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LAUNCH SYSTEM AND METHOD

TECHNOLOGICAL FIELD

The presently disclosed subject matter relates to launch systems and launch methods for delivering a payload to a high altitude.

5 BACKGROUND

Transporting payloads to high altitudes, including to the edge of space and beyond to outer space, conventionally incurs large economic costs, and many attempts at reducing such costs have been tried over the years.

Traditionally, multi-stage rockets, have been used for such purpose, and a large
10 proportion of the associated launch costs has been attributable to the configuration of such launch vehicles, in which the various stages thereof are designed to be discarded soon after their fuel is used up or the stage is decoupled from the next upper stage.

The US Space Shuttle was conceived as a reusable launch system, and the delivery cost per Kg of payload to low earth orbit via Space Shuttle at the beginning of the 1980's
15 reduced previous launch costs to about \$85,000 per Kg payload, coming down to about \$27,000 per Kg payload by the mid 1990's.

By 2017 the Falcon 9 system, in which the first stage is capable of landing and can be re-used, enables the launch costs to be managed at about \$1,900 per Kg.

Other launch systems under development include the LauncherOne system and
20 the Electron system. The LauncherOne system is a two stage orbital launch vehicle, powered by rocket engines and designed to launch payloads of about 300Kg into Sun-synchronous orbit following deployment from a carrier aircraft at high altitude, with expected launch costs of under US\$12,000,000. The Electron system is a two stage orbital launch vehicle, powered by liquid rocket engines and designed to launch payloads of
25 about 150Kg into Sun-synchronous orbit from the ground, with expected launch costs of under US\$5,000,000.

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GENERAL DESCRIPTION

According to a first aspect of the presently disclosed subject matter there is provided a composite vehicle comprising:

- 5 a payload vehicle configured for powered spaceflight at least in a space medium, comprising a rocket driven propulsion system;
- a booster vehicle configured for powered supersonic/hypersonic aerodynamic flight, comprising a ramjet propulsion system, and configured for transporting the composite vehicle between a first altitude and a second altitude under propulsive
- 10 power provided by said ramjet propulsion system;
- a first coupling system for selectively coupling and decoupling the payload vehicle with respect to the booster vehicle.

For example, said ramjet propulsion system comprises at least one of: a pure ramjet engine; a solid fuel integrated rocket ramjet engine (SFIRR); a scramjet engine; a

15 dual mode ramjet/scramjet (DMRJ).

Additionally or alternatively for example, said booster vehicle has an absence of a turbojet-based propulsion system or a turbofan based propulsion system.

Additionally or alternatively for example, the booster vehicle comprises an aerodynamic wing system configured for providing lift, stability and control to at least

20 the composite vehicle at least at supersonic/transonic conditions between the first altitude and the second altitude. For example, said aerodynamic wing system comprises a delta wing, or, said aerodynamic wing system comprises any one of: variable geometry wings; double delta wings; swept wings. Additionally or alternatively for example, said aerodynamic wing system comprises a vertical stabilizer arrangement including at least

25 one fin pivotable between a stowed position and a deployed position, wherein in the stowed position in which the at least one fin has a first height dimension, and wherein in the deployed position in which the at least one fin has a second height dimension said second height dimension being greater than said first height dimension. For example, in

30 in the deployed position the at least one fin is configured for generating stability and control moments to at least the composite vehicle. Additionally or alternatively for

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example, said booster vehicle comprises a fuselage, and said at least one fin is pivotably mounted to said fuselage, or, said booster vehicle comprises said aerodynamic wing system, and said at least one fin is pivotably mounted to said aerodynamic wing system.

Additionally or alternatively for example, said aerodynamic wing system
5 comprises a vertical stabilizer arrangement including at least one fin fixedly mounted to the booster vehicle.

Additionally or alternatively for example, said rocket propulsion system comprises at least one of: a solid fuel rocket engine; a liquid fuel rocket engine.

Additionally or alternatively for example, said payload vehicle has an absence of
10 any one of: a ramjet based propulsion system; a turbojet based propulsion system; a turbofan based propulsion system.

Additionally or alternatively for example, said payload vehicle comprises a payload vehicle payload bay configured for accommodating therein a payload.

Additionally or alternatively for example, said first coupling system is configured
15 for coupling the payload vehicle with the booster vehicle in longitudinal stacked arrangement, in which at least a forward part of the payload vehicle is longitudinally forward with respect to the booster vehicle. Alternatively for example, said first coupling system is configured for coupling the payload vehicle with the booster vehicle in transverse stacked arrangement, in which at least a first part of the payload vehicle is in
20 transverse overlying relationship with respect to the booster vehicle. Alternatively for example, said booster vehicle comprises a booster vehicle payload bay, and wherein said first coupling system is configured for coupling the payload vehicle with respect to the booster vehicle payload bay.

Additionally or alternatively for example, the payload vehicle is configured for
25 transporting the composite vehicle at least between the second altitude and a desired altitude under propulsive power provided by said rocket propulsion system, the desired altitude being higher than the second altitude.

Additionally or alternatively for example, said first altitude is the range between 10,000m and 20,000m.

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Additionally or alternatively for example, said second altitude is the range between 30,000m and 40,000m.

Additionally or alternatively for example, said desired altitude is greater than 40,000m.

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

the composite vehicle as defined herein according to the first aspect of the presently disclosed subject matter;

10 a carrier vehicle configured at least for powered subsonic/transonic/supersonic aerodynamic flight, and configured for transporting said composite vehicle to at least said first altitude from a ground location;

a second coupling system for selectively coupling and decoupling the composite vehicle with respect to the carrier aircraft.

15 For example, said carrier vehicle is a subsonic aircraft or a supersonic aircraft.

Additionally or alternatively for example, said second coupling system is configured for coupling the composite vehicle with the carrier vehicle in transverse stacked arrangement, in which the carrier vehicle is in at least partial transverse overlying relationship with respect to the composite vehicle.

20 Alternatively for example, said second coupling system is configured for coupling the composite vehicle with the carrier vehicle in said transverse stacked arrangement, in which the carrier vehicle comprises a carrier aircraft fuselage and the second coupling system is configured for selectively coupling and decoupling the composite vehicle directly with respect to a lower portion of the carrier aircraft fuselage. For example, the
25 composite air vehicle has a height dimension, when coupled to the carrier vehicle, less than the fuselage ground clearance of the carrier vehicle. For example, said carrier vehicle is a Boeing 747 type aircraft.

Alternatively for example, said second coupling system is in the form of a wing pylon affixed to a port wing or a starboard wing of the carrier vehicle, and configured for
30 coupling the composite vehicle with the carrier vehicle via the wing pylon. For example,

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said carrier vehicle is a Boeing 747 type aircraft, and said wing pylon is mounted to the port wing thereof at attached to anchor points on the underside of the port wing.

Alternatively for example, the carrier vehicle comprises two fuselages, each having an outboard wing, and further comprising an interconnecting wing interconnecting
5 the two fuselages, and wherein said second coupling system is in the form of a wing pylon affixed to the interconnecting wing, and configured for coupling the composite vehicle with the carrier aircraft via the wing pylon. For example, said second coupling system is configured for coupling the composite vehicle with the carrier aircraft in transverse stacked arrangement, in which the composite vehicle is in at least partial transverse
10 overlying relationship with respect to the carrier aircraft.

Alternatively for example, said second coupling system is configured for coupling the composite vehicle with the carrier vehicle in said transverse stacked arrangement, in which the carrier vehicle comprises a carrier aircraft fuselage and the second coupling system is configured for selectively coupling and decoupling the composite vehicle
15 directly with respect to an upper portion of the carrier aircraft fuselage.

