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BALL et al.

(54) MULTIPLE STAGE TRACTOR PROPULSION VEHICLE

(71) Applicant: **The Boeing Company**, Chicago, IL (US)

(72) Inventors: **JAMES M. BALL**, Huntington Beach, CA (US); **AARON J. KUTZMANN**, Long Beach, CA (US); **DAVID A. DEAMER**, Seal Beach, CA (US)

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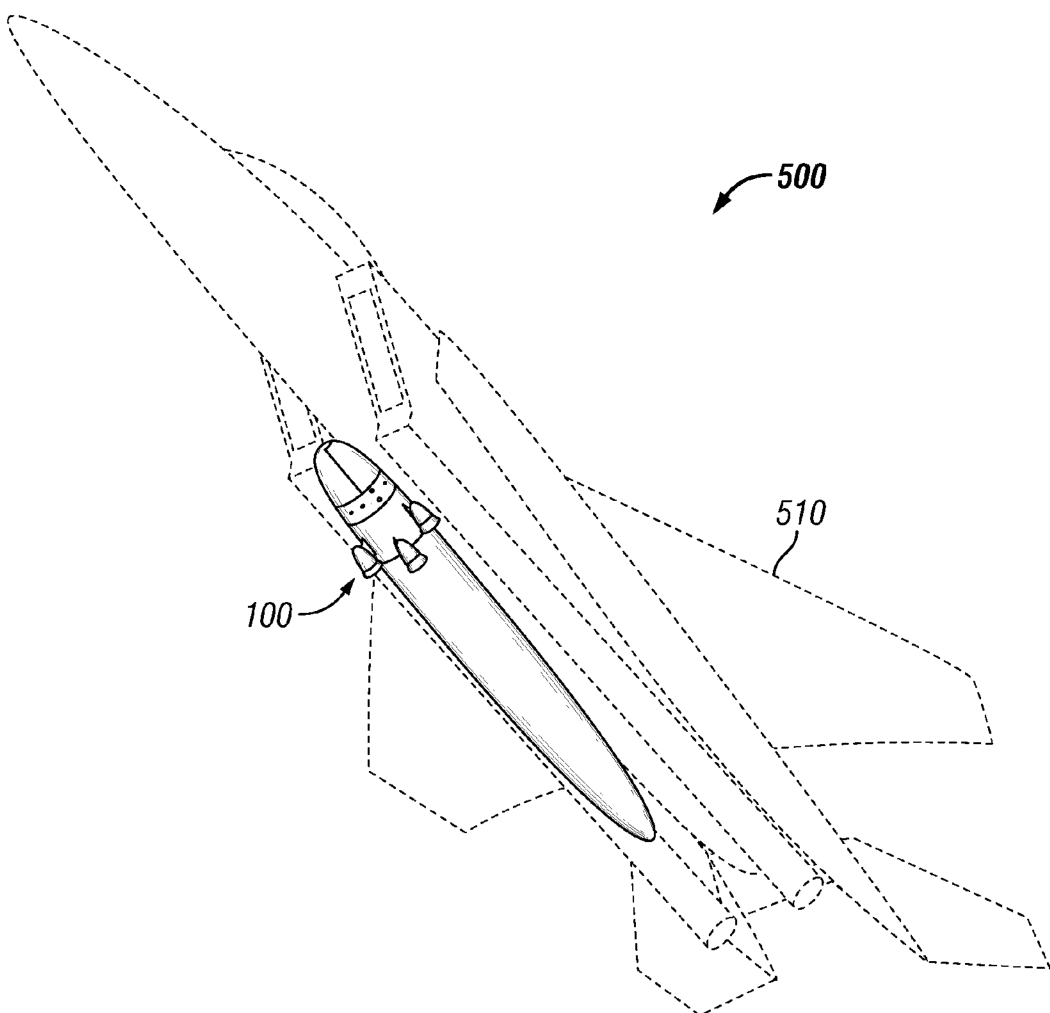
CPC ***B64G 1/005*** (2013.01); ***B64G 1/002*** (2013.01); ***B64G 1/402*** (2013.01); ***B64G 1/401*** (2013.01)

(57) **ABSTRACT**

A multiple stage orbital delivery vehicle that uses tractor propulsion to launch the vehicle into space. Only the upper stage of the vehicle includes an engine and avionics allowing the lower stages to be only liquid propellant tanks that may be dumped when empty. The liquid propellant may be either monopropellant or bi-propellant. The upper stage may include multiple nozzles that burn the propellant. Alternatively, the upper stage may include an aerospike engine instead of nozzles. The multiple stage orbital delivery vehicle may be air launched from an airborne aircraft or may be launched from the ground.



