US007066430B2

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

(10) **Patent No.: US 7,066,430 B2**
(45) **Date of Patent: Jun. 27, 2006**

(54) **METHODS AND APPARATUSES FOR CAPTURING AND RECOVERING UNMANNED AIRCRAFT, INCLUDING EXTENDABLE CAPTURE DEVICES**

(75) Inventors: **Brian D. Dennis**, White Salmon, WA (US); **Clifford Jackson**, White Salmon, WA (US); **Brian T. McGeer**, Underwood, WA (US); **Andreas H. von Flotow**, Hood River, OR (US)

(73) Assignee: **The Insitu Group, Inc.**, Bingen, WA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **10/758,956**

(22) Filed: **Jan. 16, 2004**

(65) **Prior Publication Data**

US 2006/0102783 A1 May 18, 2006

Related U.S. Application Data

(60) Provisional application No. 60/440,845, filed on Jan. 17, 2003.

(51) **Int. Cl.**
B64F 1/02 (2006.01)

(52) **U.S. Cl.** .... **244/110 F**; 244/115

(58) **Field of Classification Search** 244/110 R–110 F, 244/115–116; 114/231, 258–262, 230.1; 212/297; 254/323
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

965,881	A	8/1910	Draper
968,339	A	8/1910	Geraldson
975,953	A	11/1910	Hourwich
1,144,505	A	6/1915	Steffan
1,383,595	A	7/1921	Black
1,428,163	A	9/1922	Harriss
1,499,472	A	7/1924	Hazen
1,530,010	A	3/1925	Neilson
1,556,348	A	10/1925	Ray et al.
1,624,188	A	4/1927	Simon
1,634,964	A	7/1927	Steinmetz
1,680,473	A	8/1928	Parker
1,686,298	A	10/1928	Uhl
1,712,164	A	5/1929	Peppin
1,716,670	A	6/1929	Sperry
1,731,091	A	10/1929	Belleville
1,737,483	A	11/1929	Verret
1,738,261	A	12/1929	Perkins

(Continued)

FOREIGN PATENT DOCUMENTS

DE 4301671 A1 7/1993

(Continued)

OTHER PUBLICATIONS

U.S. Appl. No. 10/758,940, Dennis.

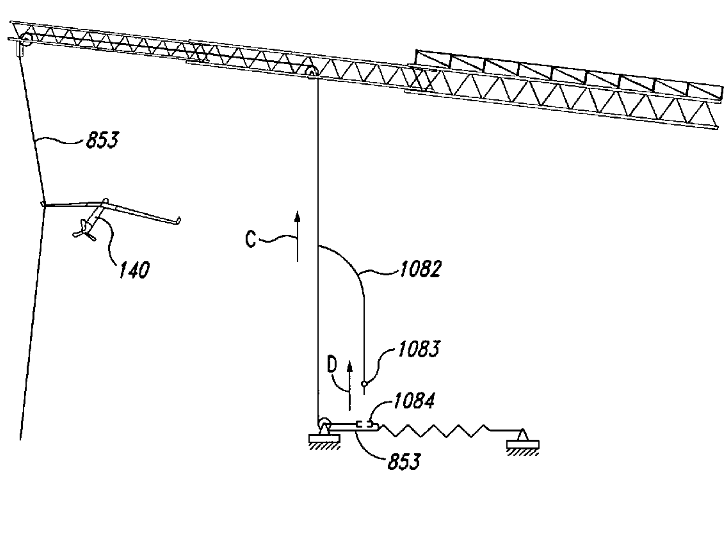
(Continued)

Primary Examiner—Galen Barefoot
(74) *Attorney, Agent, or Firm*—Perkins Coie, LLP

(57) **ABSTRACT**

Methods and apparatuses for capturing and recovering unmanned aircraft and other flight devices or projectiles are described. In one embodiment, the aircraft can be captured at an extendable boom. The boom can be extended to deploy a recovery line to retrieve the aircraft in flight. The boom can be retracted when not in use to reduce the volume it occupies. A tension device coupled to the recovery line can absorb forces associated with the impact of the aircraft and the recovery line.

33 Claims, 26 Drawing Sheets



U.S. PATENT DOCUMENTS

1,748,663	A	2/1930	Tucker	
1,756,747	A *	4/1930	Holland	244/63
1,777,167	A	9/1930	Forbes	
1,836,010	A	12/1931	Audrain	
1,842,432	A	1/1932	Stanton	
1,869,506	A	8/1932	Richardson	
1,892,357	A	12/1932	Moe	
1,912,723	A	6/1933	Perkins	
1,925,212	A	9/1933	Steiber	
1,940,030	A	12/1933	Steiber	
1,960,264	A	5/1934	Heinkel	
2,333,559	A	11/1943	Grady et al.	
2,347,561	A	4/1944	Howard et al.	
2,360,220	A	10/1944	Goldman	
2,364,527	A	12/1944	Haygood	
2,365,778	A	12/1944	Schwab	
2,365,827	A	12/1944	Liebert	
2,380,702	A	7/1945	Persons	
2,390,754	A *	12/1945	Valdene	244/110 F
2,435,197	A	2/1948	Brodie	
2,436,240	A	2/1948	Wiertz	
2,448,209	A	2/1948	Boyer et al.	
2,465,936	A	3/1949	Schultz	
2,488,050	A	11/1949	Brodie	
2,515,205	A	7/1950	Fieux	
2,526,348	A	10/1950	Gouge	
2,669,403	A	2/1954	Milligan	
2,735,391	A	2/1956	Buschers	
2,814,453	A	11/1957	Trimble et al.	
2,843,342	A	7/1958	Ward	
2,844,340	A	7/1958	Daniels et al.	
2,908,240	A	10/1959	Hodge	
2,919,871	A	1/1960	Sorensen	
2,933,183	A	4/1960	Koelsch	
3,069,118	A	12/1962	Bernard	
RE25,406	E	6/1963	Byrne et al.	
3,268,090	A *	8/1966	Wirkkala	254/323
3,454,244	A	7/1969	Walander	
3,468,500	A	9/1969	Carlsson	
3,484,061	A	12/1969	Niemkiewicz	
3,516,626	A	6/1970	Strance et al.	
3,684,219	A	8/1972	King	
3,708,200	A	1/1973	Richards	
3,765,625	A	10/1973	Myhr et al.	
3,827,660	A	8/1974	Doolittle	
3,939,988	A *	2/1976	Wellman	212/297
3,943,657	A	3/1976	Leckie	
3,980,259	A	9/1976	Greenhalgh et al.	
4,067,139	A	1/1978	Pinkerton et al.	
4,079,901	A	3/1978	Mayhew et al.	
4,143,840	A	3/1979	Bernard et al.	
4,147,317	A *	4/1979	Mayhew et al.	244/116
D256,816	S	9/1980	McMahon et al.	
4,236,686	A	12/1980	Barthelme et al.	
4,238,093	A	12/1980	Siegel et al.	
4,279,195	A	7/1981	Miller	
4,311,290	A	1/1982	Koper	
4,408,737	A	10/1983	Schwaerzler	
4,471,923	A	9/1984	Hoppner et al.	
4,523,729	A	6/1985	Frick	
4,566,658	A	1/1986	DiGiovanniantonio et al.	
4,678,143	A	7/1987	Griffin	
4,730,793	A	3/1988	Thurber, Jr. et al.	
4,753,400	A	6/1988	Reuter et al.	
4,809,933	A *	3/1989	Buzby et al.	244/110 C
4,842,222	A	6/1989	Baird	
4,909,458	A	3/1990	Martin	
4,979,701	A	12/1990	Colarik et al.	
5,007,875	A	4/1991	Dasa	
5,039,034	A	8/1991	Burgess et al.	
5,042,750	A	8/1991	Winter	
5,054,717	A *	10/1991	Taylor	244/110 F
5,109,788	A	5/1992	Heinzmann	
5,119,935	A	6/1992	Stump et al.	
5,253,605	A	10/1993	Collins	
5,253,606	A	10/1993	Ortelli	
5,509,624	A	4/1996	Takahashi	
5,583,311	A	12/1996	Rieger	
5,655,944	A	8/1997	Fusselman	
5,687,930	A	11/1997	Wagner et al.	
5,906,336	A	5/1999	Eckstein	
6,264,140	B1	7/2001	McGeer et al.	
6,457,673	B1	10/2002	Miller	
6,478,650	B1	11/2002	Tsai	
2002/0100838	A1	8/2002	McGeer et al.	
2003/0222173	A1	12/2003	McGeer et al.	
2005/0133665	A1	6/2005	Dennis et al.	

FOREIGN PATENT DOCUMENTS

FR	854371	4/1940
GB	2 080 216 A	2/1982
GB	2 150 895 A	7/1985
GB	2 219 777 A	12/1989
JP	07-304498	11/1995
WO	WO 00/75014 A1	12/2000
WO	WO 01/07318 A1	2/2001

OTHER PUBLICATIONS

U.S. Appl. No. 10/758,943, Dennis et al.
U.S. Appl. No. 10/758,948, Dennis et al.
U.S. Appl. No. 10/758,955, McGeer et al.
U.S. Appl. No. 10/759,541, McGeer.
U.S. Appl. No. 10/759,545, Dennis et al.
U.S. Appl. No. 10/759,742, Dennis.
U.S. Appl. No. 10/760,150, Roeseler et al.
U.S. Appl. No. 10/808,725, McGeer et al.
U.S. Appl. No. 10/813,906, Roeseler.
Robinson, Russell Norman, "Dynamic Analysis of a Carousel Remotely Piloted Vehicle Recovery System," master's thesis, Naval Post-Graduate School, Monterey, California, Dec. 1977, Thesis No. ADA052401.
Dickard, H. E. "Mini-RPV Recovery System Conceptual Study," final report, U. S. Army Air Mobility Research and Development Laboratory, Fort Eustis, Virginia, Aug. 1977, Contract DAAJ02-76-C-0048, Report No. USAAMRDL-TR-77-24.
Whitmore, Stephen A. et al., "Development of a Closed-Loop Strap Down Attitude System for an Ultrahigh Altitude Flight Experiment," technical memorandum, NASA Dryden Flight Research Center, Edwards, California, Jan. 1997, Report No. NASA TM-4775.
U.S. Appl. No. 10/759,742, filed Jan. 16, 2004, Dennis.
"Ames Builds Advanced Yawed-Wing RPV," Aviation Week and Space Technology, Jan. 22, 1973, p. 73.