Alternatively for example, said carrier vehicle is in the form of a rocket booster, configured for propelling the composite vehicle to at least said first altitude from the ground location. For example, the second coupling system is configured for coupling the composite vehicle with the carrier vehicle in transverse stacked arrangement, in which
20 the carrier vehicle comprises a booster rocket body and the second coupling system is configured for selectively coupling and decoupling the composite vehicle directly with respect to a side portion of the booster rocket body.

According to a third aspect of the presently disclosed subject matter there is provided a method for delivering a payload vehicle to a predetermined altitude,
25 comprising:

carrying the payload vehicle from a ground location to a first altitude, while the payload vehicle is concurrently coupled to a booster vehicle to provide a composite vehicle, via a carrier vehicle; and decoupling the composite vehicle from the carrier vehicle at said first altitude and at a first predetermined forward
30 speed;

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operating the uncoupled booster vehicle of the composite vehicle to transport the booster vehicle to at least a second altitude under propulsive power provided by a ramjet propulsion system comprised in the booster vehicle; and decoupling the payload vehicle from the booster vehicle at said second altitude and at a second predetermined forward speed;

operating the payload vehicle to transport the payload vehicle to at least said predetermined altitude and at a third predetermined forward speed under propulsive power provided by a rocket propulsion system comprised in the payload vehicle.

For example, the payload vehicle, booster vehicle and composite vehicle are as defined herein according to the first aspect of the presently disclosed subject matter.

Additionally or alternatively, for example, the carrier vehicle comprised in the launch system as defined herein according to the second aspect of the presently disclosed subject matter.

Additionally or alternatively, for example, said first altitude is the range between 10,000m and 20,000m.

Additionally or alternatively, for example, said second altitude is the range between 30,000m and 40,000m.

Additionally or alternatively, for example, said desired altitude is greater than 40,000m.

A feature of at least one example of the presently disclosed subject matter is that the respective launch system enables the propulsion system of each component vehicle thereof – in particular each one of the booster vehicle, the payload vehicle and the carrier vehicle - to provide optimal performance as a single cycle-single platform component: the carrier vehicle in some examples has turbojet/turbofan propulsion system and propels the launch system from ground level and zero forward speed to the first altitude and a subsonic forward speed exceeding Mach 0.5 at optimal conditions for such an air breathing propulsion system; the booster vehicle has ramjet propulsion system and propels the composite vehicle from the first altitude and subsonic forward speed to the second altitude and supersonic/hypersonic forward speed at optimal conditions for such

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an air breathing propulsion system; the payload vehicle has rocket propulsion system and propels the payload from the second altitude and supersonic/hypersonic forward speed to the desired altitude and desired forward speed at optimal conditions for such a non-air breathing propulsion system.

5 Another feature of at least one example of the presently disclosed subject matter is that the respective launch system enables the propulsion system of each component vehicle thereof – in particular each one of the booster vehicle, the payload vehicle and the carrier vehicle - to provide optimal performance as a single cycle-single platform component: the carrier vehicle in some examples has turbojet/turbofan propulsion system
10 and propels the launch system from ground level and zero forward speed to the first altitude and a supersonic forward speed exceeding Mach 1.0 at optimal conditions for such an air breathing propulsion system; the booster vehicle has ramjet propulsion system and propels the composite vehicle from the first altitude and low supersonic forward speed to the second altitude and supersonic/hypersonic forward speed at optimal
15 conditions for such an air breathing propulsion system; the payload vehicle has rocket propulsion system and propels the payload from the second altitude and supersonic/hypersonic forward speed to the desired altitude and desired forward speed at optimal conditions for such a non-air breathing propulsion system.

 Another feature of at least one example of the presently disclosed subject matter
20 is that the respective launch system enables the propulsion system of some of the component vehicle thereof – in particular each one of the booster vehicle, and the payload vehicle - to provide optimal performance as a single cycle-single platform component, while the carrier vehicle can be configured as a low cost rocket booster. For example, the carrier vehicle in some examples has rocket propulsion system and propels the launch
25 system from ground level and zero forward speed to the first altitude and a supersonic forward speed exceeding Mach 1.0, for example up to Mach 1.5; the booster vehicle has ramjet propulsion system and propels the composite vehicle from the first altitude and low supersonic forward speed to the second altitude and higher supersonic/hypersonic forward speed at optimal conditions for such an air breathing propulsion system; the
30 payload vehicle has rocket propulsion system and propels the payload from the second altitude and supersonic/hypersonic forward speed to the desired altitude and desired forward speed at optimal conditions for such a non-air breathing propulsion system.

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Another feature of at least one example of the presently disclosed subject matter is that the respective launch system enables a payload to be launched into the desired altitude with relatively low launch costs as compared with currently available pure rocket launch systems.

5 Another feature of at least one example of the presently disclosed subject matter is that the respective launch system can provide a larger payload weight for a given all-up weight of the composite vehicle

Another feature of at least one example of the presently disclosed subject matter is that the respective launch system, in which the composite air vehicle is air-launched
10 from a carrier vehicle in the form of a subsonic or supersonic carrier aircraft, the payload can have a larger payload weight per se within the weight limitation of the carrier aircraft, as compared with payload weight of other conventional air-launched systems for the same carrier aircraft.

BRIEF DESCRIPTION OF THE DRAWINGS

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

Fig. 1 is a schematic side view of the launch system according to a first example of the presently disclosed subject matter, including a first example of the
20 second coupling system thereof.

Fig. 2 is a schematic illustration of a launch profile of the launch system according to example of Fig.1.

Fig. 3(a) is a partial cross-sectional side view of a first example of the composite vehicle of the launch system according to example of Fig.1; **Fig. 3(b)** is a
25 partial cross-sectional top view of the example of the composite vehicle of Fig. 3(a).

Fig. 4(a) is a side view of an alternative variation of the example of the composite vehicle of Fig. 3(a); **Fig. 4(b)** is top view of the example of the composite vehicle of Fig. 4(a).

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5 **Fig. 5(a)** is a side view of another alternative variation of the example of the composite vehicle of Fig. 3(a); **Fig. 5(b)** is top view of the example of the composite vehicle of Fig. 5(a); **Fig. 5(c)** is schematic isometric view of the example of the composite vehicle of Fig. 5(a) illustrating decoupling between the respective booster vehicle and the respective payload vehicle of the composite vehicle.

10 **Fig. 6(a)** is a side view of another alternative variation of the example of the composite vehicle of Fig. 3(a); **Fig. 6(b)** is top view of the example of the composite vehicle of Fig. 6(a); **Fig. 6(c)** is schematic isometric view of the example of the composite vehicle of Fig. 6(a) illustrating decoupling between the respective booster vehicle and the respective payload vehicle of the composite vehicle.

15 **Fig. 7(a)** is a side view of another alternative variation of the example of the composite vehicle of Fig. 3(a); **Fig. 7(b)** is schematic isometric view of the example of the composite vehicle of Fig. 7(a) illustrating decoupling between the respective booster vehicle and the respective payload vehicle of the composite vehicle.

20 **Fig. 8** is a front view of an alternative variation of the example of the launch system of Fig. 1, including a second example of the second coupling system thereof.

Fig. 9 is a front view of another alternative variation of the example of the launch system of Fig. 1, including a third example of the second coupling system thereof.

25 **Fig. 10** is a front view of another alternative variation of the example of the launch system of Fig. 1, including a fourth example of the second coupling system thereof.

Fig. 11 is a schematic top view of the launch system according to a second example of the presently disclosed subject matter, including the composite vehicle according to the example of Figs. 4(a) and 4(b).

