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(54) **AUTOROTATING PAYLOAD DELIVERY DEVICE**

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(73) Assignee: **Dash Systems, Inc.**, Chatsworth, CA (US)

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Publication Classification

(51) **Int. Cl.**

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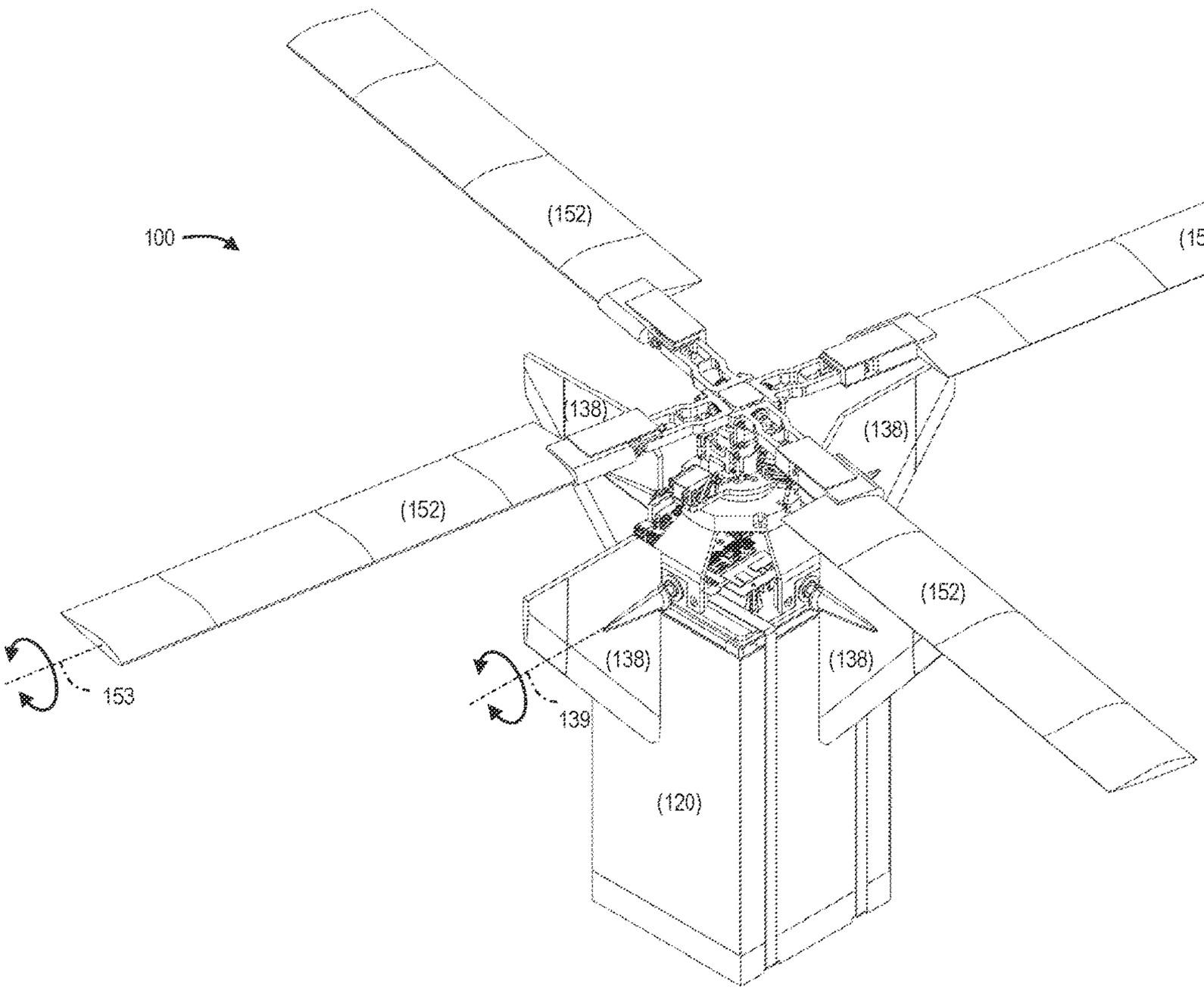
B64C 27/02	(2006.01)
B64C 39/02	(2006.01)
G05D 1/10	(2006.01)

(52) **U.S. Cl.**

CPC ***B64D 1/14*** (2013.01); ***B64C 27/02*** (2013.01); ***B64C 39/024*** (2013.01); ***G05D 1/105*** (2013.01); *B64C 2201/141* (2013.01); *B64C 2201/082* (2013.01); *B64C 2201/108* (2013.01); *B64C 2201/128* (2013.01); *B64C 2201/024* (2013.01)

(57) **ABSTRACT**

A payload delivery device configured to deliver an aircraft deployed payload along a flight path to a predetermined landing destination includes a support member configured to be removably attached to the payload, a flight control and navigation system module configured to control orientation of the plurality of control surfaces while the payload is travelling along the flight path to the predetermined landing destination, a control surface assembly module including a plurality of control surfaces, a rotor assembly including a plurality of rotor blades having a central axis of rotation, and a collective control assembly module including at least one collective servomotor configured to control a plurality of control linkages connected to the plurality of rotor blades.



