations of the above examples, the respective launch tube can have an open bottom end.

The launch system **990** can be operated, for example as follows.

- In a first, launching, step, the projectile assembly **900** is selectively launched from the launch tube **700** by operating the module propulsion system **600** to generate net thrust
10 sufficient to at least eject the projectile assembly **900** outside of the control zone **CZ** around the launch tube **700**.

- In one example of such a step, and referring to Fig. 12 and Figs. 13(a) to 13(d), the module propulsion system **500** is operated such that the first rocket motor **620A** generates a first thrust **T_A**, the second rocket motor **620B** concurrently generates a second thrust **T_B**, and
15 the third rocket motor **620C** concurrently generates a third thrust **T_C**, such that the first thrust **T_A**, the second thrust **T_B** and the third thrust **T_C** together provide a module net thrust and a corresponding module thrust vector.

- Initially, and referring also to Fig. 12 and Figs. 13(a) to 13(d), the module propulsion system **500** is operated to provide a first acceleration maneuver **AM1**, for example as
20 disclosed herein, wherein the first thrust **T_A**, the second thrust **T_B** and the third thrust **T_C** are equal to one another.

- Thereafter, the module propulsion system **500** can be operated to execute a first tilt maneuver **TM1**, for example as disclosed herein, wherein the first thrust **T_A** is greater than the second thrust **T_B** or the third thrust **T_C**, and wherein the second thrust **T_B** is equal to the
25 third thrust **T_C**. for example, the first thrust corresponds to a nominal maximum thrust level **T₃** for the first rocket motor **620A**, and the second thrust **T_B** and the third thrust **T_C** are each respective zero minimum thrusts **T₁**.

For example, the first tilt maneuver **TM1** is executed for a first time period **TP1**, and this is followed by:

- 32 -

- (I) subsequently implementing a first righting maneuver **RM1** for a second time period **TP2**, wherein for the second time period **TP2** the first thrust **T_A** is less than the second thrust **T_B** or the third thrust **T_C**, and wherein the second thrust **T_B** is equal to the third thrust **T_C**,
- 5 (II) subsequent to step (I) implementing a second righting maneuver **RM2** for a third time period **TP3**, wherein for the third time period **TP3** the first thrust **T_A**, the second thrust **T_B** and the third thrust **T_C** are equal to one another.

In another example of such a step, and referring to Fig. 14 the module executes a second tilt maneuver, for example as disclosed herein, in which the first thrust **T_A** is less
 10 than the second thrust **T_B** or the third thrust **T_C**, and wherein the second thrust **T_B** is equal to the third thrust **T_C**.

In another example of such a step, and referring to Fig. 15 and Figs. 16(a) to 16(d), the module **500** executes a third tilt maneuver **TM3**, for example as disclosed herein, wherein the first thrust **T_A** is greater than the second thrust **T_B** or the third thrust **T_C**, and
 15 wherein the second thrust **T_B** is greater than the third thrust **T_C**.

For example, the first thrust **T_A** corresponds to a nominal maximum thrust level **T₃** for the first rocket motor **620A**, and the third thrust **T_C** is the respective zero minimum thrust **T₁**, and the second thrust **T_B** is at a respective intermediate thrust **T₂**, the magnitude of which is intermediate the first thrust **T_A** and the third thrust **T_C**.

20 For example, the third tilt maneuver **TM3** is executed for a first time period, and this is followed by:

- (i) subsequently implementing a first righting maneuver **RM1'** for a second time period **TP2'** wherein for the second time period **TP2'** the first thrust **T_A**, the second thrust **T_B** and the third thrust **T_C** are each nominally zero,
- 25 (ii) subsequent to step (i), implementing a second righting maneuver **RM2'** for a third time period **TP3'**, wherein for the third time period **TP3'** the third thrust **T_C** is greater than the second thrust **T_B**, and the second thrust **T_B** is greater than the first thrust **T_A**,
- (iii) subsequent to step (ii), implementing a third righting maneuver **RM3'** for a
 30 fourth time period **TP4'**, wherein for the fourth time period **TP4'** the first

- 33 -

thrust **T_A**, the second thrust **T_B** and the third thrust **T_C** are equal to one another.