* cited by examiner

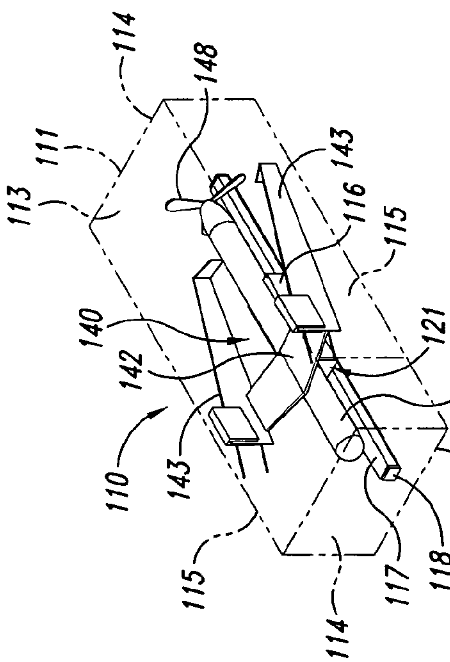


Fig. 1A

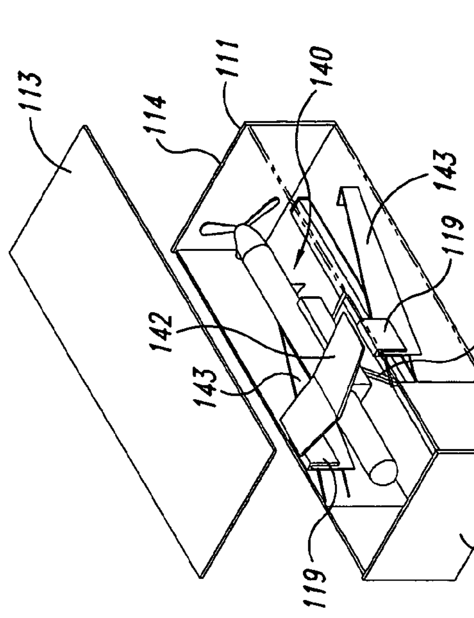


Fig. 1B

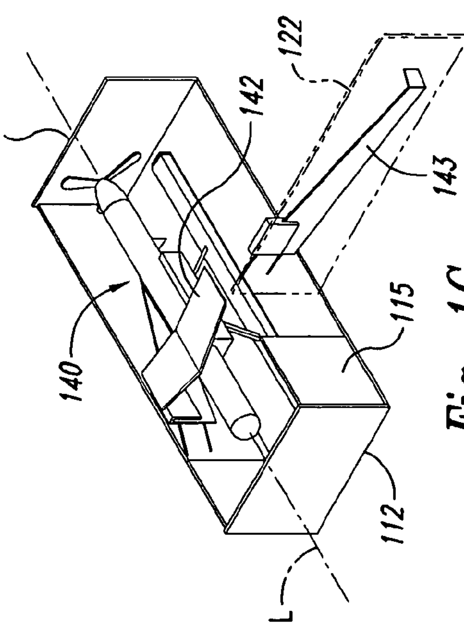


Fig. 1C

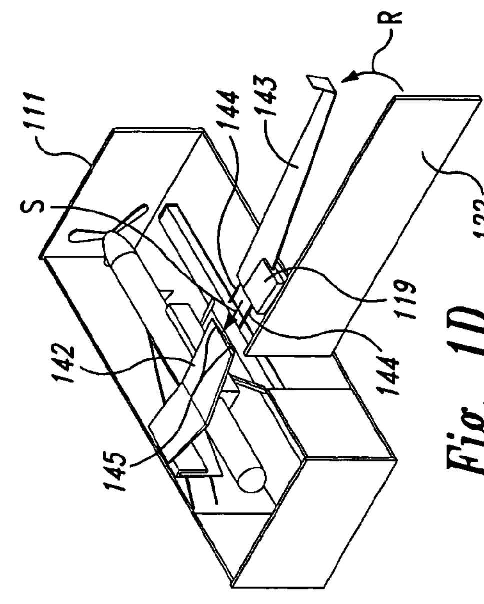


Fig. 1D

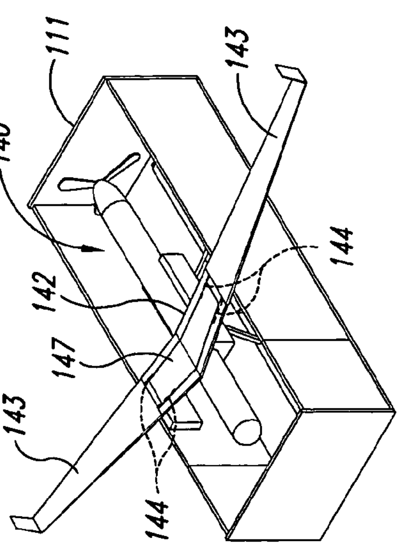


Fig. 1E

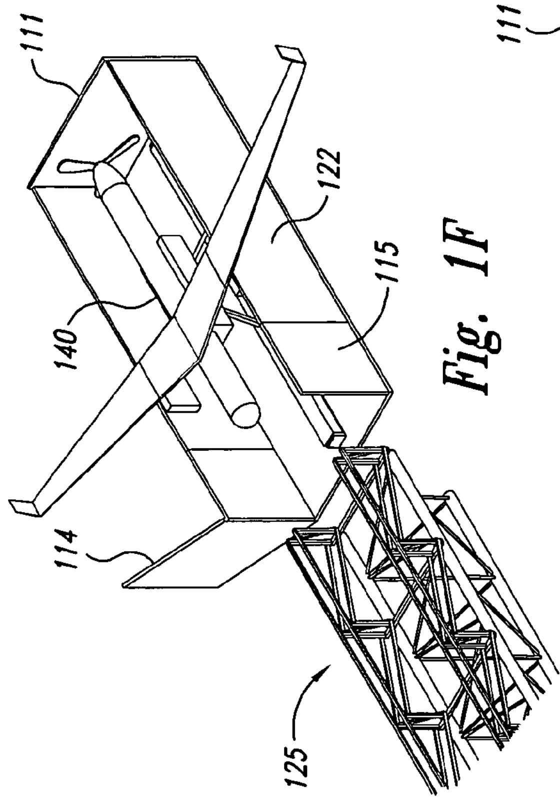


Fig. 1F

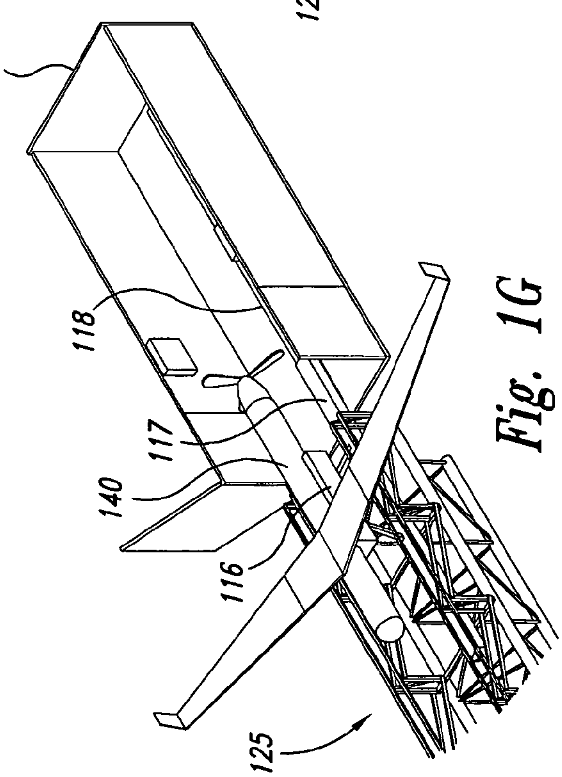


Fig. 1G

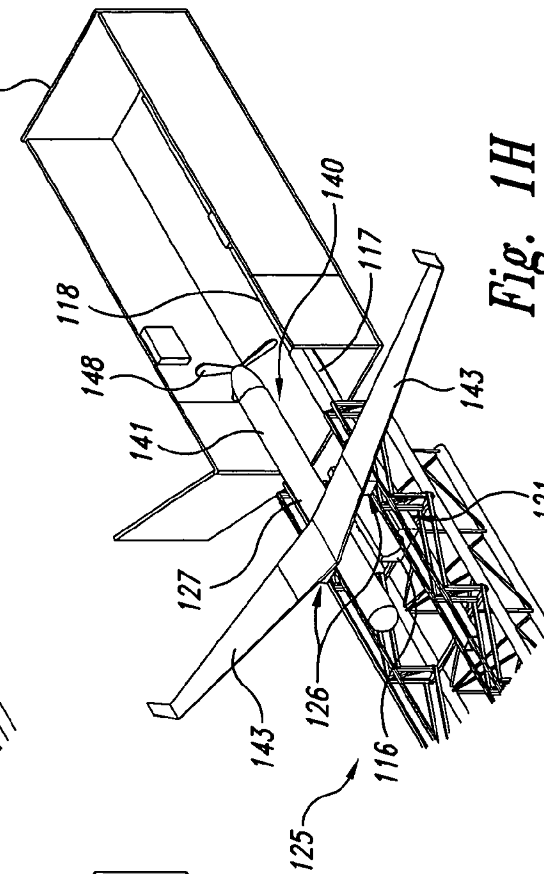


Fig. 1H

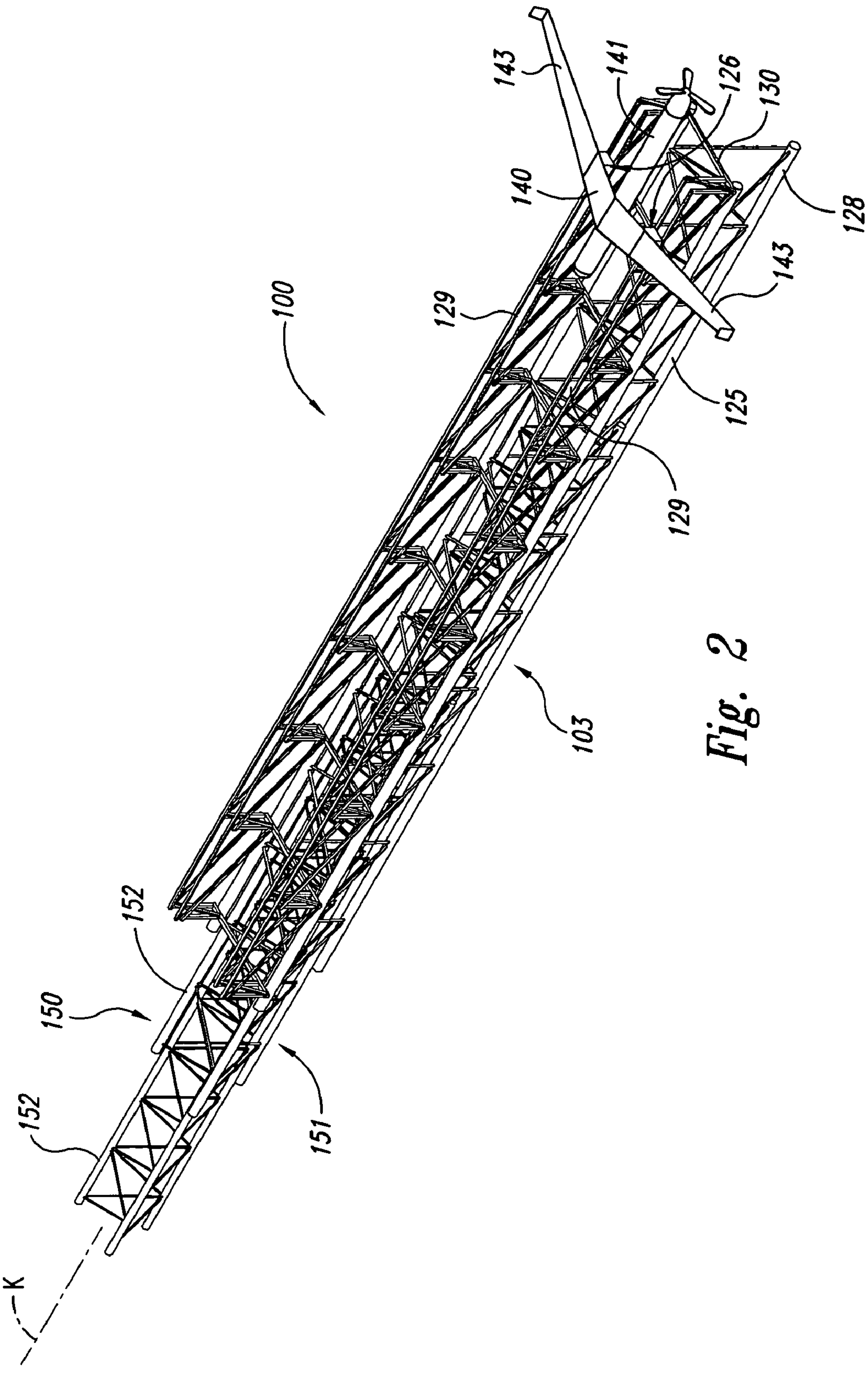


Fig. 2

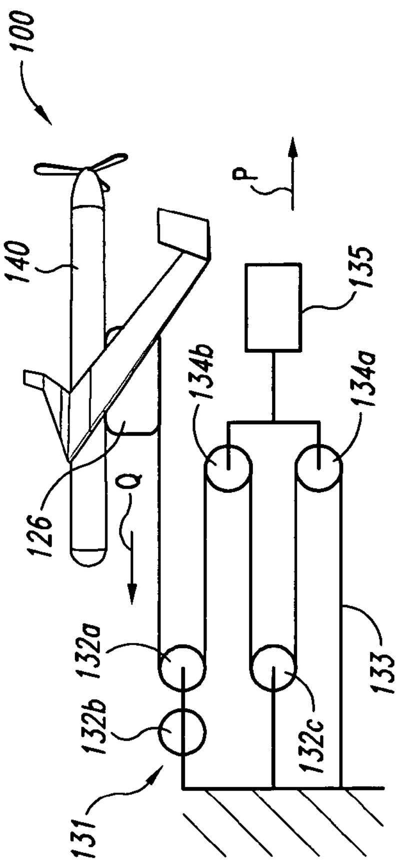

100
140
P
135
134b
134a
126
Q
132a
132b
132c
133
131

Fig. 3A

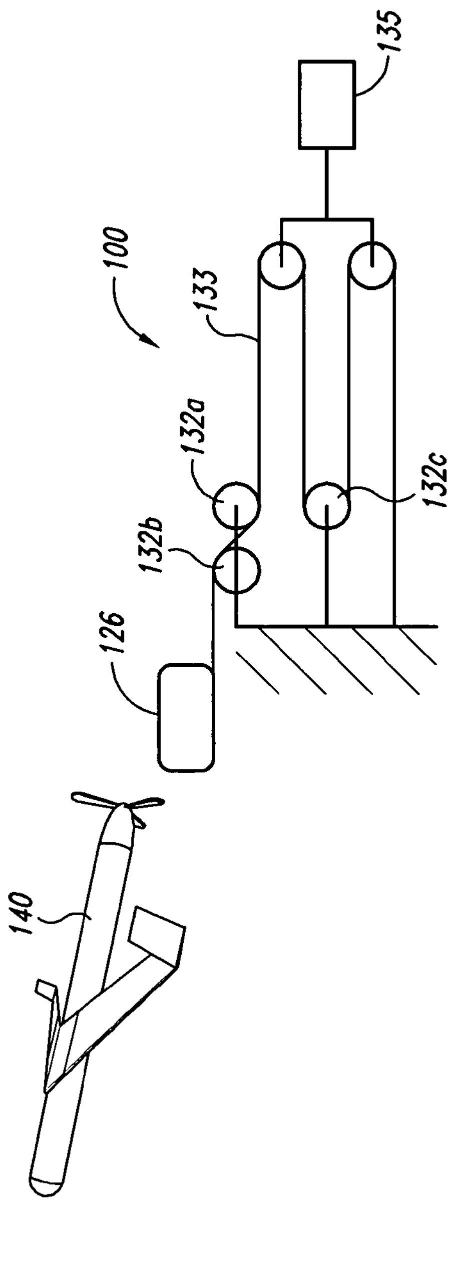

135
100
133
132a
132b
132c
126
140

Fig. 3B

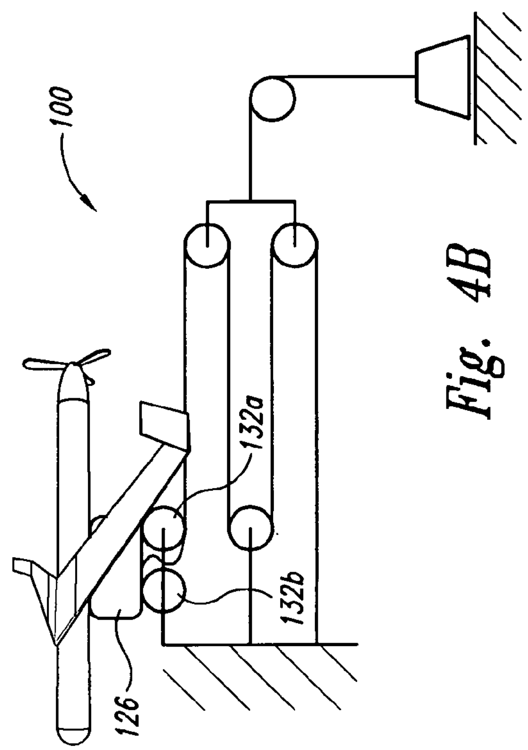


Fig. 4B

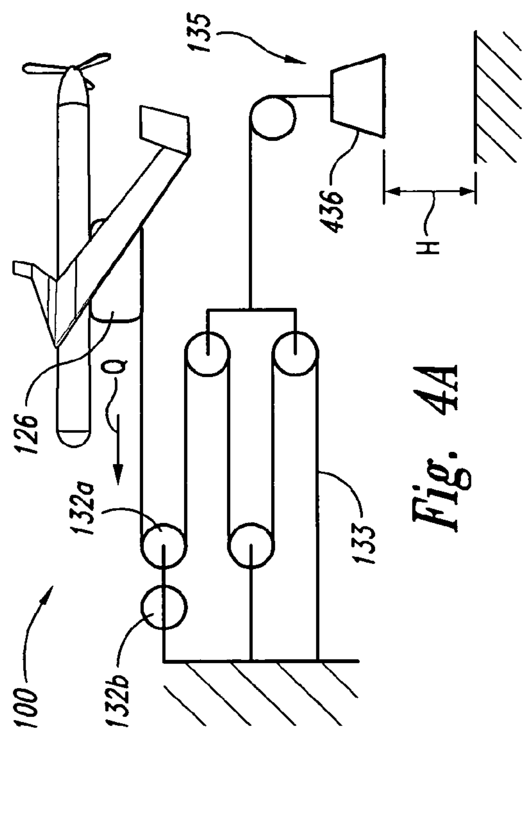


Fig. 4A

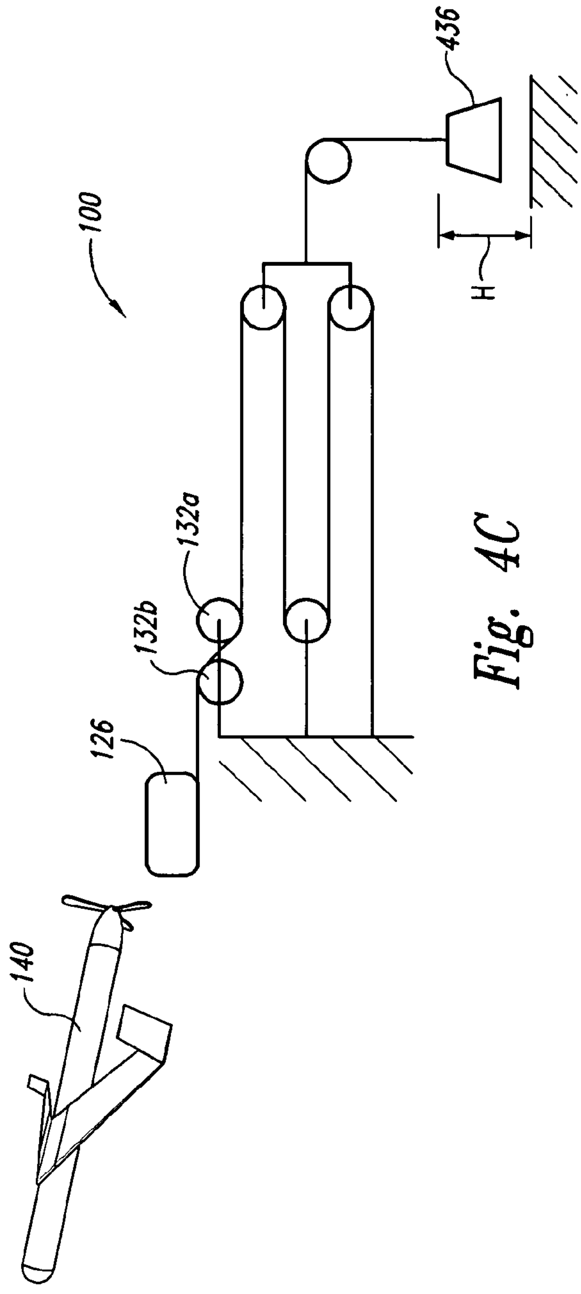


Fig. 4C

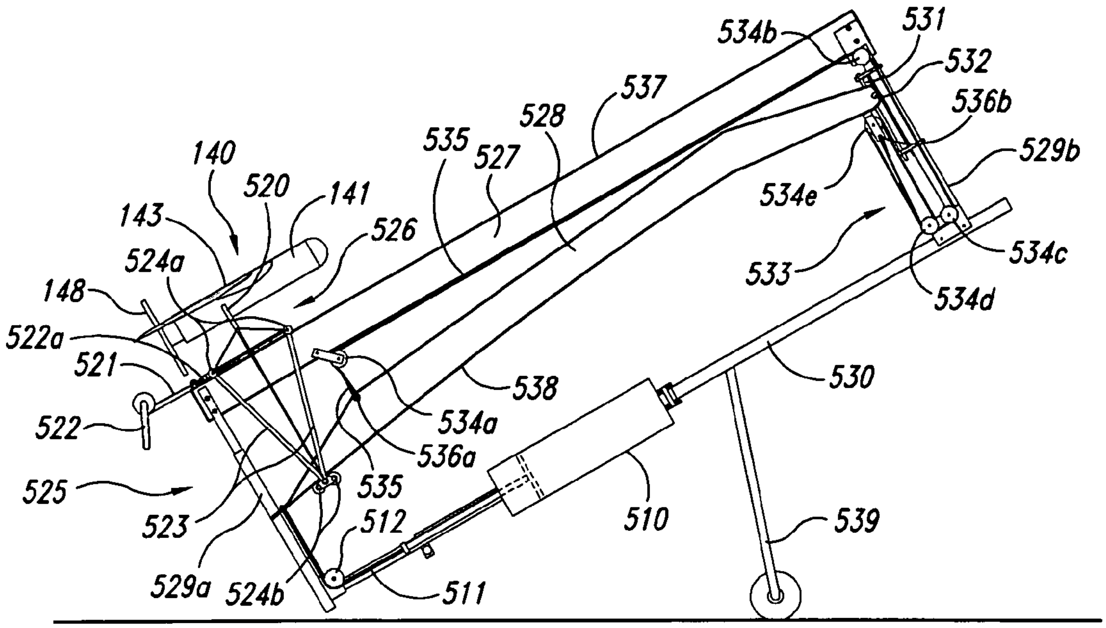

534b
531
532
537
536b
528
535
527
529b
140
534e
520
141
143
526
533
534c
524a
148
534d
522a
521
538
530
534a
522
536a
535
525
510
523
512
539
529a
524b
511