30 **Fig. 12** schematically illustrates a method for delivering a payload vehicle to a predetermined altitude according to a first example of the presently disclosed subject matter.

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DETAILED DESCRIPTION

Referring to Figs. 1 and 2, a launch system for delivering a payload to a predetermined altitude **H** according to a first example of the presently disclosed subject matter, generally designated **10**, comprises a composite vehicle **100** accommodating a payload **P**, and a carrier vehicle **500**.

In at least this example, the predetermined altitude **H** is typically not less than the range 30km to 40km, and can include altitudes up to the Karman line (about 100km) or more, for example near Earth orbital altitudes (100km to 700km), or even greater, for example sun synchronous orbits, geosynchronous orbits, or indeed outer space in which the payload vehicle **200**, or the payload **P**, can accelerate to escape velocity.

Referring also to Figs. 3(a) and 3(b), the composite vehicle **100** according to at least a first example thereof, comprises a payload vehicle **200**, a booster vehicle **300**, and a first coupling system **400**.

The payload vehicle **200** is configured for powered spaceflight at least in space medium, and comprises a rocket driven propulsion system **250**.

While in this example the payload vehicle **200** is configured as a single stage vehicle, in alternative variations of this example, and in other examples, the payload vehicle **200** is instead configured as a multi-stage vehicle, for example having two or more stacked stages, in which typically the payload **P** is accommodated in the final stage.

By “space medium” is meant a vacuum or near vacuum, or at least atmospheric conditions consistent with an altitude at which the atmosphere is too thin to support aerodynamic flight (typically about 84km or higher) and/or too thin to enable propulsive power to be generated by air-breathing engines, including ramjets, scramjets, dual mode ramjet/scramjet (DMRJ) and the like – for example about 36km to 40km for ramjets or about 75km for scramjets.

In at least this example, the rocket driven propulsion system **250** is configured as a single cycle propulsion system, in which at no time, during operation thereof to generate thrust, the rocket driven propulsion system **250** requires any external atmospheric air to

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be supplied thereto to generate thrust. Rather, all the materials, including as appropriate fuel, oxidizer and so on, are carried by the payload vehicle **200** itself.

In at least this example, the payload vehicle **200** has no other propulsion system other than the rocket driven propulsion system **250**, and thus the payload vehicle **200** has
5 an absence of air-breathing engine for the purpose of generating thrust. For example, the payload vehicle **200** has an absence of any one of: a ramjet based propulsion system; a scramjet propulsion system; a turbojet based propulsion system; a turbofan based propulsion system.

Rather, in at least this example, the rocket driven propulsion system **250** comprises
10 at least one rocket engine **260**, and suitable propellants. In at least this example, the rocket engine is a chemical rocket engine.

In at least this example, the at least one rocket engine **260** is a liquid fuel rocket engine, and the payload vehicle also comprises suitable propellant tanks **270**, including
15 for example fuel tanks and oxidizer tanks, as well as a suitable pump system **275** for supplying propellants to the rocket engine **260** from the propellant tanks **270**, and control system **278** for controlling operation of the pump system **275** and/or rocket engine **260** in particular the thrust generated thereby.

In alternative variations of this example, the rocket driven propulsion system **250** comprises at least one chemical rocket engine **260** in the form of a solid rocket engine,
20 having solid propellants.

In any case, the configuration of the rocket driven propulsion system **250**, for example the number of rocket engines **260** and/or the respective specific impulse (I_{SP}) thereof (for example in the range of 250/sec to 420/sec), can depend on the particulars of the mission for which it is intended to operate the payload vehicle **200**. Such particular
25 can include, for example the weight of the payload **P** to be carried by the payload vehicle **200**, the magnitude of the respective predetermined altitude **H**, the velocity **V_P** to be provided to the payload **P** (for example: sub orbital velocity, or, orbital velocity at a particular orbital altitude, or, escape velocity), and other mission parameters, for example whether or not the payload **P** (or part thereof) is to be returned to Earth.

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In at least this example, the payload vehicle **200** comprises a body **210** that is aerodynamically contoured for minimizing aerodynamic drag. In at least this example, the body **210** has a forward ogive-shaped nose portion **212**, and a generally cylindrical or frusto-conical aft body section **214**. In at least this example, the rocket driven propulsion
5 system **250** is provided in the aft body section **214**.

While in this example the body **210** has circular transverse cross-sections, in alternative variations of this example and in other examples, the body transverse cross sections can have any other suitable shape, for example, oval, elliptical, super-elliptical, polygonal, and so on. In yet in other alternative variations of this example and in other
10 examples, the body **210** can be configured as a lifting-body, in which the body **210** itself can generate aerodynamic lift at lower altitudes.

While in this example the payload vehicle **200** is devoid of any aerodynamic lift-producing wings, in alternative variations of this example and in other examples, the payload vehicle **200** can have aerodynamic lift-producing wings, affixed to the body **210**.

15 In at least this example, the payload vehicle **200** can be configured for spin stabilization when operating on its own, and disengaged from the booster vehicle. In such spin stabilization, the payload vehicle **200** spins in roll about a longitudinal axis **LA1** of the payload vehicle **200**.

In at least this example, the payload vehicle **200** the payload vehicle comprises a
20 payload vehicle payload bay **290**, configured for accommodating therein a payload **P**. In at least this example, the payload vehicle payload bay **290** is located within the body **210**. Furthermore, the payload vehicle can be configured for exposing the payload **P** (while still engaged to the payload vehicle **200**) with respect to the external environment, and/or for releasing the payload **P** from the payload vehicle payload bay **290**, at predetermined
25 conditions.

For example, the payload vehicle **200** can be configured with an ejectable nose portion **212**, and the nose portion **212** can be selectively ejected to expose the payload vehicle payload bay **290**, and optionally to selectively disengage the payload **P** therefrom and thereby allow separation of the payload **P** from the payload vehicle **200**.

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Alternatively, the payload vehicle **200** can be configured with openable or ejectable payload bay doors, which can be selectively opened or ejected, respectively, to expose the payload vehicle payload bay **290**, and optionally to selectively disengage the payload **P** therefrom and thereby allow separation of the payload **P** from the payload
5 vehicle **200**.

In at least some examples, the payload vehicle **200** is configured for being maneuvered (automatically, autonomously, or under human control via remote control) during and up to attaining the desired height **H**. Additionally or alternatively, at least some examples, the payload vehicle **200** is configured for re-entry or otherwise recovered
10 via ground landing or sea landing, for example using a parachute system that can be deployed from the payload vehicle **200** at predetermined conditions.

In at least this example, the booster vehicle **300** is configured for powered aerodynamic flight at least between a first altitude **H1** and a second altitude **H2**. The booster vehicle **300** is configured for powered aerodynamic flight, up to second altitude **H2**, which
15 can, in at least some examples, include, as a maximum limit, altitudes up until the atmosphere is too thin to support aerodynamic flight (i.e., typically at altitudes of about 84km or less) and/or too thin to enable propulsive power to be generated by air-breathing engines, including at least ramjets, scramjets and the like. In at least this example, the first altitude **H1**, which is lower than the second altitude **H2**, can include as a maximum limit the
20 maximum altitude at which the carrier vehicle **500** can operate in powered aerodynamic flight while concurrently carrying the composite vehicle **100**. For example, the first altitude **H1** can be in the range of 8,000m to 12,000m, or in the range 10,000m to 20,000m. For example, the second altitude **H2** can be in the range of 30,000m to 40,000m

In particular, the booster vehicle **300** is configured for powered
25 supersonic/hypersonic aerodynamic flight, i.e., for powered supersonic flight and/or for powered hypersonic flight, between the first altitude **H1** and the second altitude **H2**. The booster vehicle **300** thus comprises a ramjet propulsion system **350**, configured for transporting the composite vehicle **100** between the first altitude **H1** and the second altitude **H2** under propulsive power provided by said ramjet propulsion system **350**.

