US008678321B2

(12) **United States Patent**
Bezos et al.

(10) **Patent No.: US 8,678,321 B2**
(45) **Date of Patent: Mar. 25, 2014**

(54) **SEA LANDING OF SPACE LAUNCH VEHICLES AND ASSOCIATED SYSTEMS AND METHODS**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 533 days.

(21) Appl. No.: **12/815,306**

(22) Filed: **Jun. 14, 2010**

(65) **Prior Publication Data**

US 2011/0017872 A1 Jan. 27, 2011

Related U.S. Application Data

(60) Provisional application No. 61/218,029, filed on Jun. 17, 2009, provisional application No. 61/187,243, filed on Jun. 15, 2009.

(51) **Int. Cl.**
B64G 1/00 (2006.01)

(52) **U.S. Cl.**
USPC .... **244/158.9**; 244/114 R; 244/158.1; 114/261

(58) **Field of Classification Search**
USPC ..... 244/158.9, 158.1, 3.1, 110 D, 7 B, 114 R, 244/110 E, 171.3, 171.6; 114/258, 261
See application file for complete search history.

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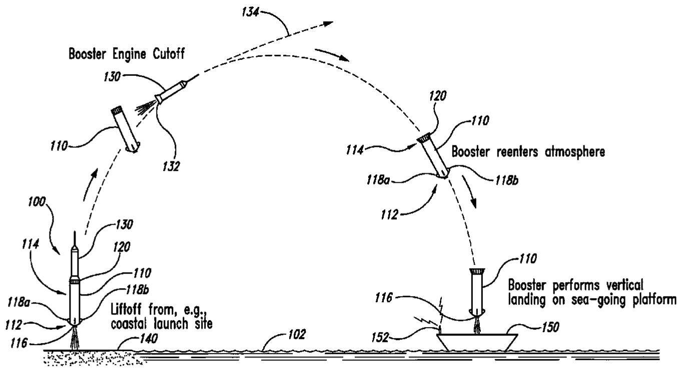
(57) **ABSTRACT**

Launch vehicle systems and methods for landing and recovering a booster stage and/or other portions thereof on a platform at sea or on another body of water are disclosed. In one embodiment, a reusable space launch vehicle is launched from a coastal launch site in a trajectory over water. After booster engine cutoff and upper stage separation, the booster stage reenters the earth's atmosphere in a tail-first orientation. The booster engines are then restarted and the booster stage performs a vertical powered landing on the deck of a pre-positioned sea-going platform. In one embodiment, bidirectional aerodynamic control surfaces control the trajectory of the booster stage as it glides through the earth's atmosphere toward the sea-going platform. The sea-going platform can broadcast its real-time position to the booster stage so that the booster stage can compensate for errors in the position of the sea-going platform due to current drift and/or other factors. After landing, the sea-going platform can be towed by, e.g., a tug, or it can use its own propulsion system, to transport the booster stage back to the coastal launch site or other site for reconditioning and reuse. In another embodiment, the booster stage can be transferred to another vessel for transport. In still further embodiments, the booster can be refurbished while in transit from a sea-based or other landing site.