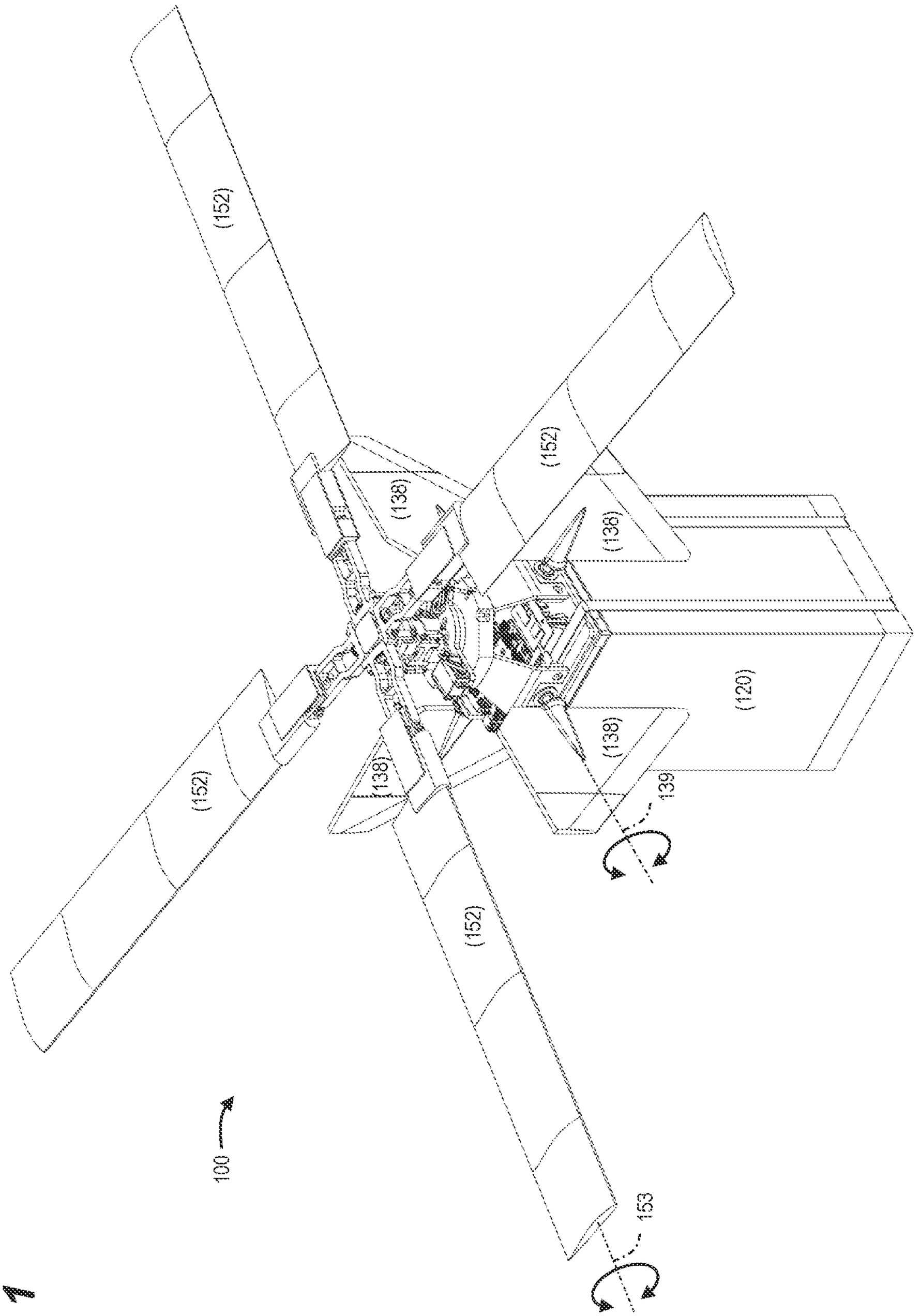


FIG. 1

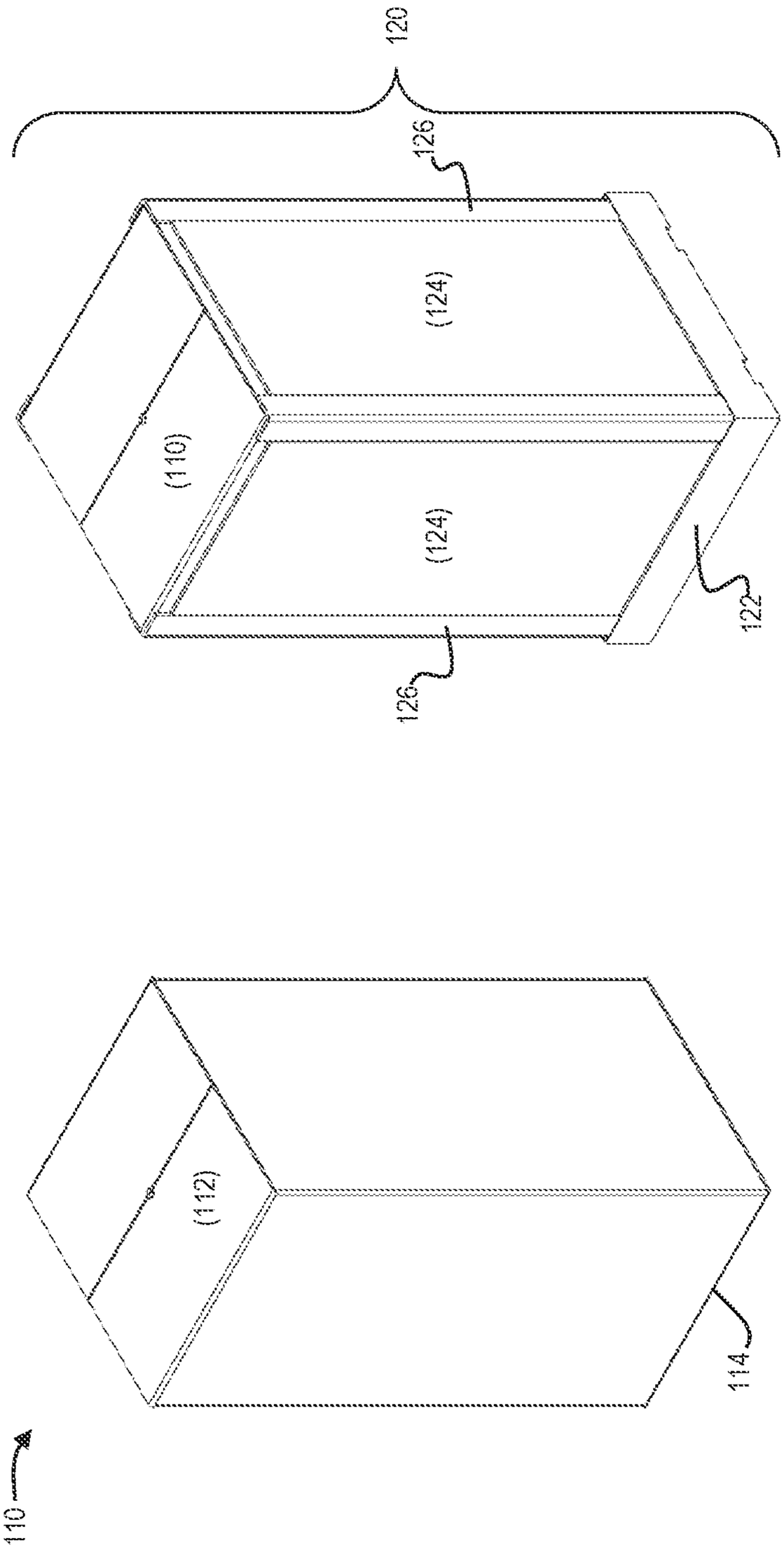


FIG. 2B

FIG. 2A

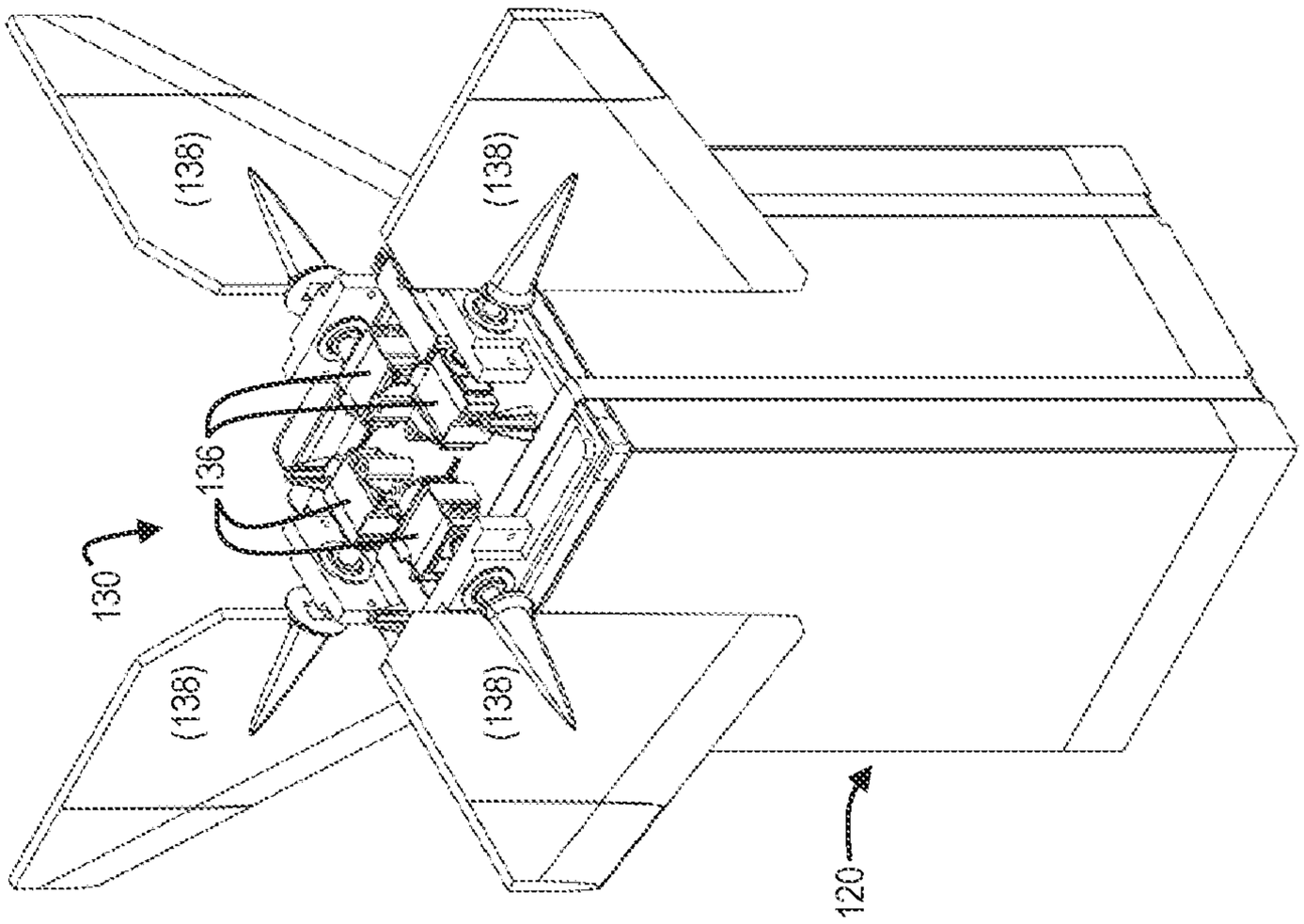


FIG. 3B

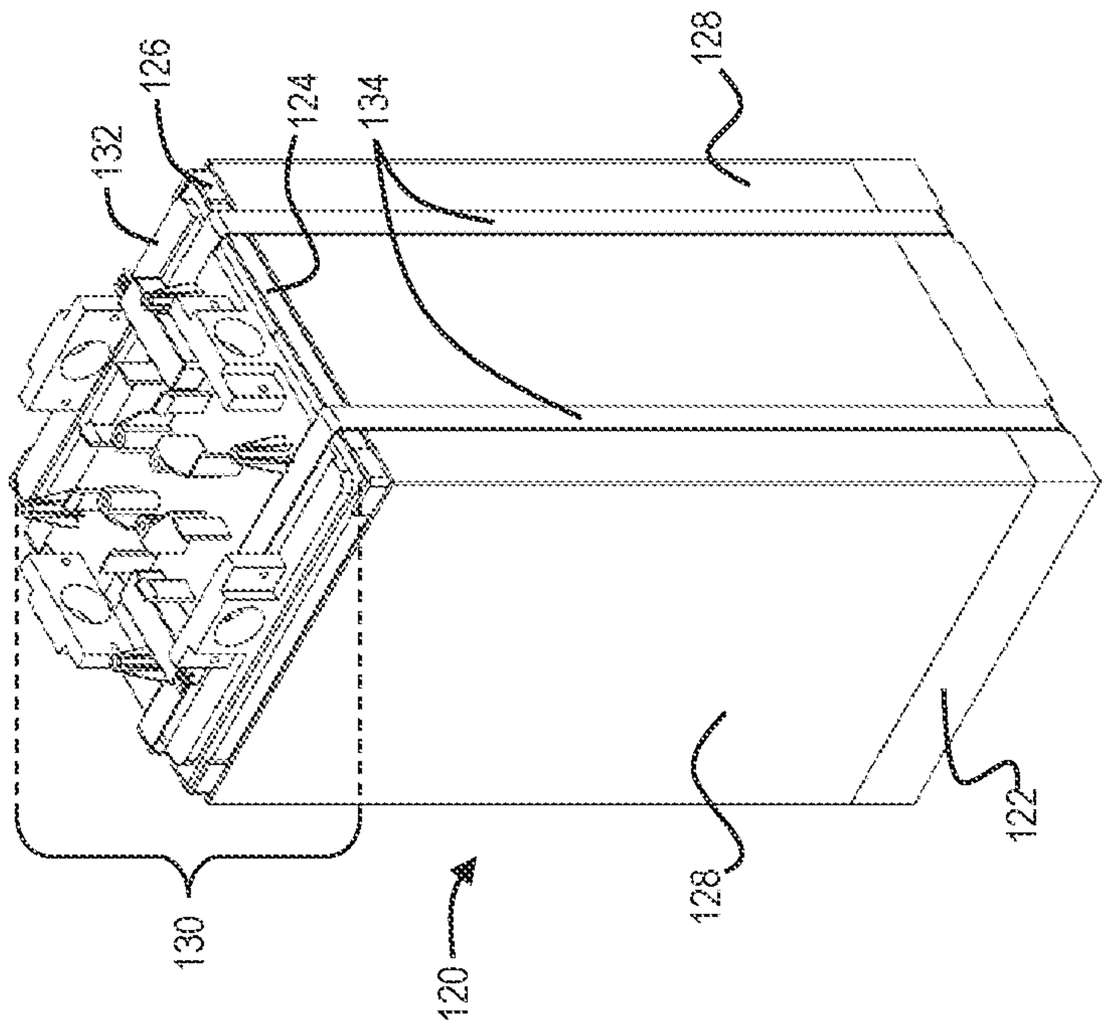
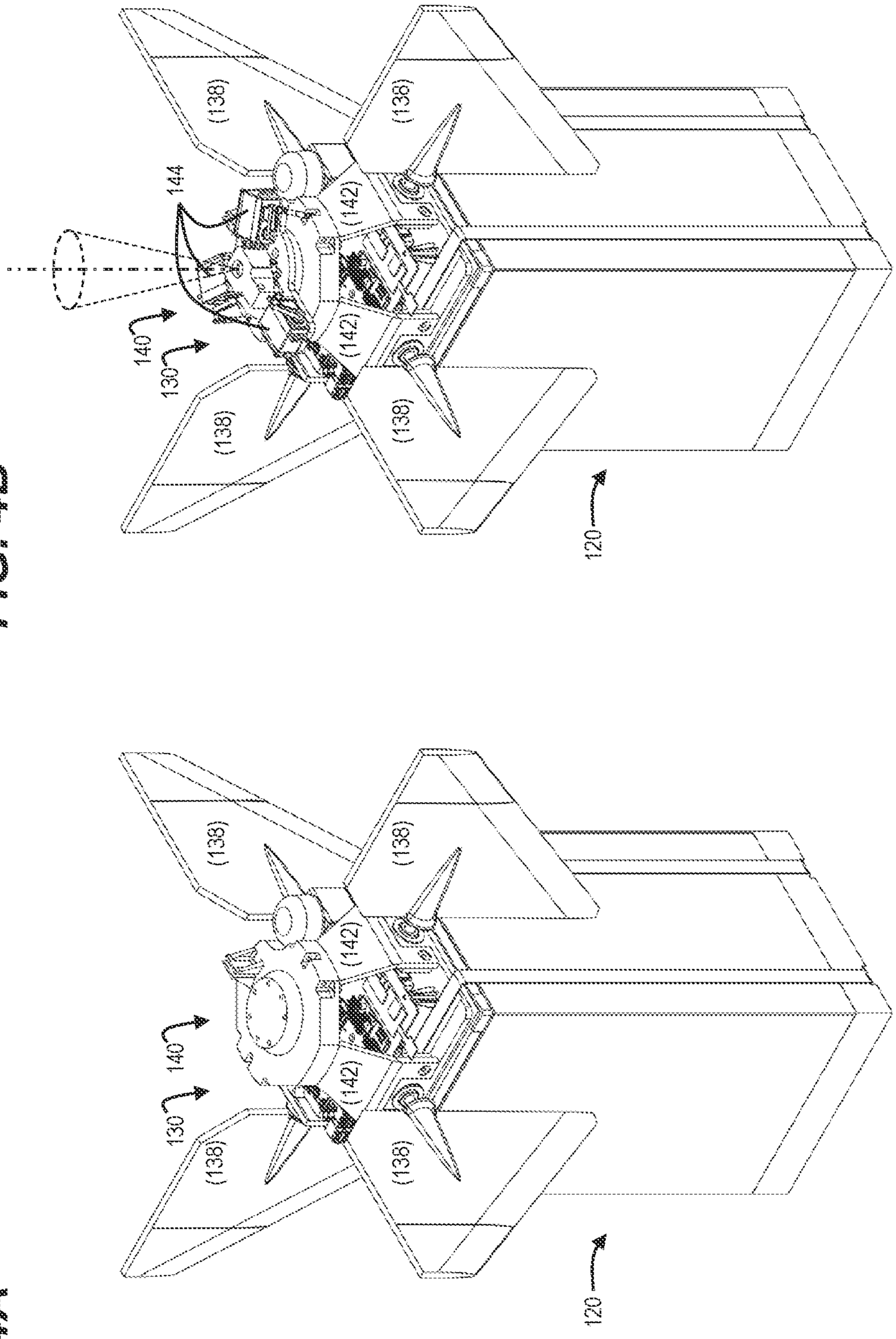