Fig. 5A

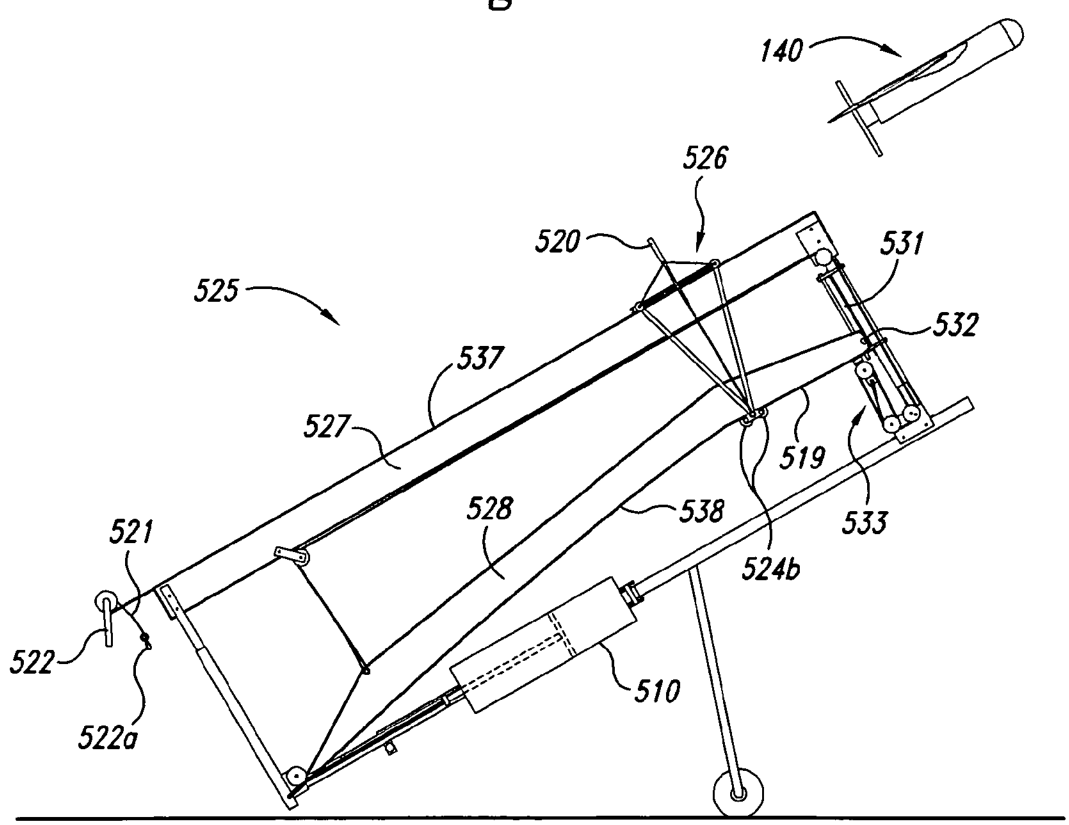

140
526
520
531
525
532
537
527
519
533
528
538
521
524b
510
522
522a

Fig. 5B

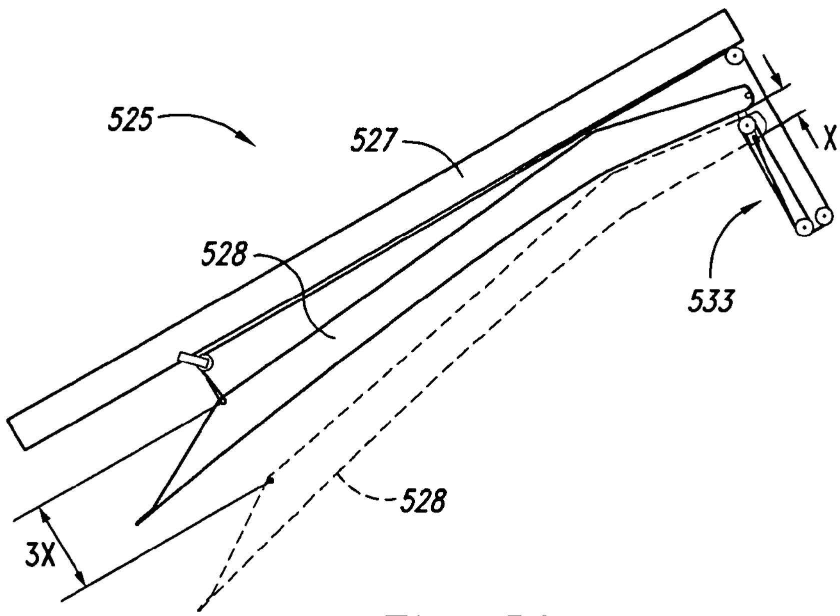

525
527
528
533
X
3X
528

Fig. 5C

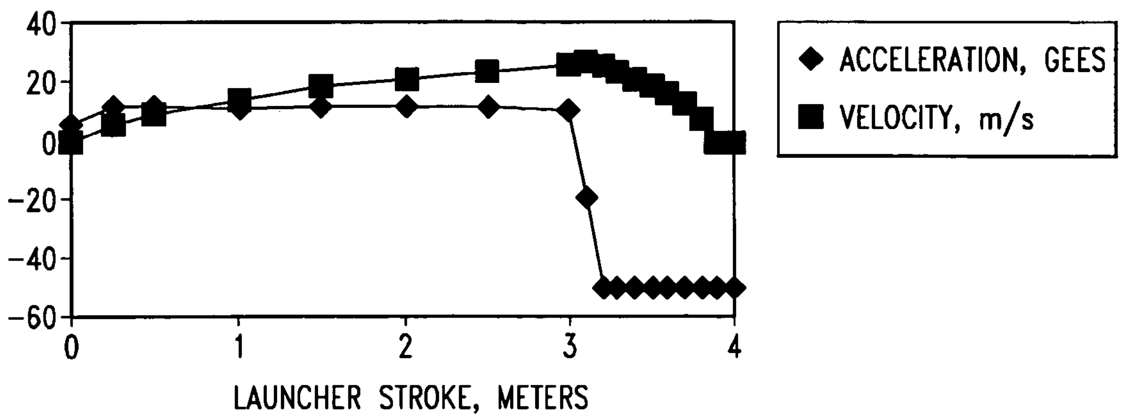

40
20
0
−20
−40
−60
0
1
2
3
4
LAUNCHER STROKE, METERS
ACCELERATION, GEES
VELOCITY, m/s

Fig. 5D

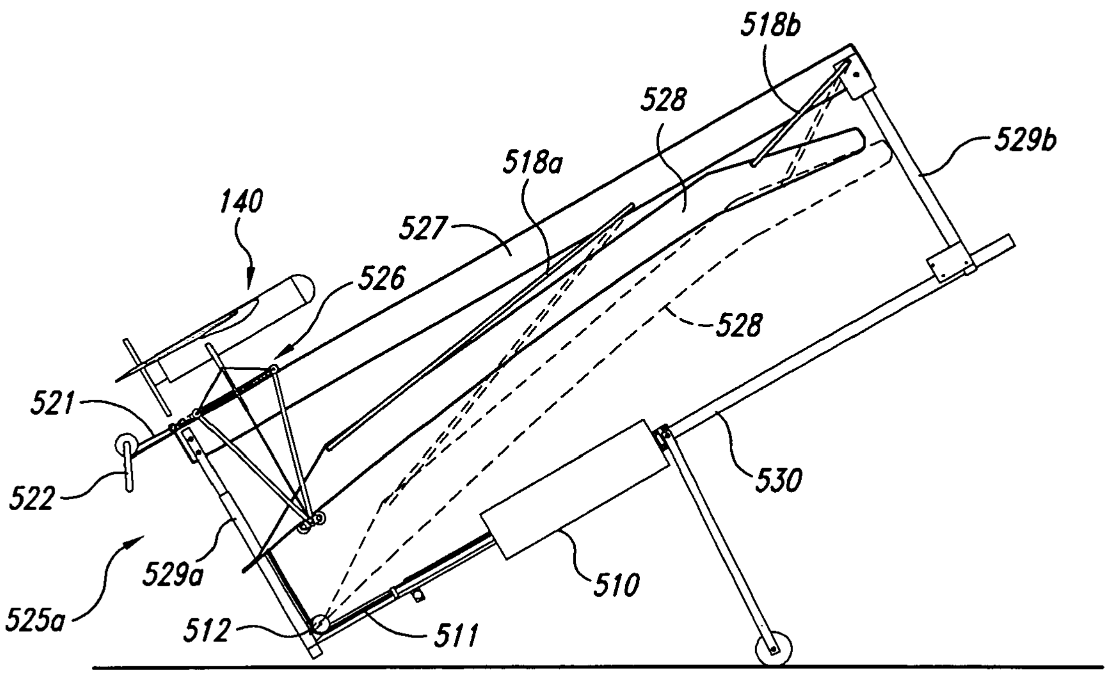

518b
528
529b
518a
140
527
526
528
521
530
522
529a
510
525a
512
511

Fig. 5E

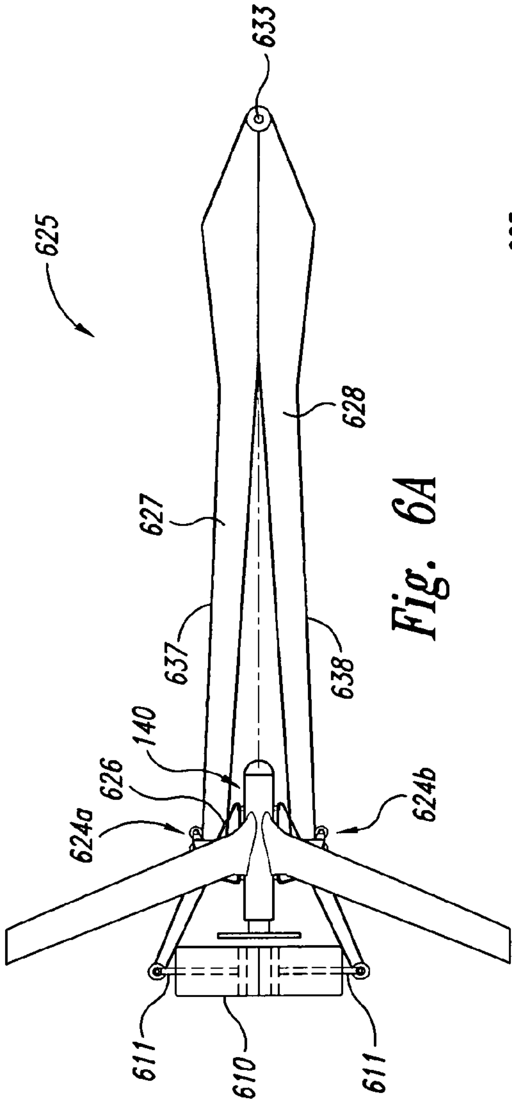

633
625
628
627
637
638
140
626
624a
624b
611
610
611

Fig. 6A

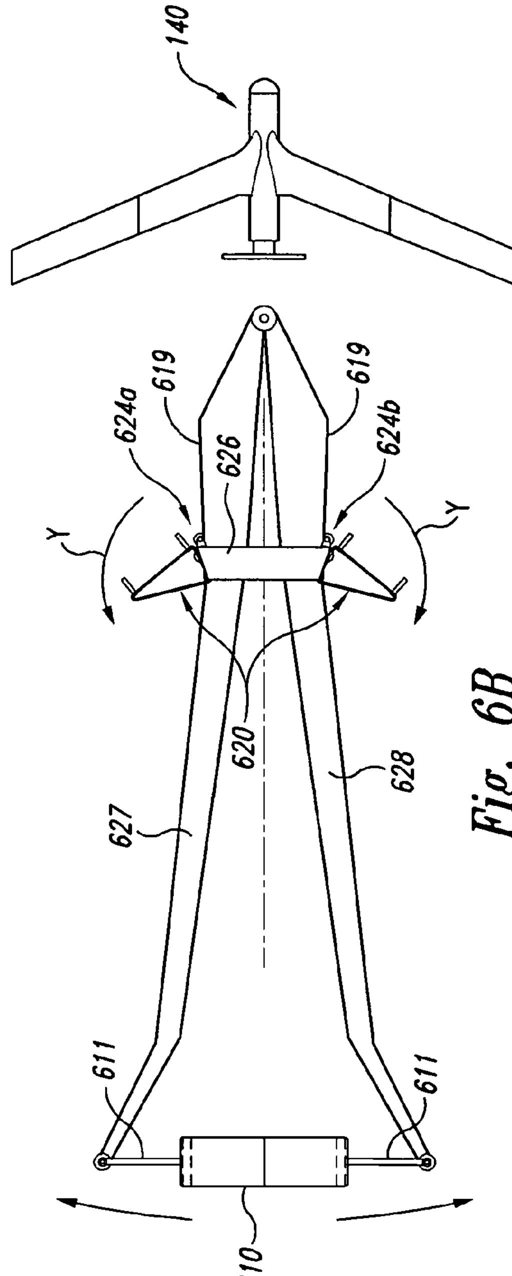

140
619
619
624a
624b
626
625
Y
Y
620
627
628
611
611
610

Fig. 6B

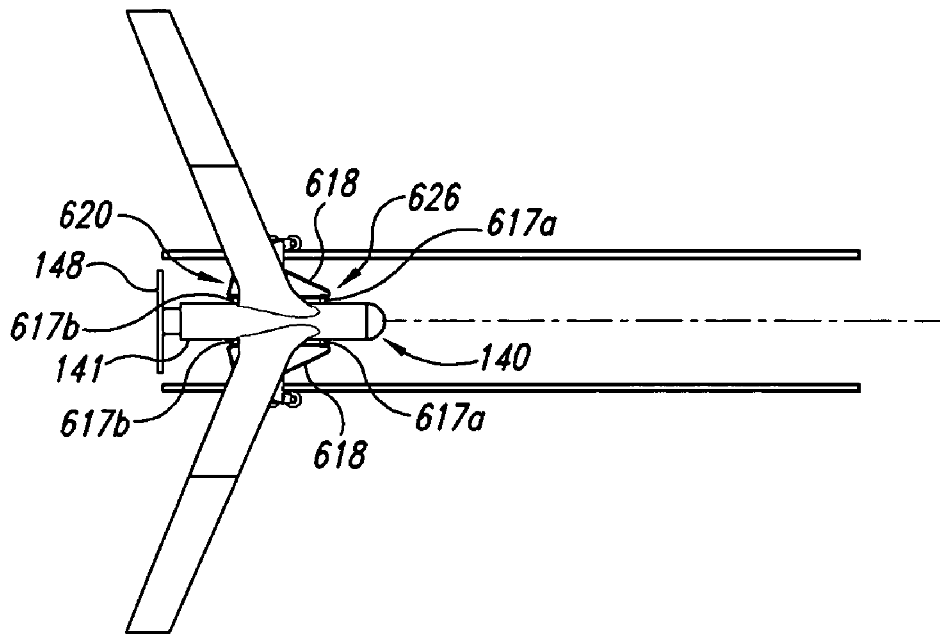

618
626
617a
620
148
617b
141
140
617b
617a
618

Fig. 6C

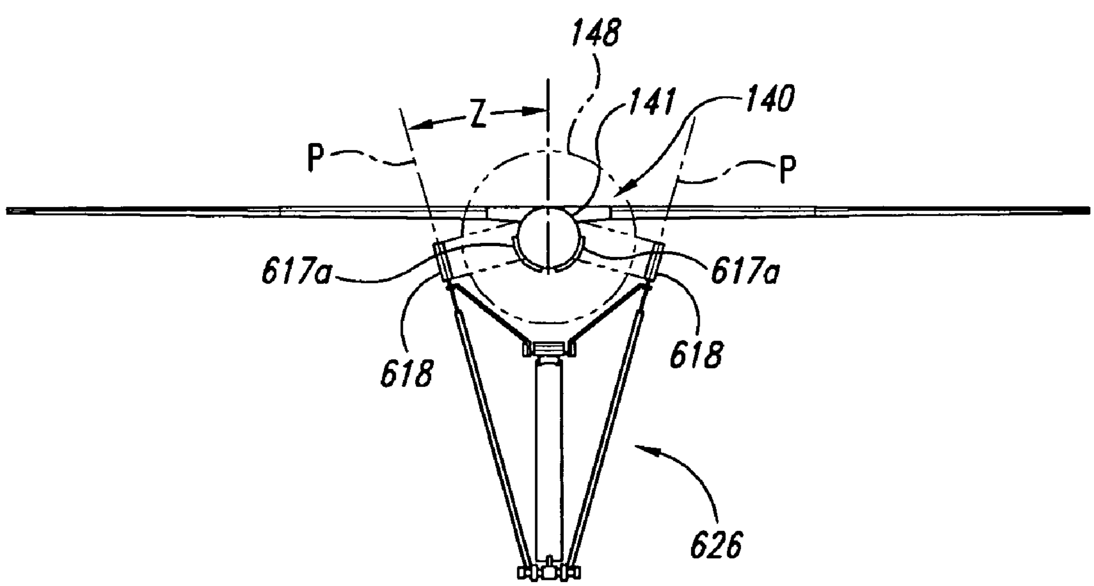

148
141
140
Z
P
P
617a
617a
618
618
626

Fig. 6D

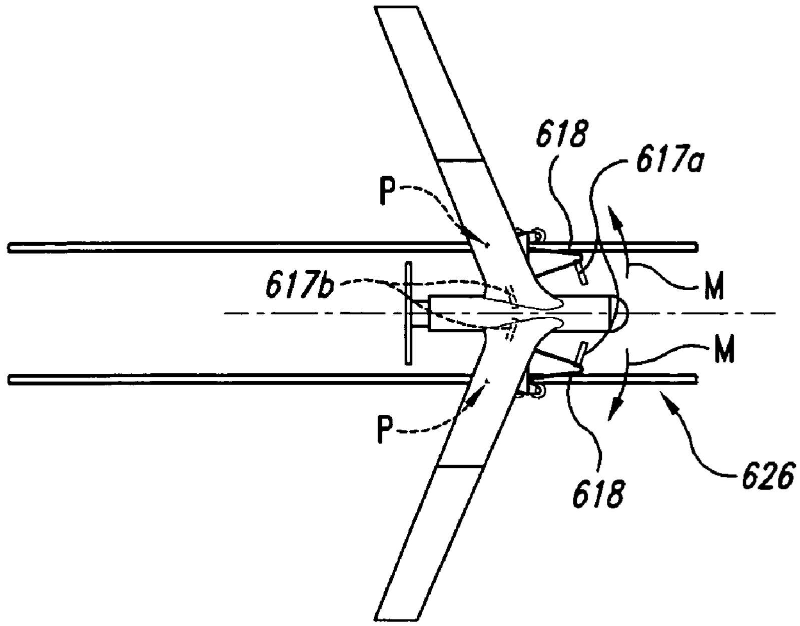


Fig. 6E