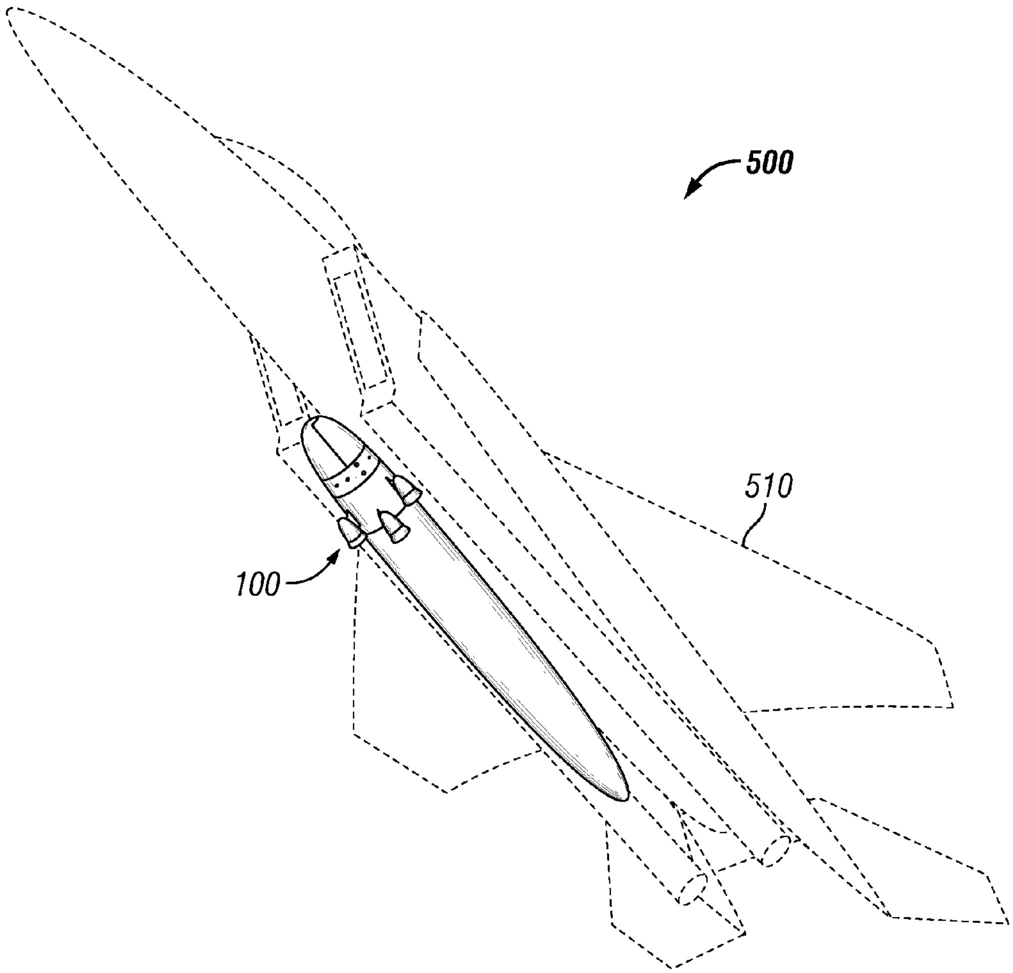


FIG. 1

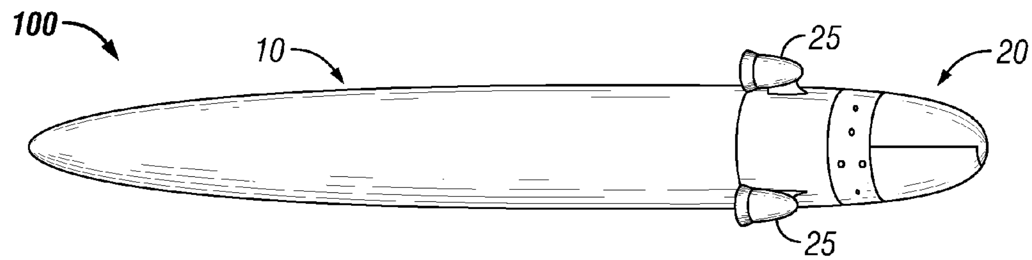


FIG. 2

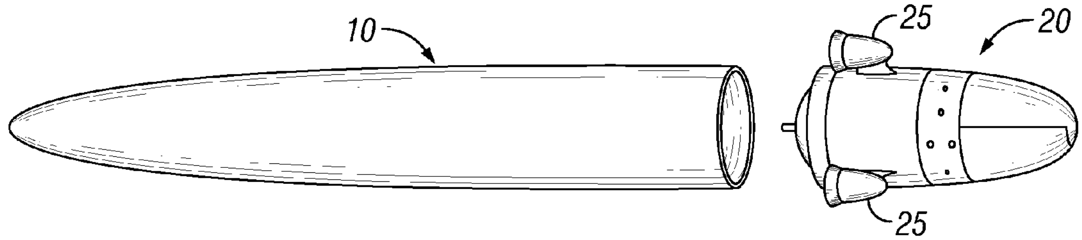


FIG. 3

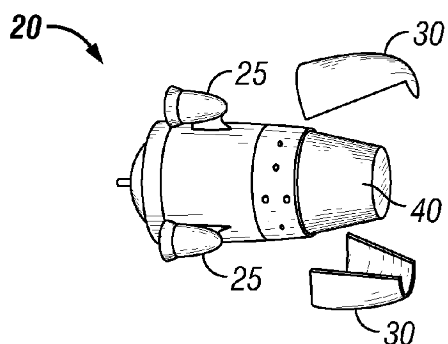


FIG. 4

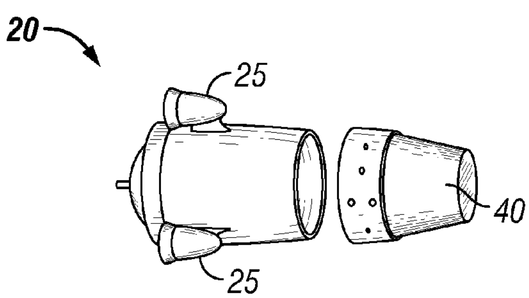
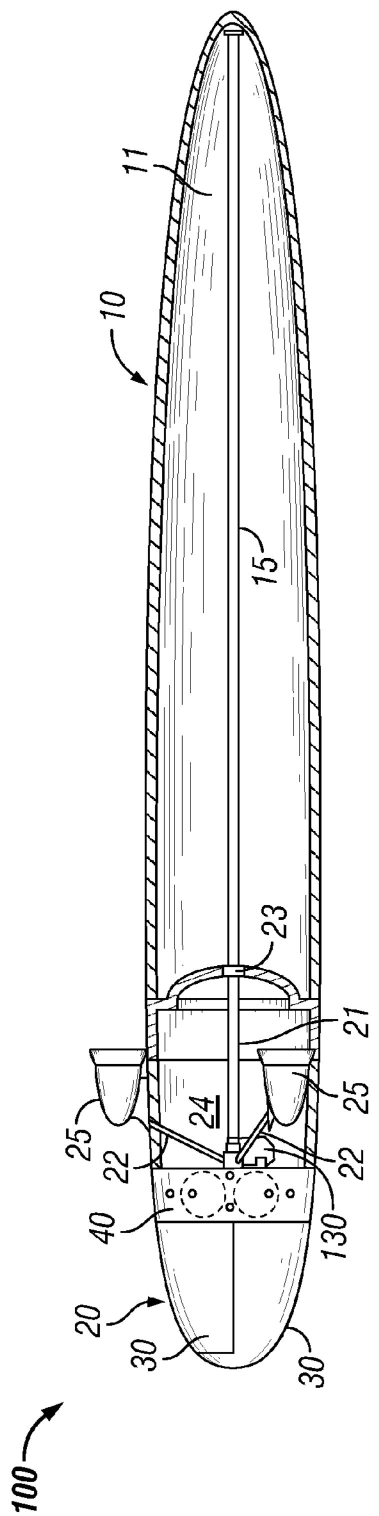


FIG. 5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130