30 In at least this example, the ramjet propulsion system **350** is configured as a single cycle propulsion system.

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By “ramjet propulsion system” is meant an air-breathing propulsion system in which at no time, during operation thereof to generate thrust, the ramjet propulsion system requires any external atmospheric air to be compressed by means of a compressor, for example a mechanical rotary-based compressor (i.e., having a rotary component that is
5 turned to thereby compress air passing through the rotary component), for example an axial compressor or a centrifugal compressor (for example of a turbojet engine or turbofan engine) to generate thrust. Rather, all the air compression required by the ramjet propulsion system **350** is provided as a result of the forward speed of the booster vehicle **300** itself, and the geometry of the intake of the ramjet engine.

10 In at least this example, the booster vehicle **300** has no other propulsion system other than the ramjet propulsion system **350**, and is thus an exclusively ramjet propulsion system. Thus the booster vehicle **300** has an absence of any air-breathing engine that includes a compressor (for example a mechanical rotary-based compressor, for example an axial compressor or a centrifugal compressor) for the purpose of generating thrust (for
15 example the booster vehicle **300** has an absence of a turbojet based propulsion system and/or an absence of a turbofan based propulsion system), and/or an absence of any type of non-air-breathing engine that does not require the continuous provision of atmospheric air for the purpose of generating thrust (for example the booster vehicle **300** has an absence of rocket engines).

20 For example, the ramjet propulsion system **350** comprises at least one of: a pure ramjet engine; a solid fuel integrated rocket ramjet engine (SFIRR); a scramjet engine, a DMRJ.

In at least this example, the ramjet propulsion system **350** comprises at least one ramjet engine **360**, and the ramjet propulsion system **350** also comprises (carried by the
25 booster vehicle **300**) suitable propellant tanks **370**, including for example fuel tanks, as well as a suitable pump system **375** for supplying propellants to the ramjet engine **360** from the propellant tanks **370**, and control system **378** for controlling operation of the pump system **375** and/or ramjet engine **360** in particular the thrust generated thereby. The ramjet engine **360** includes a suitable intake **365**, combustion chamber **366** and exhaust
30 nozzle **367**.

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In any case, the configuration of ramjet propulsion system **350**, for example the number of ramjet engines **360** and/or the respective specific impulse (I_{SP}) thereof (for example in the range 1200/sec to 2200/sec), can depend on the particulars of the mission for which it is intended to operate the booster vehicle **300**. Such particular can include, 5 for example the weight of the payload vehicle **200** to be carried by the booster vehicle **300** in the composite vehicle **100** configuration, the magnitude of the respective second altitude **H2**, the velocity V_{PV} to be provided to the payload vehicle **200** such as to enable the payload vehicle to be operated, after separation from the booster vehicle **300**, such as to provide the payload **P** with the desired velocity V_P (for example: sub orbital velocity, 10 or, orbital velocity at a particular orbital altitude, or, escape velocity), and other mission parameters.

In at least this example, the ramjet propulsion system **350** is configured for providing a baseline thrust T_{BV} at a predetermined forward velocity V_{CA} that can be provided by the carrier vehicle **500**. For example, such a predetermined forward velocity 15 V_{CA} can be Mach 0.5 or higher, for example about Mach 0.85 (when the carrier vehicle **500** is a subsonic turbofan aircraft), or for example Mach 1.5 (when the carrier vehicle **500** is a supersonic aircraft or a rocket booster vehicle). Furthermore, the ramjet propulsion system **350** is configured for providing sufficient thrust for accelerating the payload vehicle **200** (when coupled thereto in the composite vehicle **100**) to Mach number 20 in the region of 3 and 6, or beyond, for example Mach 5.

In alternative variations of this example, the ramjet propulsion system **350** comprises at least one scramjet engine and/or solid fuel integrated rocket ramjet engine (SFIRR) and/or DMRJ.

In at least this example, the booster vehicle **300** comprises a fuselage **330** that is 25 aerodynamically contoured for minimizing aerodynamic drag. In at least this example, the fuselage **330** has a forward ogive-shaped nose **312**, and a generally cylindrical or frusto-conical mid fuselage section **316**, and a tapering aft fuselage section **314**.

While in this example the fuselage **330** has circular transverse cross-sections along the longitudinal axis **LA2** thereof, in alternative variations of this example and in other 30 examples, the fuselage transverse cross sections can have any other suitable shape, for example, oval, elliptical, super-elliptical, polygonal, and so on. In yet in other alternative

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variations of this example and in other examples, the fuselage **330** can be configured as a lifting-body, in which the fuselage **330** itself can generate aerodynamic lift at lower altitudes at or below the second altitude **H2**.

In at least this example, the booster vehicle **300** comprises an aerodynamic wing system **320**, configured for providing lift, stability and control to at least the composite vehicle **100**, via the booster vehicle **300**, at least at supersonic/transonic conditions between the first altitude **H1** and the second altitude **H2**. In at least this example, the aerodynamic wing system **320** is also configured for providing lift, stability and control to the booster vehicle **300**, when disengaged from the payload vehicle **200**, within the flight envelope of the booster vehicle **300** when operated by itself.

Furthermore, in at least this example, the aerodynamic wing system **320** is configured for providing lift, stability and control to the composite vehicle **100**, as well as the booster vehicle **300** when separated from the payload vehicle, also at subsonic and transonic conditions, either when accelerating to supersonic conditions, or decelerating from supersonic conditions.

In at least this example, the booster vehicle **300** comprises a fuselage **330**, and the aerodynamic wing system **320** comprises a delta wing, having a port wing **322** and a starboard wing **324** affixed to the fuselage **330**. The port wing **322** and starboard wing **324** each comprise control surfaces in the form of elevons **325**, for pitch control as well as roll control.

In at least this example, the ramjet propulsion system **350** is affixed to the aerodynamic wing system **320**. In at least this example, the ramjet propulsion system **350** comprises two ramjet engines **360**, one ramjet engine **360** mounted to each of the port wing **322** and the starboard wing **324**. In alternative variations of this example, the ramjet propulsion system **350** can comprise more than two ramjet engines **360**, while in other alternative variations of this example, the ramjet propulsion system **350** can comprise one ramjet engine **360**, for example mounted to the fuselage **330**.

The booster vehicle **300**, particular the aerodynamic wing system **320**, further comprises a vertical stabilizer arrangement **340** for yaw control. In at least this example, the vertical stabilizer arrangement includes one fin **342** pivotable between a stowed

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position **SP** and a deployed position **DP**. In alternative variations of this example, the vertical stabilizer arrangement includes more than one fin pivotable between a respective stowed position and a respective deployed position. In any case, in the stowed position **SP** the fin **342** has a first height dimension **S1**, and in the deployed position **DP** the fin **342** has a second height dimension **S2**, the second height dimension **S2** being greater than the first height dimension **S1**. In the deployed position **DP** the fin **342** is configured for generating stability and control moments to the composite vehicle **100**, as well as to the booster vehicle **300** when separated from the payload vehicle **200**.

While in at least this example, the pivotable fin **342** is pivotably mounted to the fuselage **330** on a top part thereof, in alternative variations of this example the pivotable fin **342** can be pivotably mounted to a bottom part of the fuselage **330**, or to the aerodynamic wing system, for example at least one fin mounted to the port wing **322** and at least one fin mounted to the starboard wing **324**, for example at the wing tips thereof.