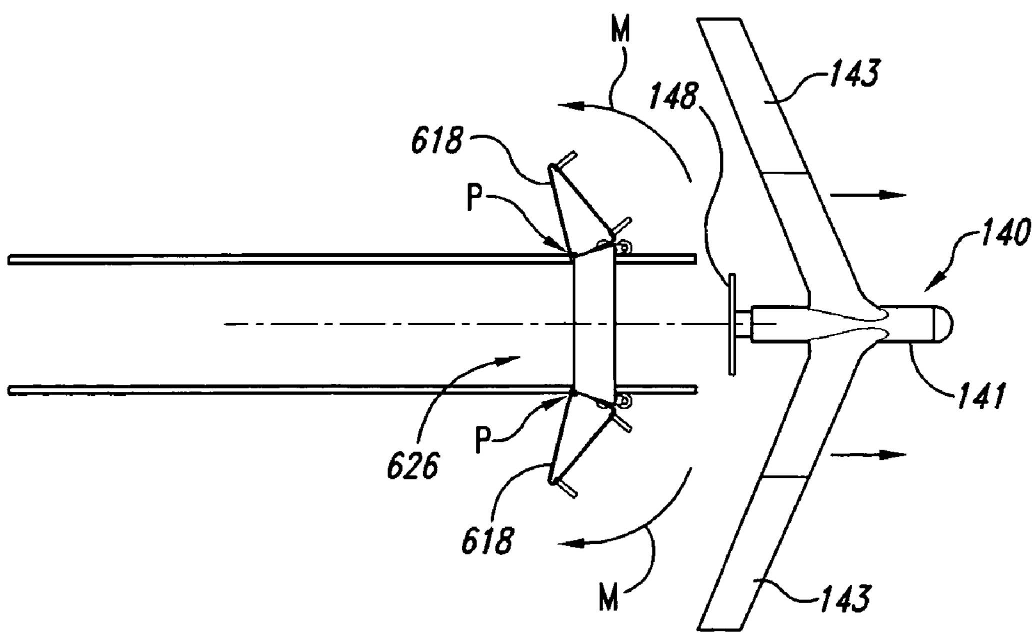


Fig. 6F

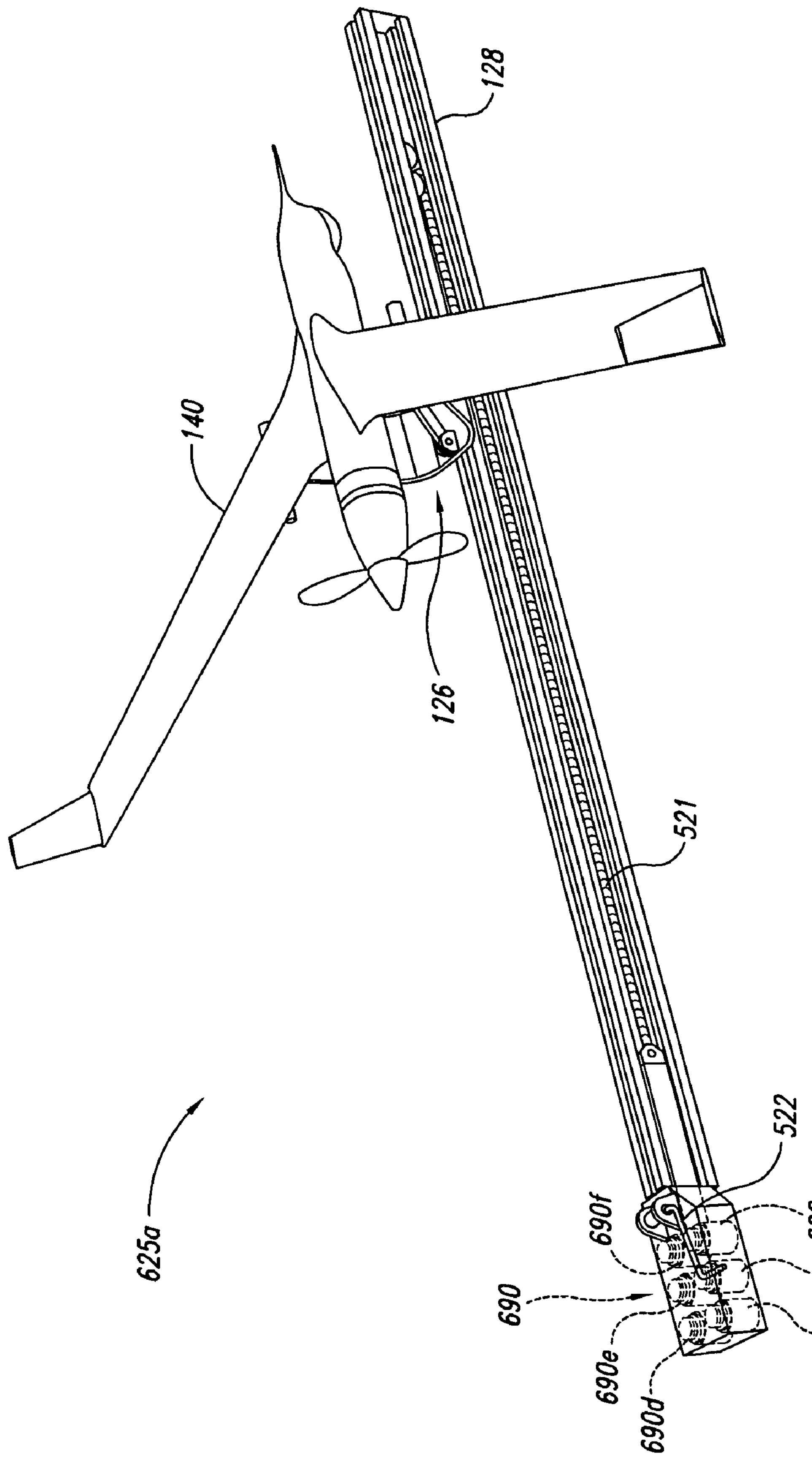


Fig. 6G

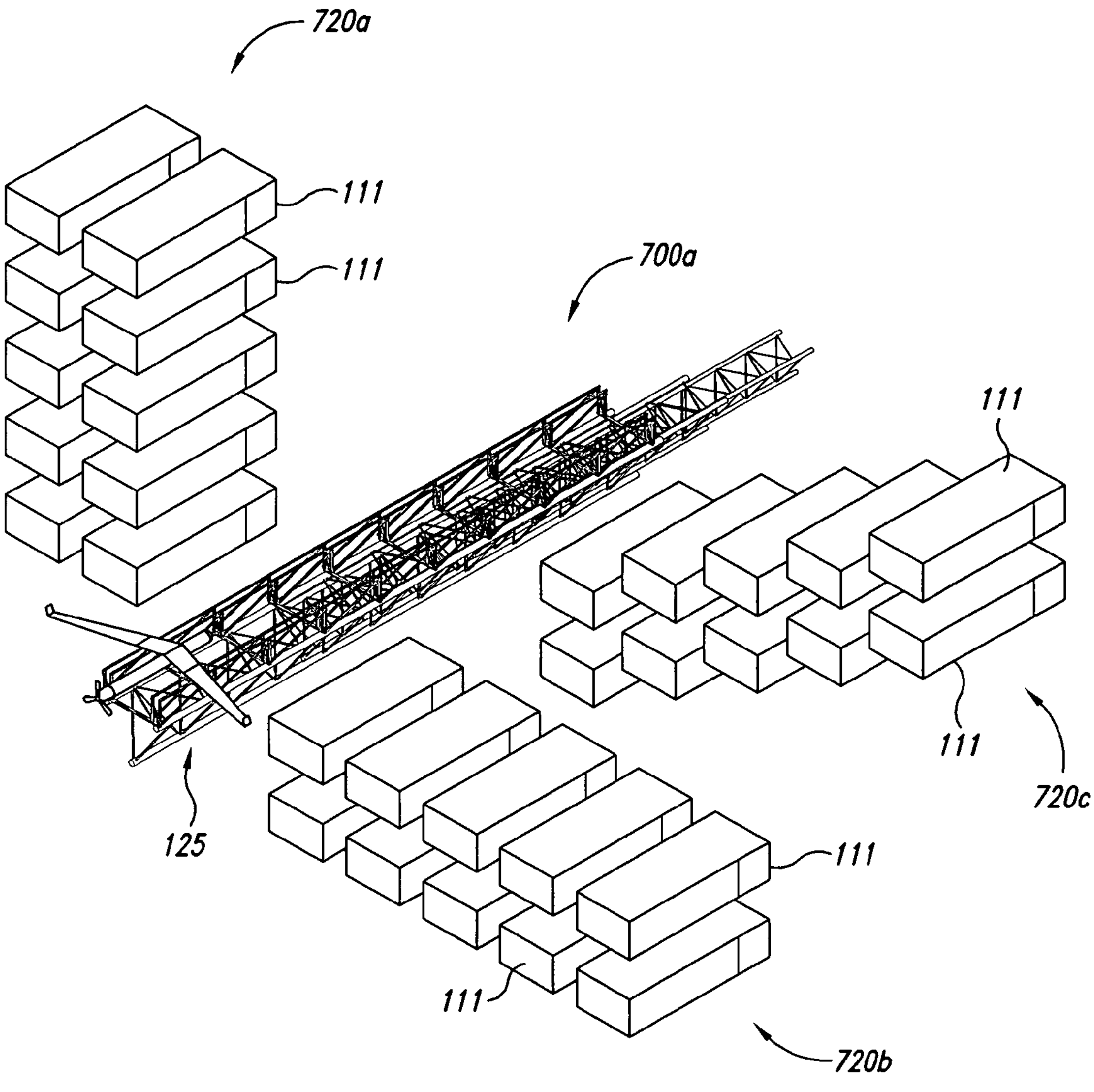


Fig. 7A

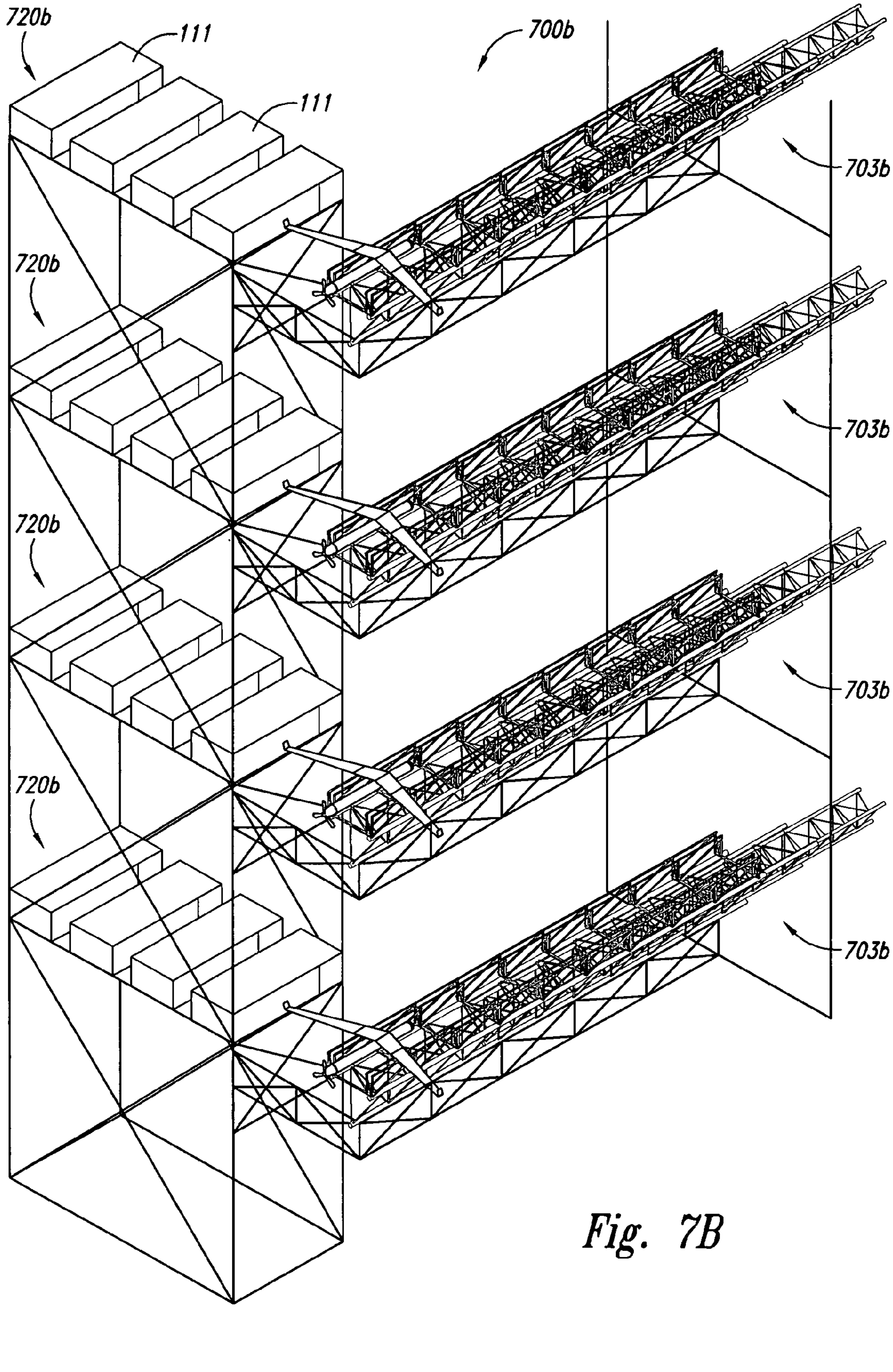


Fig. 7B

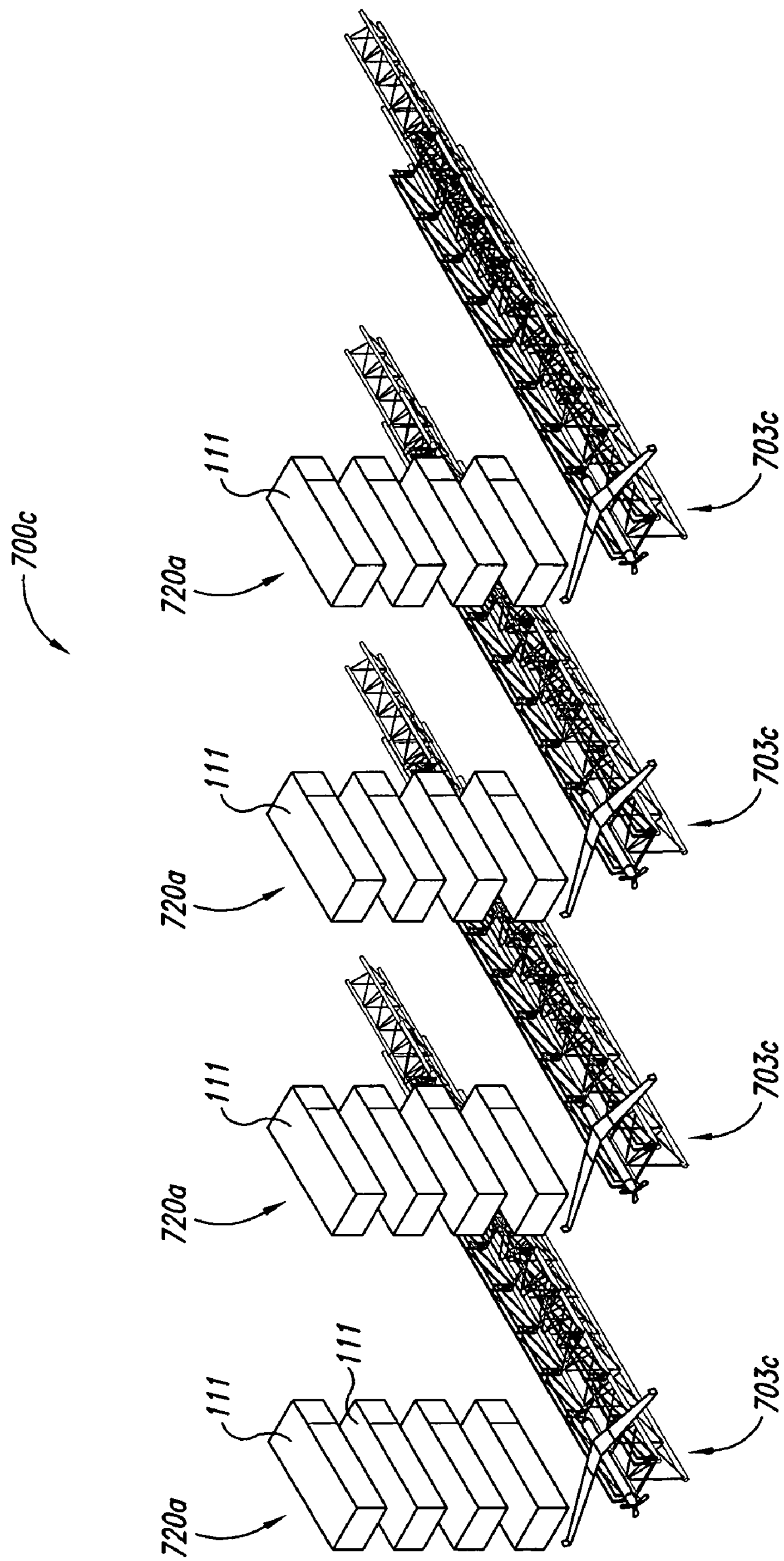

700c
720a
111
703c
720a
111
703c
720a
111
703c
720a
111
111
703c

Fig. 7C

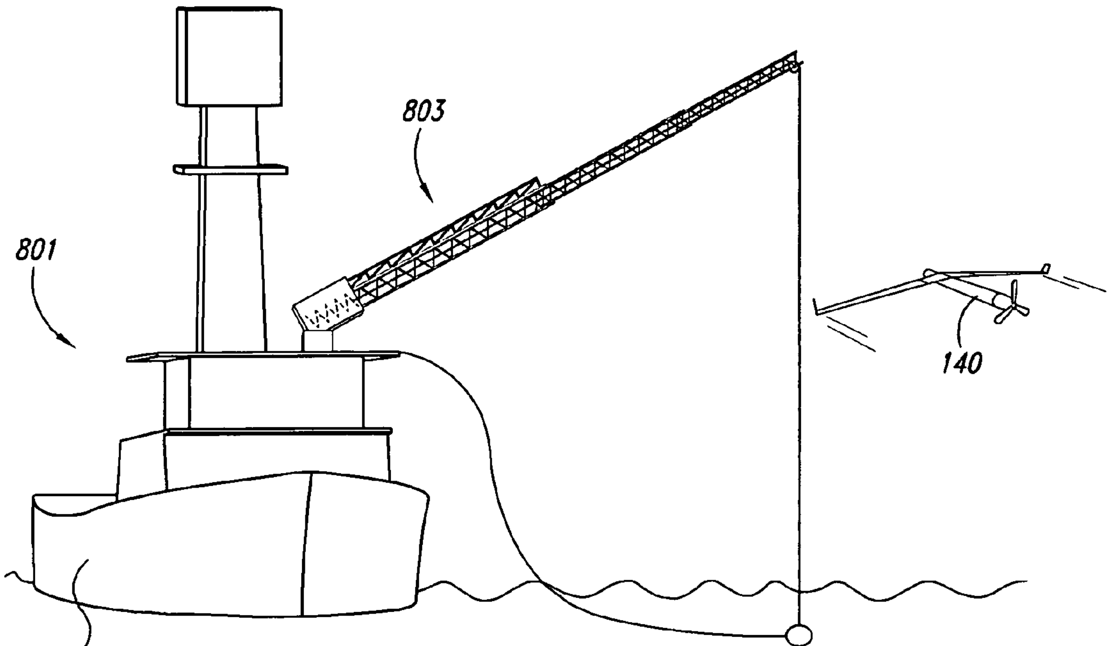

803
801
140
802

Fig. 8A

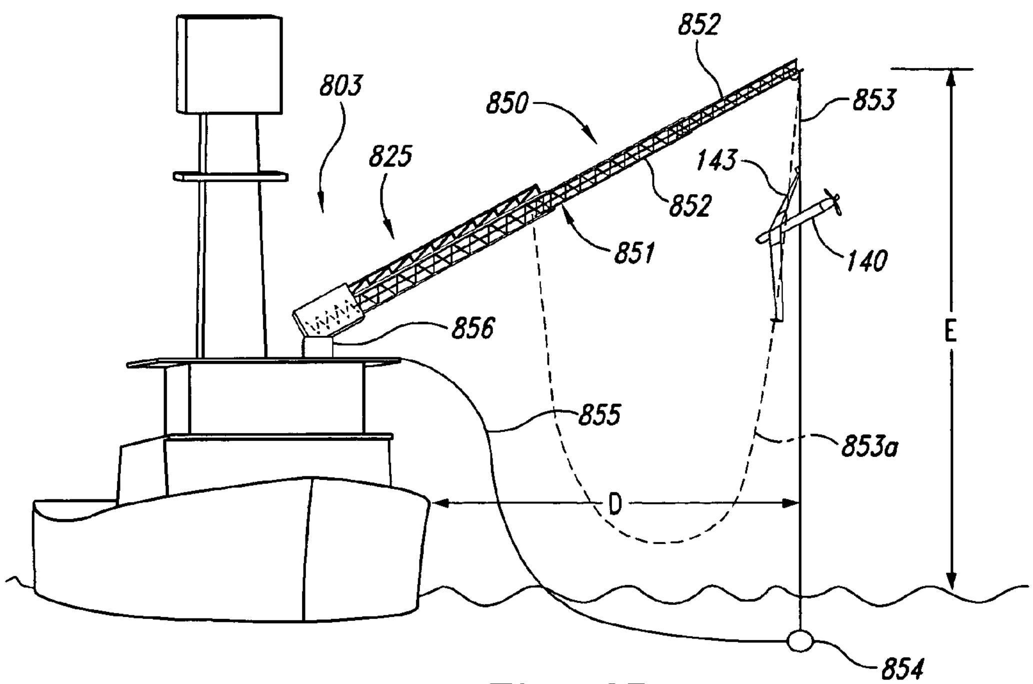

852
803
850
853
825
143
852
851
140
856
E
855
853a
D
854

Fig. 8B

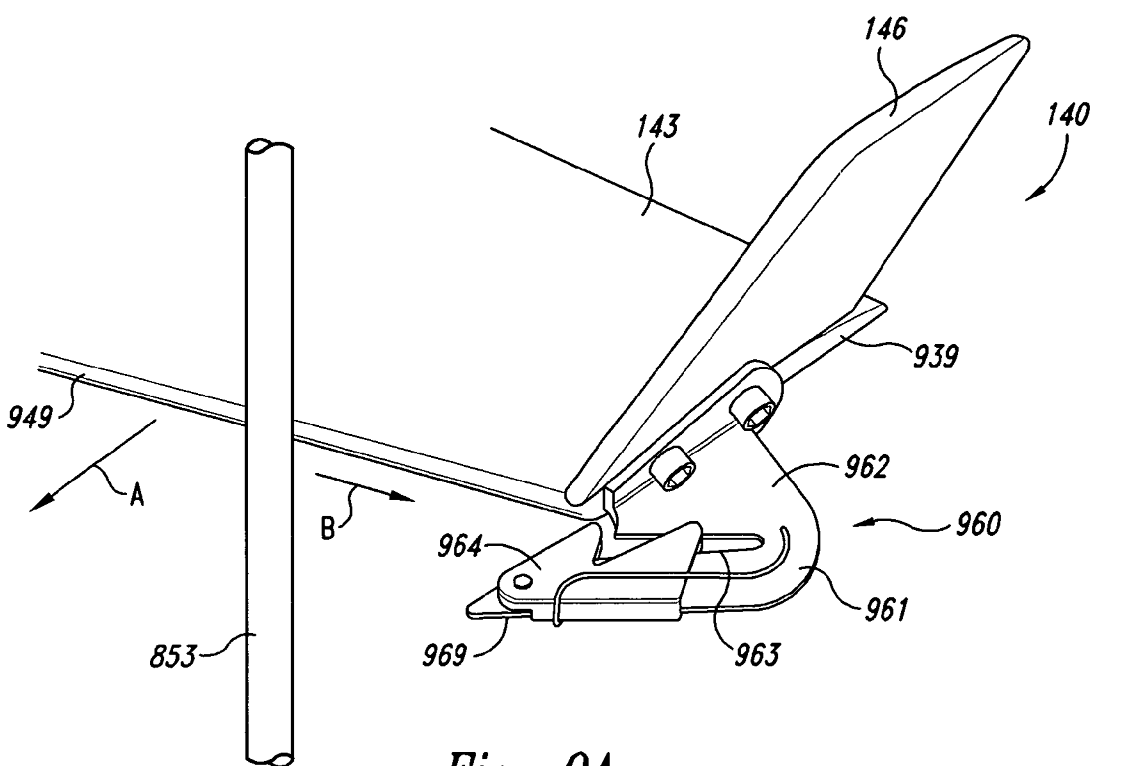

146
140
143
939
949
962
A
B
960
964
961
969
963
853

Fig. 9A

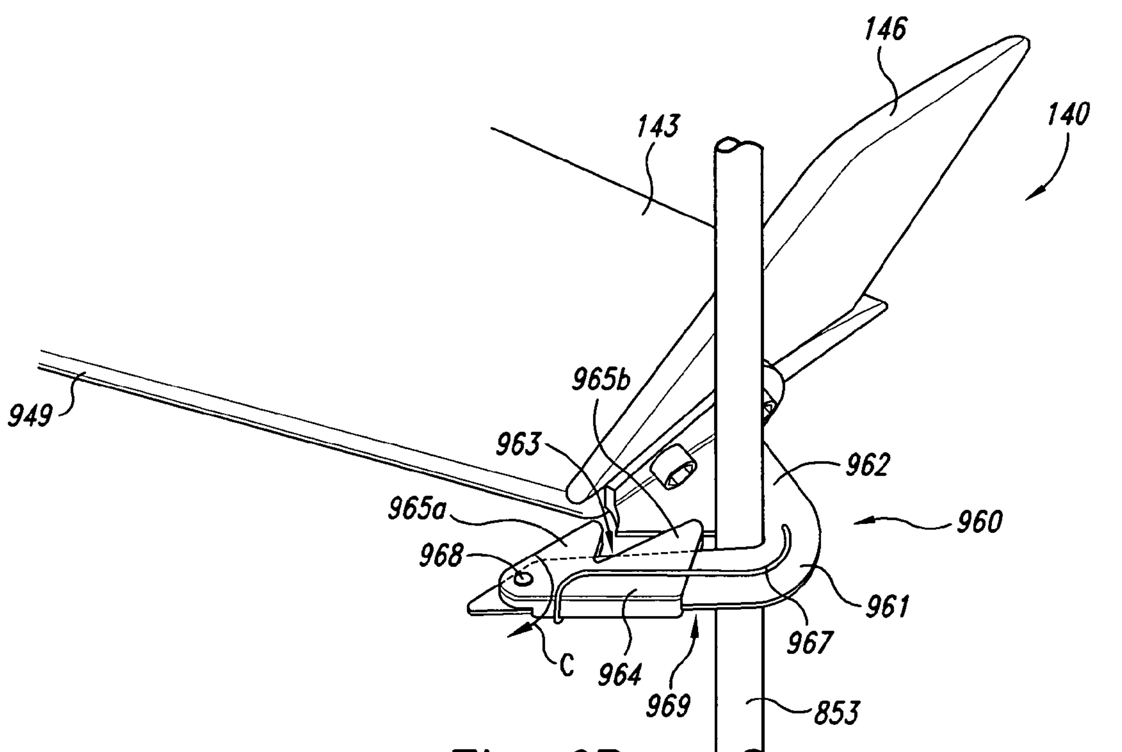

146
140
143
949
965b
963
962
965a
960
968
961
967
C
964
969
853

Fig. 9B

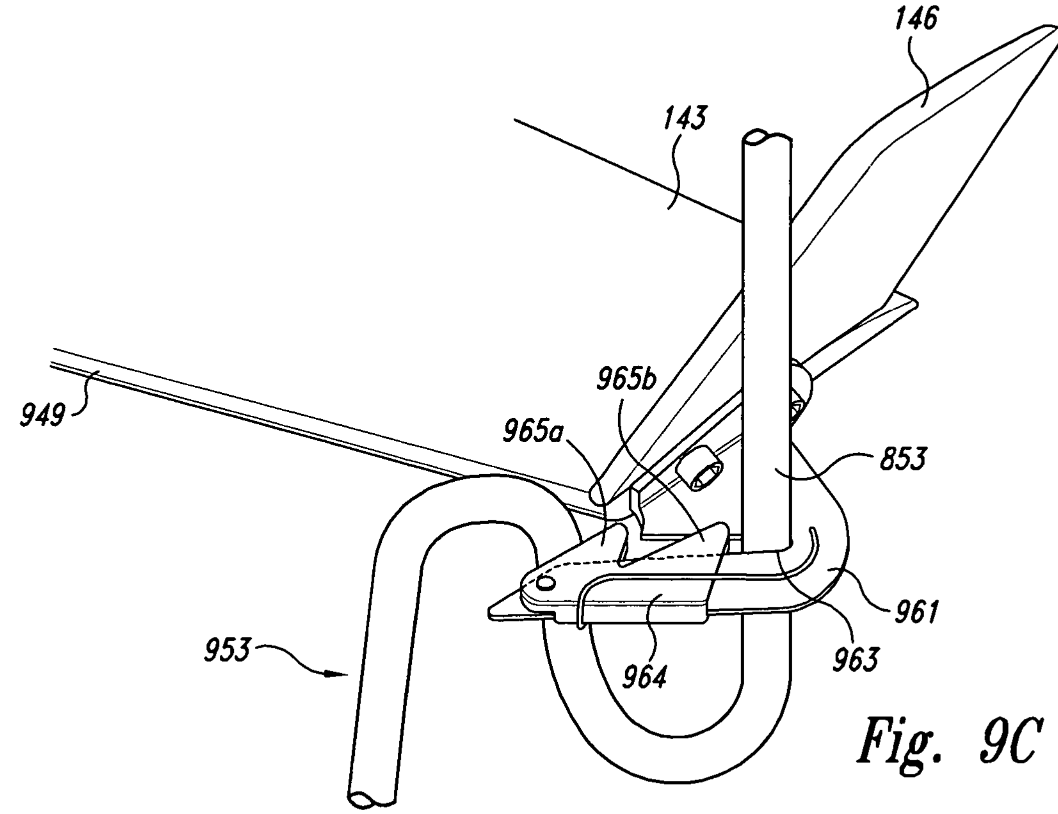

146
140
143
949
965b
965a
853
961
953
964
963

Fig. 9C

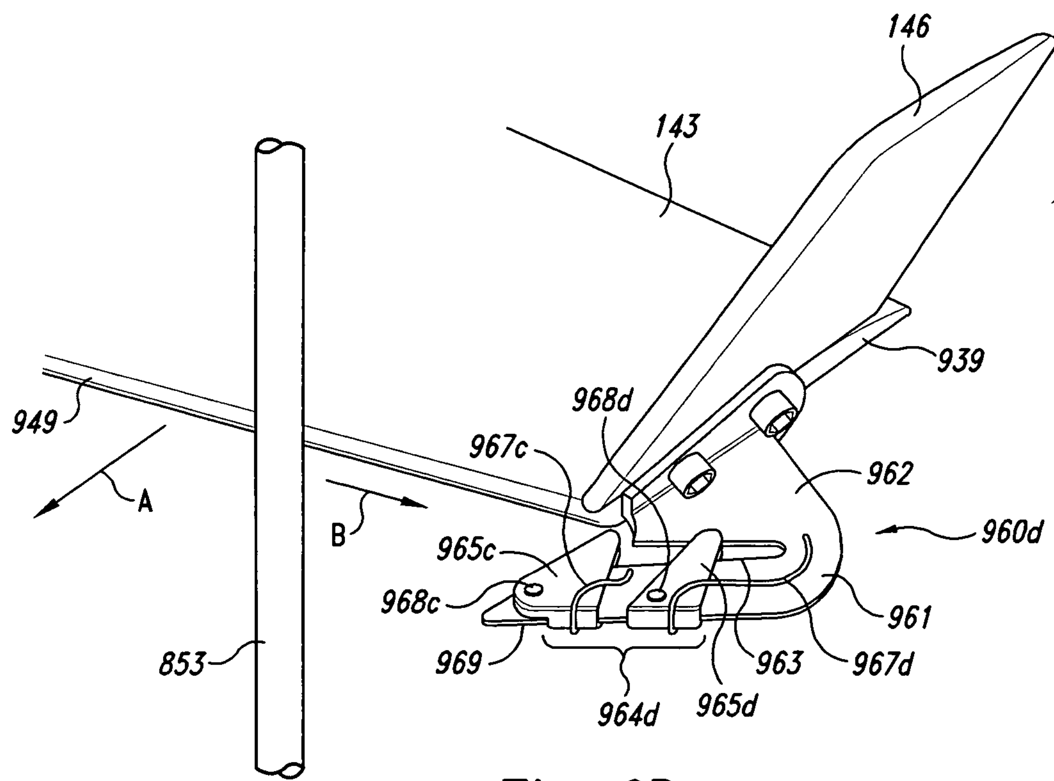

146
140
143
939
949
968d
967c
962
A
B
960d
965c
968c
961
853
969
963
967d
964d
965d