FIG. 6

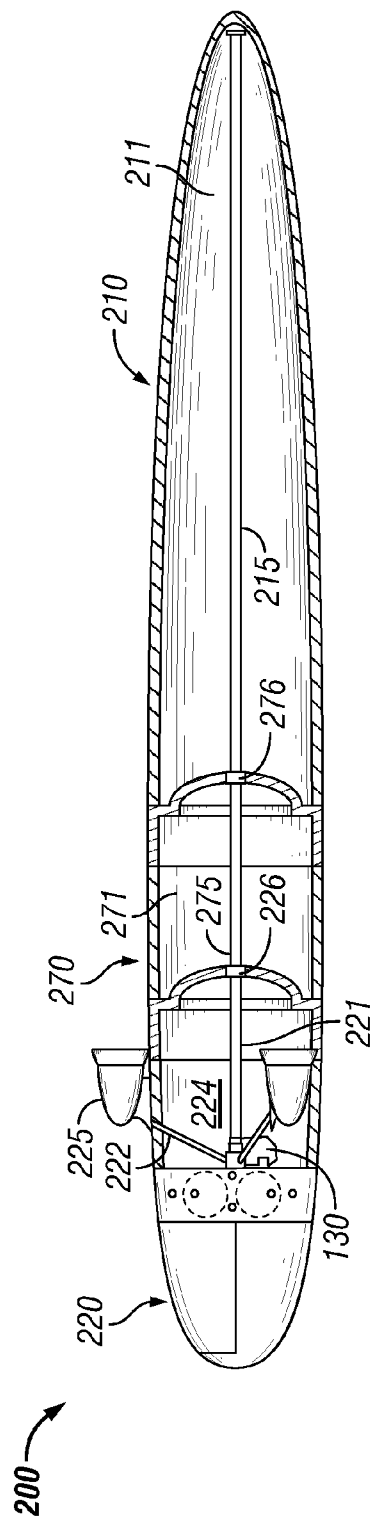
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FIG. 7

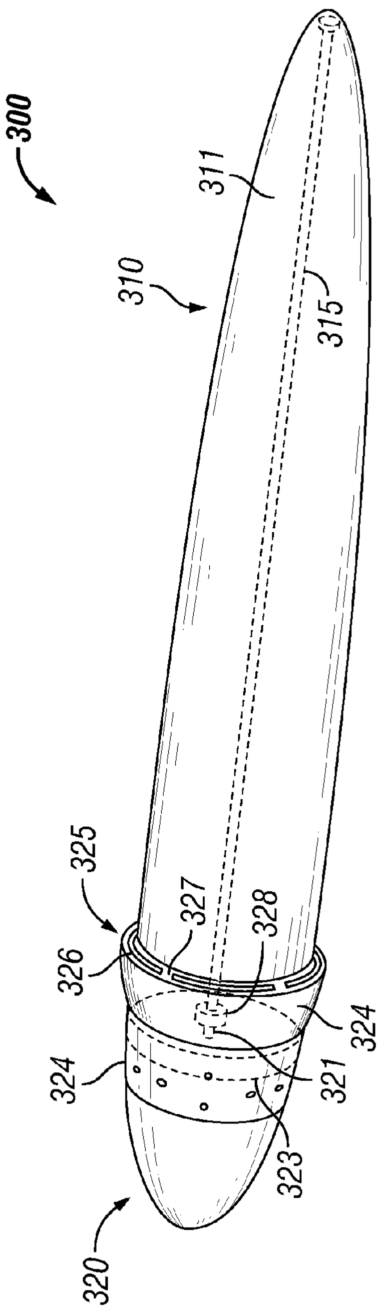
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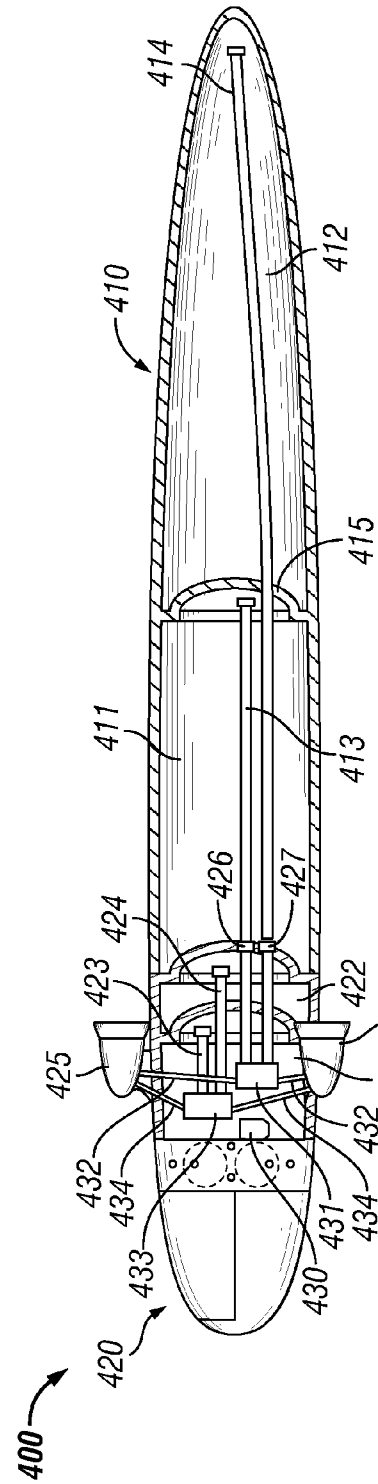
FIG. 8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400