FIG. 3A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(138)
144
(142)
140
130
(142)
(138)
(138)
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(138)
(138)
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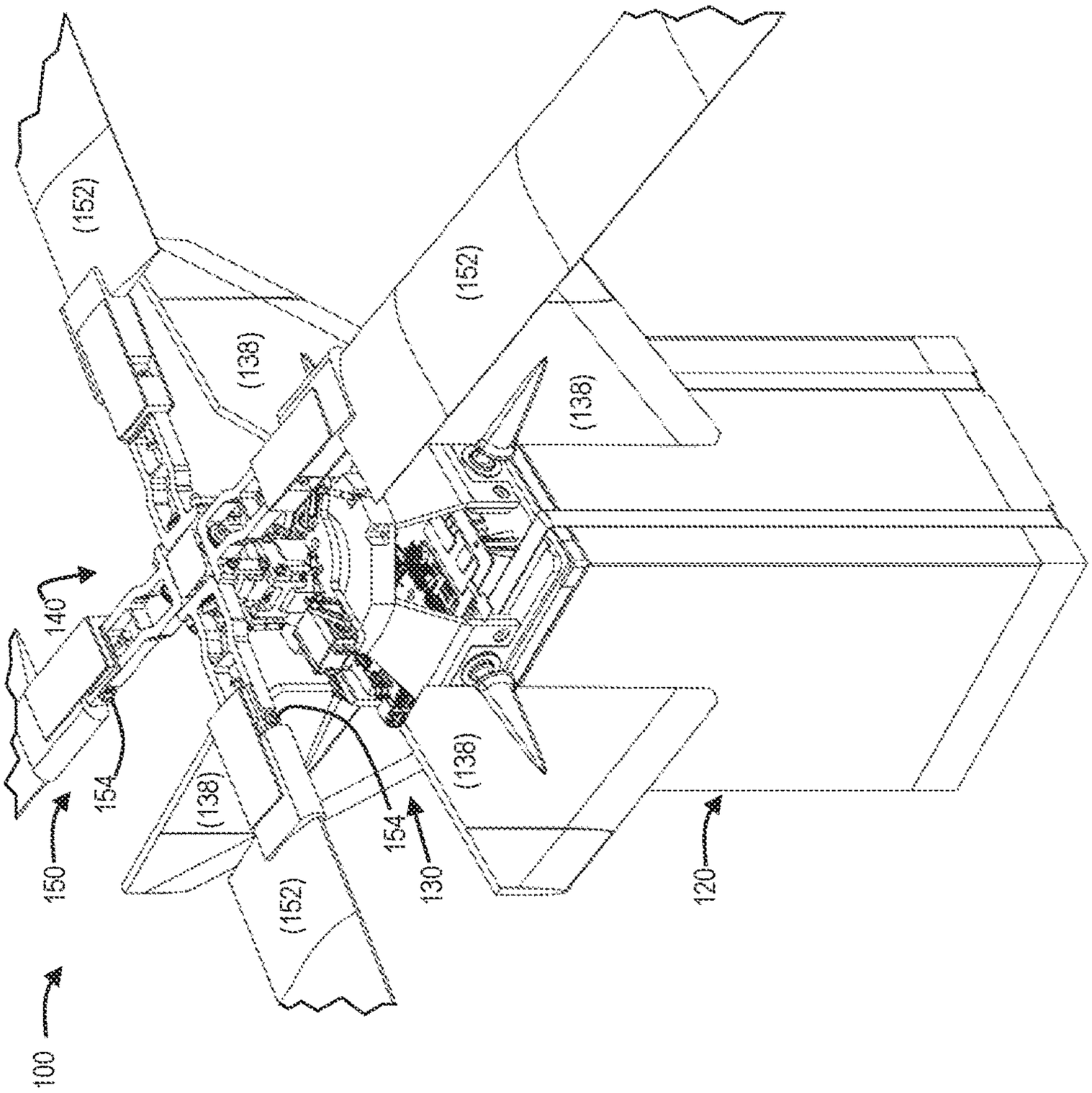
(142)
130
(142)
(138)
(138)
120

FIG. 4B

FIG. 4A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154
(138)
(138)
154
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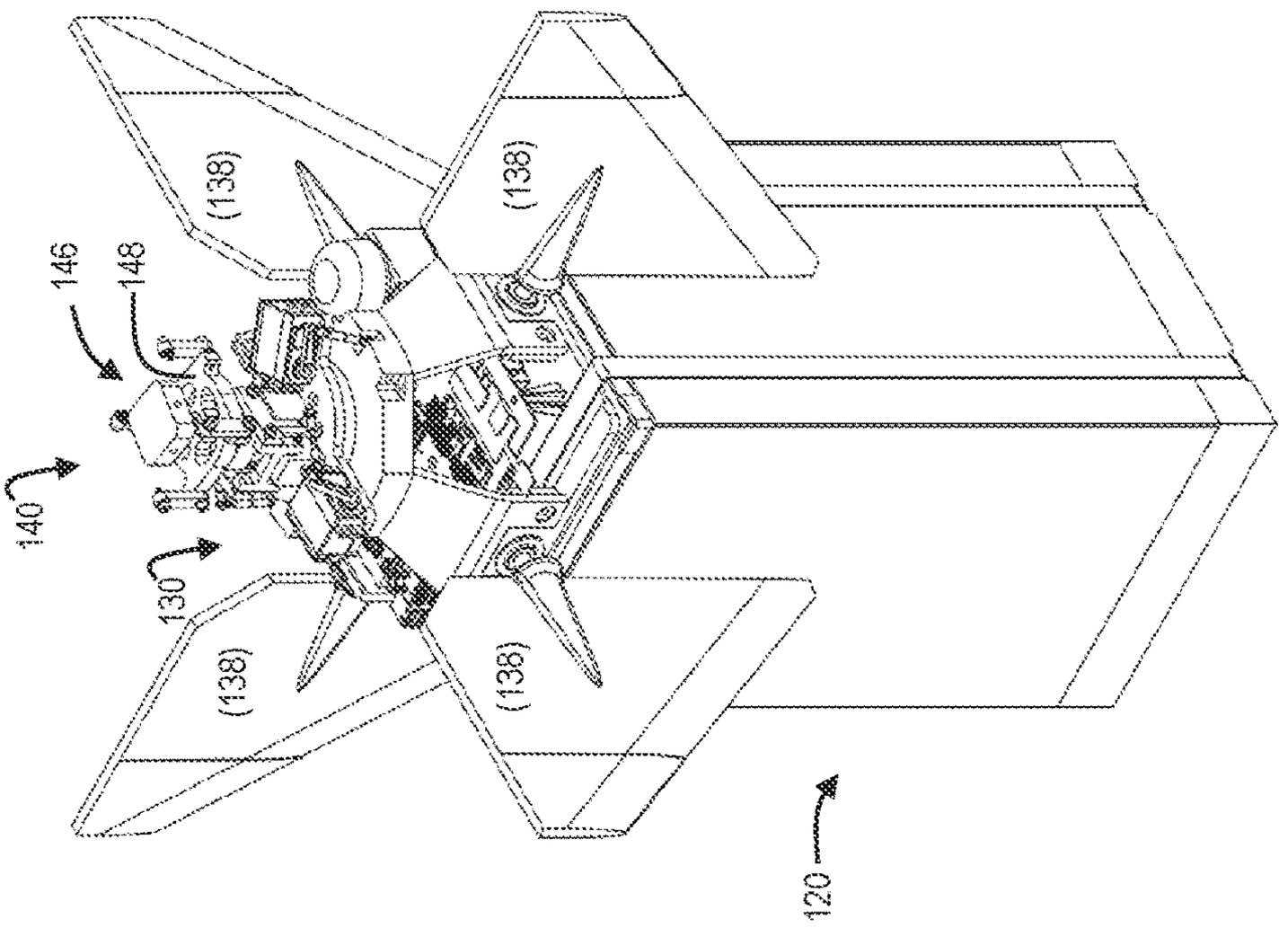
130
(152)
120
100

FIG. 5B


(138)
(138)
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148
140
130
(138)
(138)
120