In a second, decoupling, step, the module **500** is selectively decoupled from the projectile **100** according to predetermined criteria.

- 5 Such predetermined criteria includes a first criterion, wherein the first criterion requires the projectile assembly **900** to be just outside of the control zone **CZ**.

In at least some alternative variations of this example, in which the respective module propulsion system comprises only two such rocket motors, the rocket motors are circumferentially spaced at 180° from one another, and provide control of the elevation of
10 the respective projectile assembly. In such examples, the projectile assembly can be manually oriented to the desired azimuth by either fixedly setting the projectile assembly in such an azimuth at least prior to launch, or by mounting the projectile assembly on a turntable or turret, which can be rotated about a vertical axis to provide the desired azimuth.

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

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

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

CLAIMS:

1. An ejection module for ejecting a projectile, the module comprising:
 - a module forward end comprising a central axis and a module interface, the module interface configured for selectively enabling the module to be selectively
5 affixed to the projectile in a load-bearing manner, and for enabling selective disconnection between the module and the projectile; and
 - a module aft end comprising a module propulsion system, the module propulsion system comprising a plurality of rocket motors and a source of rocket propellant, wherein:
 - 10 ○ each said rocket motor is laterally spaced with respect to the central axis,
 - each said rocket motor has a respective fixed thrust vector non-parallel with respect to the central axis,
 - each said rocket motor is configured for generating a controllable level of
15 respective thrust along the respective said thrust vector, independently of the respective level of thrust generated by the other said rocket motors along their respective thrust vectors;wherein the module propulsion system is configured for enabling independently controlling the respective said level of thrust of each said rocket motor.
2. The module according to claim 1, wherein said source of rocket propellant
20 includes a predetermined quantity of propellant not greater than that required to enable the module to propel the projectile from a launch site to a predetermined range and predetermined altitude with respect to the launch site, wherein said predetermined range and said predetermined altitude correspond to a minimum safe range and a minimum safe altitude with respect to the launch site.
- 25 3. The module according to claim 2, wherein said minimum safe range and said minimum safe altitude ensures or minimizes potential damage to the launch site in event of the projectile failing to operate after disconnection from the ejection module and falls back to Earth under gravity.
4. The ejection module according to any one of claims 2 to 3, wherein said
30 predetermined safe range is between 50m and about 70m.

- 35 -

5. The ejection module according to any one of claims 2 to 4, wherein said predetermined safe altitude is between about 30m and about 20m.
6. The ejection module according to any one of claims 1 to 5, configured for providing any desired tilt after launch at least between 90° and 0° in elevation.
- 5 7. The ejection module according to any one of claims 1 to 6, configured for providing any desired azimuth after launch at least between 0° and 360° .
8. The ejection module according to any one of claims 1 to 7, wherein each said thrust vector converges towards the central axis at a respective intersection point aft of the module aft end.
- 10 9. The ejection module according to claim 8, wherein the respective intersection points of the thrust vectors are the same point.
10. The ejection module according to any one of claims 1 to 9, wherein each said thrust vector lies on a respective plane, and wherein said central axis lies on each said plane.
- 15 11. The ejection module according to claim 10, wherein each said thrust vector defines a respective thrust angle on the respective plane with respect to the central axis.
12. The ejection module according to claim 11, wherein the respective thrust angles of said rocket motors are equal in magnitude to one another.
13. The ejection module according to any one of claims 11 to 12, wherein each said thrust angle is in the range of between about 10° and about 30° .
- 20 14. The ejection module according to any one of claims 1 to 13, wherein said rocket motors are configured as liquid fuel rocket motors, and wherein said source of rocket propellant includes at least one liquid fuel tank and at least one oxidizer tank.
15. The ejection module according to any one of claims 1 to 14, configured for providing a forward velocity to the projectile at least sufficient to enable the projectile to steer via fins.
- 25 16. The ejection module according to any one of claims 1 to 15, configured for providing a forward velocity to the projectile at least greater than 20 m/s.