In alternative variations of the above example, the aerodynamic wing system **320** comprises a vertical stabilizer arrangement including at least one fin fixedly mounted to the booster vehicle **300**, for example to the fuselage **330**, and/or to the wings **342**, **344**.

In yet other alternative variations of the above examples, the booster vehicle **300** does not have a fuselage, and is provided as a flying wing – comprised mostly of the aerodynamic wing system **320**.

In yet other alternative variations of the above examples, the booster vehicle **300** is configured as a blended wing body vehicle, integrating the fuselage **330** and the aerodynamic wing system **320**.

In these or other alternative variations of the above examples, the aerodynamic wing system **320** further comprises canards, which can be affixed to the nose **312**; alternatively, the canards can be affixed to the payload vehicle **200**, and are only needed while the booster vehicle **300** and the payload vehicle **200** are coupled together to form the composite vehicle **100**.

In yet other alternative variations of the above examples, the aerodynamic wing system is in the form of variable geometry wings (so-called “swing wing”), or double delta wings, or swept wings.

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The first coupling system **400** is for selectively coupling and decoupling the payload vehicle **200** with respect to the booster vehicle **300**. When the first coupling system **400** is in coupled configuration, the payload vehicle **200** is coupled to the booster vehicle **300** and the two vehicles operate together as a single vehicle – the composite vehicle **100**. In the decoupled configuration, the payload vehicle **200** is decoupled with respect to the booster vehicle **300**, and each one of payload vehicle **200** and the booster vehicle **300** operate independently of one another.

In at least this example, the first coupling system **400** is configured for coupling the payload vehicle **200** with the booster vehicle **300** in longitudinal stacked arrangement, in which at least a forward part of the payload vehicle **200** is longitudinally forward with respect to the booster vehicle **300**, along the first longitudinal axis **LA1** and the second longitudinal axis **LA2**. For example, the first coupling system **400** comprises a plurality of explosive bolts that, in the coupled configuration, mechanically hold together the payload vehicle **200** with the booster vehicle **300** in load bearing relationship, and when actuated in the uncoupled configuration enable the payload vehicle **200** to separate from the booster vehicle **300**.

The booster vehicle **300** is further configured for being flown independently of the payload vehicle **200**, and thus can be maneuvered (automatically, autonomously, or under human control via remote control) to be flown to a recovery site, and recovered there by controlled horizontal landing, in which case the booster vehicle **300** comprises a suitable undercarriage. For example such undercarriage can be conventional deployable/retractable undercarriage, or alternatively, can be “down only” landing gear that only deploys (and has no hydraulic mechanism for retraction of the landing gear – this can only be done by work crews on the ground) thereby saving weight and complexity. Alternatively, the booster vehicle **300** can be recovered via parachute that can be deployed from the booster vehicle **300** at predetermined conditions.

As best seen in Figs. 3(a) and 3(b), in at least this example the composite vehicle **100** further comprises a payload module adaptor **110** in the form of a fairing that interconnects the payload vehicle **200** with the booster vehicle **300** while in coupled mode. The payload module adaptor **110** provides aerodynamic continuity between the payload vehicle **200** and the booster vehicle **300**, and can be discarded when the payload

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vehicle **200** becomes uncoupled with the booster vehicle **300** in uncoupled mode. The first coupling system **400** can be provided between the payload module adaptor **110** and the payload vehicle **200**, and/or between the payload module adaptor **110** and the booster vehicle **300**.

5 Referring to Figs. 4(a) and 4(b), an alternative variation of the example of Figs. 3(a) and 3(b) is illustrated, in which the booster vehicle **300** has a modified nose **312A** that is directly coupled to the aft end of the payload vehicle **200** in the coupled mode. The modified nose **312A** is blunt and comprises a forward periphery **315A** that couples directly to an aft periphery **215A** of the aft body section **214** via explosive bolts or the like, for example.

10 Referring to Figs. 5(a), 5(b) and 5(c), an alternative variation of the example of Figs. 3(a), 3(b), 4(a), 4(b) is illustrated, in which the respective first coupling system **400** is configured for coupling the payload vehicle **200** with the booster vehicle **300** in longitudinal stacked arrangement, in which at least a forward part of the booster vehicle **300** is longitudinally forward with respect to the payload vehicle **200**, along the first
15 longitudinal axis **LA1** and the second longitudinal axis **LA2**. In this example, the port wing **322A** and starboard wing **324A** of the corresponding aerodynamic wing system are mounted on booms **342**, **344**, respectively, that project aft from the aft end of respective fuselage **330A**. The booms **342**, **344** are co-extensive with the payload vehicle **200**, and are thus located on either side of the payload vehicle **200** when the payload vehicle **200**
20 is coupled with the booster vehicle **300**. In this example, the aerodynamic wing system **320** comprises a vertical stabilizer arrangement including at least one fin fixedly mounted to the booster vehicle **300**, for example to the wing tips of wings **342A**, **344A**. As illustrated in Fig. 5(c), in decoupled configuration, first coupling system **400** decouples the payload vehicle **200** with respect to the booster vehicle **300**, and each one of the
25 payload vehicle **200** and the booster vehicle **300** follows its respective trajectory.

Referring to Figs. 6(a), 6(b) and 6(c), an alternative variation of the examples of Figs. 3(a) to 5(c) is illustrated, in which the respective first coupling system **400** is configured for coupling the payload vehicle **200** with the booster vehicle **300** in transverse stacked arrangement, in which at least a first part **290** of the payload vehicle **200** is in
30 transverse overlying relationship with respect to which at least a first part **390** the booster vehicle **300**, along a direction not parallel to the first longitudinal axis **LA1** and the second

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longitudinal axis **LA2**. In this example, the first part **390** of the booster vehicle **300** is provided by an upper fuselage portion **395** of fuselage **330B** of the booster vehicle **300**. In this example the upper fuselage portion **395** can be relatively flat. In this example, the first part **290** of the payload vehicle **200** is provided by a lower body portion **295** of body **210B** of the payload vehicle **200**. In this example the lower body portion **295** is relatively flat, and essentially abuts or at least overlies the upper fuselage portion **395** in coupled configuration. As illustrated in Fig. 6(c), in decoupled configuration, the respective first coupling system **400** decouples the payload vehicle **200** with respect to the booster vehicle **300**, and each one of the payload vehicle **200** and the booster vehicle **300** follows its respective trajectory.

Referring to Figs. 7(a) and 7(b), an alternative variation of the examples of Figs. 3(a) to 6(c) is illustrated, in which the booster vehicle **300** comprises a booster vehicle payload bay **380**, which has an internal geometry and dimensions sufficient for enabling the payload vehicle **200** to be accommodated in the booster vehicle payload bay **380**. The booster vehicle payload bay **380** is further configured for allowing egress of the payload vehicle **200** therefrom, and for this purpose the respective fuselage **330** comprises payload doors **389** which can selectively open to expose the booster vehicle payload bay **380** to the external environment. The respective first coupling system **400** is configured for selectively coupling and decoupling the payload vehicle **200** with respect to the booster vehicle payload bay **380** of the booster vehicle **300**. As illustrated in Fig. 7(c), in decoupled configuration, the respective first coupling system **400** decouples the payload vehicle **200** with respect to the booster vehicle **300**, and the payload vehicle **200** egresses from the booster vehicle payload bay **380**; thereafter each one of the payload vehicle **200** and the booster vehicle **300** follows its respective trajectory.