FIG. 5A

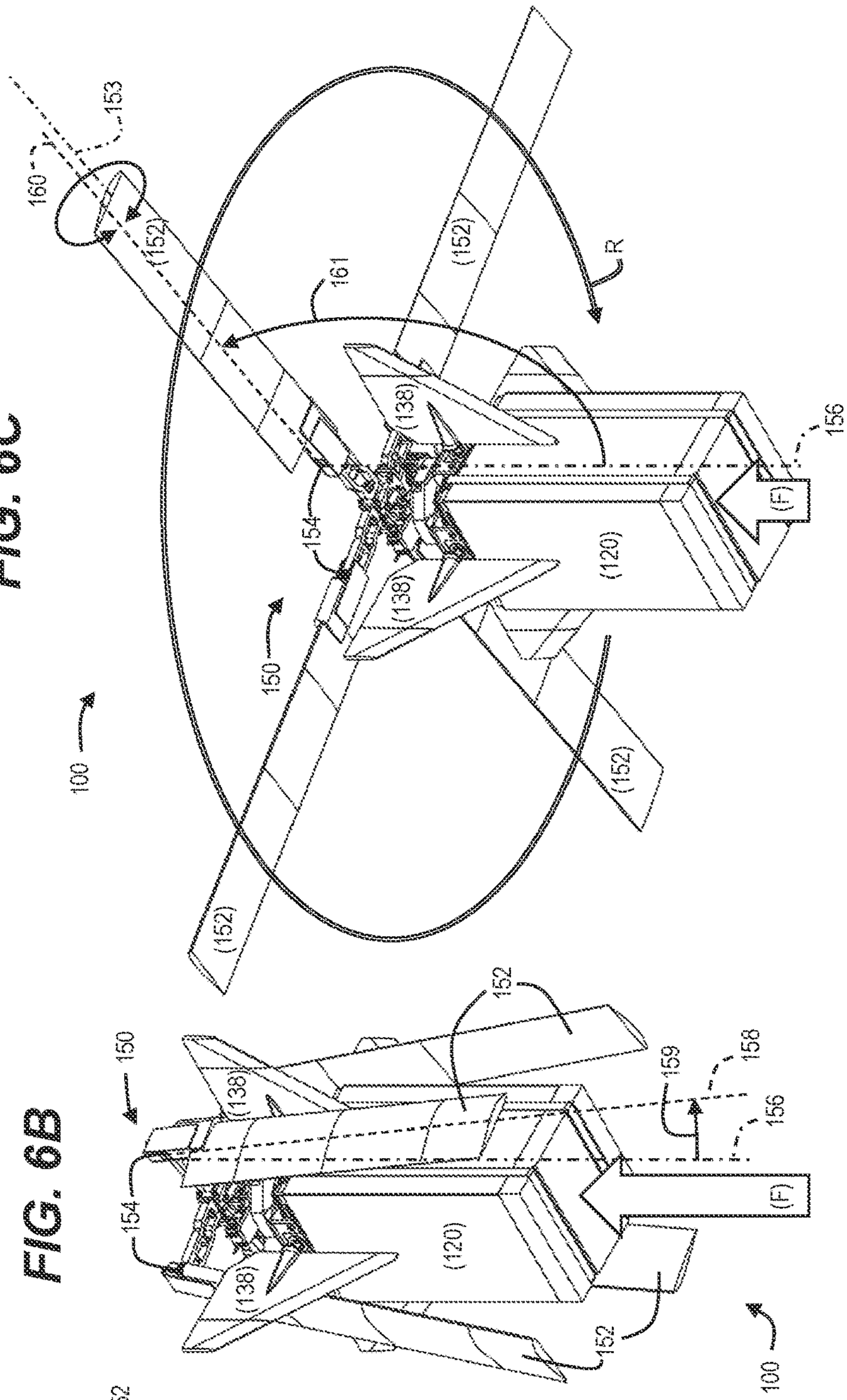


FIG. 6C

FIG. 6B

FIG. 6A

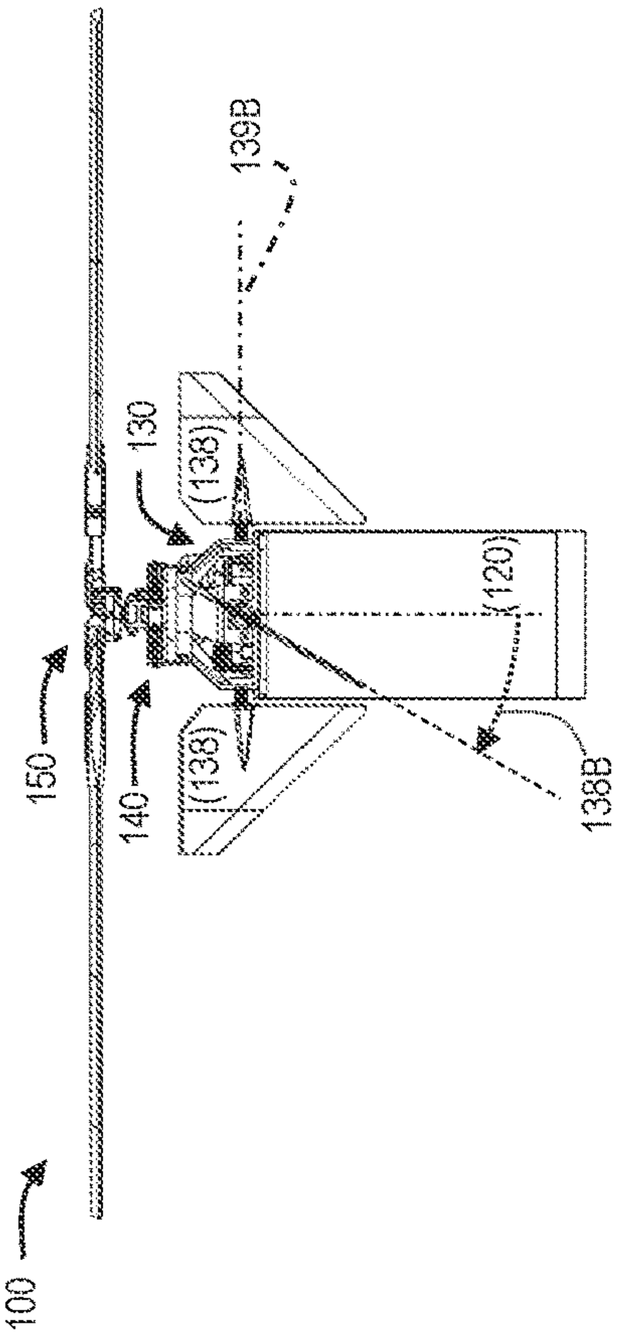


FIG. 7C

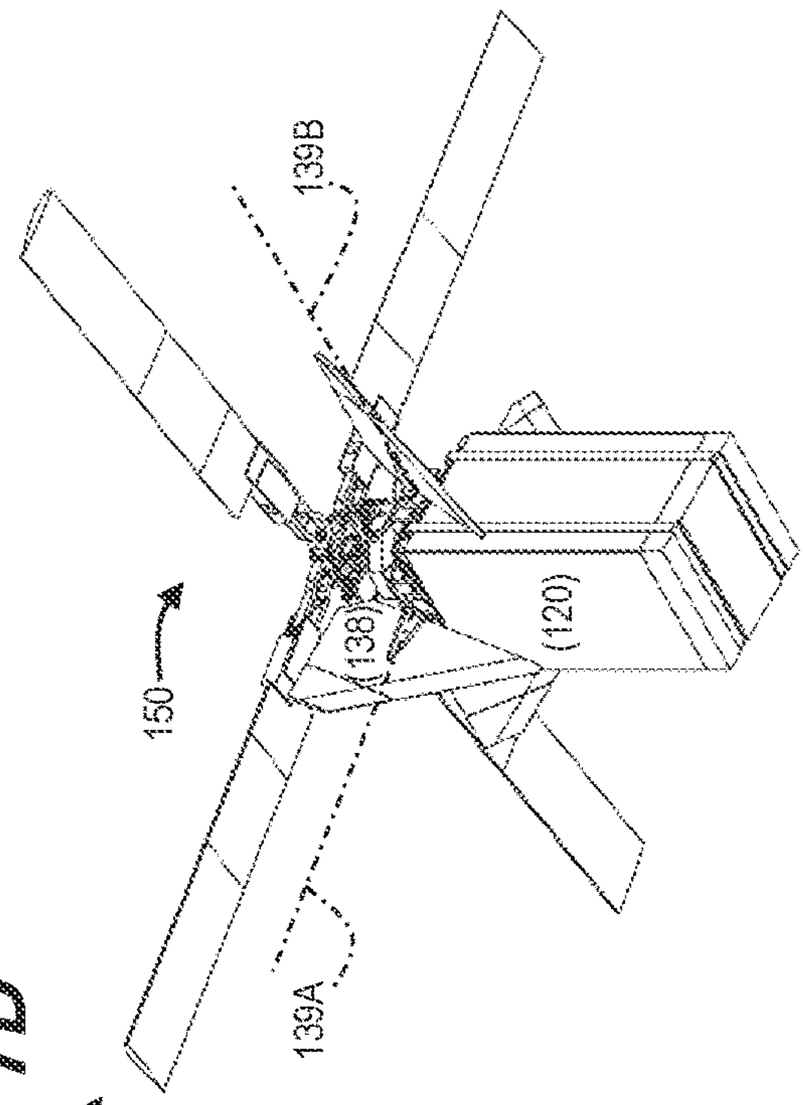


FIG. 7D

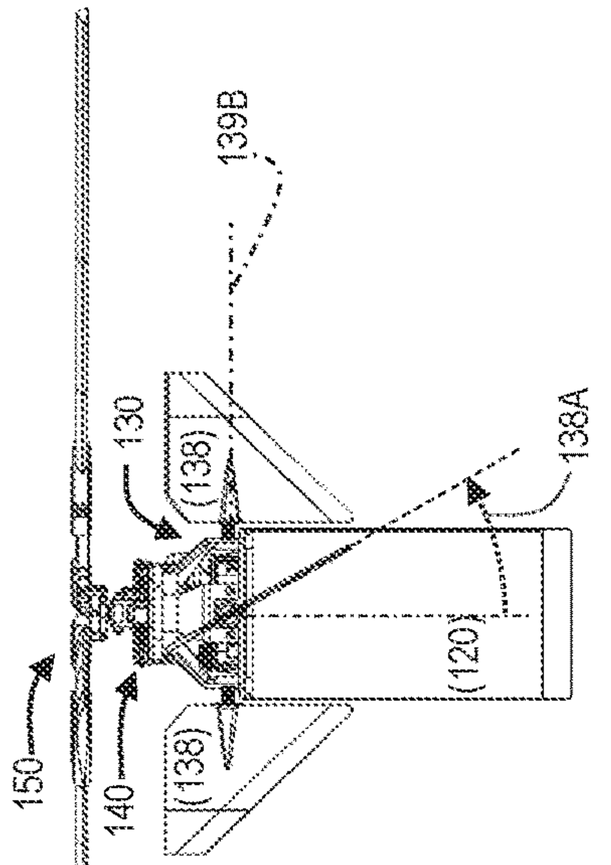


FIG. 7A

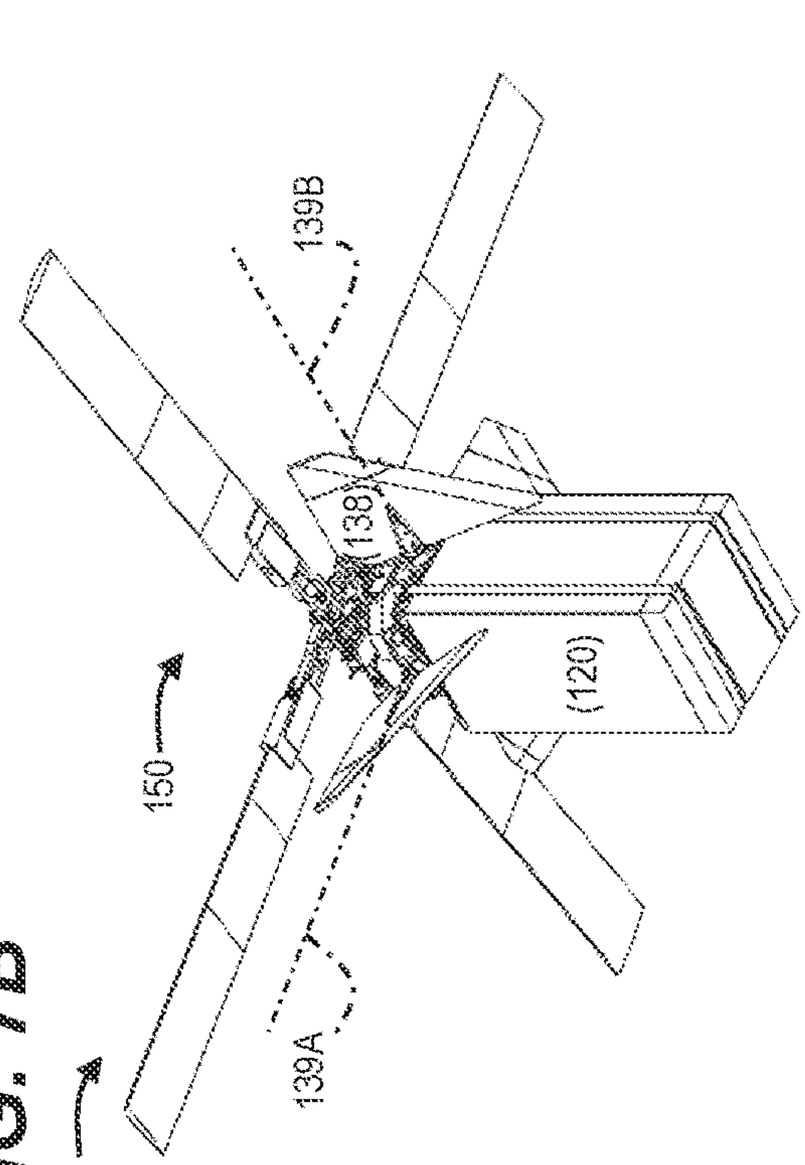


FIG. 7B

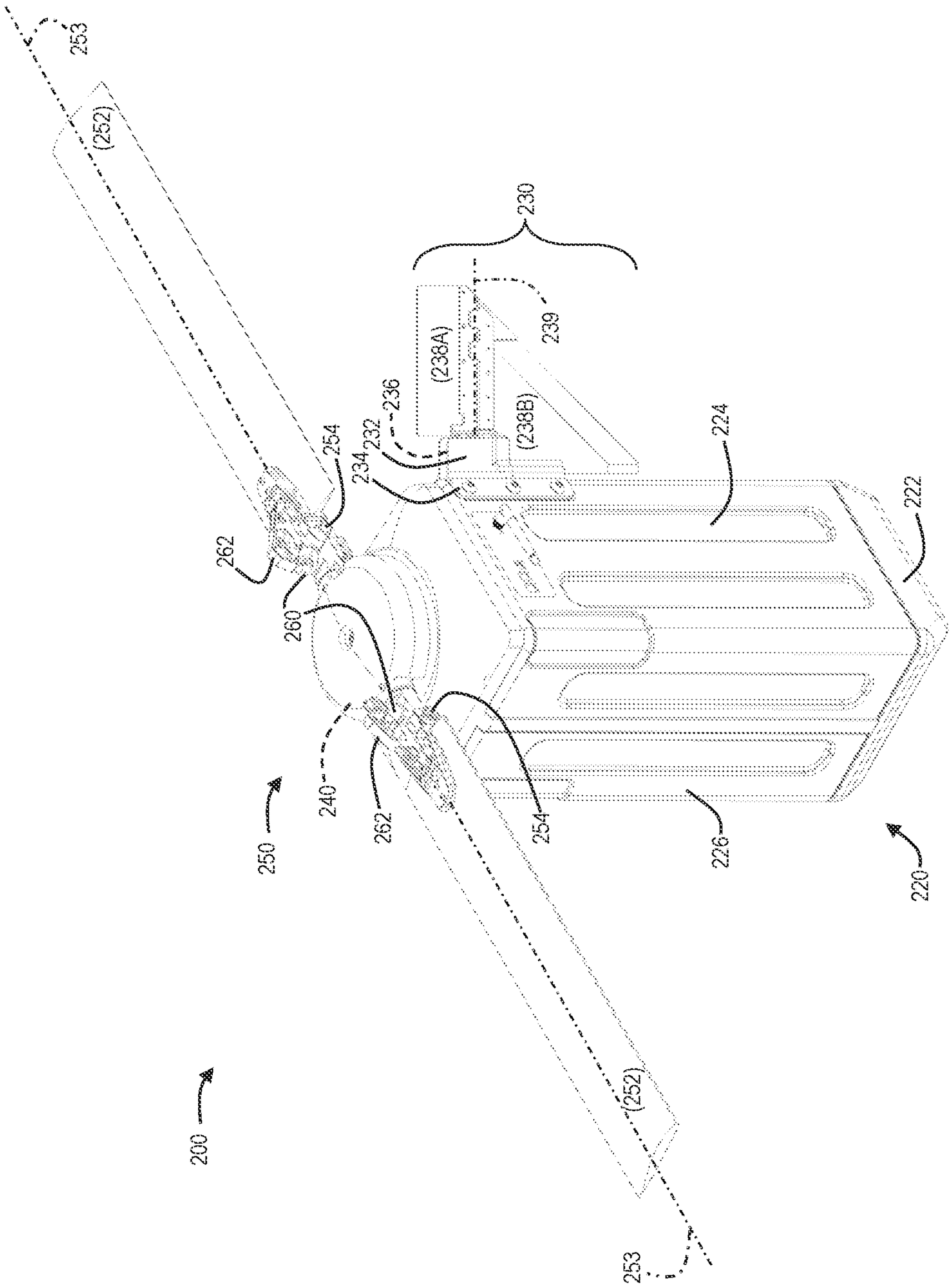
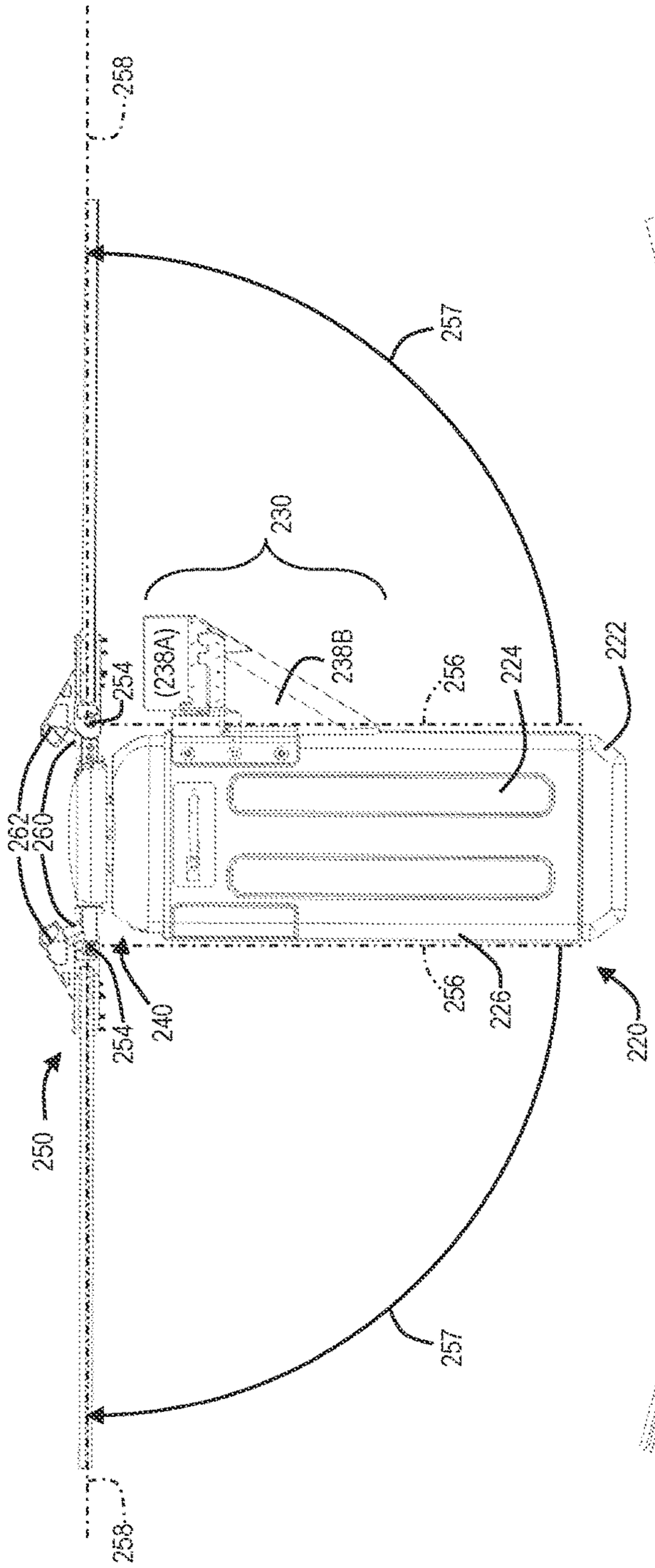

253
(252)
230
239
(238A)
(238B)
236
232
234
254
262
260
240
250
224
222
226
220
200

FIG. 8