- 36 -

17. The ejection module according to any one of claims 1 to 16, further comprising a control unit operatively coupled to the module propulsion system, the control unit being configured for enabling independently controlling the respective said level of thrust of each said rocket motor.
- 5 18. The ejection module according to claim 17, wherein the control unit is accommodated in the ejection module.
19. The ejection module according to claim 17, wherein the control unit is accommodated in the projectile.
20. The ejection module according to any one of claims 17 to 19, wherein said control
10 unit is configured for operating the module to provide sufficient thrust to launch the projectile.
21. The ejection module according to any one of claims 17 to 20, wherein said control unit is configured for operating the module propulsion system such that the plurality of said rocket motors provide equal thrust to enable the module to provide a net thrust co-
15 axial with the central axis.
22. The ejection module according to any one of claims 17 to 22, wherein said control unit is configured for operating the module propulsion system to provide any desired tilt maneuver.
23. The ejection module according to claim 22, wherein said control unit is configured
20 for operating the module propulsion system such that at least one said rocket motor generates less thrust than at least one other said rocket motor.
24. The ejection module according to any one of claims 1 to 23, wherein said module propulsion system comprises a first said rocket motor, a second said rocket motor and a third said rocket motor, wherein said first rocket motor, said second rocket motor and said
25 third rocket motor are uniformly spaced circumferentially with respect to the central axis.
25. The ejection module according to claim 24, wherein each said rocket motor comprises a respective exhaust nozzle fixedly mounted to the rocket motor in alignment with the respective said thrust vector.

- 37 -

26. The ejection module according to any one of claims 24 to 25, wherein the control unit is configured for operating the module propulsion system such that the first rocket motor generates a first said thrust, the second rocket motor concurrently generates a second said thrust, and the third rocket motor concurrently generates a third said thrust,
5 such that the first thrust, the second thrust and the third thrust together provide a module net thrust and a corresponding module thrust vector.

27. The ejection module according to claim 26, operable for selectively causing the module to execute a first acceleration maneuver, wherein said first thrust, said second thrust and said third thrust are equal to one another.

10 28. The ejection module according to claim 26, operable for selectively causing the module to execute a first tilt maneuver, wherein said first thrust is greater than said second thrust or said third thrust, and wherein said second thrust is equal to said third thrust.

29. The ejection module according to claim 26, wherein said first thrust corresponds to a nominal maximum thrust level for the said first rocket motor, and wherein said second
15 thrust and said third thrust are each nominally zero.

30. The ejection module according to claim 26, operable for executing said first tilt maneuver for a first time period, and for subsequently implementing a first righting maneuver for a second time period wherein for said second time period the said first thrust is less than said second thrust or said third thrust, and wherein said second thrust is equal
20 to said third thrust, followed by implementing a second righting maneuver for a third time period, wherein for said third time period said first thrust, said second thrust and said third thrust are equal to one another.

31. The ejection module according to claim 26, operable for enabling the module to execute a second tilt maneuver, wherein said first thrust is less than said second thrust or
25 said third thrust, and wherein said second thrust is equal to said third thrust.

32. The ejection module according to claim 26, operable for enabling the module to execute a third tilt maneuver, wherein said first thrust is greater than said second thrust or said third thrust, and wherein said second thrust is greater than said third thrust.

- 38 -

- 33.** The ejection module according to claim 32, wherein said first thrust corresponds to a nominal maximum thrust level for the said first rocket motor, and wherein said third thrust is nominally zero, and wherein said second thrust is intermediate in magnitude between said first thrust and said third thrust.
- 5 **34.** The ejection module according to any one of claims 32 to 33, wherein the control unit is configured for executing said third tilt maneuver for a first time period, and for subsequently implementing a first righting maneuver for a second time period wherein for said second time period said first thrust, said second thrust and said third thrust are each nominally zero, followed by implementing a second righting maneuver for a third
10 time period, wherein for said third time period said third thrust is greater than said second thrust, and said second thrust is greater than said first thrust, followed by implementing a third righting maneuver for a fourth time period, wherein for said fourth time period said first thrust, said second thrust and said third thrust are equal to one another.
- 35.** The ejection module according to claim 26, operable for enabling the module to
15 execute a third tilt maneuver, wherein said first thrust is greater than said second thrust or said third thrust, and wherein said second thrust is less than said third thrust.
- 36.** The ejection module according to any one of claims 32 to 35, wherein said third tilt maneuver is configured to provide a desired change in azimuth during execution of said third tilt maneuver.
- 20 **37.** A projectile assembly, comprising:
- a projectile having a projectile propulsion system and an aft projectile end, the aft projectile end comprising a projectile interface;
 - an ejection module as defined in any one of claims 1 to 36;
- wherein the projectile interface is configured for being selectively and reversibly
25 coupled with respect to the module interface, such that when thus coupled the module is reversibly affixed to the projectile in a load-bearing manner, and such that when the projectile interface is decoupled with respect to the module interface, the module is disconnected from the projectile.