FIG. 9

MULTIPLE STAGE TRACTOR PROPULSION VEHICLE

RELATED APPLICATION

[0001] This application is a divisional application of U.S. patent application Ser. No. 13/562,637 filed Jul. 31, 2012, and entitled "MULTIPLE STAGE TRACTOR PROPULSION VEHICLE," the disclosure of which is hereby incorporated by referenced in its entirety.

BACKGROUND

[0002] 1. Field of the Disclosure

[0003] The embodiments described herein relate to a multiple stage orbital delivery vehicle that uses tractor propulsion.

[0004] 2. Description of the Related Art

[0005] Multiple stage rockets have been used to launch orbiting devices, such as satellites, in the past. These have included both ground and air launched systems. However, the multiple stage rockets are complex, requiring both engines and control actuation systems to steer each stage. These control systems typically utilize actuators in both the pitch and yaw control planes to point the engine nozzle in a method referred to as thrust vector control, and require either electrical or hydraulic power sources which are added cost and complexity. Each stage has to be ignited as the lower stage is dropped from the vehicle. If a stage fails to ignite, the vehicle may not be successful in delivering the satellite into orbit. Further, conventional small multiple stage rockets often use solid propellant stages, which are heavier, less efficient, and more expensive than liquid propellant. Once solid propellant has been ignited it is difficult to stop the combustion until the entire propellant has been consumed unless higher complexity pintle techniques are used. Varying thrust or throttling the thrust level is also a challenge for solid propellant rocket motors.

[0006] Further, launch vehicle overall reliability is a function of part count, and increasing the launch vehicle reliability needs to be addressed by either increasing the reliability of individual components with an associated expense, or else reducing the number of components.

SUMMARY

[0007] The present disclosure is directed to a multiple stage orbital delivery vehicle that uses tractor propulsion and overcomes some of the problems and disadvantages discussed above. The present disclosure is directed to the simplicity of a multi-stage launch vehicle employing only a single set of engines resulting in a lower overall part count, higher reliability, and lower cost compared to multiple stages each having separate engines and steering actuation systems. These advantages are magnified for smaller payload and air launched systems since the cost of engines, steering actuation, and support subsystems for each stage can dominate the total costs for smaller launch systems. The reliability of a simpler, lower part count implementation, particularly one employing monopropellant, is lower cost than multiple stages each with their own propulsion designed for the same level of reliability.

[0008] One embodiment of a multiple stage orbital delivery vehicle comprises a first stage releasably connected to the orbital delivery vehicle. The first stage includes a first fuel tank and first fuel system. The first fuel system may include a first fuel line. The orbital delivery vehicle includes a second stage including a second fuel tank and a second fuel system. The second fuel system may include second fuel line in releasable fluid communication with the first fuel line of the first fuel system. The second stage comprises one or more engines in fluid communication with the first and second fuel systems. The one or more engines use fuel from the first fuel tank or the second fuel tank. In an embodiment, only a single stage of the orbital delivery vehicle includes an engine.

[0009] The multiple stage orbital delivery vehicle may further comprise a payload bay that may be selectively opened. The multiple stage orbital delivery vehicle may further comprise a spacecraft positioned in the payload bay. The first fuel tank and the second fuel tank may be adapted to contain a liquid propellant, which may be a monopropellant or a bipropellant. The second fuel line may include a valve to prevent leakage of fuel from the second fuel tank upon the disconnection of the first stage from the orbital delivery vehicle. The orbital delivery vehicle may include multiple engines each having a nozzle spaced around the exterior of the second stage. The orbital delivery vehicle may include a single engine having multiple nozzles spaced around the exterior of the second stage. The orbital delivery vehicle may include a guidance, navigation, and control system configured to control the operation of the engine(s).

[0010] The engine of the orbital delivery vehicle may be an altitude compensating nozzle engine, suitable engines may include a linear, curvilinear, annular, or toroidal aerospike engine. The engine of the orbital delivery vehicle may comprise an aerospike engine including an annular combustion chamber, throat, and nozzle. The nozzle of the aerospike engine being located around the exterior of the second stage. The nozzle of the aerospike engine may include multiple septums dividing the nozzle into multiple sections.