Fig. 9D

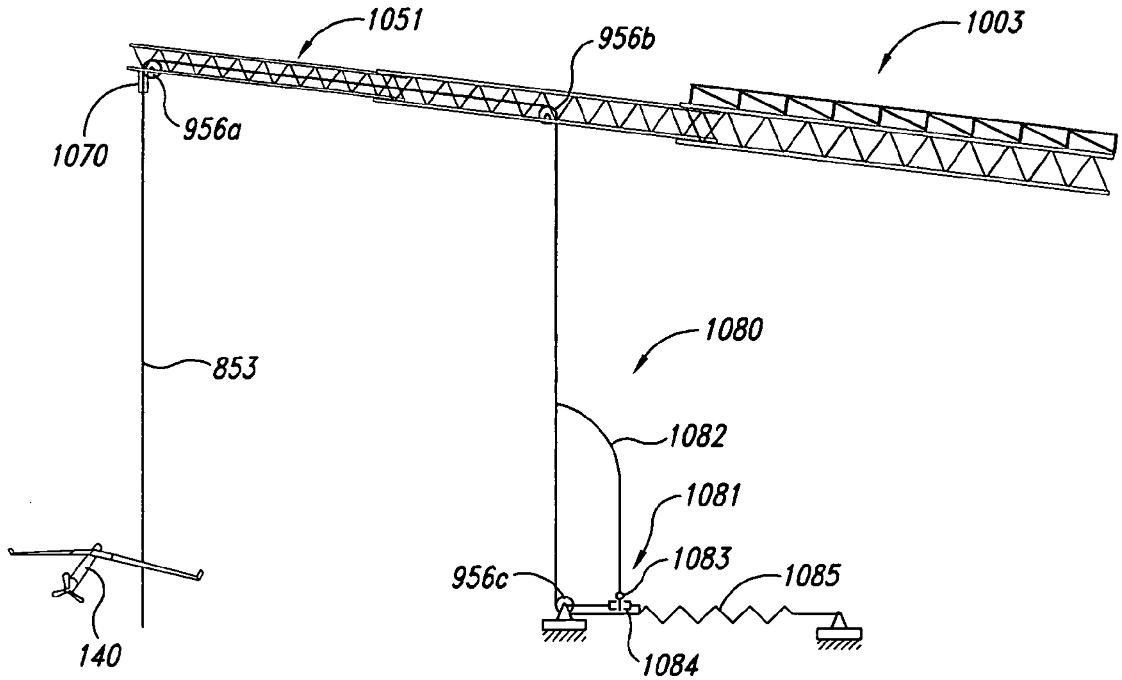


Fig. 10A

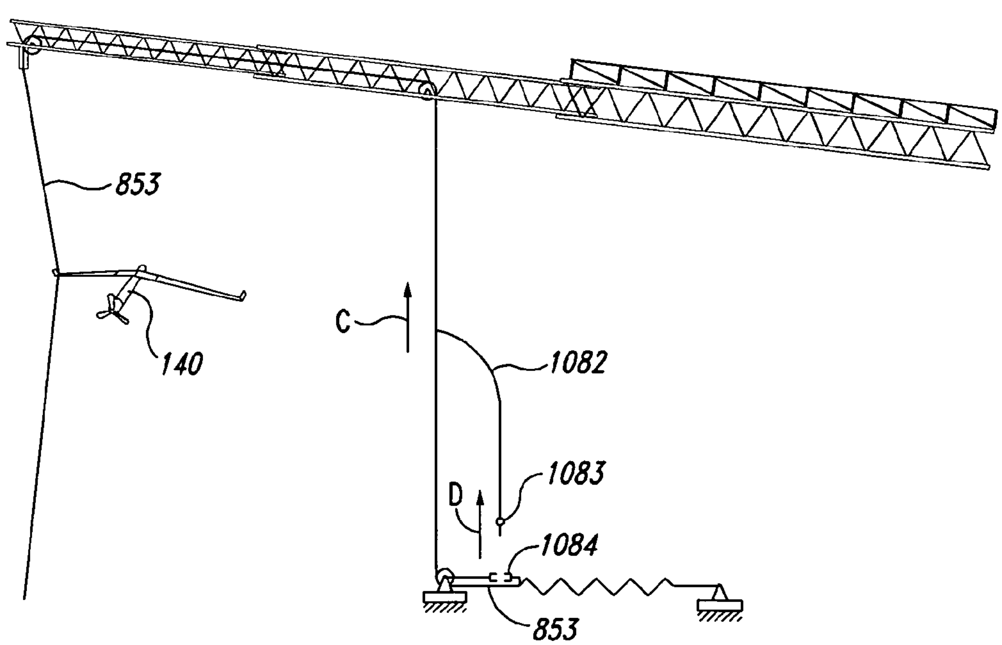


Fig. 10B

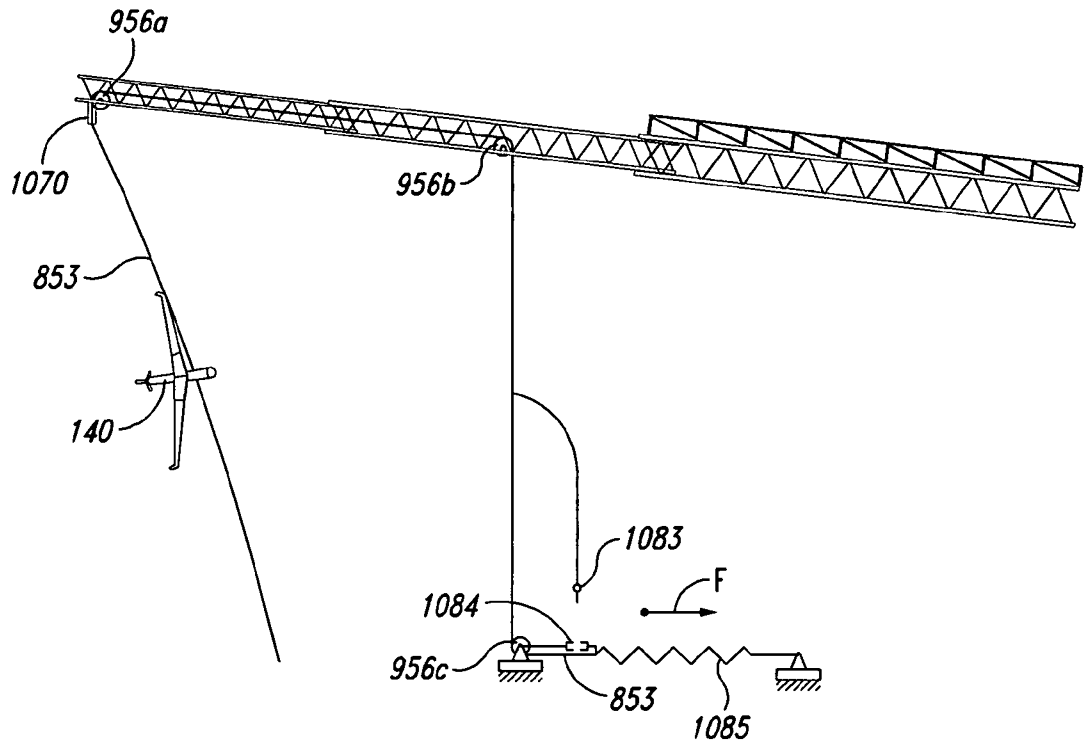


Fig. 10C

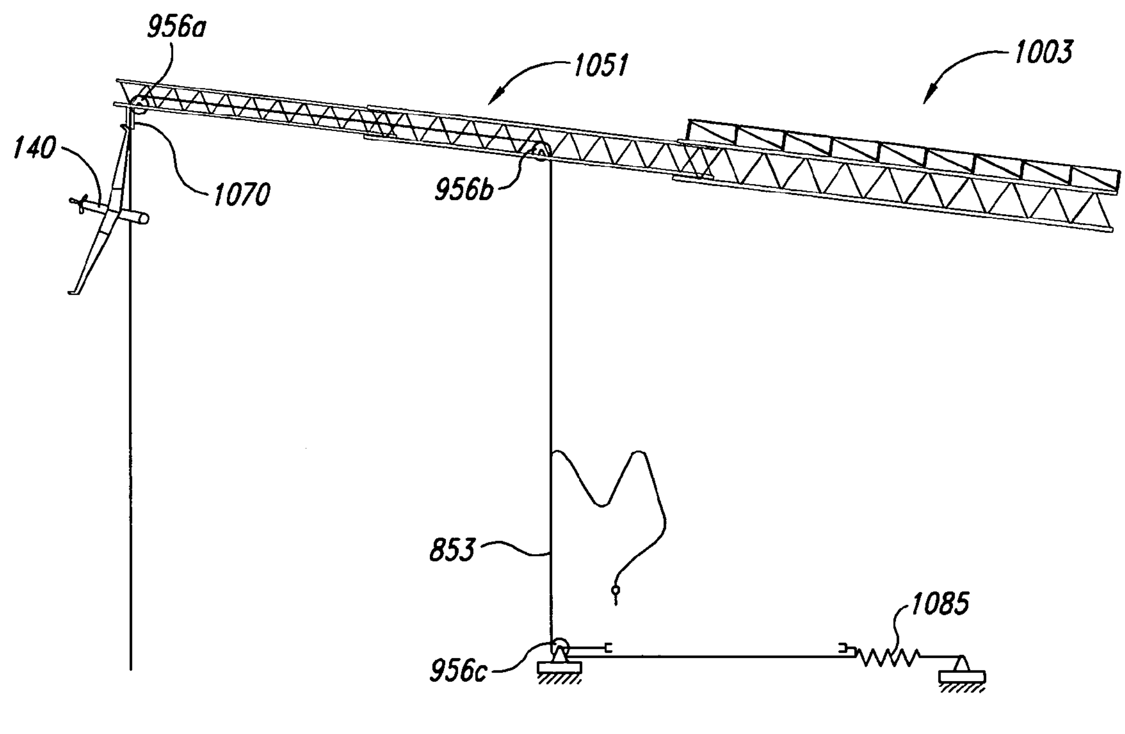


Fig. 10D

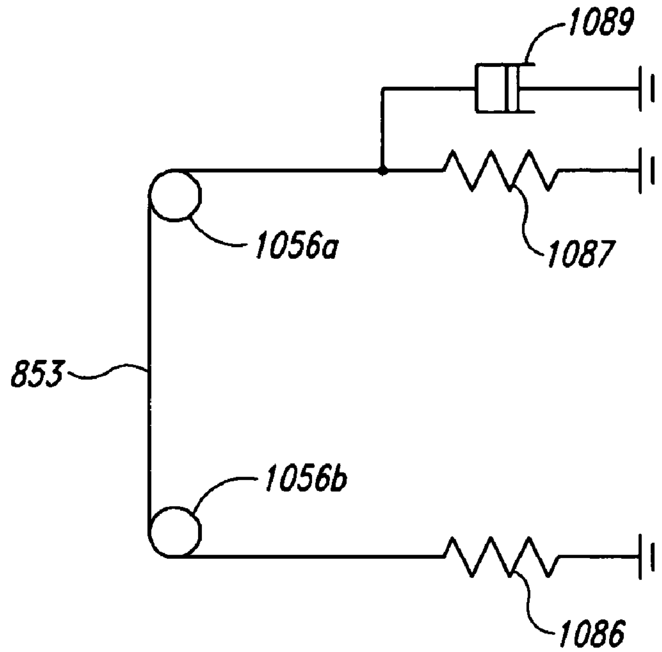


Fig. 10E

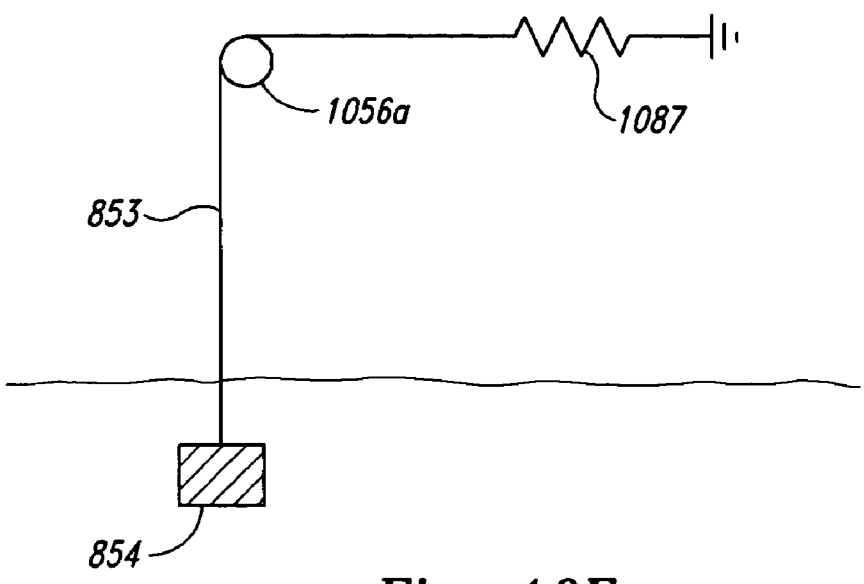


Fig. 10F

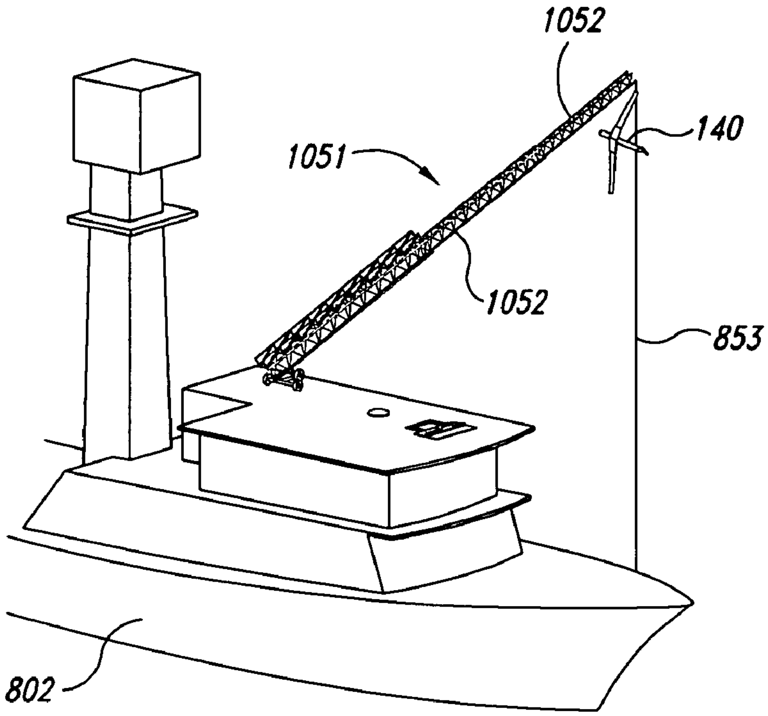


Fig. 11A

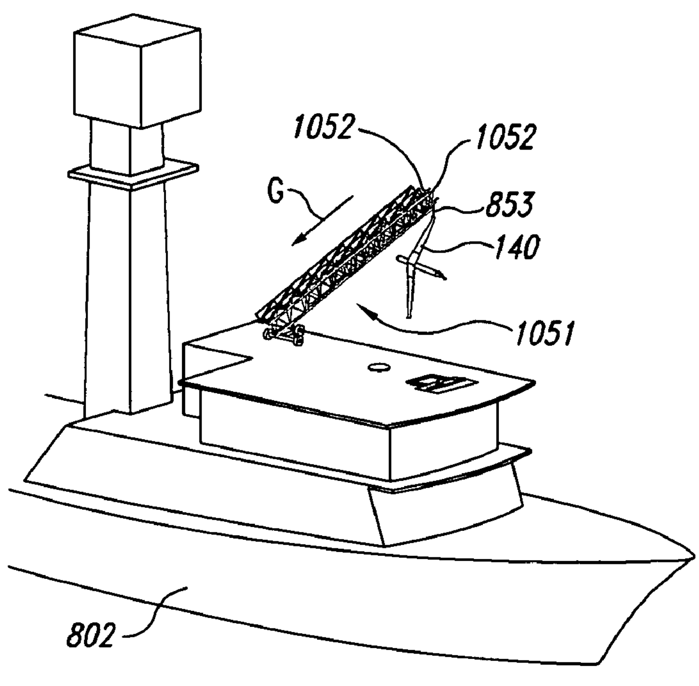


Fig. 11B

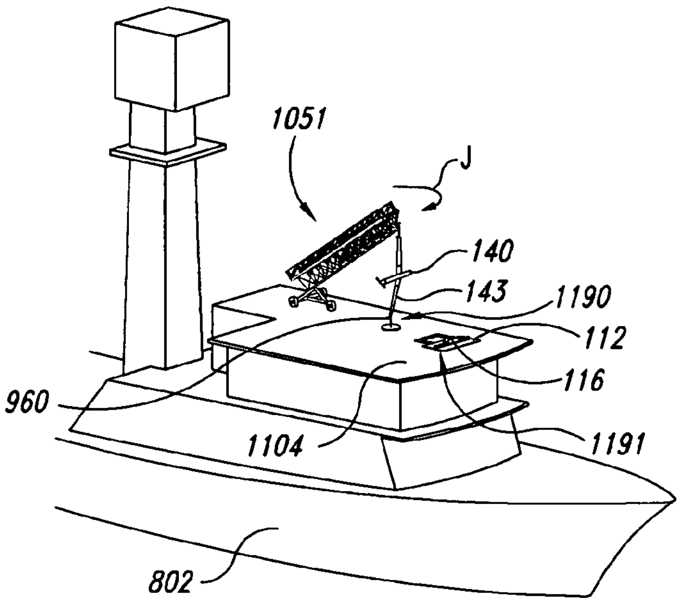


Fig. 11C

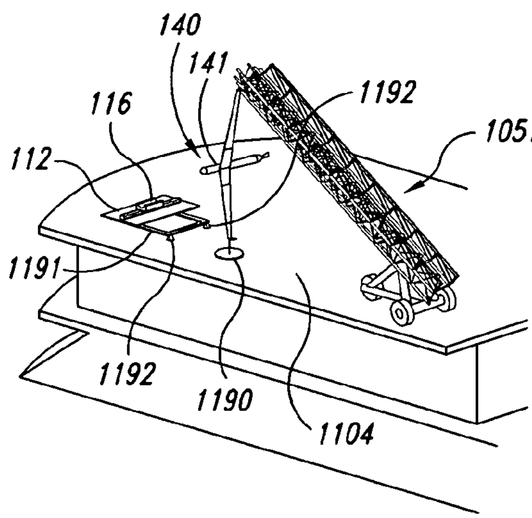


Fig. 11D

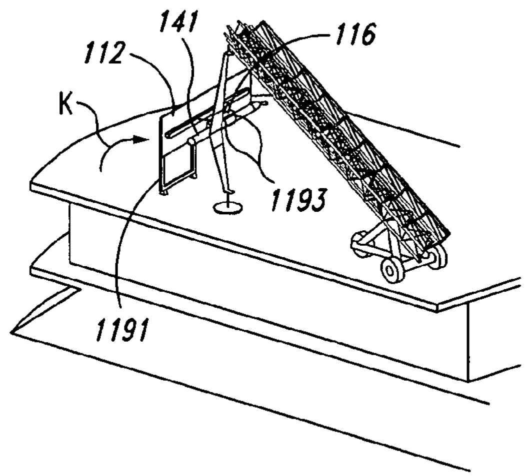


Fig. 11E

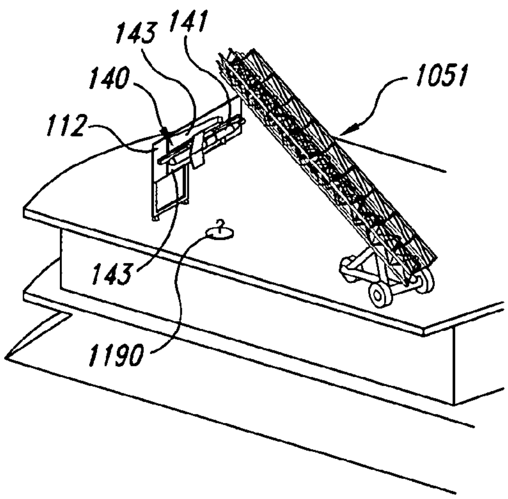


Fig. 11F

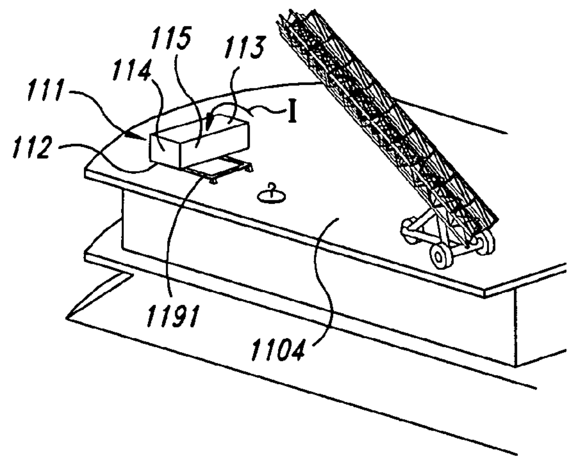


Fig. 11G

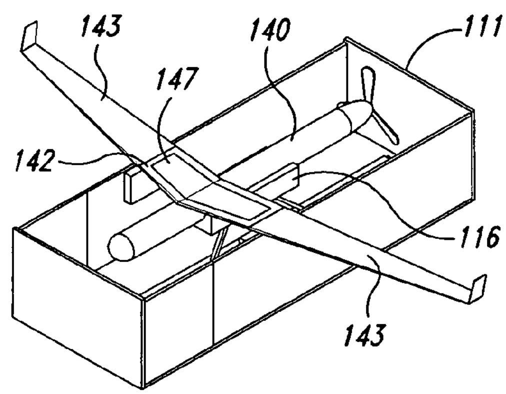


Fig. 12A

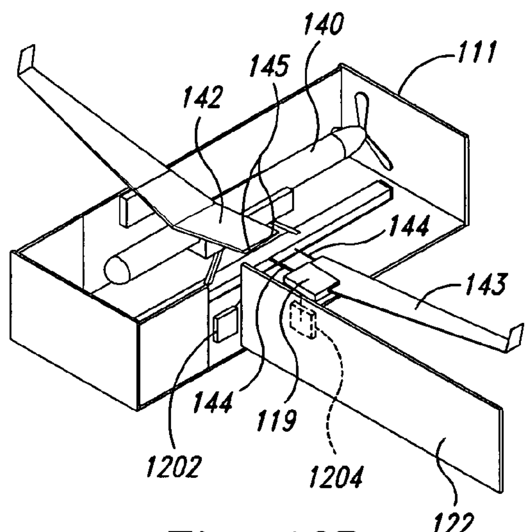


Fig. 12B

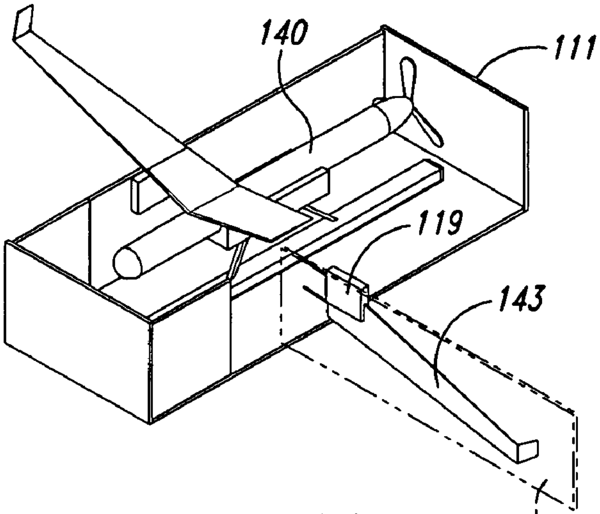


Fig. 12C

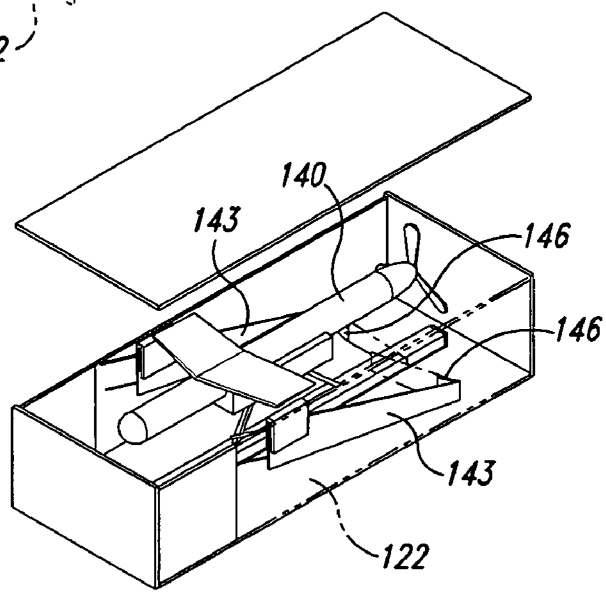


Fig. 12D

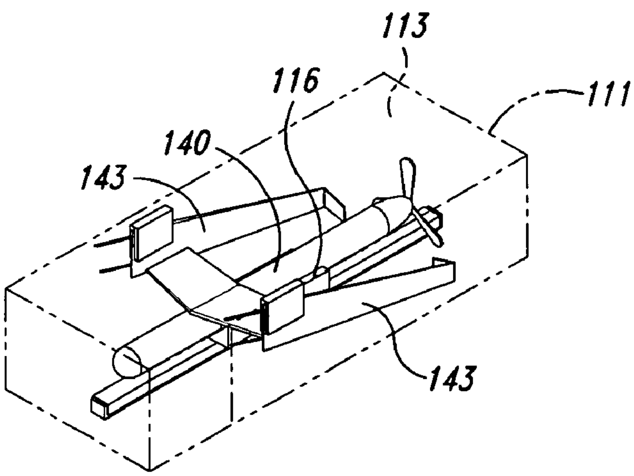


Fig. 12E

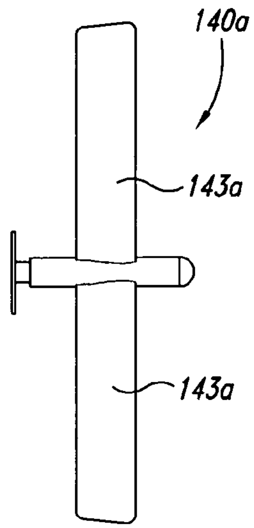


Fig. 13A

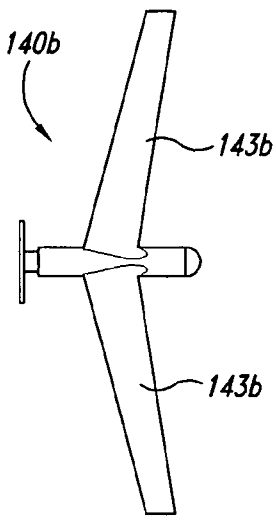


Fig. 13B

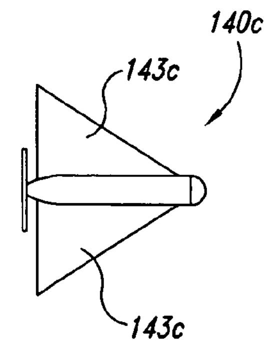


Fig. 13C

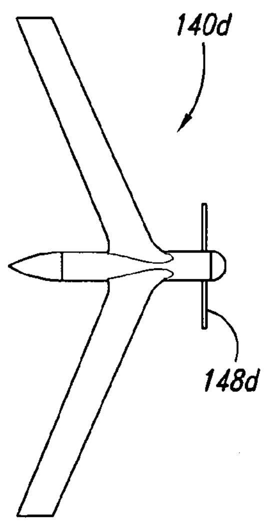


Fig. 13D

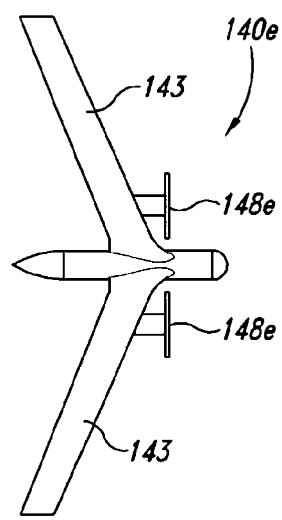


Fig. 13E

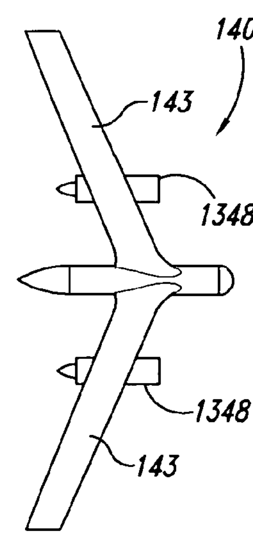


Fig. 13F

METHODS AND APPARATUSES FOR CAPTURING AND RECOVERING UNMANNED AIRCRAFT, INCLUDING EXTENDABLE CAPTURE DEVICES

CROSS-REFERENCE TO RELATED APPLICATION

The present application claims priority to pending U.S. Provisional Application No. 60/440,845, filed Jan. 17, 2003 and incorporated herein in its entirety by reference.

TECHNICAL FIELD

The present disclosure describes methods and apparatuses for capturing and recovering unmanned aircraft, including extendable capture devices.

BACKGROUND

Unmanned aircraft or air vehicles (UAVs) provide enhanced and economical access to areas where manned flight operations are unacceptably costly and/or dangerous. For example, unmanned aircraft outfitted with remotely controlled cameras can perform a wide variety of surveillance missions, including spotting schools of fish for the fisheries industry, monitoring weather conditions, providing border patrols for national governments, and providing military surveillance before, during and/or after military operations.

Existing unmanned aircraft systems suffer from a variety of drawbacks. For example, existing unmanned aircraft systems (which can include the aircraft itself along with launch devices, recovery devices, and storage devices) typically require substantial space. Accordingly, these systems can be difficult to install and operate in cramped quarters, such as the deck of a small fishing boat, land vehicle, or other craft. Another drawback with some existing unmanned aircraft is that, due to small size and low weight, they can be subjected to higher acceleration and deceleration forces than larger, manned air vehicles and can accordingly be prone to damage, particularly when manually handled during recovery and launch operations in hostile environments, such as a heaving ship deck. Yet another drawback with some existing unmanned aircraft systems is that they may not be suitable for recovering aircraft in tight quarters, without causing damage to either the aircraft or the platform from which the aircraft is launched and/or recovered.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. **1**A–**1**H illustrate an apparatus and process for storing and assembling an unmanned aircraft prior to launch in accordance with an embodiment of the invention.