15 Claims, 2 Drawing Sheets



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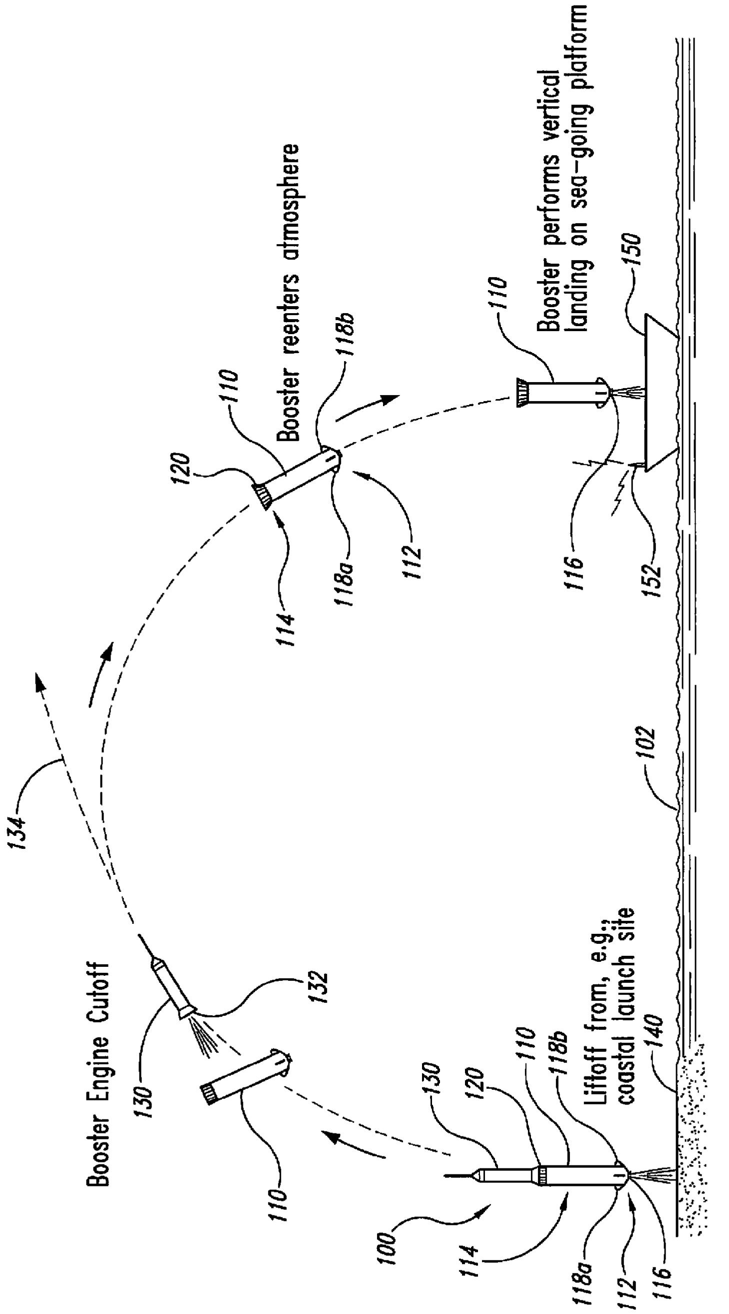
Booster Engine Cutoff
Booster reenters atmosphere
Booster performs vertical
landing on sea-going platform
Liftoff from, e.g.,
coastal launch site
100
102
110
112
114
116
118a
118b
120
130
132
134
140
150
152