[0011] The multiple stage orbital delivery vehicle may further comprise a third stage releasably connected to the orbital delivery vehicle below the first stage. The third stage may comprise a third fuel tank and a third fuel system. The engine (s) of the orbital delivery vehicle may use fuel from the third fuel tank when the third stage is connected to the orbital delivery vehicle, may use fuel from the first fuel tank when the third stage has been disconnected from the orbital delivery vehicle while the first stage is connected to the orbital delivery vehicle, and may use fuel from the second fuel tank when the first stage has been disconnected from the orbital delivery vehicle. The engine(s) of the orbital delivery vehicle may be adapted to use fuel from any fuel tank that is connected to the orbital delivery vehicle. The engine may be adapted to use fuel from fuel tanks in a specific order or may be adapted to use fuel simultaneously from any fuel tank connected to the orbital delivery vehicle. The guidance, navigation, and control system may control the use of fuel by the engine(s) from the fuel tanks connected to the multiple stage orbital delivery vehicle.

[0012] The multiple stage orbital delivery vehicle may further comprise a first oxidizer tank and first oxidizer system in the first stage and a second oxidizer tank and a second oxidizer system in the second stage. The first oxidizer system may comprise a first oxidizer line and the second oxidizer system may comprise a second oxidizer line. The second oxidizer line may be in releasable fluid communication with the first oxidizer line. The engine(s) of the multiple stage orbital delivery vehicle may use a combination of fuel and oxidizer from the first fuel tank and the first oxidizer tank or from the second fuel tank and the second oxidizer tank. In an embodiment, the engine(s) of the multiple stage orbital delivery vehicle may use a combination of fuel and oxidizer from the first fuel tank and the first oxidizer tank when the first stage is connected to the orbital delivery vehicle and use a combination of fuel and oxidizer from the second fuel tank and the second oxidizer tank when the first stage has been disconnected from the orbital delivery vehicle.

[0013] One embodiment is a method of launching a multiple stage orbital delivery vehicle. The method comprises using fuel from a first fuel tank of a lower stage of the orbital delivery vehicle in an engine connected to an upper stage of the orbital delivery vehicle. The lower stage is releasably connected to the orbital delivery vehicle. The method comprises disconnecting the lower stage from the orbital delivery vehicle and using fuel in the engine from a second fuel tank located in the upper stage of the orbital delivery vehicle. The lower stage may be disconnected from the multiple stage orbital delivery vehicle when the first fuel tank becomes empty of fuel. The lower stage may be disconnected from the multiple stage orbital delivery vehicle before it becomes empty of fuel. For example, the lower stage may be disconnected upon the vehicle reaching a predetermined altitude or after a predetermined amount of time has elapsed.

[0014] The method may further comprise dropping the orbital delivery vehicle from an airborne aircraft. The method may further comprise using fuel from a third fuel tank in the engine after disconnecting the lower stage with the third fuel tank being located in a middle stage between the lower stage and the upper stage of the orbital delivery vehicle. The engine may be adapted to use fuel from the third fuel tank prior to disconnecting the lower stage from the orbital delivery vehicle. The engine may be adapted to use fuel from any fuel tank that is connected to the orbital delivery vehicle. The method may include disconnecting the middle stage from the orbital delivery vehicle prior to using fuel from the second fuel tank in the upper stage of the orbital delivery vehicle. The middle stage may be disconnected from the multiple stage orbital delivery vehicle when the third fuel tank becomes empty of fuel. The middle stage may be disconnected from the multiple stage orbital delivery vehicle before it becomes empty of fuel. For example, the middle stage may be disconnected upon the vehicle reaching a predetermined altitude or after a predetermined amount of time has elapsed.

[0015] The method may include opening a payload bay of the upper stage and launching a spacecraft from the payload bay. The method may include flowing fuel through a first fuel line in the lower stage and through a second fuel line in the upper stage to the engine(s). The method may include flowing fuel through a first fuel line in the lower stage and through a second fuel line in the upper stage to the engine(s) and flowing an oxidizer through a first oxidizer line in the lower stage and a second oxidizer line in the upper stage to the engine(s).

[0016] One embodiment of a multiple stage orbital delivery vehicle comprises a first stage comprising a first fuel tank and a first fuel system and a second stage comprising a second fuel tank and a second fuel system. The multiple stage orbital delivery vehicle comprises one or more engines in fluid communication with the first fuel tank and the second fuel tank. The one or more engines are adapted to be shared by the first stage and the second stage. The multiple stage orbital delivery vehicle may further comprise a third stage comprising a third fuel tank and a third fuel system. The third stage may be adapted to share one or more engines with the first stage or the second stage.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] FIG. **1** shows an embodiment of a launch system for a two-stage orbital delivery vehicle.

[0018] FIG. **2** shows an embodiment of a two stage orbital delivery vehicle with the lower stage connected to the upper stage.

[0019] FIG. **3** shows an embodiment of a two stage orbital delivery vehicle with the lower stage disconnected from the upper stage.

[0020] FIG. **4** shows an embodiment of an upper stage of a two stage orbital delivery vehicle with the fairings being jettisons away to reveal the payload.

[0021] FIG. **5** shows an embodiment of an upper stage of a two stage orbital delivery vehicle with the payload being launched from the upper stage.

[0022] FIG. **6** shows a partial cross-section view of an embodiment of a two stage orbital delivery vehicle.

[0023] FIG. **7** shows a partial cross-section view of an embodiment of a multi-stage orbital delivery vehicle.

[0024] FIG. **8** shows a partial cross-section view of an embodiment of a multi-stage orbital delivery vehicle that includes an aerospike engine.

[0025] FIG. **9** shows a partial cross-section view of an embodiment of a two stage orbital delivery vehicle adapted to use a bi-propellant.