200
250
258
257
230
(238A)
238B
254
256
224
222
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260
240
254
256
226
220
258

FIG. 9A

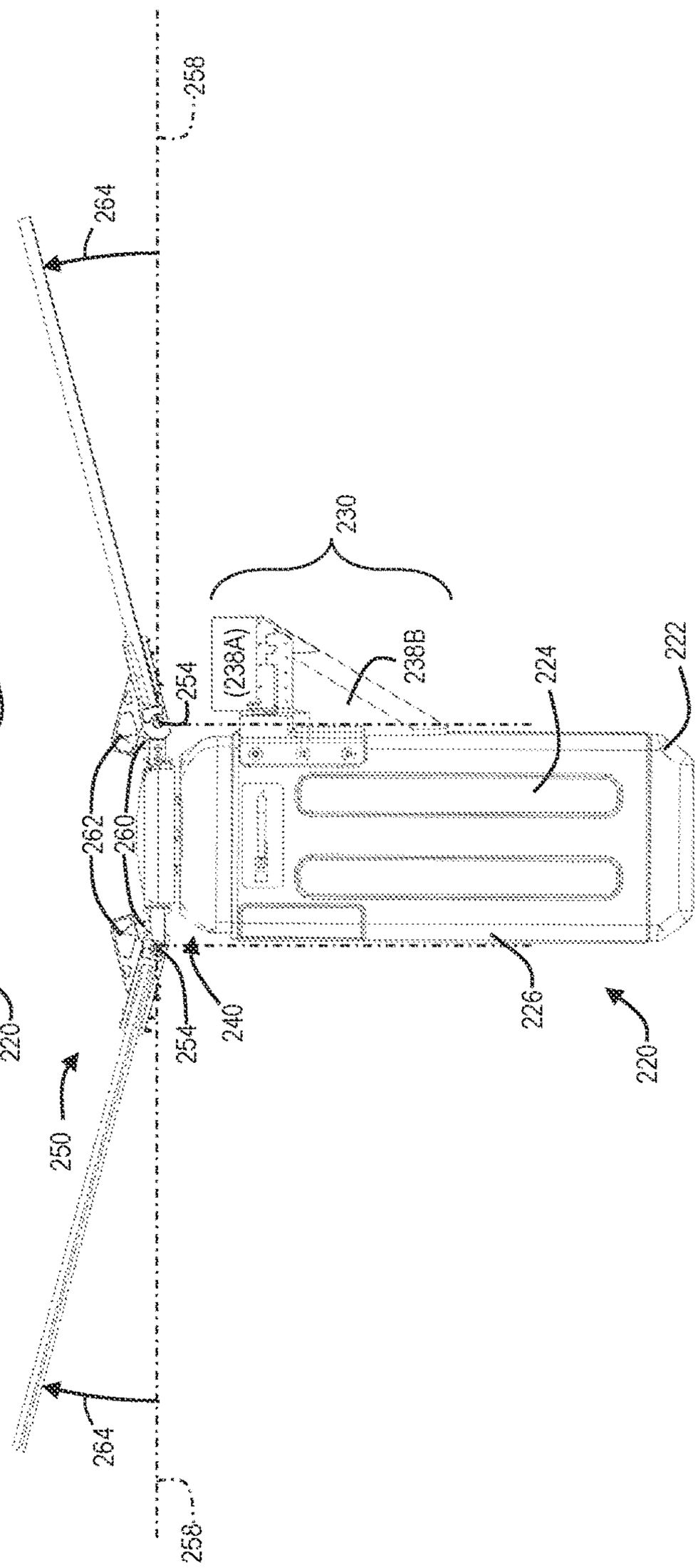

200
250
258
264
230
(238A)
238B
254
224
222
262
260
240
254
226
220
264
258

FIG. 9B

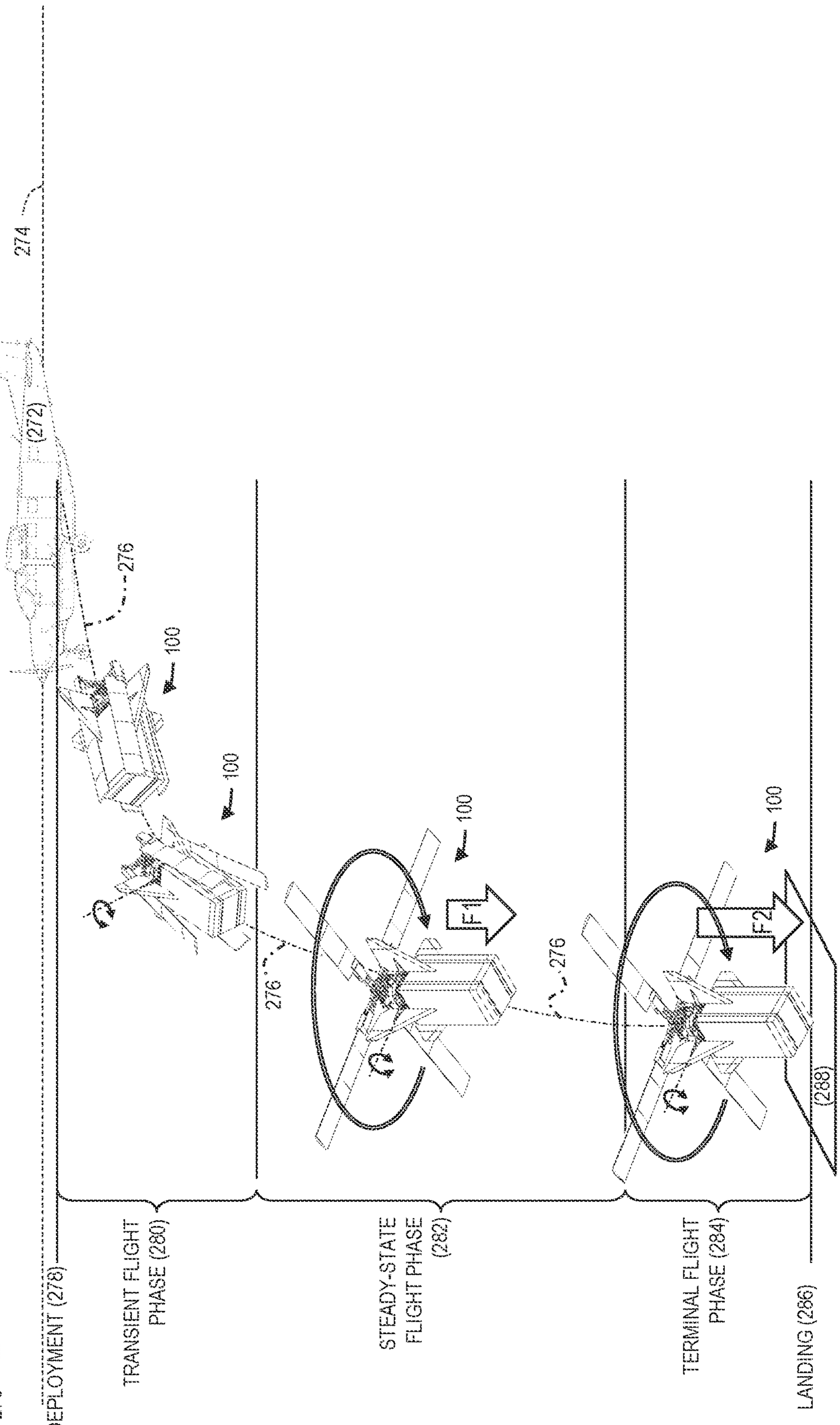

270
DEPLOYMENT (278)
TRANSIENT FLIGHT PHASE (280)
STEADY-STATE FLIGHT PHASE (282)
TERMINAL FLIGHT PHASE (284)
LANDING (286)
274
272
276
100
F1
F2
288