FIG. **2** is a partially schematic illustration of an apparatus configured to both launch and recover an unmanned aircraft in accordance with an embodiment of the invention.

FIGS. **3**A–**3**B schematically illustrate an apparatus for providing acceleration to launch an unmanned aircraft, and a corresponding deceleration of parts of the apparatus, which deceleration acts as a brake.

FIGS. **4**A–**4**C schematically illustrate one type of energy source to provide motive power to an apparatus for accelerating an unmanned aircraft and braking moving components of the apparatus in accordance with an embodiment of the invention.

FIGS. **5**A–**5**E are partially schematic illustrations of an apparatus having at least one movable link for launching an unmanned aircraft in accordance with another embodiment of the invention.

FIGS. **6**A–**6**B are partially schematic illustrations of an apparatus having a movable link for launching an unmanned aircraft in accordance with another embodiment of the invention.

FIGS. **6**C–**6**F are partially schematic illustrations of a carriage having a gripper arrangement for releasably carrying an unmanned aircraft in accordance with an embodiment of the invention.

FIG. **6**G illustrates an apparatus for launching an unmanned aircraft in accordance with another embodiment of the invention.

FIGS. **7**A–**7**C illustrate apparatuses for storing and/or launching multiple unmanned aircraft in accordance with yet further embodiments of the invention.

FIGS. **8**A–**8**B illustrate an apparatus configured to recover an unmanned aircraft in accordance with an embodiment of the invention.

FIGS. **9**A–**9**D illustrate a line capture device configured in accordance with an embodiment of the invention.

FIGS. **10**A–**10**D are partially schematic illustrations of a portion of a recovery system, configured to recover an unmanned aircraft and control post-recovery motion of the aircraft in accordance with an embodiment of the invention.

FIGS. **10**E–**10**F are schematic illustrations of portions of recovery systems configured to provide tension in a recovery line in accordance with further embodiments of the invention.

FIGS. **11**A–**11**G are partially schematic illustrations of a system and method for securing and stowing an unmanned aircraft after capture in accordance with an embodiment of the invention.

FIGS. **12**A–**12**E are partially schematic illustrations of a container and method for disassembling and stowing an unmanned aircraft in accordance with another embodiment of the invention.

FIGS. **13**A–**13**F are partially schematic illustrations of aircraft configurations in accordance with further embodiments of the invention.

DETAILED DESCRIPTION

The present disclosure describes unmanned aircraft and corresponding methods and apparatuses for launching and retrieving or recovering such aircraft. Included in the disclosure are methods and apparatuses for handling small unmanned aircraft in a secure and efficient cycle from flight through retrieval, dismantling, storage, servicing, assembly, checkout, launch, and back to flight. Many specific details of certain embodiments of the invention are set forth in the following description and in FIGS. **1**A–**13**F to provide a thorough understanding of these embodiments. One skilled in the art, however, will understand that the present invention may have additional embodiments, and that the invention may be practiced without several of the details described below. For example, many of the aspects described below in the context of launching, recovering, and storing unmanned aircraft may be applicable as well to other self-propelled and/or projectile airborne devices.

In particular embodiments, aspects of the invention can enable and improve handling of unmanned aircraft from retrieval to launch. They address the problem of vulnerability to damage during manual handling and storage, retrieval, and launch aboard ship or in a similarly confined space, and efficient operation of multiple aircraft. Components of the invention can be used individually or together in a secure and efficient handling cycle. Aspects of the apparatuses and methods can include (1) compact storage; and (2) constrained motion. Accordingly, embodiments of the system can discourage freehanding of the unprotected aircraft, whole or in pieces, and instead can include provisions for dismantling, packing, and assembling the aircraft along prescribed paths, with the storage apparatus and its interfaces with the launch and retrieval apparatus shielding the aircraft from abuse.

The following description includes four sections, each focused on a particular aspect of unmanned aircraft operation. Section 1 focuses on methods and apparatuses for assembling unmanned aircraft, Section 2 focuses on methods and apparatuses for launching unmanned aircraft, Section 3 focuses on methods and apparatuses for retrieving unmanned aircraft, and Section 4 focuses on methods and apparatuses for disassembling and stowing unmanned aircraft. Each of the following Sections describes several embodiments of the corresponding structures and methods that are the focus of that Section. Overall systems in accordance with other embodiments of the invention can include any of a wide variety of combinations and variations of the following embodiments.

1. Aircraft Assembly

FIGS. **1**A–**1**H illustrate a method and apparatus for storing and assembling an unmanned aircraft prior to launch, in accordance with an embodiment of the invention. In anticipation of launch, a closed storage container as shown in FIG. **1**A can be secured to a launch apparatus as shown in FIG. **1**G, thereby establishing a secure workstand for assembly, and a path for constrained motion of the aircraft onto the launcher.

Beginning with FIG. **1**A, a stowage system **110** in accordance with one aspect of this embodiment can include a container **111** (shown in phantom lines in FIG. **1**A) having one or more movable panels defining a volume in which an unmanned aircraft **140** is stowed. The aircraft **140** can be carried on an aircraft support member, which can include a cradle **116**, which is in turn supported by a movable dolly or car **117**. The car **117** can be mounted on a rail **118** or another controlled motion system for movement relative to the container **111**, as described in greater detail below with reference to FIG. **1**G. In one aspect of this embodiment, the cradle **116** can be mounted to the car **117** with a jack **121** to move the aircraft **140** vertically relative to the container **111**, as described in greater detail below with reference to FIG. **1**B.

The container **111** can have a generally box-like shape and can include a bottom **112** (which supports the rail **118**), opposing ends **114** extending upwardly from the bottom **112**, and sides **115** positioned between the opposing ends **114**. A removable top **113** can seal the aircraft **140** within the container **111**. In one embodiment, the aircraft **140** can include a fuselage **141**, an aft-mounted propeller **148**, and a wing stub **142**. Wings **143** can be stowed against the sides **115** of the container **111** and can be attached to the wing stub **142** as described in greater detail below with reference to FIGS. **1**B–**1**E. In other embodiments, the aircraft **140** can have other configurations when stowed.

Referring now to FIG. **1**B, the jack **121** can be activated to elevate the aircraft **140** relative to the container **111**. For example, in one embodiment, the aircraft **140** can be elevated at least until the wing stub **142** is positioned above the upper edges of the container sides **115**. With the wing stub **142** in this position, the wings **143** can be aligned for attachment to the aircraft **140**. Each wing **143** can have a wing gripper **119** attached to it. As described in greater detail below, the wing grippers **119** can eliminate the need for the operator (not shown in FIGS. **1**A–**1**H) to have direct manual contact with the wings **143** during wing assembly.

Referring now to FIG. **1**C, a section **122** of one of the container sides **115** can be pivoted outwardly from the container **111** and slid aft, parallel to a longitudinal axis L of the aircraft **140**. This motion can position a corresponding one of the wings **143** proximate to the wing stub **142**. In one aspect of this embodiment, the degrees to which the section **122** pivots outwardly and slides longitudinally are controlled by stops (not visible in FIG. **1**C) positioned in the bottom **112** of the container **111**. Accordingly, the stops can orient the wing **143** for attachment to the wing stub **142** with precision. The overall motion of the section **122** relative to the container **111** is constrained by a guide structure (e.g., a pin of the section **122** received in a slot of the container). Accordingly, the section **122** moves along a constrained, section guide path.

Referring now to FIG. **1**D, the wing **143** can be rotated upwardly (as indicated by arrow R) until forward and aft spars **144** of the wing **143** are aligned with corresponding spar receptacles **145** in the wing stub **142**. In one aspect of this embodiment, the operator can rotate the wing **143** by engaging only the wing gripper **119**, reducing the likelihood for contaminating the wing surfaces with debris and/or damaging the wing surfaces. Once the spars **144** are aligned with the corresponding spar receptacles **145**, the operator can slide the wing gripper **119** along a track located on the inner surface of the section **122** of the container **111** to insert the spars **144** into the corresponding spar receptacles **145**, as indicated by arrow S. Accordingly, the motion of the wing gripper **119** is constrained to be along a gripper guide path. For purposes of illustration, communication lines (such as electrical cables) which run between the fuselage **141** and the wing **143** are not shown in FIG. **1**D. These lines can include sufficient extra length to allow the wing **143** to be moved toward and away from the fuselage **141** during assembly and disassembly, and take-up devices such as reels or spring-loaded loops to adjust the lines appropriately.

Referring now to FIG. **1**E, the operator can lock the wing **143** relative to the wing stub **142** by removing a hatch **147** from the wing stub **142** and inserting wing retainers (not visible in FIG. **1**E) which lock the spars **144** in firm engagement with the wing stub **142**. The process described above with reference to FIGS. **1**B–**1**E can then be repeated for the other wing **143** to fully assemble the aircraft **140** in preparation for launch. While the aircraft **140** is carried on the cradle **116**, it can be serviced. For example, the aircraft **140** can be fueled and/or electrically powered prior to flight, de-fueled and/or powered down after flight, and can receive/transmit data before and/or after flight.

FIG. **1**F shows the container **111** with the fully assembled aircraft **140** positioned in preparation for a controlled transfer of the aircraft **140** onto a launch system **125**. In one embodiment, the forward end **114** of the container **111** can then be removed or pivoted out of the way to allow the aircraft **140** to slide onto the launch system **125**, as described below with reference to FIG. **1**G.

In one embodiment (shown in FIG. **1**G), an operator or motorized device can slide the car **117**, the cradle **116**, and the aircraft **140** (as a unit) relative to the rail **118** to position the aircraft **140** on the launch system **125**. In other embodiments, the container **111** can include other arrangements for moving the aircraft **140** into position for launch via the launch system **125**. In any of these embodiments, the aircraft **140** can be moved from the container **111** to the launch system **125** without unconstrained motion or manual handling of the aircraft **140**. For example, an operator can move the car **117** by grasping or engaging the cradle **116** or the car **117** rather than the aircraft **140**. In another embodiment, all of the motions made after securing the storage container to the launch apparatus can be fully automated.

As shown in FIG. **1**H, the launch system **125** can include a launch carriage **126** which is moved into position to receive the aircraft **140** from the cradle **116**. The launch carriage **126** can releasably support the wings **143** (as shown in FIG. **1**H) or the fuselage **141**, or other portions of the aircraft **140** during launch. In any of these embodiments, once the aircraft **140** is supported by the launch carriage **126**, the operator can retract the cradle **116** downwardly by activating the jack **121**. The operator can then slide the car **117**, with the retracted cradle **116**, back along the rail **118** into the container **111**. The container **111** can then be moved away from the launch system **125** so as not to interfere with the propeller **148** or any other portion of the aircraft **140**.

2. Aircraft Launch

FIG. **2** is a partially schematic, rear isometric illustration of an apparatus **100** that includes the aircraft **140** positioned on an aircraft handling system **103**. The aircraft handling system **103** can include an embodiment of the launch system **125** (described briefly above) configured to launch the aircraft **140**, and a recovery system **150** configured to recover the same aircraft **140** at the end of its flight.

In one aspect of an embodiment shown in FIG. **2**, the launch system **125** can include a launch support member **128** that carries a launch track **130** having two launch rails **129**. The launch system **125** can further include a launch carriage **126**, such as that described above with reference to FIG. **1**H. In one embodiment, the launch carriage **126** can include two independent components, each of which supports one of the wings **143** and each of which travels along one of the launch rails **129**. In other embodiments, the launch carriage **126** can include a generally unitary structure that supports both wings **143** and travels along both launch rails **129**. In still further embodiments, the launch carriage **126** can support other portions of the aircraft **140**, such as the fuselage **141**. In yet another embodiment, only one launch rail can support the launch carriage **126**. In any of these embodiments, the carriage **126** can be propelled along the launch track **130** to launch the aircraft **140**, as described below with reference to FIGS. **4**A–**6**F.

In another aspect of an embodiment of the apparatus shown in FIG. **2**, the recovery system **150** can be integrated with the launch system **125** to reduce the overall volume occupied by these two systems. For example, in one particular embodiment, the recovery system **150** can include an extendable (and retractable) boom **151** having a plurality of nested segments **152**. An operator can extend the nested segments **152** along a launch axis K defined by the launch track **130** to retrieve the aircraft **140** after its flight. Further details of embodiments of the extendable boom **151** and its operation are described below with reference to FIGS. 11A–11G.

FIG. **3**A is a partially schematic, side elevational view of a portion of the apparatus **100** described above with reference to FIG. **2**, illustrating an energy reservoir **135** that provides power to and receives power from the launch carriage **126**. Accordingly, the energy reservoir **135** can accelerate the launch carriage **126** to launch the aircraft **140** and then absorb the kinetic energy of the launch carriage **126** to slow it down. In one aspect of this embodiment, the energy reservoir **135** can include a hydraulic cylinder, a spring, a pneumatic cylinder, an electric motor, a flywheel, a steam-powered apparatus, an explosive charge, and/or a weight (as described below with respect to FIGS. **4**A–**4**C). In another aspect of this embodiment, the energy reservoir **135** is coupled to the launch carriage **126** with a transmission **131**. In a further aspect of this embodiment, the transmission **131** can include a cable **133**, a plurality of fixed pulleys **132** (shown as first, second, and third fixed pulleys **132***a–c*, respectively) and a plurality of traveling pulleys **134** (shown as first and second traveling pulleys **134***a–b*, respectively) arranged in a block and tackle configuration. When the energy reservoir **135** moves the traveling pulleys **134** aft (as indicated by arrow P), the carriage **126** and the aircraft **140** accelerate and move forward (as indicated by arrow Q). In one aspect of this embodiment, the energy reservoir **135** can be configured to provide a relatively high force with a relatively low acceleration over a relatively short distance, and the transmission **131** can provide to the carriage **126** a relatively smaller force with a relatively higher acceleration over a relatively longer distance. For example, in one aspect of an embodiment shown in FIG. **3**A, the acceleration at the carriage **126** can be about four times the acceleration of the traveling pulleys **134**. In other embodiments, the apparatus **100** can include other block and tackle configurations or other transmissions **131** that provide the same or different acceleration levels to the carriage **126**. In any of these embodiments, the energy reservoir **135** and the transmission **131** can be tailored to the aerodynamic characteristics of the aircraft **140** to provide the aircraft **140** with an adequate takeoff velocity.

FIG. **3**B schematically illustrates the apparatus **100** with the energy reservoir **135** activated to move the carriage **126** from a position aft of the fixed pulleys **132** to a position forward of the fixed pulleys **132**. As the carriage **126** passes the first fixed pulley **132***a* and the cable **133** begins to engage the second fixed pulley **132***b*, the carriage **126** rapidly decelerates. At the same time, the aircraft **140** continues forward to lift off the carriage **126** and become airborne.

As the carriage **126** passes the first fixed pulley **132***a*, it also begins to exert a force on the energy reservoir **135** via the cable **133**. One effect of this coupling between the carriage **126** and the energy reservoir **135** is that the carriage **126** rapidly decelerates. Accordingly, the apparatus **100** need not accommodate a long post-launch travel distance for the carriage **126**. As a result, the apparatus **100** can be more compact than some existing launch/recovery devices. Another effect is that the energy associated with decelerating the carriage **126** can be reversibly absorbed by the energy reservoir **135**. Accordingly, the energy reservoir **135** can be returned partially to its pre-launch state and can accordingly be closer to a state of readiness for the next launch.

FIGS. **4**A–**4**C schematically illustrate a particular embodiment of the apparatus **100** for which the energy reservoir **135** includes a weight **436**. Prior to launch, the weight **436** is positioned as shown in FIG. **4**A so that it has an available potential energy determined by a height H. The weight is then released, accelerating the aircraft **140**, as indicated by arrow Q. The acceleration provided by the falling weight **436** is completed when the weight **436** reaches its lower limit. Just before the weight **436** reaches its lower limit, the cable **133** passes from the first fixed pulley **132***a* to the second fixed, pulley **132***b*, as shown in FIG. **4**B, which reverses the accelerating force on the carriage **126**. The carriage **126** immediately begins to decelerate, as shown in FIG. **4**C, releasing the aircraft **140** into flight. As the carriage **126** continues for some distance beyond the second fixed pulley **132***b*, it raises the weight **436** by some fraction of the height H. Prior to a subsequent launch operation, the weight **436** can be raised completely to the height H, and the carriage **126** can be moved to the position shown in FIG. **4**A for another launch.

One feature of embodiments of the apparatus **100** described above with reference to FIGS. **3**A–**4**C is that the energy provided by the energy reservoir **135** can accelerate the aircraft **140** at a rapid rate. Accordingly, the aircraft **140** can be accelerated to its lift-off speed without requiring a lengthy takeoff run. An advantage of this feature is that the apparatus **100** can be compact and suitable for operation in cramped quarters.

Another feature of an embodiment of the apparatus described above with reference to FIGS. **3**A–**4**C is that the energy reservoir **135** can be configured to absorb energy from the carriage **126** after the carriage **126** has released the aircraft **140**. In some cases, as described above, the energy reservoir **135** can reversibly regain a portion of the energy required to conduct a subsequent launch. An advantage of this feature is that the time and energy required to ready the apparatus **100** for a subsequent launch can be reduced. A further advantage of this arrangement is that the apparatus **100** does not require a braking device separate from the energy reservoir **135**.

FIGS. **5**A–**6**F illustrate launch systems configured in accordance with further embodiments of the invention. Beginning with FIG. **5**A, a launch system **525** in accordance with one embodiment of the invention can include a base **530** carrying two or more supports **529** (shown in FIG. **5**A as a first support **529***a* and a second support **529***b*). The base **530** can be configured to incline relative to the ground (for example, with a jack **539**) to orient the aircraft **140** for launch. The base **530** can be mounted to a vehicle, including a trailer or a boat, or to a fixed platform, including a building.

The launch system **525** can further include a first member **527** (e.g., a first launch member **527**) and a second member **528** (e.g., a second launch member **528**), both of which support a carriage **526**, which in turn carries the aircraft **140** via a releasable gripper **520**. At least one of the first member **527** and the second member **528** is movable relative to the other. For example, in one embodiment, the first member **527** can be fixed relative to the base **530**, and the second member **528** can be movable relative to the base **530**. In other embodiments, the first and second members **527**, **528** can have different arrangements. In any of these embodiments, the movement of at least one of the first and second members **527**, **528** can accelerate the carriage **526** to launch the aircraft **140**, as described in greater detail below.

In one embodiment, the second member **528** can translate and/or rotate relative to the first member **527**. In a particular aspect of this embodiment, the motion of the second member **528** relative to the first member **527** can be controlled by a pin **532**, which depends from the second member **528** and which is received in an elongated guide slot **531** of the support **529***b*. The motion of the second member **528** can be further controlled by a block and tackle **533**. In one embodiment, the block and tackle **533** can include a coupling line **535** attached to the second member **528** at a first line attachment point **536***a*. The coupling line **535** passes through a series of pulleys **534***a*–**534***e* to a second attachment point **536***b*, also on the second member **528**. In other embodiments, the second member **528** can be supported relative to the first member **527** in other arrangements.

In any of the embodiments described above, the carriage **526** can engage both the first member **527** and the second member **528**. For example, in one embodiment, the first member **527** can include a first roller surface **537** (which engages first wheels **524***a* of the carriage **526**), and the second member **528** can include a second roller surface **538** (which engages second wheels **524***b* of the carriage **526**). Carriage arms or links **523** can support the second wheels **524***b* relative to the first wheels **524***a*.

In one embodiment, the second roller surface **538** can have a curved profile to control the acceleration of the carriage **526**. In other embodiments, the second roller surface **538** can have other shapes. In any of these embodiments, the carriage **526** can travel (from left to right as shown in FIG. **5**A) along the first roller surface **537** while engaging the second surface roller surface **538**. In a particular aspect of this embodiment, the second roller surface **538** an be inclined relative to the first roller surface **537** and can move in a wedge fashion, so as to force the carriage **526** from left to right to launch the aircraft **140**.

In one embodiment, the force required to move the second member **528** relative to the first member **527** can be provided by an actuator **510**. The actuator can be coupled with an actuator line **511** to the second member **528**, after passing around an actuator pulley **512**. In one aspect of this embodiment, the actuator **510** can include a compressed gas cylinder, having a piston that retracts the actuator line **511** to draw the second member **528** downwardly away from the first member **527**, as described in greater detail below with reference to FIG. **5**B. In other embodiments, the actuator **510** can have other arrangements, such as a hydraulic cylinder, a bungee, or a spring. In any of these embodiments, the actuator **510** can move the second member **528** relative to the first member **527**, forcing movement of the carriage **526** from left to right.

The launch system **525** can include a carriage return crank or winch **522** having a carriage return line **521** with a releasable trigger **522***a* connected to the carriage **526**. The launch carriage **526** is held back in a pre-launch position by the carriage return line **521** while a launch force is applied to the launch carriage **526**. The releasable trigger **522***a* is then disengaged, allowing the launch carriage **526** to accelerate. The carriage return line **521** can be used to reset the carriage **526** after launch, as described in greater detail below with reference to FIG. **5**B.

FIG. **5**B illustrates the launch system **525** after the carriage **526** has been accelerated to launch the aircraft **140**. In one aspect of this embodiment, the actuator **510** has rapidly drawn the second member **528** downwardly in a manner controlled by the block and tackle **533** and the pin **532** positioned in the slot **531**. As the second member **528** moves downwardly relative to the first member **527**, the carriage **526** is forced from left to right at a high rate of speed, until the second wheels **524***b* engage a braking portion **519** of the second roller surface **538**. Accordingly, the angle between the second roller surface **538** and the first roller surface **537** changes at the braking portion **519**. At this point, the carriage **526** rapidly decelerates, while the gripper **520** releases, allowing the aircraft **140** to continue forward as it is launched into flight.

Once the actuator **510** has moved the second member **528**, it can be effectively decoupled while an operator couples the carriage return line **521** to the launch carriage and activates the carriage return crank **522** to return the carriage **526** to the position shown in FIG. **5**A. For example, when the actuator **510** includes a gas powered piston, the volume of the cylinder in which the piston moves can be opened to atmospheric pressure so that the operator does not need to compress the air within the cylinder when returning the carriage **526** to the launch position. Once the carriage **526** has been returned to the position shown in FIG. **5**A, the actuator **510** can be readied for the next launch, for example, by charging the cylinder in which the piston operates with a compressed gas. In other embodiments, the energy of deceleration can be used to reversibly regain energy to be used during the next launch. In still further embodiments, the actuator **510** can be recharged by the carriage return crank **522**. As the carriage return crank **522** is actuated, it can force the second member **528** to its original position as the carriage **526** returns. This movement can also force the piston on the actuator **510** to its starting position and restore gas pressure in the actuator **510**.

FIG. **5**C is a partially schematic illustration of a portion of the launch system **525** illustrating the first member **527**, along with the second member **528** (shown in its pre-launch configuration in solid lines and in its post-launch configuration in dashed lines). As shown in FIG. **5**C, the portion of the second member **528** to which the coupling line **535** is attached can move by distance 3X, which is three times the distance X moved by the right most portion of the second member **528**. The wedge angle between the first member **527** and the second member **528** increases by translating and pivoting the second member **528** relative to the first member **527**. By increasing the wedge angle during the launch process, the carriage **526** is accelerated at a constant or nearly constant rate, even as the force from the actuator decreases near the end of the actuator's power stroke.