In the above examples the booster vehicle **300** and the payload vehicle **200** are each unmanned, and thus each comprises a respective control system including one or more of a communications module, a navigation module, and a control module, for controlling the various functions of the booster vehicle **300** and the payload vehicle **200**, respectively. Such control systems enable the composite vehicle **100** to be flown to the desired second altitude **H2** after separation from the carrier vehicle **500**, enable the booster vehicle **300** and the payload vehicle **200** to become decoupled from one another, and further allows the payload vehicle **200** to continue under power to the desired height

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H to thereby deploy or operate the payload **P**, while enabling the booster vehicle **300** to be flown back to a desired location and landed there. In alternative variations of this example, and in other examples, the booster vehicle **300** and/or the payload vehicle **200** can be configured as manned vehicles.

5 Referring again to Fig. 1, in at least this example the carrier vehicle **500** is configured at least for powered subsonic aerodynamic flight, and further configured for transporting the composite vehicle **100** to at least the first altitude **H1** from a ground location **GL**. For example, the carrier vehicle **500** has a fuselage **530**, main lift generating wings **540** and empennage **560**, and a propulsion system **580** that is configured to enable
10 the carrier vehicle **500**, while carrying the composite vehicle **100**, to reach at least the first altitude **H1**, as well as the aforesaid predetermined forward velocity **V_{CA}**, which can be Mach 0.5 or higher for example. Thus the payload weight capacity of the carrier vehicle **500** is at least equal to the all-up weight of the composite vehicle **100**.

For example, such a carrier vehicle **500** can be a Boeing 747 aircraft; alternatively,
15 such a carrier vehicle **500** can be any one of a Boeing 767 aircraft, Airbus 320 aircraft, Airbus 380 aircraft, White Knight 2 aircraft, Stratolaunch, and so on.

In this example and in other examples, the system **10** further comprises a second coupling system **700** for selectively coupling and decoupling the composite vehicle **100** with respect to the carrier vehicle **500**.

20 In the first example of the second coupling system **700** illustrated in Fig. 1, the second coupling system **700** is configured for coupling the composite vehicle **100** with the carrier vehicle **500** in transverse stacked arrangement, in which the carrier vehicle **500** is in at least partial transverse (vertical) overlying relationship with respect to the composite vehicle **100**. In other words, the composite vehicle **100** is vertically below the
25 underside of the carrier aircraft when coupled thereto via the second coupling system **700**.

In this example, the second coupling system **700** is configured for coupling the composite vehicle **100** with the carrier vehicle **500** in the aforesaid transverse stacked arrangement, wherein the carrier vehicle **500** fuselage is already configured to, or alternatively is modified structurally to, incorporate the second coupling system **700**. In
30 particular the second coupling system **700** is configured for selectively coupling and

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decoupling the composite vehicle **100** directly with respect to a lower portion **535** of the carrier aircraft fuselage **530**. The second coupling system **700** can therefore be mounted with respect to hard points on the lower portion **535** of the carrier aircraft fuselage **530**.

For example, the second coupling system **700** can comprise one or more hooks
5 provided in the lower portion **535** of the carrier aircraft fuselage **530**, and configured to engage with lugs provided in the upper portion of the composite vehicle **100**, either on one or both of the booster vehicle **300** and the payload vehicle **200**. For example, on actuation, the hooks can be selectively moved from an engaged position, in load bearing contact with the lugs, to a disengaged position, in which the hooks are disengaged from
10 the lugs, allowing the composite air vehicle **100** to separate from the carrier vehicle **500**.

In at least this example, and referring again to Fig.1, the carrier vehicle **500** has a fuselage ground clearance **C1**, being defined as the vertical spacing between the underside of the carrier aircraft fuselage **530** and the ground **GR**, when the carrier aircraft has the undercarriage deployed and is resting statically on the ground.

15 In this example, and referring also to Fig. 3(a), the composite vehicle **100** has a height dimension **C2**, when coupled to the carrier vehicle **500**, less than the fuselage ground clearance **C1** of the carrier vehicle **500**, leaving a composite vehicle ground clearance **C3** between the underside of the composite vehicle **100** and the ground **GR**.

It is to be noted that composite vehicle ground clearance **C3** is not least than the
20 minimum fuselage ground clearance permitted for the particular type of carrier vehicle **500**.

It is to be noted that in the first example of the composite vehicle **100**, illustrated in Fig. 3(a) and 3(b), the fin **342** is pivotable between the stowed position **SP** and the deployed position **DP**, such that when the composite vehicle **100** is coupled to the carrier
25 vehicle **500** the composite vehicle height dimension **C2** is minimized, enabling the composite vehicle **100** to be mounted on the underside of the carrier vehicle **500** while still retaining an allowable composite vehicle ground clearance **C3** to enable safe take-off of the launch system **10**, and/or to enable safe landing of the launch system **10**, for example in emergency cases where it is required to land the carrier vehicle **500** together
30 with the composite vehicle **100**

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It is to be noted that such an example of the second coupling system **700** can be used for coupling the composite vehicle **100**, according to any of the examples illustrated in Figs. 1 to 7(b), to the carrier vehicle **500**, subject to weight limitations as permitted for the carrier aircraft fuselage.

5 Referring to Fig. 8, in a second example of the second coupling system, the second coupling system, generally designated with reference numeral **700A** is similar to the second coupling system **700** of the first example, *mutatis mutandis*, and is similarly configured for coupling the composite vehicle **100** with the carrier vehicle **500** in transverse stacked arrangement, in which the carrier vehicle **500** is in at least partial
10 transverse (vertical) overlying relationship with respect to the composite vehicle **100**. In other words, the composite vehicle **100** is vertically below the underside of the carrier aircraft when coupled thereto via the second coupling system **700A**.

However in the second example, the second coupling system **700A** is in the form of a wing pylon **710** affixed to a wing **540** of the carrier aircraft, and configured for
15 coupling the composite vehicle **100** with the carrier vehicle **500** via the wing pylon **710**. For example, the carrier vehicle **500** can be modified to provide such a load-carrying pylon **710** on the underside of the port wing or of the starboard wing thereof.

Alternatively, and when such a carrier vehicle **500** is a Boeing 747 aircraft, in at least some examples of such a carrier aircraft, the carrier aircraft already has a pylon
20 attachment zone **PZ** with suitable anchor points **715** provided on the port wing between the fuselage and the inner engine, and such a pylon attachment zone **PZ** is sometimes used to ferry a fifth, non-operational engine by the carrier aircraft, by mounting the fifth engine to the pylon attachment zone **PZ**. In such examples, in which the carrier aircraft is a Boeing 747 type aircraft, the wing pylon **710** can be mounted to the port wing **540**
25 thereof, and attached to the aforesaid anchor points on the underside of the port wing, inboard of the operating engines of the carrier vehicle **500**.

For example, the wing pylon **710** can comprise one or more hooks configured to engage with lugs provided in the upper portion of the composite vehicle **100**, either on one or both of the booster vehicle **300** and the payload vehicle **200**. For example, on
30 actuation, the hooks can be selectively moved from an engaged position, in load bearing

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contact with the lugs, to a disengaged position, in which the hooks are disengaged from the lugs, allowing the composite air vehicle **100** to separate from the carrier vehicle **500**.

It is to be noted that the second coupling system **700A**, particularly in the form of a wing pylon **710**, can be used for coupling the composite vehicle **100**, according to any
5 of the examples illustrated in Figs. 1 to 8, to the carrier vehicle **500**, subject to weight limitations as permitted for the aforesaid anchor points. For example, in a standard Boeing 747 fitted with such a wing pylon **710**, the maximum all-up weight of the composite vehicle **100** can be, for example, up to 6,500Kg or for example up to 22,500Kg.