FIG. 10

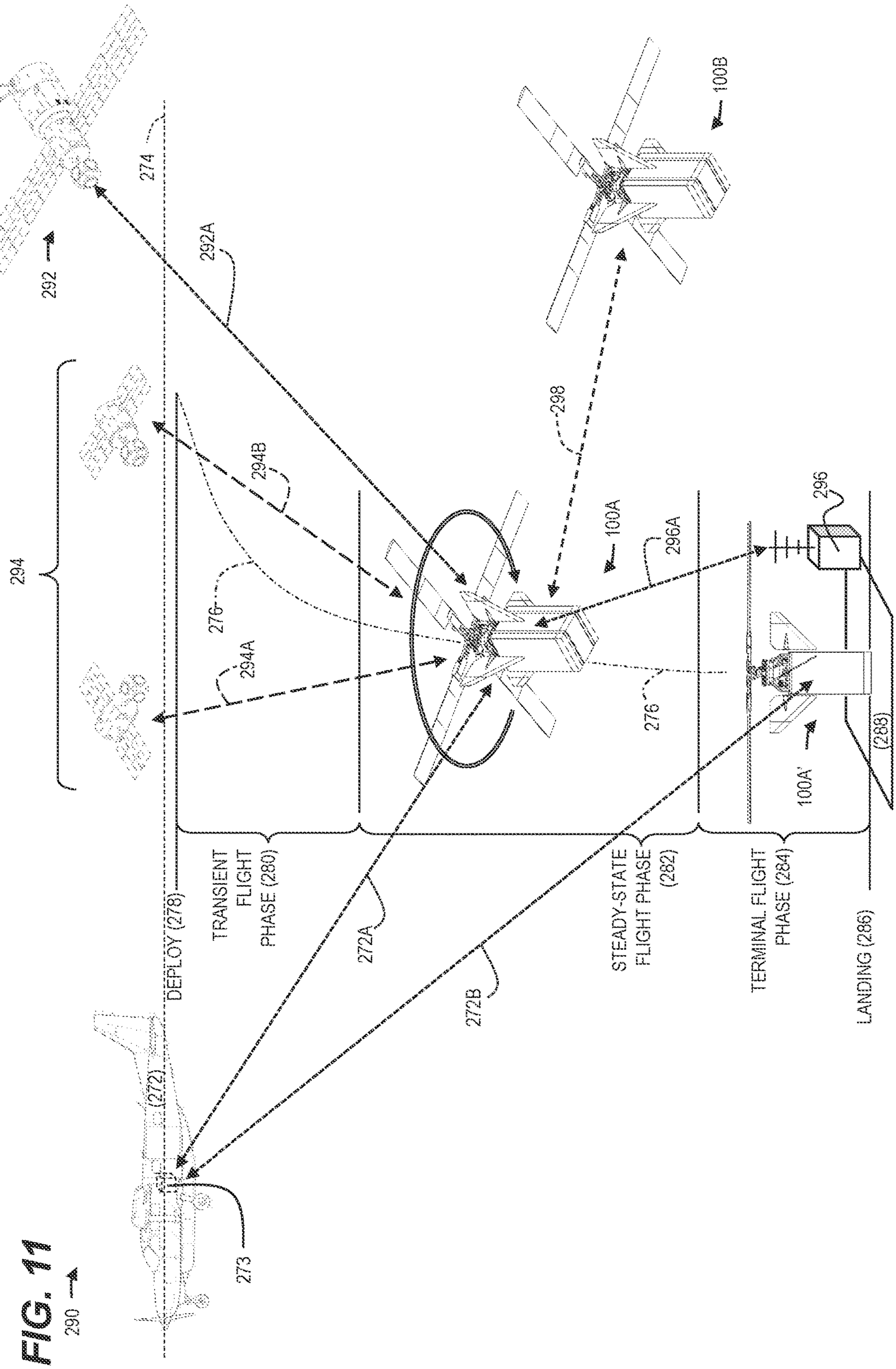

290
(272)
DEPLOY (278)
TRANSIENT FLIGHT PHASE (280)
STEADY-STATE FLIGHT PHASE (282)
TERMINAL FLIGHT PHASE (284)
LANDING (286)
294
292
274
292A
294B
276
294A
272A
272B
273
298
100B
100A
100A'
296A
296
(283)