Fig. 1

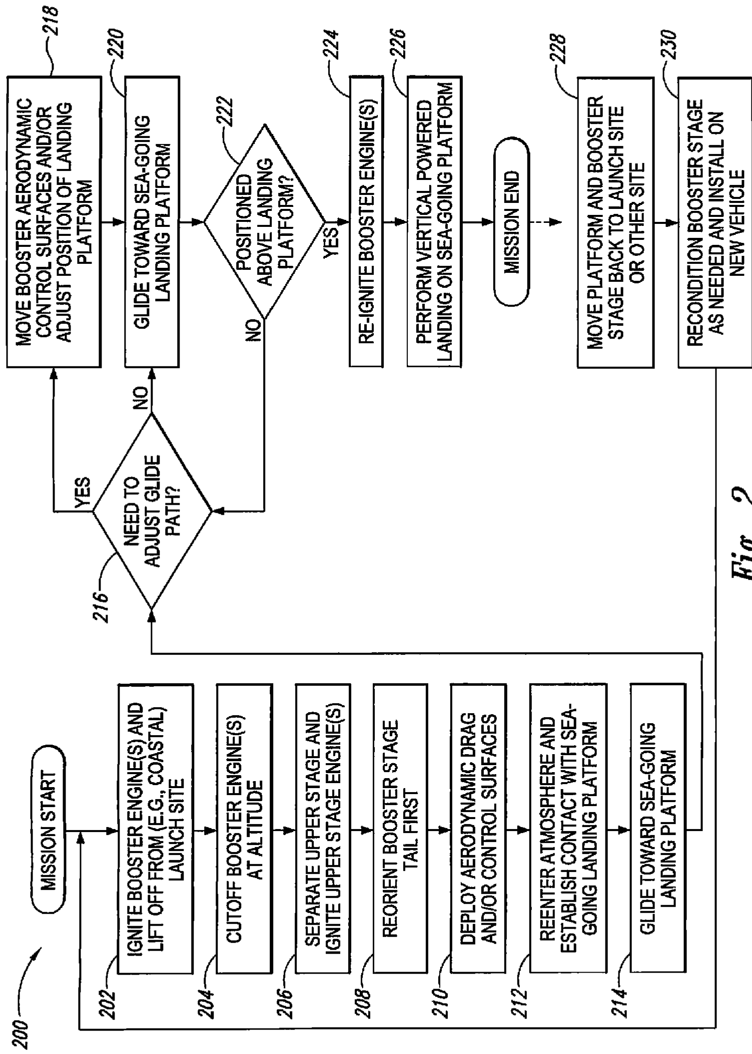
200
MISSION START
202
IGNITE BOOSTER ENGINE(S) AND LIFT OFF FROM (E.G., COASTAL) LAUNCH SITE
204
CUTOFF BOOSTER ENGINE(S) AT ALTITUDE
206
SEPARATE UPPER STAGE AND IGNITE UPPER STAGE ENGINE(S)
208
REORIENT BOOSTER STAGE TAIL FIRST
210
DEPLOY AERODYNAMIC DRAG AND/OR CONTROL SURFACES
212
REENTER ATMOSPHERE AND ESTABLISH CONTACT WITH SEA-GOING LANDING PLATFORM
214
GLIDE TOWARD SEA-GOING LANDING PLATFORM
216
NEED TO ADJUST GLIDE PATH?
YES
NO
218
MOVE BOOSTER AERODYNAMIC CONTROL SURFACES AND/OR ADJUST POSITION OF LANDING PLATFORM
220
GLIDE TOWARD SEA-GOING LANDING PLATFORM
222
POSITIONED ABOVE LANDING PLATFORM?
NO
YES
224
RE-IGNITE BOOSTER ENGINE(S)
226
PERFORM VERTICAL POWERED LANDING ON SEA-GOING PLATFORM
MISSION END
228
MOVE PLATFORM AND BOOSTER STAGE BACK TO LAUNCH SITE OR OTHER SITE
230
RECONDITION BOOSTER STAGE AS NEEDED AND INSTALL ON NEW VEHICLE

Fig. 2

SEA LANDING OF SPACE LAUNCH VEHICLES AND ASSOCIATED SYSTEMS AND METHODS

CROSS-REFERENCE TO RELATED APPLICATIONS INCORPORATED BY REFERENCE

The present application claims priority to U.S. Provisional Patent Application No. 61/218,029, filed Jun. 17, 2009 and titled "SEA LANDING OF SPACE LAUNCH VEHICLES AND ASSOCIATED SYSTEMS AND METHODS, INCLUDING EN ROUTE VEHICLE REFURBISHMENT," and U.S. Provisional Patent Application No. 61/187,243, filed Jun. 15, 2009 and titled "SEA LANDING OF SPACE LAUNCH VEHICLES AND ASSOCIATED SYSTEMS AND METHODS," both of which are incorporated herein in their entireties by reference.

The present application incorporates the subject matter of the following patent applications in their entireties by reference: U.S. Provisional Patent Application No. 61/155,115, filed Feb. 24, 2009 and titled "ROCKETS WITH DEPLOYABLE FLARE SURFACES, AND ASSOCIATED SYSTEMS AND METHODS;" U.S. Non-provisional patent application Ser. No. 12/712,156, filed Feb. 24, 2010 and titled "LAUNCH VEHICLES WITH FIXED AND DEPLOYABLE DECELERATION SURFACES, AND/OR SHAPED FUEL TANKS, AND ASSOCIATED SYSTEMS AND METHODS;" U.S. Provisional Patent Application No. 61/187,268, filed Jun. 15, 2009 and titled "BIDIRECTIONAL CONTROL SURFACES FOR USE WITH HIGH SPEED VEHICLES, AND ASSOCIATED SYSTEMS AND METHODS;" and U.S. Non-provisional patent application Ser. No. 12/712,083, filed Feb. 24, 2010 and titled "BIDIRECTIONAL CONTROL SURFACES FOR USE WITH HIGH SPEED VEHICLES, AND ASSOCIATED SYSTEMS AND METHODS."