Referring to Fig. 9, in a third example of the second coupling system, the second
10 coupling system, generally designated with reference numeral **700B** is similar to the second coupling system **700** of the first example or second example, *mutatis mutandis*, and is similarly configured for coupling the composite vehicle **100** with the carrier vehicle **500** in transverse stacked arrangement, in which the carrier vehicle **500** is in at least partial transverse (vertical) overlying relationship with respect to the composite vehicle **100**. In
15 other words, the composite vehicle **100** is vertically below the underside of part of the carrier aircraft when coupled thereto via the second coupling system **700B**.

However in the third example, the carrier vehicle is also in the form of a carrier aircraft, generally designated **500B** in Fig. 9, comprises two fuselages **530B**, each having an outboard wing **540B**, and further comprising an interconnecting wing **545B**
20 interconnecting the two fuselages **530B**. the carrier vehicle **500B** also has an empennage **560B**, and a propulsion system **580B** that is configured to enable the carrier vehicle **500B**, while carrying the composite vehicle **100**, to reach at least the first altitude **H1**, as well as the aforesaid predetermined forward velocity **V_{CA}**, which can be Mach 0.5 or higher for example. Thus the payload weight capacity of the carrier vehicle **500B** is at least equal to
25 the all-up weight of the composite vehicle **100**.

In this example, the second coupling system **700B** is in the form of a wing pylon **710B** affixed to the interconnecting wing **545B** of the carrier vehicle **500B**, and is configured for coupling the composite vehicle **100** with the carrier vehicle **500B** via the wing pylon **710B**. For example, such a carrier vehicle **500** can be similar in type to the
30 White Knight Two aircraft, provided by Scaled Composites, USA, or the Stratolaunch aircraft provided by Scaled Composites, USA.

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For example, the wing pylon **710B** can comprise one or more hooks configured to engage with lugs provided in the upper portion of the composite vehicle **100**, either on one or both of the booster vehicle **300** and the payload vehicle **200**. For example, on actuation, the hooks can be selectively moved from an engaged position, in load bearing
5 contact with the lugs, to a disengaged position, in which the hooks are disengaged from the lugs, allowing the composite air vehicle **100** to separate from the carrier vehicle **500**.

It is to be noted that the second coupling system **700B**, particularly in the form of a wing pylon **710B**, can be used for coupling the composite vehicle **100**, according to any of the examples illustrated in Figs. 1 to 7(b), to the carrier vehicle **500B**, subject to weight
10 limitations as permitted for the aforesaid wing pylon **710B**. For example, in a Whiteknight 2 fitted with such a wing pylon **710B**, the maximum all-up weight of the composite vehicle **100** can be, for example, up to 17,000Kg.

Referring to Fig. 10, in a fourth example of the second coupling system, the second coupling system, generally designated with reference numeral **700C** is similar to
15 the second coupling system **700** of the first example, second example or third example, *mutatis mutandis*, and is similarly configured for coupling the composite vehicle **100** with the carrier vehicle **500** in transverse stacked arrangement. However, in this example, in transverse stacked arrangement the composite vehicle **100** is in at least partial transverse (vertical) overlying relationship with respect to the carrier vehicle **500**. In other words,
20 the composite vehicle **100** is vertically above the upper part of the carrier aircraft when coupled thereto via the second coupling system **700C**.

In the fourth example, the second coupling system **700C** is in the form of a plurality of fuselage struts **710C** affixed to an upper part of the fuselage **530** of the carrier vehicle **500**, and configured for coupling the composite vehicle **100** with the carrier
25 vehicle **500** via the fuselage struts **710C**. For example, the carrier vehicle **500** can be modified to provide such fuselage struts **710C** on the upper part of the fuselage **530** thereof. For example, such a carrier vehicle **500** is a Boeing 747 aircraft.

In this example, the second coupling system **700C** is configured for coupling the composite vehicle **100** with the carrier vehicle **500** in the aforesaid transverse stacked
30 arrangement, wherein the carrier aircraft fuselage is modified structurally to incorporate the second coupling system **700C**. In particular the second coupling system **700C** is

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configured for selectively coupling and decoupling the composite vehicle **100** directly with respect to a upper portion of the carrier aircraft fuselage **530**. The second coupling system **700C** can therefore be mounted to hard points on the upper portion of the carrier aircraft fuselage **530**.

5 For example, the second coupling system **700C** can comprise one or more hooks provided in the lower portion of the composite vehicle **100**, and configured to engage with lugs provided in the upper portions of the fuselage struts **710C**. For example, on actuation, the hooks can be selectively moved from an engaged position, in load bearing contact with the lugs, to a disengaged position, in which the hooks are disengaged from
10 the lugs, allowing the composite air vehicle **100** to separate from the carrier vehicle **500**.

In a second example of the carrier vehicle, and referring to Fig. 11, the carrier vehicle **500** is configured as a rocket booster vehicle, and is designated herein the reference number **500C**. in the illustrated example, the rocket booster vehicle **500C** comprises a port booster **500C1** and a starboard booster **500C2**, each of which comprises
15 booster body **530C**, accommodating suitable propellants (for example solid rocket propellants or liquid propellants) and one or more suitable rocket engines **520C**. The the rocket booster vehicle **500C**, in particular the port booster **500C1** and a starboard booster **500C2**, and a fifth example of the second coupling system, the second coupling system, generally designated with reference numeral **700D**, which is similar to the second
20 coupling system **700** of the first example, second example, third example or fourth example, *mutatis mutandis*, and is similarly configured for coupling the composite vehicle **100** with the carrier vehicle **500C** in transverse stacked arrangement. However, in this example, in transverse stacked arrangement the composite vehicle **100** is in at least partial transverse (sideways) overlying relationship with respect to the carrier vehicle
25 **500C**, in particular with respect to each of the booster bodies **530C**, when the rocket booster vehicle **500** is in vertical orientation suitable for vertical take-off. In other words, the composite vehicle **100** is adjacent to the carrier vehicle when coupled thereto via the second coupling system **700D**.

In the fifth example, the second coupling system **700D** is in the form of a plurality
30 of struts affixed to a side part of the booster body **530** of each one of the port booster

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500C1 and starboard booster **500C2**, of carrier vehicle **500C**, and configured for coupling the composite vehicle **100** with the carrier vehicle **500C** via the struts.

In particular the second coupling system **700D** is configured for selectively coupling and decoupling the composite vehicle **100** directly with respect to each one of the two booster bodies **530C**. For example, the second coupling system **700D** can comprise one or more hooks provided in the lower portion of the composite vehicle **100**, and configured to engage with lugs provided in the corresponding portions of the struts **710D**. For example, on actuation, the hooks can be selectively moved from an engaged position, in load bearing contact with the lugs, to a disengaged position, in which the hooks are disengaged from the lugs, allowing the composite air vehicle **100** to separate from the carrier vehicle **500C**.

Referring again to Fig. 2, the launch system **10** can be operated according to a first operating method delivering the payload vehicle **200** to a predetermined altitude, for example the desired altitude **H**.

Referring also to Fig. 12, a first example of such a method, generally designated with reference numeral **1000**, for example comprises the following steps:

Step **1100** – first (subsonic/transonic/low supersonic) phase;

Step **1200** – second (supersonic/hypersonic) phase;

Step **1300** – third (airless) phase.

Step **1100** comprises carrying the payload vehicle **200** from a ground location **GL** to a first altitude **H1** and at a first predetermined forward speed **V_{CA}**, while the payload vehicle **200** is concurrently coupled to the booster vehicle **300** (to provide the composite vehicle **100**), via the carrier vehicle **500**. For example, the launch system **10**, with the composite vehicle **100** coupled to the carrier vehicle **500** via the second coupling system **700** (of the first example thereof, or alternatively via the second coupling system **700A**, **700B**, or **700C** of the examples of Figs. 8, 9, 10, respectively) takes off from a runway at ground location **GL** in a conventional manner, and climbs to altitude **H1** with a forward speed of **V_{CA}** also in the conventional manner, under the power of the conventional propulsion system **580**. Thereafter, the composite vehicle **100** is decoupled from the

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carrier vehicle **500** at the first altitude **H1** and at a first predetermined forward speed V_{CA} . In at least this example, the minimum value of forward speed V_{CA} is the minimum forward speed at which the ramjet propulsion system **530** can provide a minimum and sustainable thrust for enabling acceleration and climb of the composite vehicle **100**.