FIG. **5**D is a graph illustrating predicted acceleration and velocity values for a carriage **526** propelled by a launch system **525** in accordance with an embodiment of the invention. In one aspect of this embodiment, the launch system **525** can provide a generally constant acceleration to the carriage **526**, which instantaneously reverses (when the carriage **526** reaches the braking portion **519** described above). This acceleration profile can provide a generally uniform increase in velocity, as is also shown in FIG. **5**D, up to at least the take-off velocity of the aircraft **140**. In other embodiments, the carriage **526** can be propelled in manners that result in different acceleration and velocity profiles.

FIG. **5**E is a partially schematic illustration of a launch system **525***a* configured in accordance with another embodiment of the invention and having many characteristics in common with the launch system **525** described above with reference to FIGS. **5**A–**5**C. In one aspect of this embodiment, the launch system **525***a* includes a first link **518***a* and a second link **518***b* coupled between the first member **527** and the second member **528**, in lieu of the block and tackle **533** and pin **532** arrangement described above. The motion of the second member **528** relative to the first member **527** can be generally similar to that described above with reference to FIGS. **5**A and **5**B, to provide acceleration and velocity profiles generally similar to those described above with reference to FIG. **5**D.

FIGS. **6**A–**6**B illustrate a launch system **625** configured in accordance with still another embodiment of the invention. In one aspect of this embodiment, the launch system **625** can include a first member **627** coupled to a second member **628** at a pivot point **633**. An actuator **610** can be coupled to the first member **627** and the second member **628** with actuator rods **611** to force the first and second members **627**, **628** apart from each other in a transverse plane. A carriage **626** can carry the aircraft **140** and can engage a first roller surface **637** of the first member **627** with first wheels **624***a*. The carriage **626** can also engage a second roller surface **638** of the second member **628** with second wheels **624***b*.

Referring now to FIG. **6**B, the actuator **610** can be activated to spread the first member **627** and the second member **628** apart from each other, forcing the carriage **626** from left to right. When the carriage **626** reaches braking portions **619** of the first and second members **627**, **628**, it rapidly decelerates, causing a gripper **620** to open (as indicated by arrows Y) while the aircraft **140** continues forward and is launched into flight. In other embodiments, the launch system **625** can have other arrangements.

One feature of embodiments of the launch systems described above with reference to FIGS. **5**A–**6**B is that the "wedge action" of the first and second members relative to each other can rapidly accelerate the carriage (and therefore the aircraft **140**) in a relatively short distance. An advantage of this arrangement is that the launch systems can be used in cramped quarters, including the deck of a fishing vessel or a towed trailer.

Another feature of embodiments of the launch systems described above is that the wedge angle between the first and second members can increase as they move relative to one another. This arrangement can provide a constant or nearly constant acceleration to the carriage (and the aircraft **140**), even if the force provided by the actuator decreases near the end of the actuator's power stroke. An advantage of this arrangement is that the aircraft **140** is less likely to be subject to sudden changes in acceleration, which can damage the aircraft **140**.

Yet another feature of the launch systems described above with reference to FIGS. **5**A–**6**B is that at least one of the first and second members can include a braking portion which rapidly and safely decelerates the carriage carried by the launch system. An advantage of this feature is that the rail length required for deceleration can be short relative to that for acceleration, and the overall length of the system can be correspondingly limited. Further details of the manner in which the carriage releases the aircraft are described below with reference to FIGS. **6**C–**6**F.

Another feature of the launch systems described above with reference to FIGS. **5**A–**6**B is that the number of components that move at high speed during the launch process is relatively small. For example, in a particular embodiment, the only rolling elements that are traveling at high speed are the carriage wheels, and no high speed pulleys are included. Accordingly, the potential losses associated with components moving at high speed, including losses caused by ropes attached to the carriage suddenly accelerating and decelerating (e.g., "rope slurping") can be reduced and/or eliminated.

FIGS. **6**C–**6**F illustrate an arrangement for supporting the aircraft **140** during launch, suitable for use with any of the launch systems described above. In one embodiment, shown in FIG. **6**C, the arrangement can include a carriage **626** having a gripper **620** which includes two gripper arms **618**. Each gripper arm **618** can include a forward contact portion **617***a* and an aft contact portion **617***b* configured to releasably engage the fuselage **141** of the aircraft **140**.

FIG. **6**D is a front end view of the carriage **626** and the aircraft **140**. As shown in FIG. **6**D, each contact portion **617***a* can have a curved shape so as to conform to the curved shape of the fuselage **141**. Each gripper arm **618** can be pivotably coupled to the carriage **626** to rotate about a pivot axis P. In one aspect of this embodiment, each pivot axis P is canted outwardly away from the vertical by an angle Z. As described in greater detail below, this arrangement can prevent interference between the gripper arms **618** and the aircraft **140** as the aircraft **140** is launched. In another aspect of this embodiment, the gripper arms **618** can pivot to a slightly over-center position to securely engage the fuselage **141** and to resist ambient wind loads, gravity, propeller thrust (e.g., the maximum thrust provided to the aircraft **140**), and other external transitory loads.

FIG. **6**E is a top plan view of the carriage **626** as it reaches the end of its launch stroke. As the carriage **626** decelerates, the forward momentum of the gripper arms **618** causes them to fling open by pivoting around the pivot axes P, as indicated by arrows M, which can overcome the over-center action described above. As the gripper arms **618** begin to open, the contact portions **617***a*, **617***b* begin to disengage from the aircraft **140**.

Referring now to FIG. **6**F, the carriage **626** has come to a stop and the gripper arms **618** have pivoted entirely away from the aircraft **140**, allowing the aircraft **140** to become airborne. As shown in FIG. **6**F, the gripper arms **618** have pivoted in a manner so as not to interfere with the fuselage **141**, the wings **143** or the propeller **148** of the aircraft **140**. For example, as described above, the gripper arms **618** pivot about a canted pivot axis P. As a result, the gripper arms **618** can rotate downwardly (as well as outwardly) away from the aircraft **140** as the aircraft **140** takes flight.

One feature of an embodiment of the carriage **626** described above with reference to FIGS. **6**C–**6**F is that the gripper arms **618** can engage the fuselage **141** of the aircraft **140**. An advantage of this arrangement is that the gripping action provided by the gripper arms **618** can be distributed fore and aft over the fuselage **141**, thus distributing the gripping load. A further advantage of embodiments of the foregoing arrangement is that the gripper arms **618** can be configured to quickly and completely rotate out of the way of the aircraft **140** as the aircraft **140** takes flight. Still a further advantage of the foregoing arrangement is that no additional hardware, with associated weight and drag, need be provided to the aircraft **140** to allow it to be releasably carried by the carriage **626**.

FIG. **6**G illustrates a launch system **625***a* configured in accordance with still another embodiment of the invention. In one aspect of this embodiment, the launch system **625***a* can include a launch support member **128**. A carriage **126** can carry the aircraft **140** along the launch support member **128** for takeoff. The force required to move the carriage **126** relative to the launch support member **128** can be provided by one or more constant force springs **690** (six are shown in FIG. **6**G as springs **690***a*–**690***f*). The springs **690** can be operatively coupled to the carriage **126** to force movement of the carriage **126** from left to right. In the illustrated embodiment, the springs **690***a*–**690***f* are arranged in parallel. The number of springs **690** required to provide the necessary launch force can be adjusted based on specific operating conditions (e.g., the size of the aircraft **140**, the length of the launch support member **128**, and the local atmospheric conditions). Suitable constant force springs are available from Vulcan Spring and Mfg. Company of Telford, Pa. The launch system **625***a* can further include a carriage return crank or winch **522** (FIG. **5**A) which can operate as described above to return the carriage from a post-launch position to a pre-launch position.

In one aspect of this embodiment, the springs **690** provide a constant force to the launch carriage **126**. One advantage of using one or more constant force springs is that the resulting launch distance is reduced. Furthermore, when using a constant force spring, the acceleration of the launch carriage can be constant or nearly constant during launch, which can reduce the stresses applied to the aircraft **140**. Another advantage of this arrangement is that the peak force on the launch system can be reduced by providing a constant force, which can in turn reduce the amount of structure (and therefore weight) required by the launch system.

In other embodiments, the apparatus can be configured to rapidly launch a plurality of the aircraft **140**. For example, as shown in FIG. **7**A, an apparatus **700***a* configured in accordance with an embodiment of the invention can include multiple containers **111** positioned proximate to a launch system **125**. In one aspect of this embodiment, the containers **111** can be positioned in one or more container groups **720** (shown in FIG. **7**A as a vertical container group **720***a*, a horizontal container group **720***b*, and a diagonal container group **720***c*). In one embodiment, a single type of container group (e.g., a vertical container group **720***a*) can be positioned adjacent to a single launch system **125**. In other embodiments, multiple container groups of different types can be positioned adjacent to a single launch system **125**. In any of these embodiments, the containers **111** within each container group **720** can be easily accessible to operators preparing the aircraft **140** within the containers **111** for launch. Furthermore, the containers can be mechanically fed to the launcher, and assembly and positioning for launch then completed automatically as previously discussed. Accordingly, multiple aircraft **140** can be rapidly launched from a single launch system **125**. An advantage of this arrangement is that in some circumstances, the targets toward which the aircraft **140** are launched extend over a wide territorial range, and/or change rapidly enough that a single aircraft **140** is unable to provide suitable coverage. By rapidly launching multiple aircraft **140**, widely dispersed targets that change rapidly with time can more easily be surveilled or otherwise engaged.

In other embodiments, multiple launchers can be employed in combination with multiple containers to quickly deploy a plurality of the aircraft **140**. For example, referring now to FIG. **7**B, an apparatus **700***b* can include multiple aircraft handling systems **703***b* arranged vertically, and multiple container groups **720***b*, also arranged vertically. Each container group **720***b* can have horizontally grouped containers **111**. In another arrangement shown in FIG. **7**C, an apparatus **700***c* can include horizontally spaced-apart aircraft handling systems **703***c*, each supplied with aircraft **140** from containers **111** positioned in vertically stacked container groups **720***a*.

In any of the embodiments described above with reference to FIGS. **7**A–**7**C, the aircraft handling systems can be supplied with containers **111** via gravity feed systems, mechanical rollers, slides, or other mechanisms. In a further aspect of these embodiments, each container group can also be mobile, for example, by placing stacks or rows of containers **111** on independently wheeled carriages, or on rails, skids, bearings, or floats. Accordingly, in still another aspect of these embodiments, the aircraft handling systems (in addition to the container groups) can also be mobile, for example, by positioning the aircraft handling systems on independently wheeled carriages, rails, skids, bearings or floats. As described above, an advantage of any of these embodiments is that multiple aircraft **140** can be deployed in rapid succession.

3. Vehicle Capture

FIGS. **8**A–**10**F illustrate apparatuses and methods for capturing unmanned aircraft (including the aircraft **140** described above) in accordance with several embodiments of the invention. Beginning with FIG. **8**A, the aircraft **140** can be captured by an aircraft handling system **803** positioned on a support platform **801**. In one embodiment, the support platform **801** can include a boat **802** or other water vessel. In other embodiments, the support platform **801** can include other structures, including a building, a truck or other land vehicle, or an airborne vehicle, such as a balloon. In many of these embodiments, the aircraft handling system **803** can be configured solely to retrieve the aircraft **140** or, as described above with reference to FIG. **2**, it can be configured to both launch and retrieve the aircraft **140**.

Referring now to FIG. **8**B, the aircraft handling system **803** can include a recovery system **850** integrated with a launch system **825**. In one aspect of this embodiment, the recovery system **850** can include an extendable boom **851** having a plurality of segments **852**. The boom **851** can be mounted on a rotatable base **856** or turret for ease of positioning. The segments **852** are initially stowed in a nested or telescoping arrangement (generally similar to that described above with reference to FIG. **2**) and are then deployed to extend outwardly as shown in FIG. **8**B. In other embodiments, the extendable boom **851** can have other arrangements, such as a scissors arrangement, a parallel linkage arrangement or a knuckle boom arrangement. In any of these embodiments, the extendable boom **851** can include a recovery line **853** extended by gravity or other forces. In one embodiment, the recovery line **853** can include 0.25 inch diameter polyester rope, and in other embodiments, the recovery line **853** can include other materials and/or can have other dimensions. In any of these embodiments, a spring or weight **854** at the end of the recovery line **853** can provide tension in the recovery line **853**. The aircraft handling system **803** can also include a retrieval line **855** connected to the weight **854** to aid in retrieving and controlling the motion of the weight **854** after the aircraft recovery operation has been completed. In another embodiment, a recovery line **853***a* can be suspended from one portion of the boom **851** and attachable to another point on the boom **851**, in lieu of the recovery line **853** and the weight **854**.

In one aspect of this embodiment, the end of the extendable boom **851** can be positioned at an elevation E above the local surface (e.g., the water shown in FIG. **8**B), and a distance D away from the nearest vertical structure projecting from the local surface. In one aspect of this embodiment, the elevation E can be about 15 meters and the distance D can be about 10 meters. In other embodiments, E and D can have other values, depending upon the particular installation. For example, in one particular embodiment, the elevation E can be about 17 meters when the boom **851** is extended, and about 4 meters when the boom **851** is retracted. The distance D can be about 8 meters when the boom **851** is extended, and about 4 meters when the boom **851** is retracted. In a further particular aspect of this embodiment, the boom **851** can be configured to carry both a vertical load and a lateral load via the recovery line. For example, in one embodiment, the boom **851** can be configured to capture an aircraft **140** having a weight of about 30 pounds, and can be configured to withstand a side load of about 400 pounds, corresponding to the force of the impact between the aircraft **140** and the recovery line **853** with appropriate factors of safety.

In any of the foregoing embodiments, the aircraft **140** is captured when it flies into the recovery line **853**. Once captured, the aircraft **140** is suspended from the recovery line by the wing **143**. Further details of apparatuses and methods for capturing the aircraft **140** are described below with reference to FIGS. **9**A–**10**D.

FIG. **9**A is a partially schematic, isometric illustration of an outboard portion of the wing **143** and the winglet **146** of the aircraft **140** shown in FIG. **8**B. In one aspect of this embodiment, the wing **143** includes a leading edge **949** (which can be swept), an outboard edge **939**, and a line capture device **960** positioned at the outboard edge **939**. In other embodiments, each wing **143** can include a plurality of line capture devices **960** located along the span of the wing **143**. In any of these embodiments, the line capture device **960** can include a cleat **961** fixedly attached to the wing **143** that engages the recovery line **853** to releasably and securely attach the aircraft **140** to the recovery line **853**. The cleat **961** can include a cleat body **962**, a cleat slot **963** positioned in the cleat body **962**, and a gate or retainer **964** attached to the cleat body **962**. As the aircraft **140** flies toward the recovery line **853** (as indicated by arrow A), the recovery line **853** strikes the wing leading edge **949** and causes the aircraft to yaw toward the recovery line **853**, which then slides outboard along the leading edge **949** toward the line capture device **960** (as indicated by arrow B). The recovery line **853** then passes into the cleat slot **963** and is retained in the cleat slot **963** by the retainer **964**, as described in greater detail below with reference to FIGS. **9**B–**9**C. In other embodiments, the retainer **964** can be eliminated and the recovery line **853** can still be securely pinched in the cleat slot **963**.

If the aircraft **140** is not properly aligned with the recovery line **853** during its approach, the recovery line **853** may strike the line capture device **960** instead of the leading edge **949**. In one embodiment, the cleat body **962** includes a cleat leading edge **969** which is swept aft so as to deflect the recovery line **853** away from the aircraft **140**. This can prevent fouling of the line **853** and can reduce the yawing moment imparted to the aircraft **140**, allowing the aircraft **140** to recover from the missed capture and to return for another capture attempt.

FIG. **9**B is an enlarged, isometric illustration of a portion of the wing **143** and the line capture device **960** described above with reference to FIG. **9**A. As described above with reference to FIG. **9**A, the recovery line **853** travels outboard along the wing leading edge **949** to position the recovery line **853** at the cleat slot **963** of the line capture device **960**. In one aspect of this embodiment, the retainer **964** of the cleat **961** includes two or more closure arms **965** (two are shown in FIG. **9**B as a first closure arm **965***a* and a second closure arm **965***b*) that extend over the cleat slot **963**. The retainer **964** is pivotally mounted to the cleat body **962** at a pivot joint **968**, and is forced toward a closed position (shown in FIG. **9**B) by a spring **967**. As the recovery line **853** strikes the first closure arm **965***a* from outside the cleat slot **963**, the force on the first closure arm **965***a* forces the retainer **964** to rotate about the pivot joint **968** (as indicated by arrow C) to an open position, allowing the recovery line **853** to move into the cleat slot **963**. The recovery line **853** continues through the cleat slot **963**, allowing the retainer **964** to begin closing as it passes the first closure arm **965***a*. The recovery line **853** then strikes the second closure arm **965***b* to force the retainer **964** back open again, and then travels further in the slot **963**. In one aspect of this embodiment, the slot **963** (which can be tapered) has a width that is less than a diameter of the recovery line **853**. Accordingly, the recovery line **853** can be pinched in the slot **963** as the recovery line **853** travels outboard and aft, securing the aircraft **140** to the recovery line **853**. The momentum of the aircraft **140** relative to the recovery line **853** provides the impetus to securely engage the recovery line **853** with the line capture device **960**.

As described above, the retainer **964** can include a first closure arm **965***a* and a second closure arm **965***b*. One advantage of a retainer **964** having a first closure arm **965***a* and a second closure arm **965***b* is that, if the relative velocity between the recovery line **853** and the aircraft **140** is insufficient to cause the recovery line **853** to travel to the end of the cleat slot **963**, the retainer **964** can close around the recovery line **853**, with the recovery line **853** positioned between the first closure arm **965***a*, and the second closure arm **965***b*. Accordingly, this arrangement can arrest and secure the aircraft **140** even though the recovery line **853** has a relatively low outboard and aft velocity component relative to the capture device **960**.

Another advantage of the foregoing features, as shown in FIG. **9**C is that, as the aircraft **140** is captured on the recovery line **853**, the recovery line **853** may twist so as to form a looping portion **953**. The retainer **964** can prevent the recovery line **853** from passing out of the cleat slot **963**, even if the recovery line **853** experiences forces inboard and forward relative to the capture device **960**. The recovery line **853**, secured in the cleat slot **963**, also serves to resist further opening of the retainer **964**. Furthermore, without the closure arms **965**, tension on the end of a loop **953** could pull the recovery line **853** free of the cleat slot **963**. The closure arms **965** can prevent this by admitting only one diameter of the recovery line **853**.

FIG. **9**D is a partially schematic, isometric illustration of a portion of a wing **143** of the aircraft **140** with a line capture device **960***d* positioned at the outboard edge **939** of the wing **143** in accordance with another embodiment of the invention. In one aspect of this embodiment, the line capture device **960***d* includes a cleat body **962** and a retainer **964***d* having two cleat arms **965***c*, **965***d* that pivot independently relative to the cleat slot **963**. Each cleat arm **965***c*, **965***d* is pivotally mounted to the cleat body **962** at a corresponding pivot joint **968***c*, **968***d*, and is forced toward a closed position by a corresponding spring **967***c*, **967***d*. The individual cleat arms **965***c*, **965***d* can provide generally the same function as the cleat arms **965***a*, **965***b* described above with respect to FIGS. **9**B–**9**C, e.g., to consistently and securely capture the recovery line **853**.

FIGS. **10**A–**10**D illustrate a method and apparatus for further securing the aircraft **140** after it is attached to the recovery line **853**. Referring first to FIG. **10**A, an aircraft handling system **1003** in accordance with an embodiment of the invention can include a hoist device **1080** coupled to the recovery line **853**. The recovery line **853** can pass over a series of pulleys **956**, shown in FIG. **10**A as a first pulley **956***a*, a second pulley **956***b* and a third pulley **956***c*. The recovery line **853** can also pass through a restraining device **1070** operatively coupled to the extendable boom **1051**.

The hoist device **1080** can include a spring **1085** or other forcing mechanism (including a weight, a hydraulic or pneumatic actuator, or an electric motor) coupled to the recovery line **853** in a deployable or triggerable manner that allows the spring **1085** to take up the recovery line **853**. The hoist device **1080** can also include a damper (not shown in FIG. **10**A) to smooth out the action of the spring **1085**. In one aspect of this embodiment, the hoist device **1080** can include a release mechanism **1081** configured to activate the spring **1085**. In a further aspect of this embodiment, the release mechanism **1081** can include a release link **1082** coupled to the recovery line **853**. The release link **1082** can include a trigger **1083** received in a corresponding trigger receptacle **1084**. The trigger receptacle **1084** is positioned at an interface between the spring **1085** and the recovery line **853**. Before the aircraft **140** strikes the recovery line **853**, the trigger **1083** can be engaged with the trigger receptacle **1084**, so that the spring **1085** does not act on the recovery line **853**.

Referring now to FIG. **10**B, as the aircraft **140** strikes and engages with the recovery line **853**, it imparts a vertical force on the release link **1082** (as indicated by arrow C), causing the trigger **1083** to pull out of the trigger receptacle **1084**, as indicated by arrow D. Accordingly, in this embodiment, the trigger **1083** is activated when a threshold extension or travel of the recovery line **853** is exceeded. In other embodiments, the trigger **1083** can be activated by other mechanisms, for example, when a threshold tension in the recovery line **853** is exceeded.

Referring next to FIG. **10**C, once the trigger **1083** has been released from the trigger receptacle **1084**, the spring **1085** begins to exert a force (indicated by arrow F) on the recovery line **853**. Concurrently, the aircraft **140** may be swinging from side to side as it is suspended from the recovery line **853**, thus exerting a centrifugal force on the recovery line **853**. The force F exerted by the spring **1085** on the recovery line **853** compensates for the weight of the aircraft **140** hanging on the recovery line **853** and the centrifugal force caused by the aircraft swinging on the line after capture. As shown in FIG. **10**D, the spring **1085** can draw the recovery line **853** around the pulleys **956** to reduce the line length between the first pulley **956***a* and the aircraft **140**. As the spring **1085** acts, it hoists the aircraft **140** up toward the restraining device **1070** at the end of the extendable boom **1051**. The spring **1085** can be sized so as not to exert so much force on the recovery line **853** that the aircraft **140** strikes the restraining device **1070** with excessive force and damages the aircraft **140**.

The restraining device **1070** is configured to releasably engage a portion of the aircraft **140**, thus stabilizing the aircraft **140** after it is hoisted up by the recovery line **853** to the extendable boom **1051**. In one embodiment, the restraining device **1070** can include a piece of pipe operatively connected to the end of the boom **1051**. In other embodiments, the restraining device **1070** can include both active and passive devices to engage and restrain at least a portion of the aircraft **140**, including an innertube apparatus configured to surround at least a portion of the aircraft **140**, a plurality of cushions configured to "sandwich" the aircraft **140**, or an umbrella which softly closes around the aircraft **140**. In other embodiments, the restraining device can have other arrangements, or the restraining device may be omitted.