TECHNICAL FIELD

The present disclosure relates generally to space launch vehicles and, more particularly, to systems and methods for landing space launch vehicles at sea, and/or refurbishing such vehicles en route from a landing site.

BACKGROUND

Rocket powered launch vehicles have been used for many years to carry human and non-human payloads into space. Rockets delivered the first humans to the moon, and have launched many satellites into earth orbit, unmanned space probes, and supplies and personnel to the orbiting international space station.

Despite the rapid advances in manned and unmanned space flight, delivering astronauts, satellites, and other payloads to space continues to be an expensive proposition. One reason for this is that most conventional launch vehicles are only used once, and hence are referred to as "expendable launch vehicles" or "ELVs." The advantages of reusable launch vehicles (RLVs) include the potential of providing low cost access to space.

Although NASA's space shuttle is largely reusable, reconditioning the reusable components is a costly and time consuming process that requires extensive ground based infrastructure. Moreover, the additional shuttle systems required for reentry and landing reduce the payload capability of the shuttle. As commercial pressures increase, the need remains for lower-cost access to space for both human and non-human payloads.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic diagram illustrating a mission profile of a space launch vehicle that lands on a sea-going platform in accordance with an embodiment of the disclosure.

FIG. **2** is a flow diagram illustrating a routine for launching a space launch vehicle from a land-based or other launch site and landing the space launch vehicle on a sea-going platform in accordance with an embodiment of the disclosure.

DETAILED DESCRIPTION

Certain aspects of the present disclosure are directed generally to vertical powered landings of reusable launch vehicles on sea-going platforms, and associated systems and methods. Other aspects of the disclosure relate to refurbishing reusable launch vehicles en route from a sea-based or other landing site. Certain details are set forth in the following description and in FIGS. **1** and **2** to provide a thorough understanding of various embodiments of the disclosure. Those of ordinary skill in the relevant art will appreciate, however, that other embodiments having different configurations, arrangements, and/or components may be practiced without several of the details described below. In particular, other embodiments of the disclosure may include additional elements, or may lack one or more of the elements or features described below with reference to FIGS. **1** and **2**. Moreover, several details describing structures and processes that are well-known and often associated with space launch vehicles and launching and landing space launch vehicles are not set forth in the following description to avoid unnecessarily obscuring the various embodiments of the disclosure.

In the Figures, identical reference numbers identify identical or at least generally similar elements. To facilitate the discussion of any particular element, the most significant digit or digits of any reference number refers to the Figure in which that element is first introduced. For example, element **110** is first introduced and discussed with reference to FIG. **1**.

Space launch vehicles are typically launched from coastal launch sites along flight corridors that take them out and over the ocean for much of their trajectory. This trajectory avoids exposing the public to the potential risks associated with rocket overflight, and results in the booster stage falling into the water. Water landings, however, make reuse of the booster stage costly and difficult for a number of reasons. For example, sea water can be very corrosive to rocket components. Moreover, many of the rocket components get very hot during use, and quenching these hot components in cold sea water can result in cracking and other forms of damage. Recovery and reuse of solid rocket stages after water landings with a parachute is feasible because a solid rocket motor is little more than an empty casing after firing. Liquid-fueled rocket stages, however, are considerably more complex. As a result, few, if any liquid-fueled rocket stages have been reused after water landings.

Concepts exist for landing a booster stage on land. These concepts include landing the booster stage horizontally, like an airplane, or vertically, under its own power or by parachute or other means. All of these approaches, however, limit operational flexibility because they require a ground landing site for every launch azimuth and potential downrange landing area.

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