[0026] While the disclosure is susceptible to various modifications and alternative forms, specific embodiments have been shown by way of example in the drawings and will be described in detail herein. However, it should be understood that the disclosure is not intended to be limited to the particular forms disclosed. Rather, the intention is to cover all modifications, equivalents and alternatives falling within the scope of the invention as defined by the appended claims.

DETAILED DESCRIPTION

[0027] FIG. **1** shows one embodiment of a launch system **500** comprising an optional launch assist aircraft **510** carrying a multiple stage orbital delivery vehicle **100**. In the illustrated embodiment, the optional launch assist aircraft **510** comprises a Boeing F-15 Eagle fighter aircraft, although those of ordinary skill in the art will appreciate that the optional launch assist aircraft **510** may comprise a wide variety of other suitable aerial vehicles. In some embodiments, the multiple stage orbital delivery vehicle **100** is launched from the optional launch assist aircraft **510** after obtaining a predetermined altitude to assist in the launch of the multiple stage orbital delivery **100** into orbit. In other embodiments, the multiple stage orbital delivery vehicle **100** is adapted to launch off the ground and obtain orbit without the assistance of the optional launch assist aircraft **510**.

[0028] FIG. **2** shows an embodiment of a multiple stage orbital delivery vehicle **100** that includes a first or lower stage **10** connected to a second or upper stage **20**. The depiction of two stages is for illustrative purposes only, as the multiple stage orbital delivery vehicle **100** may include various number of stages necessary for the vehicle **100** to obtain orbit. The upper stage **20** includes one or more engines **25** that burn fuel to provide thrust in launching the multiple stage orbital delivery vehicle **100** into orbit. The multiple stage orbital delivery vehicle **100** may include a single engine having multiple nozzles around the perimeter of the vehicle. The engine(s) **25** may be located around the perimeter of the vehicle **100**. The number of engines **25** and the spacing around the perimeter of the vehicle **100** may be varied as would be appreciated by one or ordinary skill in the art having the benefit of this disclosure.

[0029] In one embodiment only a single stage of the multiple stage orbital vehicle **100** includes an engine **25** (or a plurality of engines **25**). The single stage that includes an engine **25** is the upper stage **20**. In some embodiments (not shown), the upper stage **20** includes a single engine **25** with a plurality of nozzles connected to the single engine **25**. In some embodiments, two stages may share an engine or engines located on the upper stage. With only the upper stage **20** including an engine **25**, the design of the multiple stage orbital delivery vehicle **100** can advantageously be simplified. One or more lower stages **10** can simply comprise fuel tanks that are selectively connected to the upper stage **20** to provide fuel to the engine(s) **25** in the upper stage **20**. Once a lower stage **10** is empty of fuel, the lower stage **10** may be dropped from the multiple stage orbital delivery vehicle **100**. This configuration also permits the vehicle **100** to include only one vehicle attitude control system that is located in the upper stage **10** to control the operation of the engine(s) **25**. The vehicle axial and attitude control system controls a valve (s) in the engine(s) **25** to control the thrust from each individual engine. In operation, the guidance, navigation, and control system **130** (shown in FIG. **6**) controls the combustion of fuel in each engine **25** to adjust the thrust provided by each individual engine **25**, thereby controlling the flight of the multiple stage orbital delivery vehicle **100**.

[0030] FIGS. **3-5** show the multiple stage orbital delivery vehicle **100** dropping the lower stage **10** and launching a payload **40**. The lower stage **10** is typically dropped after the tank in the lower stage **10** has become empty, as shown in FIG. **3**. Although only one lower stage **10** is shown in the illustrated embodiment, the multiple stage orbital delivery vehicle **100** could include multiple lower stages **10** that could also be dropped during the flight of the vehicle **100**. To launch the payload **40**, which may be an orbiting device such as a satellite, from the upper stage **20**, the upper stage **20** may include fairings **30** that are jettisoned away from the upper stage **20** to reveal the payload, as shown in FIG. **4**. The payload **40** may then be deployed from the upper stage **20**, as shown in FIG. **5**.

[0031] FIG. **6** shows a cross-section of an embodiment of a multiple stage orbital delivery vehicle **100** that uses a liquid monopropellant fuel. The lower stage **10** comprises a fuel tank **11** and a fuel line **15** that connects to a fuel line **21** in the upper stage **20** to provide fuel to the engine(s) **25** via lines **22**. Once the fuel tank **11** in the lower stage **10** is dropped from the multiple stage orbital delivery vehicle **100**, the engine(s) **25** will begin to burn fuel from the fuel tank **24** in the upper stage **20** delivered via fuel lines **21** and **22**. The lower stage **10** may be dropped when the fuel tank **11** has become substantially empty. However, the lower stage **10** may be selectively dropped from the multiple stage orbital delivery vehicle **100** prior to the fuel tank **11** becoming substantially empty. The lower end of the fuel line **21** of the upper stage **20** may include a valve **23**, such as a check valve, that prevents downward flow of fuel out of line **21** after the lower stage **10** has been dropped from the multiple stage orbital delivery vehicle **100**.

[0032] The upper stage **20** includes one or more engines **25** that burn fuel from the fuel tanks **11**, **24** in each stage to produce the thrust to launch the multiple stage orbital delivery vehicle **100** into orbit. As discussed above, a guidance, navigation, and control system **130** may be used to control the thrust provided by each individual engine **25** to control the vehicle **100** during flight. The engine(s) **25** may be moved to change the thrust vector. The movement of the each individual engine **25** may also be controlled by the guidance, navigation, and control system **130**.