FIG. 11

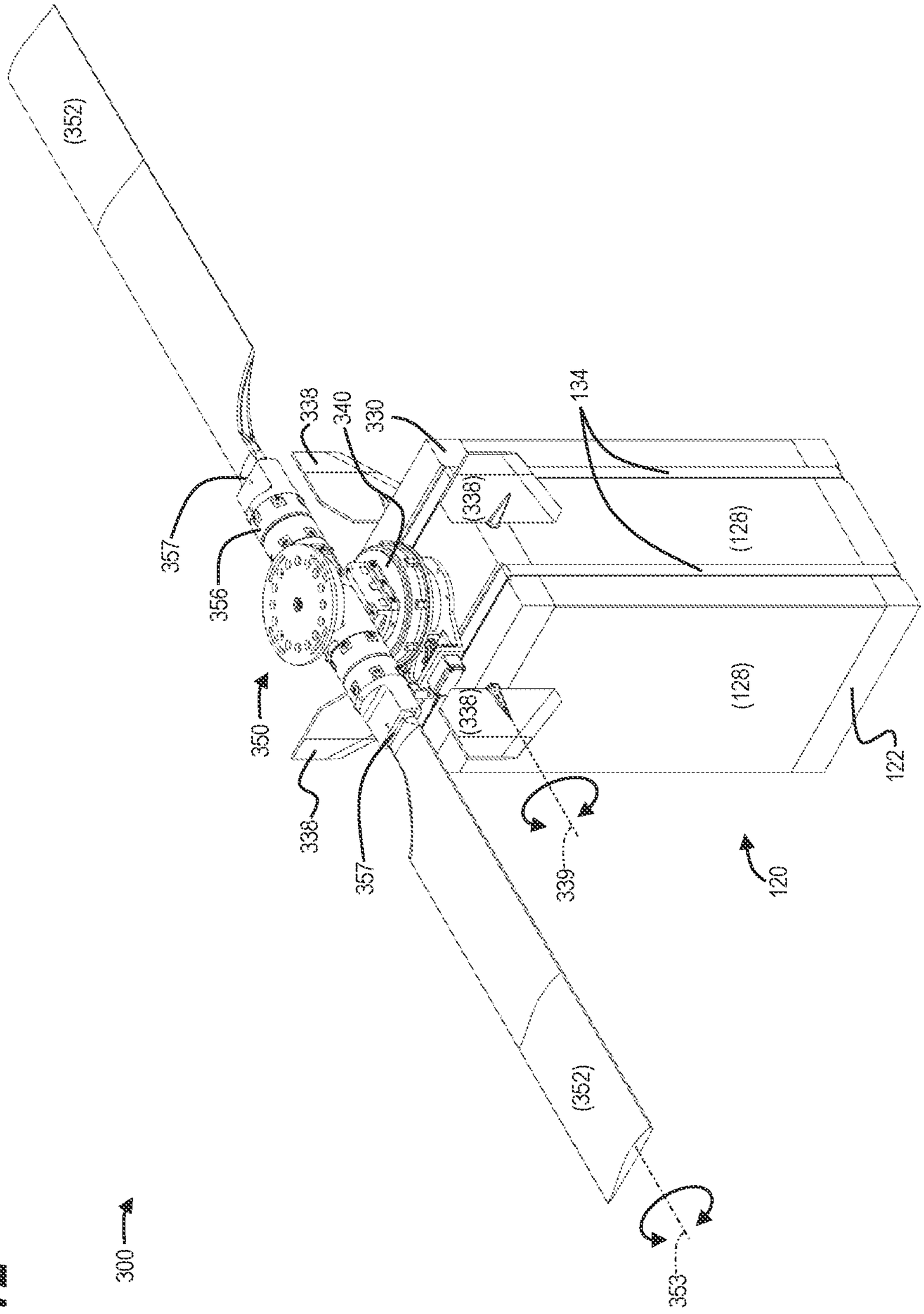


FIG. 12

FIG. 13C

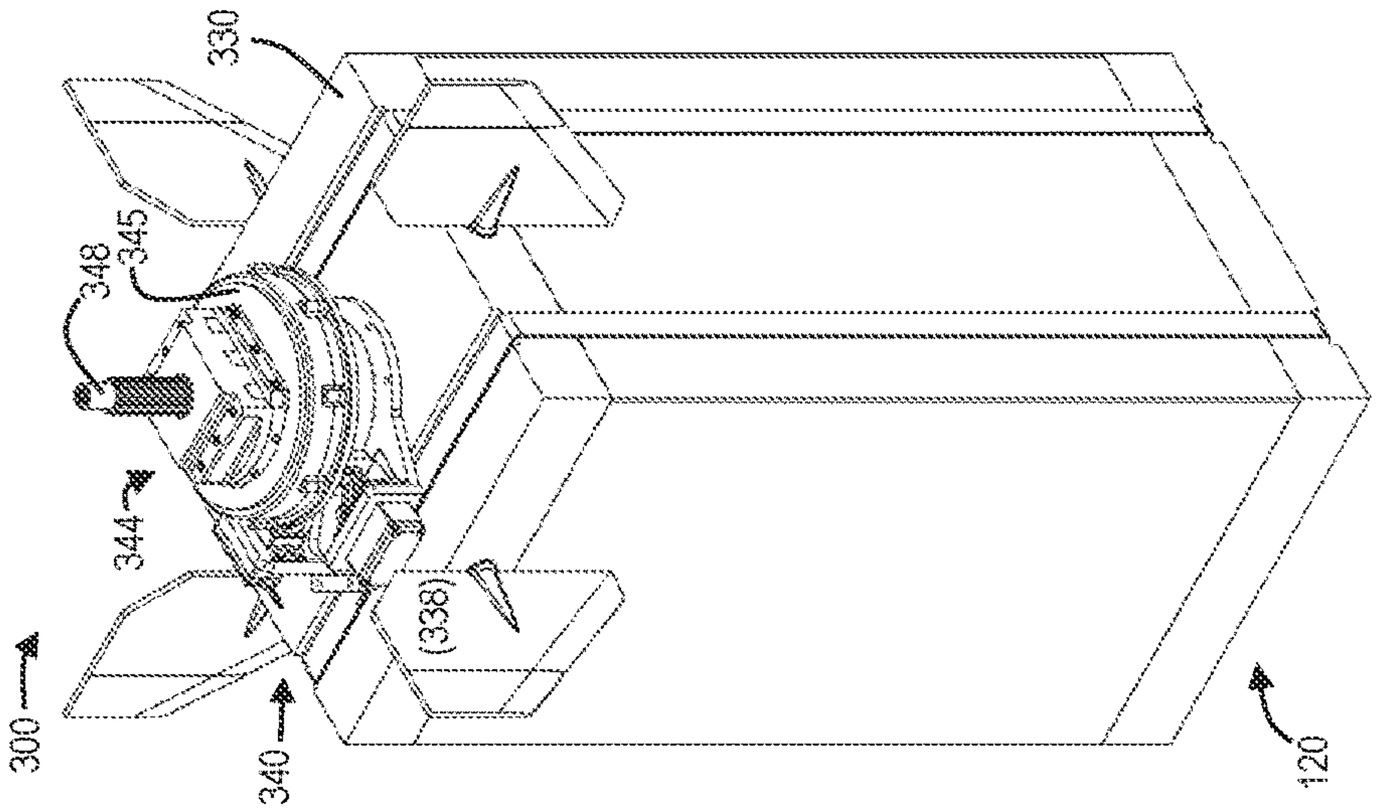


FIG. 13B

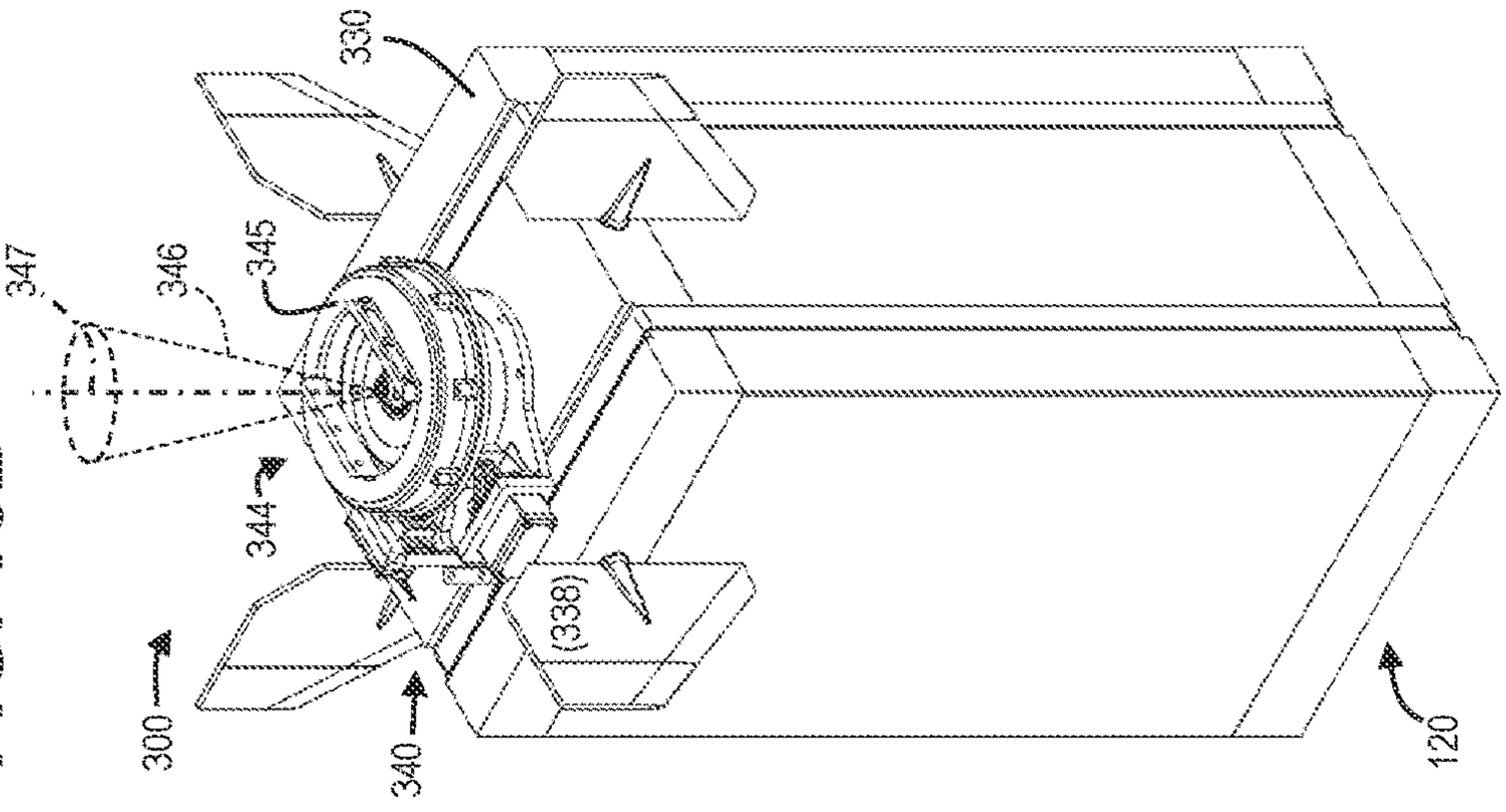
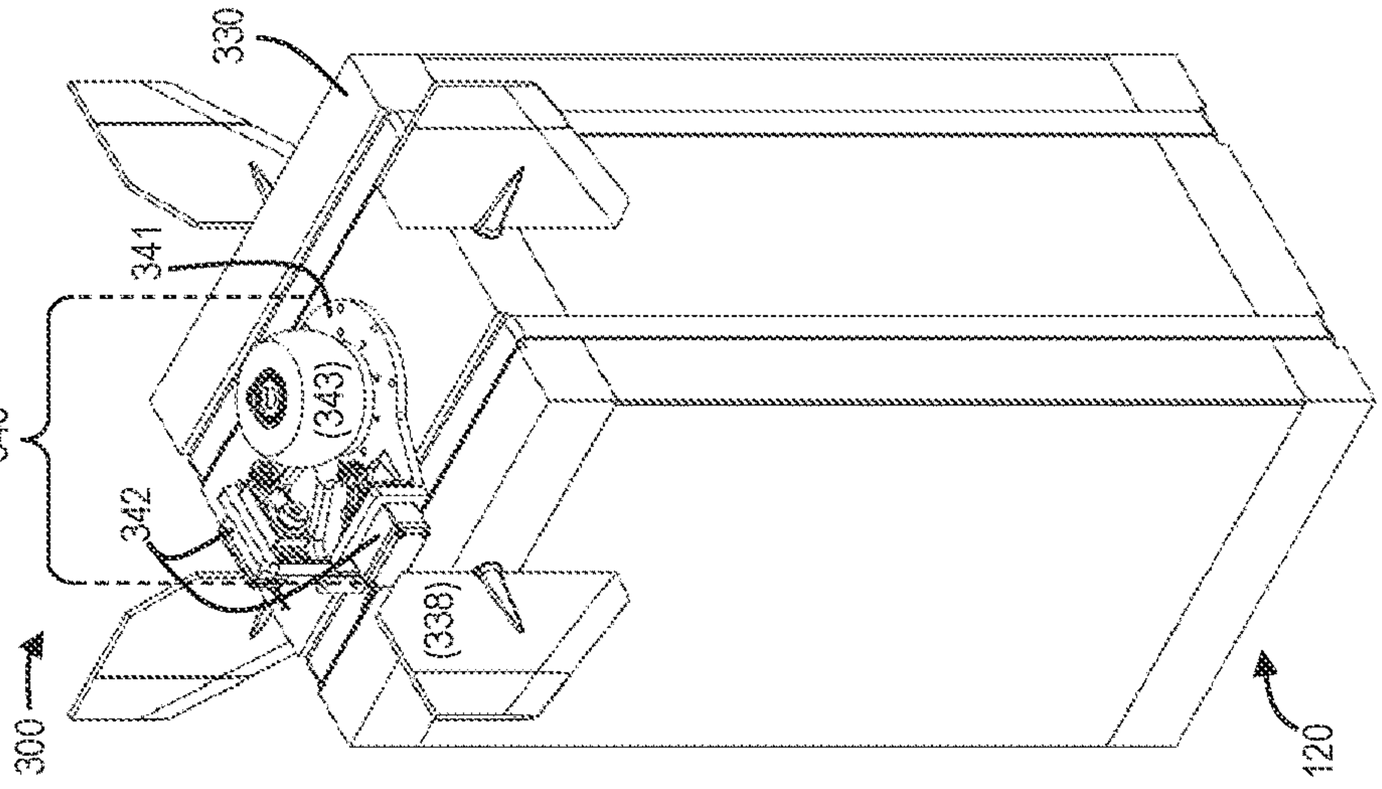