5 Thus, if the conditions at the first altitude **H1** and at the first predetermined forward speed V_{CA} are sufficient for enabling the ramjet propulsion system **530** to operate to generate thrust, in particular sufficient thrust to enable the composite vehicle **100** to accelerate and climb, the method continues directly to step **1200**. For example, such a first altitude **H1** can be in the range of 10,000m to 20,000m, and forward speed V_{CA}
10 which can be at least Mach 0.5, which allow efficient operation of the propulsion system **580** to provide sufficient thrust to maintain altitude. In such conditions, particularly of forward speed V_{CA} , there can be sufficient associated air compression to enable the ramjet propulsion system **350** to ignite and begin to operate to generate thrust.

While at least some ramjet engines are known in the art to be capable of being
15 started, theoretically, at very low speeds around 200km/hour, these engines do not tend to generate any significant thrust until airspeeds of about Mach 0.5. Conventionally, ramjet engines operate at optimal or maximum efficiency at Mach No 3 to 5, and can operate up to a maximum Mach number of about 6. On the other hand, scramjets conventionally operate at optimal or maximum efficiency at Mach No 6 to 10, and can
20 operate up to a maximum Mach number of about 12, but are typically more expensive than ramjets, have thrust-to-weight ratios much lower than ramjets (for example in the order of about 2 as compared with for example 30 for Scramjets), and require a much greater forward speed than ramjets to start operating.

Alternatively, in alternative variations of this example in which the carrier vehicle
25 **500** cannot achieve the minimum forward speed for operation of the ramjet propulsion system **350**, the composite vehicle **100**, in particular the booster vehicle **300**, can be operated to maneuver into a controlled dive, after separation from the carrier vehicle **500**, to thereby accelerate the speed of the composite vehicle **100**, until such a minimum forward speed can be achieved and the ramjet propulsion system **350** can begin to
30 generate sustainable and sufficient thrust to thereby allow the composite vehicle **100** to recover from the dive at a particular saddlepoint altitude, and thereafter begin to climb.

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Thereafter, the composite vehicle **100** is decoupled from the carrier vehicle **500** at the first altitude **H1** and at a first predetermined forward speed V_{CA} . For example, the composite vehicle **100** can be decoupled from carrier vehicle **500** at an altitude higher than first altitude **H1**, such that the aforesaid saddlepoint altitude occurs at the first
5 altitude **H1**.

In examples in which the carrier vehicle **500** is in the form of a booster rocket, for example as in the example of Fig. 11, the launch system **10** takes off vertically, and at the first altitude **H1** the composite vehicle **100** disengages from the carrier rocket **500C**.

In any case, once the composite vehicle **100** is uncoupled with respect to the
10 respective carrier vehicle **500**, each one continues along its trajectory – the composite vehicle proceeds to step **1200**, while the carrier vehicle **500** can return and land on a suitable runway, for example at the ground location **GL**, in examples in which the carrier vehicle **500** is an aircraft. In other examples in which the carrier vehicle **500** is a rocket booster, the carrier vehicle **500** can be recovered, for example via parachute, or discarded.

Thus, in the first (subsonic/transonic/low supersonic) phase - Step **1100** – the
15 propulsion to the first altitude **H1** can be carried out using the optimal propulsion system for these conditions, i.e., based on turbojet or turbofan engine systems, that typically have a specific impulse I_{SP} of between 3,000/sec to 5,000/sec or more, and aerodynamic lift generating wings provide lift to the launch system **10** in an efficient and cost-effective
20 manner in the corresponding flight envelope.

In examples in which the carrier vehicle **500** is a subsonic aircraft, for example a subsonic turbofan aircraft as are well known in the art, the carrier vehicle **500** can provide a high subsonic forward speed, for example Mach 0.85.

In other examples, in which the carrier vehicle **500** is a supersonic aircraft, for
25 example as are well known in the art, or in which the carrier vehicle **500** is a rocket booster, the carrier vehicle **500** can provide a low supersonic forward speed, for example Mach 1.5, for more efficient ignition and operation of the ramjet propulsion system **350**.

In the next Step **1200**, the uncoupled booster vehicle **300** of the composite vehicle
30 **100** is operated to transport the booster vehicle **300** to at least the second altitude **H2** under propulsive power provided by the ramjet propulsion system **350** comprised in the

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booster vehicle **300**. As the Mach number of the composite vehicle **100** increases past Mach 1 and up to about Mach 6, the efficiency and thrust output of the ramjet propulsion system **350** increase, further facilitating acceleration and climb of the composite vehicle **100**. Once the second altitude **H2** and a second predetermined forward speed **V_{PV}** is
5 achieved by the composite vehicle **100**, the payload vehicle **200** is decoupled with respect to the booster vehicle **300**.

Once the payload vehicle **200** is uncoupled with respect to the booster vehicle **300**, each one continues along its trajectory – the payload vehicle **200** proceeds to step **1300**, while the booster vehicle **300** can return and land on a suitable runway, for example at
10 the ground location **GL**, in a conventional horizontal controlled landing or by parachute, for example.

Thus, in the second (supersonic/hypersonic) phase - Step **1200** – the propulsion to the second altitude **H2** is carried out using the optimal propulsion system for these conditions, i.e., based on ramjet engine systems, that typically have a specific impulse **I_{sp}**
15 of between 1,200/sec to 2,200/sec or more, and aerodynamic lift generating wings provide lift to the composite vehicle **100** in an efficient and cost-effective manner in the corresponding flight envelope.

In the next Step **1300** the payload vehicle **200** is operated to transport the payload vehicle **200** to at least the predetermined or desired altitude **H** and at a third predetermined
20 forward speed **V_P** under propulsive power provided by the rocket propulsion system **250** comprised in the payload vehicle **200**. Depending on the mission for the payload **P**, the forward speed **V_P** can be orbital velocity, or, orbital velocity at a particular orbital altitude, or, escape velocity, sufficient for the payload **P** to obtain sub orbital trajectory, or, orbital trajectory at a particular orbital altitude, or, escape the earth's gravitational pull,
25 respectively.

Optionally, the payload **P** can be detached from the payload vehicle **200**, or can be maintained attached thereto.

The payload **P** can of course comprise any suitable or desired cargo – for example one or more satellites – for example communication satellites.

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Thus, in the third (airless) phase - Step **1300** – the propulsion to the desired altitude **H** is carried out using the optimal propulsion system for these conditions, i.e., based on rocket engine systems, that typically have a specific impulse I_{SP} of between 300/sec to 400/sec or more.

5 In at least one implementation of the above examples, the payload vehicle **200** can be configured with an all-up weight of 7664Kg, including a payload weight of 450Kg for the payload **P**, and the at least one rocket engine **260** is configured for delivering the payload vehicle **200** from a second altitude **H2** of 37,000m to desired altitude **H** of 151,000m. In this implementation, or in at least one other implementation of the above
10 examples, the booster vehicle **300** can be configured with an all-up weight of 1475Kg, and the at least one ramjet engine **360** is configured for delivering the composite vehicle **100** from a first altitude **H1** of 10,700m to a second altitude **H2** of 37,000m.

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

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

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