- 39 -

38. The projectile assembly according to claim 37, wherein the projectile comprises a plurality of fins.
39. A launch system comprising:
- 5 - a projectile assembly as defined in any one of claims 37 to 38;
 - a launch tube configured for accommodating the projectile launch assembly therein at least in a launch-ready configuration, and for enabling selective launch of the projectile launch assembly from the launch tube.
- 10 40. The launch system according to claim 39, wherein said launch tube has a closed bottom end, and wherein said launch tube includes an excess pressure venting arrangement configured for enabling venting of the launch tube responsive to a pressure within the launch tube exceeding a predetermined threshold pressure.
- 15 41. A method for launching a projectile, comprising:
- (a) providing a launch system as defined in any one of claims 39 to 40;
 - (b) selectively launching the projectile launch assembly from the launch tube by operating the module propulsion system to generate thrust sufficient to at least eject the projectile launch assembly outside of a control zone around the launch
 - 20 tube;
 - (c) decoupling the module from the projectile according to predetermined criteria including a first criterion, wherein said first criterion requires the projectile launch assembly to be outside of said control zone.
- 25 42. The method according to claim 41, wherein at least during step (b) the projectile propulsion system is not operated.
43. The method according to any one of claims 41 to 42, wherein the module is as defined in any one of claims 24 to 38, and wherein the module propulsion system is
- 30 operated such that the first rocket motor generates a first said thrust, the second rocket motor concurrently generates a second said thrust, and the third rocket motor concurrently generates a third said thrust, such that the first thrust, the second thrust and the third thrust together provide a module net thrust and a corresponding module thrust vector.

- 40 -

44. The method according to claim 43, wherein said first thrust, said second thrust and said third thrust are equal to one another.

45. The method according to claim 43, wherein the module executes a first tilt maneuver, wherein said first thrust is greater than said second thrust or said third thrust,
5 and wherein said second thrust is equal to said third thrust.

46. The method according to claim 45, wherein said first tilt maneuver is executed for a first time period, and further comprising:

(I) subsequently implementing a first righting maneuver for a second time period wherein for said second time period the said first thrust is less than said
10 second thrust or said third thrust, and wherein said second thrust is equal to said third thrust,

(II) subsequent to step (I) implementing a second righting maneuver for a third time period, wherein for said third time period said first thrust, said second thrust and said third thrust are equal to one another.

15 47. The method according to claim 43, wherein the module executes a third tilt maneuver, wherein said first thrust is greater than said second thrust or said third thrust, and wherein said second thrust is greater than said third thrust.

48. The method according to claim 47, wherein said first thrust corresponds to a nominal maximum thrust level for the said first rocket motor, and wherein said third thrust
20 is nominally zero, and wherein said second thrust is intermediate in magnitude between said first thrust and said third thrust.

49. The method according to any one of claims 47 to 48, wherein the third tilt maneuver is executed for a first time period, and further comprising:

(i) subsequently implementing a first righting maneuver for a second time period
25 wherein for said second time period said first thrust, said second thrust and said third thrust are each nominally zero,

(ii) subsequent to step (i), implementing a second righting maneuver for a third time period, wherein for said third time period said third thrust is greater than said second thrust, and said second thrust is greater than said first thrust,

- 41 -

(iii) subsequent to step (ii), implementing a third righting maneuver for a fourth time period, wherein for said fourth time period said first thrust, said second thrust and said third thrust are equal to one another.

50. The method according to any one of claims 47 to 49, wherein said third tilt
5 maneuver is configured to provide a desired change in azimuth during execution of said third tilt maneuver.