[0033] The upper stage **20** includes a payload **40**, which may comprise an orbital device such as a satellite, located in a cavity in the upper stage **20**. The upper stage **20** could include a nose cap that is jettisoned away with the fairings **30** to expose the payload **40**. In one embodiment, the guidance, navigation, and control system **130** may be integral with the payload **40** and used to control both the payload **40** after deployment from the upper stage **20**, as well as the operation of the engine(s) **25** during the launch of the vehicle **100**.

[0034] FIG. **7** shows an embodiment of a multiple stage orbital delivery vehicle **200** that includes a first or lower stage **210**, a second or middle stage **270**, and a third or upper stage **220**. The multiple stage orbital delivery vehicle **200** comprises one or more engines **225** located in the upper stage **220** only. The lower stage **210** and middle stage **270** do not include any engines. In the embodiment illustrated in FIG. **7**, the lower stage **210** includes a fuel tank **211** and a fuel line **215** that is connected to a fuel line **275** in the middle stage **270**, which is in turn connected to a fuel line **221** in the upper stage **220**. Fuel lines **222** connect fuel line **221** with the engines **225** of the upper stage **220**.

[0035] In operation, fuel can be delivered from the fuel tank **211** in the lower stage **210** to the engine(s) **225** located on the upper stage **220** via fuel lines **211**, **275**, **221**, and **222**. Once the fuel tank **211** of the lower stage **210** is empty, the lower stage **210** will be dropped from the multiple stage orbital delivery vehicle **200**. The engine(s) **225** of the vehicle **200** will then begin to burn fuel from the fuel tank **271** of the middle stage **270**. Fuel from the fuel tank **271** in the middle stage **270** will be delivered to the engine(s) **225** via fuel lines **275**, **221**, and **222**. Fuel line **275** may include a valve **276**, such as a check valve, at the lower end that prevents the downward flow of fuel out of the end of fuel line **275** after the lower stage **210** has been disconnected from the multiple stage orbital delivery vehicle **200**. Once the fuel tank **271** of the middle stage **270** is empty, the middle stage **270** may be dropped from the vehicle **200**. The engine(s) **225** will then burn fuel from the fuel tank **224** in the upper stage **220**, with the fuel being delivered to the engine(s) **225** via fuel lines **222** and **223**. Fuel line **222** may include a valve **226** that prevents the downward flow of fuel out of the end of fuel line **222**. The upper stage **220** may then launch a payload device in the same manner as discussed above. The multiple stage orbital delivery vehicle **200** may include more stages than three stages as depicted, as would be recognized by one of ordinary skill in the art having the benefit of this disclosure.

[0036] FIG. **8** shows an embodiment of a multiple stage orbital delivery vehicle **300** that includes a lower stage **310** having a fuel tank **311** and fuel line **315** that is connected to a fuel line **321** of the upper stage **320**. In the embodiment shown in FIG. **8**, the upper stage **320** includes an aerospike engine **325** comprising a combustion chamber **323**, throat **324**, and nozzle **326**. Fuel line **321** may be connected directly to the combustion chamber **323**. Alternatively, an additional fuel line may connect fuel line **321** to the combustion chamber **323**. The throat **324** connects the nozzle **326** to the combustion chamber **323**. The nozzle **326** encircles the entire perimeter of the upper stage **320**. The aerospike engine **325** may include a plurality of septums **327** that divide the nozzle **326** into a plurality of sections. The plurality of sections can be controlled by a navigation and guidance system to adjust the thrust of each section controlling the flight of the multiple stage orbital delivery vehicle **300**. As described above, the lower stage **310** of the multiple stage orbital delivery vehicle **300** may be dropped after the fuel tank **311** becomes empty. The fuel line **321** may include a valve **328** to prevent leakage of fuel after the lower stage **310** has been disconnected.

[0037] FIG. **9** shows an embodiment of a multiple stage orbital delivery vehicle **400** that uses a bi-propellant fuel. The multiple stage orbital delivery vehicle **400** includes a lower stage **410** connected to an upper stage **420**. Additional stages could be connected to the multiple stage orbital delivery vehicle **400**, as would be appreciated by one of ordinary skill in the art. The multiple stage orbital delivery vehicle **400** comprises one or more engines **425** located in the upper stage **420** only. The lower stage **410** does not include any engines.

[0038] The lower stage **410** includes an oxidizer tank **411** with an oxidizer line **413** connected to a manifold **431** in the upper stage **420**. The lower stage **410** also includes a fuel tank **412** with a fuel line **414** connected to a the manifold **431** in the upper stage **420**. A bulkhead or wall **415** divides the lower stage into an oxidizer tank **411** and a fuel tank **412**. In operation, the oxidizer in the oxidizer tank **411** is delivered to the engine(s) **425** on the upper stage **420** via oxidizer line **413**, manifold **431**, and lines **432** and the fuel in the fuel tank **412** is delivered to the engine(s) **425** on the upper stage **420** via fuel line **414**, manifold **431**, and lines **432**.

[0039] Thrust is provided by the combination of the oxidizer and the fuel at the engine(s) **425** of the upper stage **420**. The thrust of each engine **425** may be controlled by the guidance, navigation, and control system **430**, which may comprise a conventional navigation and guidance system that may be incorporated into a payload device in the upper stage **420**. Once the oxidizer tank **411** and fuel tank **412** are empty, the lower stage **410** will be dropped from the upper stage **420**. Oxidizer line **413** and fuel line **414** are adapted to break apart when the lower stage **410** is dropped from the upper stage **410** with a portion of the lines remaining in the upper stage **410**. The upper portion of lines **413** and **414** may include valves **426** and **427** that prevent the downward flow of oxidizer and fuel out of tanks **421** and **422** upon the separation of the lower stage **410** from the upper stage **420**. After the lower stage **410** is disconnected from the upper stage **420**, oxidizer will be delivered to the engine(s) **425** from oxidizer tank **421** via oxidizer line **423**, manifold **433**, and lines **434**. Likewise, fuel will be delivered to the engine(s) **425** from fuel tank **422** via fuel line **424**, manifold **433**, and lines **434**. A bulk head or wall **428** divides the upper stage into an oxidizer tank **421** and a fuel tank **422**. The configuration of the oxidizer and fuel tanks is for illustrative purposes and may be varied.