If, after the aircraft **140** is caught and substantially decelerated, it is allowed to swing freely on the recovery line **853** (in response to wind or motion of the boom **1051**) then it may be damaged by collision with structures in the swing space including (when the boom **1051** is carried by a ship) the ship's mast and deck. The vulnerability of the aircraft **140** to damage can be much reduced by hoisting the recovery line **853** such that the line capture device **960** (FIGS. **9**A–**9**B) or nearby surfaces of the aircraft **140** are pulled firmly against the restraining device **1070** or a stiff object attached to the boom **1051**. The aircraft's freedom to swing is thereby much reduced. Firm contact between the aircraft **140** and the boom **1051** can be maintained as the aircraft **140** is lowered, for example, by articulation of the boom **1051** or by translation on a trolley. When sufficiently close to the deck, the aircraft **140** can be securely removed from the recovery line **853** and stowed.

FIGS. **10**E–**10**F are schematic illustrations of apparatuses for providing tension in the recovery line **853** before, during, and after aircraft capture. Referring first to FIG. **10**E, the recovery line **853** can pass over a series of pulleys **1056**, shown as a first pulley **1056***a* and a second pulley **1056***b*. In another aspect of this embodiment, the recovery line **853** can be operatively coupled to a first axially resilient member **1086** and a second axially resilient member **1087**. The first and second axially resilient members **1086**, **1087** can provide tension in the recovery line **853** before the aircraft (not shown) intercepts the recovery line at a location between the first pulley **1056***a* and the second pulley **1056***b*. In one embodiment, the axially resilient members **1086**, **1087** can include a spring or other forcing mechanism (including a weight, a hydraulic or pneumatic actuator, or an electric motor) coupled to the recovery line **853**. In another aspect of this embodiment, a damper **1089** can be operatively coupled to the recovery line **853** in parallel or in series with at least one of the axially resilient members **1086**, **1087** to smooth out the action of the axially resilient members **1086**, **1087**. In another embodiment, the axially resilient members **1086**, **1087** can be omitted and the recovery line **853** can be operatively coupled to only the damper **1089**. In this embodiment, the damper **1089** provides only a drag force on the recovery line **853**.

Referring next to FIG. **10**F, in another embodiment, the recovery line **853** can be operatively coupled to a weight **854** and an axially resilient member **1086** to provide tension in the line. In one embodiment, the axially resilient member **1086** can include a constant force spring similar to the constant force spring **690** described above with respect to FIG. **6**G.

An advantage of the foregoing arrangements is that the aircraft **140** can be less likely to swing about in an uncontrolled manner (e.g., when acted on by the wind) during subsequent portions of the recovery operation. Accordingly, the aircraft **140** will be less likely to become damaged by inadvertent contact with the ground, water, or the support platform from which the aircraft handling system **1003** extends. The aircraft will also be less likely to damage surrounding structures. In other embodiments, the boom **1051** can also be elevated as or after the recovery line **853** is taken up, to keep the aircraft **140** clear of surrounding structures.

4. Vehicle Disassembly and Stowage

FIGS. **11**A–**11**G illustrate a method for removing the aircraft **140** from the recovery line **853** and further securing and disassembling the aircraft **140**. FIG. **11**A is an isometric view of the aircraft **140** suspended from the extendable boom **1051**, which is in turn carried by the boat **802** or other support platform. As shown in FIG. **11**A, the motion of the aircraft **140** has been arrested and the aircraft **140** has been hoisted to the end of the boom **1051**. Referring now to FIG. **11**B, the boom **1051** can be retracted (as indicated by arrow G), by nesting the segments **1052** of the boom **1051**. The aircraft **140** is accordingly brought closer to the boat **802** or other support platform while its motion is constrained (e.g., by the restraining device **1070**). For purposes of illustration, the portion of the recovery line **853** below the aircraft **140** is not shown in FIGS. **11**B–**11**E.

Referring next to FIG. **11**C, the boom **1051** can then be swiveled (as indicated by arrow J) to align one of the wings **143** of the aircraft **140** with a securement hook **1190** positioned on a deck **1104** of the boat **802**. In one aspect of this embodiment, the securement hook **1190** can engage the line capture device **960** at the end of the wing **143**, and in other embodiments, the securement hook **1190** can engage other portions of the aircraft **140**. In any of these embodiments, the securement hook **1190** can be positioned proximate to a bracket **1191** that includes a cradle **116** connected to a container bottom **112**. As described in greater detail below with reference to FIGS. **11**D–G, the bracket **1191** can be movable to position the cradle **116** proximate to the aircraft **140** in preparation for stowage.

FIG. **11**D is an aft isometric view of the aircraft **140** releasably suspended between the retracted boom **1051** and the securement hook **1190** in accordance with an embodiment of the invention. The bracket **1191** can be mounted to the deck **1104** such that the cradle **116** is positioned properly for receiving the fuselage **141** of the aircraft **140**. In one aspect of this embodiment, the aircraft **140** can be engaged with the cradle **116** by lowering the boom **1051** until the fuselage **141** rests in the cradle **116**. In another embodiment, the bracket **1191** can be pivotably coupled to the deck **1104** at a pair of pivot joints **1192**. Accordingly (referring now to FIG. **11**E), the bracket **1191** (with the container floor **112** and the cradle **116** attached) can be rotated upwardly as indicated by arrow K to engage the cradle **116** with the fuselage **141**. An operator can then secure clamps **1193** around the fuselage **141** to firmly and releasably attach the aircraft **140** to the cradle **116**.

Referring now to FIG. **11**F, the operator can detach the two wings **143** from the extendable boom **1051** and the securement hook **1190**, respectively. The wings **143** can then be detached from the aircraft **140**. In a further aspect of this embodiment, the removed wings **143** can be stowed on the container floor **112** adjacent to the fuselage **141** of the aircraft **140**.

Referring now to FIG. **11**G, the bracket **1191** can be rotated downwardly as indicated by arrow I until the container bottom **112** rests on the deck **1104**. The aircraft **140** (not visible in FIG. **11**G) can then be completely enclosed by adding ends **114**, sides **115**, and a top **113** to the container bottom **112**, forming a protective sealed container **111** around the aircraft **140**.

In another embodiment, illustrated schematically in FIGS. **12**A–**12**E, the aircraft **140** can be disassembled and stowed in a manner that is generally the reverse of the method described above with reference to FIGS. **1**A–**1**E. Accordingly, (referring first to FIG. **12**A), the aircraft **140** can be attached to the cradle **116**, with the container **111** fully assembled except for the container top **113** (not shown in FIG. **12**A). The wing retainers (which connect the wings **143** to the wing stub **142**) can be accessed for removal by opening the hatch **147** positioned in the wing stub **142**. As shown in FIG. **12**B, an operator can detach the wing **143** from the wing stub **142** by translating and rotating the container section **122** to engage the gripper **119** with the wing **143**. The operator can then slide the gripper **119** along a track on the inner surface of the container section **122** to withdraw the spars **144** from the spar receptacles **145**, and to fully release the wing **143** from the rest of the aircraft **140**. The wing **143** can then be folded downwardly against the inner surface of the container section **122**, as shown in FIG. **12**C, and the container section **122** can be pivoted back into position as shown in FIG. **12**D. The foregoing steps can be repeated for the other wing **143** to complete the disassembly of the aircraft **140**. In one aspect of this embodiment, the wings **143** can be offset longitudinally from each other when stowed so that the stowed winglets **146** (if long enough) do not interfere with each other within the container **111**. Referring now to FIG. **12**E, the cradle **116** can be lowered into the container **111** and the top **113** placed on the container **111** to complete the stowage operation.

The above-described process can be fully automated following the initial attachment of the aircraft **140** to the cradle **116** by the addition of actuators. Referring to FIG. **12**B, in an exemplary embodiment an actuator **1202** (shown schematically) can move the container section **122** relative to the rest of the container **111**. Actuator **1204** (shown schematically) can move the gripper **119** relative to the container section **122**. Further actuators (not shown) can move other portions of the container **111** and/or aircraft **140**. This process can operate in reverse order to fully automate the aircraft assembly process, as described above with respect to FIGS. **1**A–**1**E.

One feature of embodiments of the apparatuses and methods described above for securing and stowing the aircraft **140** is that at least one portion of the container can move relative to the aircraft for disassembly of at least portions of the aircraft. This can limit the amount of unconstrained or freehand handling that an operator must undertake when stowing the aircraft **140**. An advantage of this feature is that the likelihood for inadvertently damaging the aircraft **140** as it is being secured and stowed can be reduced when compared with existing manual techniques for securing and stowing such aircraft. Another advantage of this feature is that the potential risk to people and nearby objects can be reduced. A system in accordance with an embodiment of the invention can provide for a secure and efficient cycle from flight through retrieval, dismantling, storing, servicing, assembly, checkout, launch, and back to flight and can include (a) a storage and assembly apparatus (such as a container); (b) means for supporting the storage and assembly apparatus at a station positioned for retrieval of the aircraft; (c) means for attaching the assembled aircraft to the storage and assembly apparatus; (d) means for controllably dismantling the aircraft and storing dismantled components of the aircraft within the storage and assembly apparatus; (e) means for servicing the aircraft within the container, including for example, means for transferring fuel and electrical power to the aircraft, and data to and/or from the aircraft; (f) means for supporting the storage and assembly apparatus at least proximate to a launch apparatus; (g) means for controlled assembly of the aircraft; and (h) means for controlled transfer of the aircraft to the launch apparatus such that the aircraft is available for launching.

In other embodiments, the systems and methods described above with reference to FIGS. **1**A–**12**E can be used in conjunction with aircraft having configurations different than those described above. For example, in one embodiment shown in FIG. **13**A, an aircraft **140*a*** can include generally unswept wings **143*a***. In another embodiment shown in FIG. **13**B, an aircraft **140*b*** can include forward swept wings **143*b***. Line capture devices on the wings **143*b*** can be installed toward the wing roots. In still another embodiment shown in FIG. **13**C, an aircraft **140*c*** can include delta wings **143*c***.

In still further embodiments, the aircraft can have propulsion systems that are different than, and/or are arranged differently than, those described above with reference to FIGS. **1**A–**12**E. For example, as shown in FIG. **13**D, an aircraft **140*d*** can include a nose-mounted propeller **148*d***. In an embodiment shown in FIG. **13**E, an aircraft **140*e*** can include twin propellers **148*e***, each mounted to one of the wings **143**. In still another embodiment shown in FIG. **13**F, an aircraft **140*f*** can include jet engines **1348** mounted to the wings **143**. In still further embodiments, the aircraft can have other configurations, while remaining compatible with some or all of the systems and methods described above for storing, launching, and capturing the aircraft.

From the foregoing, it will be appreciated that specific embodiments of the invention have been described herein for purposes of illustration, but that various modifications may be made without deviating from the spirit and scope of the invention. For example, the systems described above can be used to store, launch and recover aircraft having arrangements different than those described above. In other embodiments, these systems can handle projectiles or other airborne devices. Further details of related systems and methods are described in the following co-pending U.S. applications, filed concurrently herewith and incorporated herein by reference: U.S. application Ser. No. 10/758,943, entitled "Methods and Apparatuses for Capturing and Storing Unmanned Aircraft, Including Methods and Apparatuses for Securing the Aircraft After Capture"; U.S. application Ser. No. 10/758,948, entitled "Methods and Apparatuses for Launching Unmanned Aircraft, Including Methods and Apparatuses for Transmitting Forces to the Aircraft During Launch"; U.S. application Ser. No. 10/759,742, entitled "Methods and Apparatuses for Launching and Capturing Unmanned Aircraft, Including a Combined Launch and Recovery System"; U.S. application Ser. No. 10/759,545, entitled "Methods and Apparatuses for Capturing Unmanned Aircraft and Constraining Motion of the Captured Aircraft"; U.S. application Ser. No. 10/758,940, entitled "Methods and Apparatus for Capturing and Recovering Unmanned Aircraft, Including a Cleat for Capturing Aircraft on a Line"; U.S. application Ser. No. 10/759,541, entitled "Methods and Apparatuses for Launching, Capturing, and Storing Unmanned Aircraft, Including a Container Having a Guide Structure for Aircraft Components"; U.S. application Ser. No. 10/760,150, entitled "Methods and Apparatuses for Launching Unmanned Aircraft, Including Methods and Apparatuses for Launching Aircraft with a Wedge Action"; and U.S. application Ser. No. 10/758,955, entitled "Methods and Apparatuses for Launching Unmanned Aircraft, Including Methods and Apparatuses for Releasably Gripping Aircraft During Launch". Accordingly, the invention is not limited except as by the appended claims.

We claim:

1. An apparatus for handling an unmanned aircraft, comprising:

a support structure having a first portion and a second portion, at least one of the first and second portions being axially extendable relative to the other between a first position and a second position;

a flexible recovery line carried by the second portion of the support structure, wherein the recovery line is spaced apart from a point on the first portion of the support structure by a first distance when the at least one of the first and second portions is in the first position, and wherein the recovery line is spaced apart from the point on the first portion of the support structure by a second distance greater than the first distance when the at least one of the first and second portions is in the second position; and

an axially extendable resilient member coupled to the recovery line, the resilient member being positioned to extend when tension is applied to the recovery line and retract when the tension is reduced.

2. The apparatus of claim **1** wherein the support structure includes an extendable boom, and wherein the first position is a retracted position and the second position is an extended position.

3. The apparatus of claim wherein the support structure includes an extendable boom, with the at least one of the first and second portions being telescopically received in the other portion.

4. The apparatus of claim **1** wherein the axially extendable resilient member includes a spring.

5. The apparatus of claim **1** wherein the flexible recovery line is configured to capture an unmanned aircraft in flight.

6. The apparatus of claim **1**, further comprising a rotatable base, wherein the support structure is pivotally attached to the rotatable base.

7. The apparatus of claim **1** wherein the flexible recovery line is suspendable from the second portion of the support structure to hang at least generally downward.

8. The apparatus of claim **1** wherein the flexible recovery line is suspendable from the second portion of the support structure, the flexible recovery line having a first recovery line portion hanging generally downward and a second recovery line portion attachable to a point on the support structure.

9. The apparatus of claim **1**, further comprising an unmanned aircraft having a lifting surface and a capture device mounted to the lifting surface, the capture device being configured to releasably secure the aircraft to the recovery line when the aircraft intercepts the recovery line.

10. The apparatus of claim **1**, further comprising a retrieval line operatively coupled to the recovery line, wherein the retrieval line is positioned to at least partially control motion of the recovery line.

11. The apparatus of claim **1** wherein the support structure is configured to carry both a lateral load and a vertical load via the recovery line.

12. An apparatus for handling an unmanned aircraft, comprising:

an extendable boom, the boom having a proximal end and a distal end spaced apart from the proximal end, wherein the boom is extendable along a longitudinal axis from a retracted position to an extended position;

a flexible recovery line suspendable from the boom when the boom is in the extended position, the recovery line being movable between a retracted position and a deployed position, wherein the recovery line in the deployed position extends at least generally downward; and

an axially extendable resilient member coupled to the recovery line, the resilient member being positioned to extend when tension is applied to the recovery line and retract when the tension is reduced.

13. The apparatus of claim **12** wherein the extendable boom includes a first segment and a second segment, with the at least one of the first and second segments being movable relative to the other as the extendable boom moves along the longitudinal axis between the retracted position and the extended position.

14. The apparatus of claim **12** wherein the flexible recovery line is configured to capture an unmanned aircraft in flight.

15. The apparatus of claim **12**, further comprising a rotatable base, wherein the extendable boom is pivotally attached to the rotatable base.

16. The apparatus of claim **12**, further comprising an unmanned aircraft having a lifting surface and a capture device mounted to the lifting surface, the capture device being configured to releasably secure the aircraft to the recovery line when the aircraft intercepts the recovery line.

17. The apparatus of claim **12**, further comprising a retrieval line operatively coupled to the recovery line, wherein the retrieval line is positioned to at least partially control motion of the recovery line.

18. The apparatus of claim **12** wherein the support structure is configured to carry both a lateral load and a vertical load via the recovery line.

19. An apparatus for handling an unmanned aircraft, comprising:

support means having a first portion and a second portion, at least one of the first and second portions being axially extendable relative to the other between a first position and a second position;

recovery means for intercepting and capturing an unmanned aircraft in flight, wherein the recovery means is carried by the support means; and

tension means operatively coupled to the recovery means, wherein the tension means is configured extend when tension is applied to the recovery line and retract when the tension is reduced.

20. The apparatus of claim **19** wherein the support means includes an extendable boom, with the at least one of the first and second portions being movable relative to the other on a longitudinal axis extending along the boom between the first position and the second position, and wherein the first position is a retracted position and the second position is an extended position.

21. The apparatus of claim **19** wherein the recovery means includes a flexible recovery line suspendable from the support means when the support means is in the second position.

22. The apparatus of claim **19** wherein the tension means includes a spring operatively coupled to the recovery means.

23. A method for handling an unmanned aircraft, comprising:

moving a first portion of a single boom relative to a second portion of the single boom to increase the length of the single boom;

deploying a flexible recovery line from the single boom;

flying an unmanned aircraft to intercept the flexible recovery line in flight; and

releasably capturing the aircraft in flight with the recovery line.

24. The method of claim **23** wherein the flexible recovery line is spaced apart from a point on the first portion of the single boom by a first distance when the at least one of the first and second portions of the single boom is in a first position, and wherein the recovery line is spaced apart from the point on the first portion of the single boom by a second distance greater than the first distance when the at least one of the first and second portions of the single boom is in a second position.

25. The method of claim **23** wherein the aircraft includes a wing, and wherein capturing the aircraft includes releasably securing the wing to the recovery line.

26. The method of claim **23**, further comprising applying tension to the flexible recovery line after deploying the recovery line and before releasably capturing the aircraft.

27. The method of claim **23**, further comprising retrieving the aircraft from the recovery line after releasably capturing the aircraft.

28. A method for handling an unmanned aircraft, comprising:

moving a first portion of a single extendable boom relative to a second portion of the single extendable boom to increase the length of the boom;

deploying a flexible recovery line from the second portion of the single extendable boom, wherein the recovery line is suspended at least generally in a downward direction from the boom;

flying an unmanned aircraft to intercept the flexible recovery line in flight;

releasably capturing the aircraft in flight with the recovery line; and

retrieving the aircraft from the flexible recovery line.

29. The method of claim **28** wherein the aircraft includes a wing, and wherein capturing the aircraft includes releasably securing the wing to the recovery line.

30. The method of claim **28** wherein the at least one of the first and second portions of the single extendable boom are placed in a retracted position before retrieving the aircraft from the flexible recovery line.

31. The method of claim **28**, further comprising applying tension to the flexible recovery line after deploying the recovery line and before capturing the aircraft.

32. The method of claim **28** wherein the method further comprises controlling the flexible recovery line with a retrieval line.

33. The method of claim **28**, further comprising lengthening an extendable tension member coupled to the flexible recovery line when intercepting the aircraft with the flexible recovery line.

* * * * *

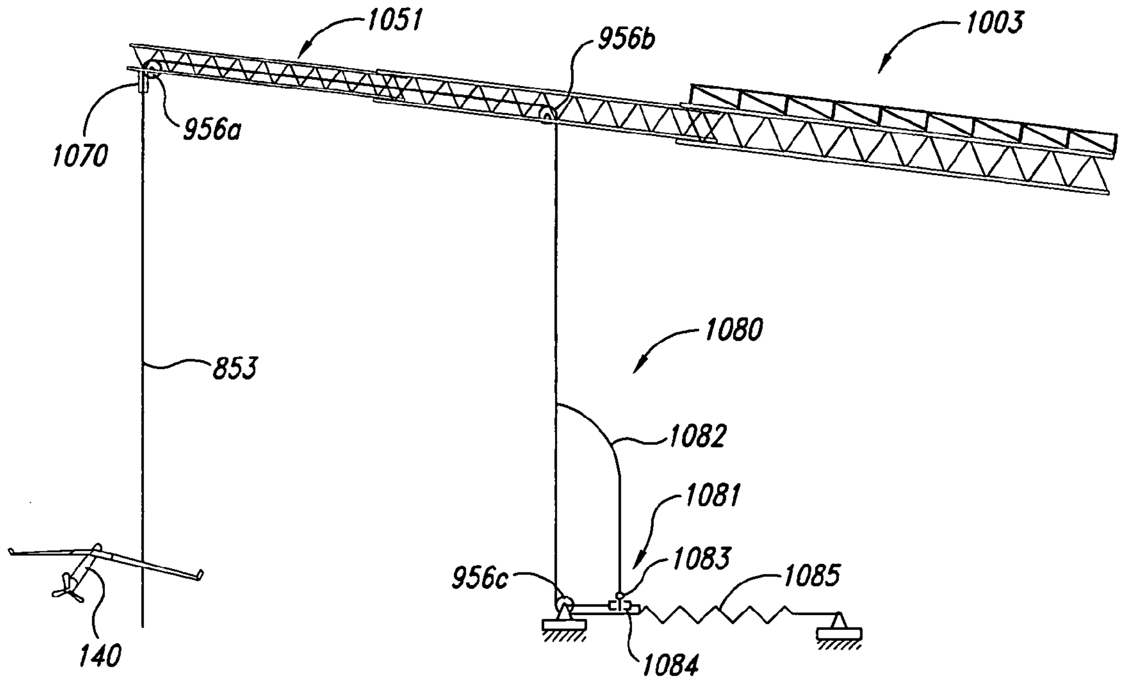


Fig. 10A

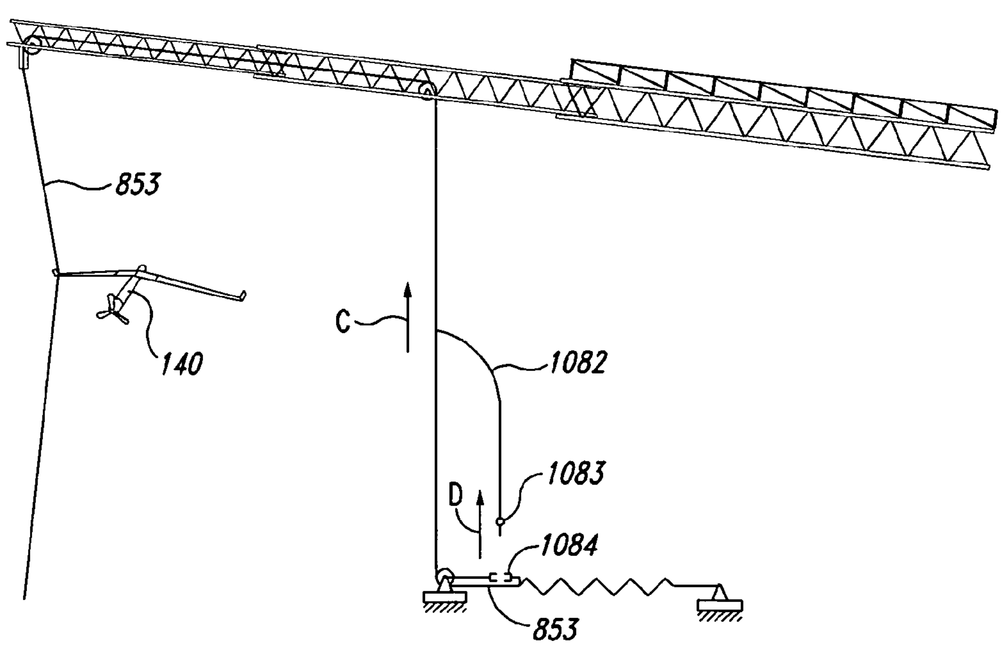


Fig. 10B