[0040] Although this invention has been described in terms of certain preferred embodiments, other embodiments that are apparent to those of ordinary skill in the art, including embodiments that do not provide all of the features and advantages set forth herein, are also within the scope of this invention. Accordingly, the scope of the present invention is defined only by reference to the appended claims and equivalents thereof.

1. A method of launching a multiple stage orbital delivery vehicle, the method comprising:

burning fuel from a first fuel tank of a lower stage of the orbital delivery vehicle in an engine connected to an upper stage of the orbital delivery vehicle while the lower stage is connected to the orbital delivery vehicle, the lower stage being releasably connected to the orbital delivery vehicle, wherein the lower stage is coaxial with the upper stage;

disconnecting the lower stage from the orbital delivery vehicle; and

burning fuel in the engine from a second fuel tank located in the upper stage of the orbital delivery vehicle.

2. The method of claim **1** further comprising dropping the orbital delivery vehicle from an airborne aircraft.

3. The method of claim **1** further comprising burning fuel from a third fuel tank in the engine, the third fuel tank being located in a middle stage between the lower stage and the upper stage of the orbital delivery vehicle.

4. The method of claim **3** further comprising disconnecting the middle stage from the orbital delivery vehicle prior to burning fuel from the second fuel tank of the upper stage.

5. The method of claim **1** further comprising:

opening a payload bay of the upper stage; and

launching a spacecraft from the payload bay of the upper stage.

6. The method of claim **1**, wherein burning fuel from the first fuel tank of the lower stage further comprises flowing fuel through a first fuel line in the lower stage and through a second fuel line in the upper stage to the engine.

7. The method of claim **1**, wherein burning fuel from the first fuel tank of the lower stage further comprises:

flowing fuel through a first fuel line in the lower stage and through a second fuel line in the upper stage to the engine; and

flowing an oxidizer through a first oxidizer line in the lower stage and a second oxidizer line in the upper stage to the engine.

8. A method of launching a multiple stage orbital delivery vehicle, the method comprising:

burning fuel from a first fuel tank of a lower stage of the orbital delivery vehicle in an engine connected to an upper stage of the orbital delivery vehicle while the lower stage is connected to the orbital delivery vehicle, the lower stage being releasably connected to the orbital delivery vehicle, wherein the lower stage is below the upper stage in reference to the direction of travel of the orbital delivery vehicle from the engine;

disconnecting the lower stage from the orbital delivery vehicle; and

burning fuel in the engine from a second fuel tank located in the upper stage of the orbital delivery vehicle.

9. The method of claim **8** further comprising dropping the orbital delivery vehicle from an airborne aircraft.

10. The method of claim **8** further comprising burning fuel from a third fuel tank in the engine, the third fuel tank being located in a middle stage between the lower stage and the upper stage of the orbital delivery vehicle.

11. The method of claim **10** further comprising disconnecting the middle stage from the orbital delivery vehicle prior to burning fuel from the second fuel tank of the upper stage.

12. The method of claim **8** further comprising:

opening a payload bay of the upper stage; and

launching a spacecraft from the payload bay of the upper stage.

13. The method of claim **8**, wherein burning fuel from the first fuel tank of the lower stage further comprises flowing fuel through a first fuel line in the lower stage and through a second fuel line in the upper stage to the engine.

14. The method of claim **8**, wherein burning fuel from the first fuel tank of the lower stage further comprises:

flowing fuel through a first fuel line in the lower stage and through a second fuel line in the upper stage to the engine; and

flowing an oxidizer through a first oxidizer line in the lower stage and a second oxidizer line in the upper stage to the engine.

15. A method of launching a multiple stage orbital delivery vehicle, the method comprising:

burning fuel from a first fuel tank of a lower stage of the orbital delivery vehicle in an engine connected to an upper stage of the orbital delivery vehicle while the lower stage is connected to the orbital delivery vehicle to provide thrust to move the orbital delivery vehicle in a first direction, the lower stage being releasably connected to the orbital delivery vehicle, wherein the lower stage is below the upper stage in reference to the first direction;

disconnecting the lower stage from the orbital delivery vehicle; and

burning fuel in the engine from a second fuel tank located in the upper stage of the orbital delivery vehicle.

16. The method of claim **15** further comprising burning fuel from a third fuel tank in the engine, the third fuel tank being located in a middle stage between the lower stage and the upper stage of the orbital delivery vehicle.

17. The method of claim **16** further comprising disconnecting the middle stage from the orbital delivery vehicle prior to burning fuel from the second fuel tank of the upper stage.

18. The method of claim **15** further comprising:

opening a payload bay of the upper stage; and

launching a spacecraft from the payload bay of the upper stage.

19. The method of claim **15**, wherein burning fuel from the first fuel tank of the lower stage further comprises flowing fuel through a first fuel line in the lower stage and through a second fuel line in the upper stage to the engine.

20. The method of claim **15**, wherein burning fuel from the first fuel tank of the lower stage further comprises:

flowing fuel through a first fuel line in the lower stage and through a second fuel line in the upper stage to the engine; and

flowing an oxidizer through a first oxidizer line in the lower stage and a second oxidizer line in the upper stage to the engine.

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