FIG. 13A



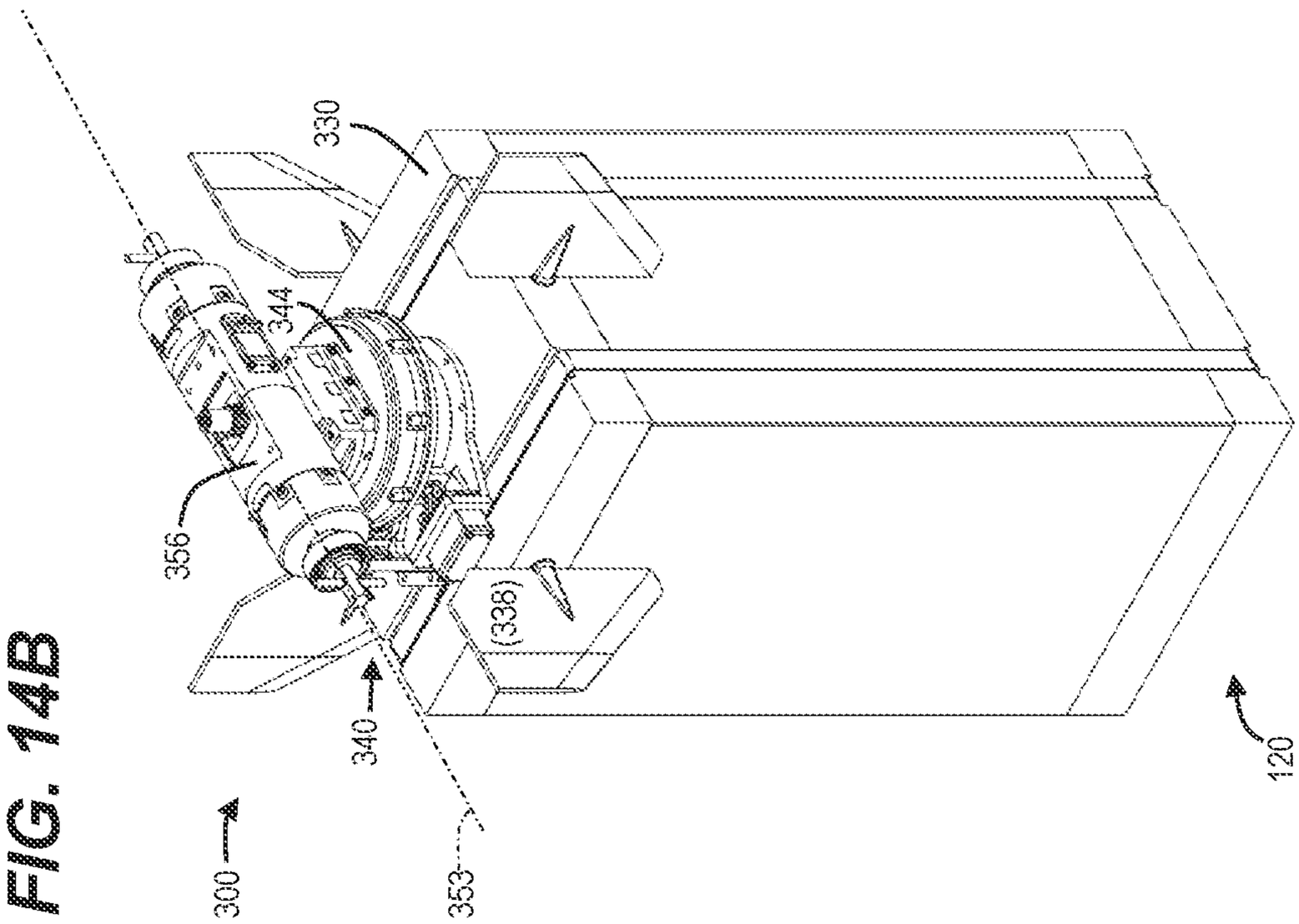


FIG. 14B

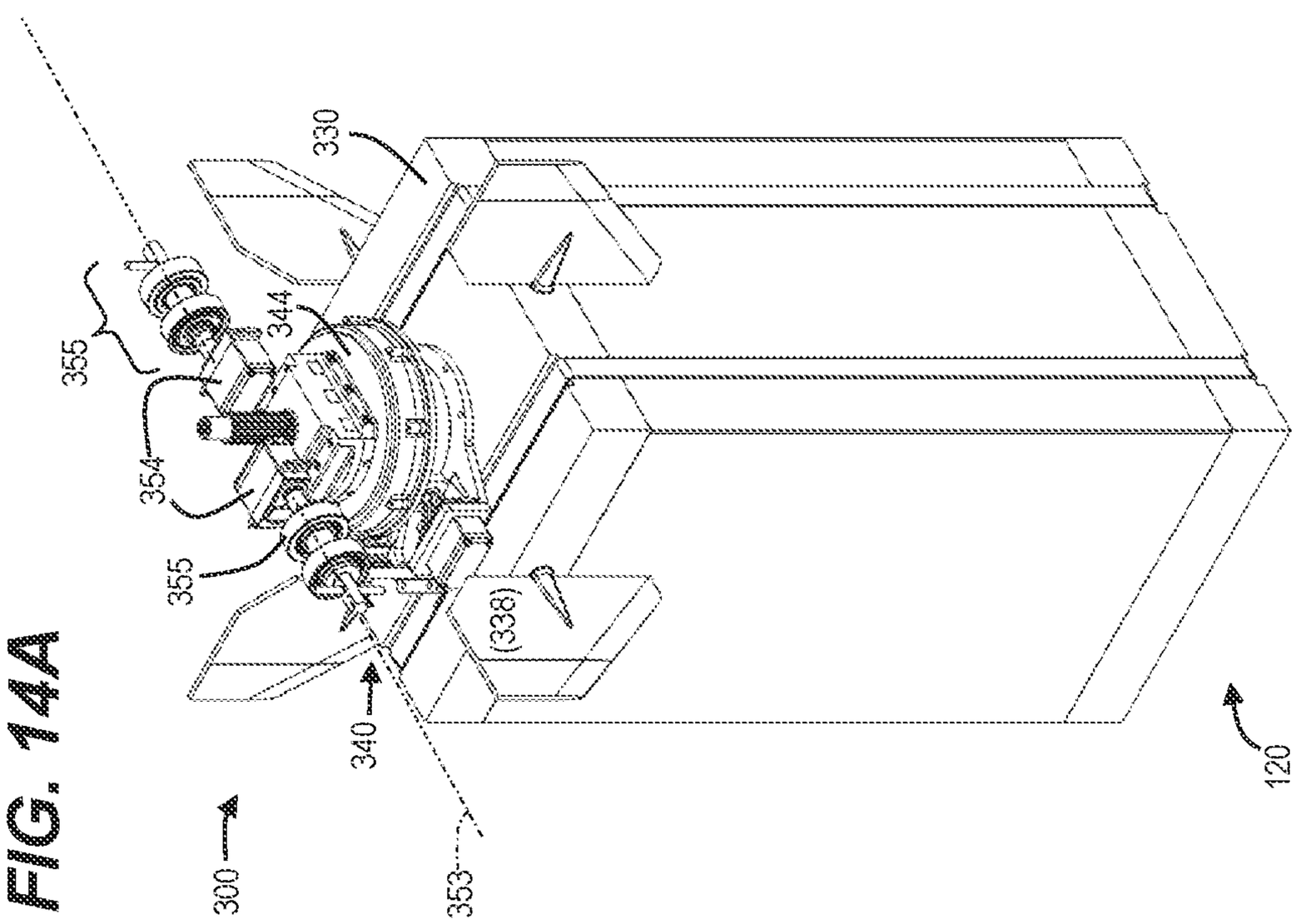


FIG. 14A

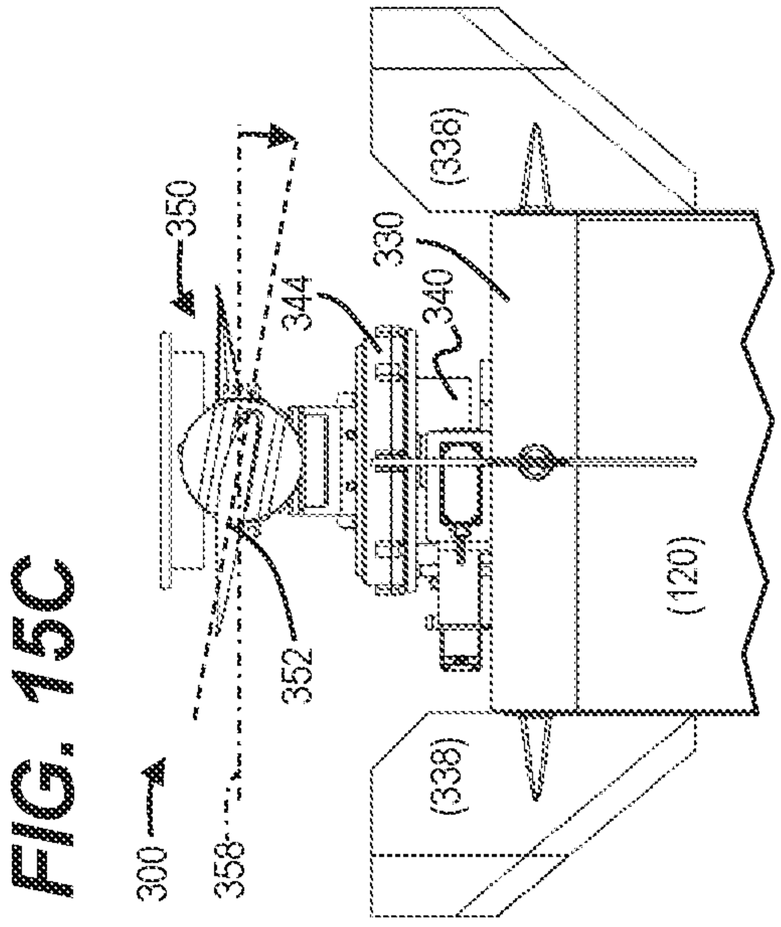


FIG. 15C
300
358
350
352
344
340
330
(338)
(120)
(338)

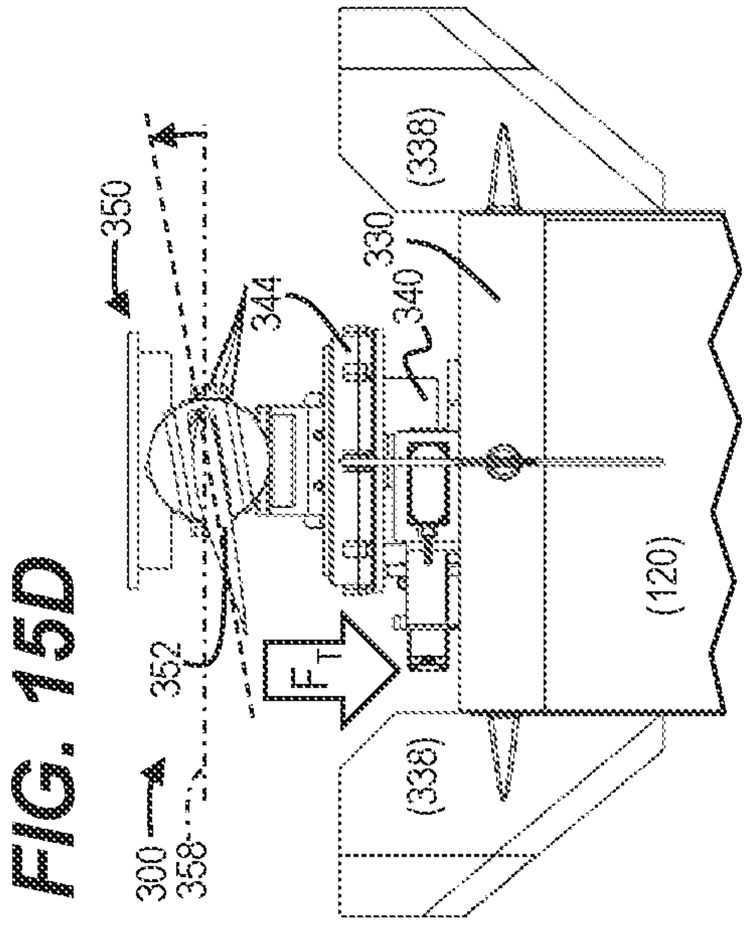


FIG. 15D
300
358
350
352
F_T
344
340
330
(338)
(120)
(338)

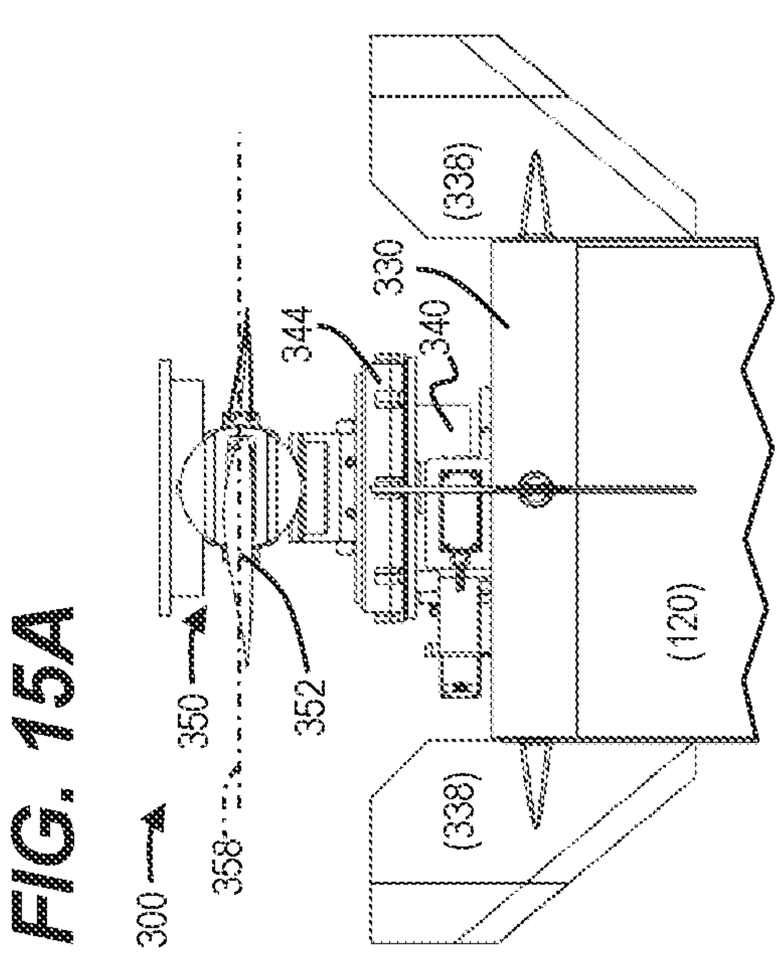


FIG. 15A
300
358
350
352
344
340
330
(338)
(120)
(338)

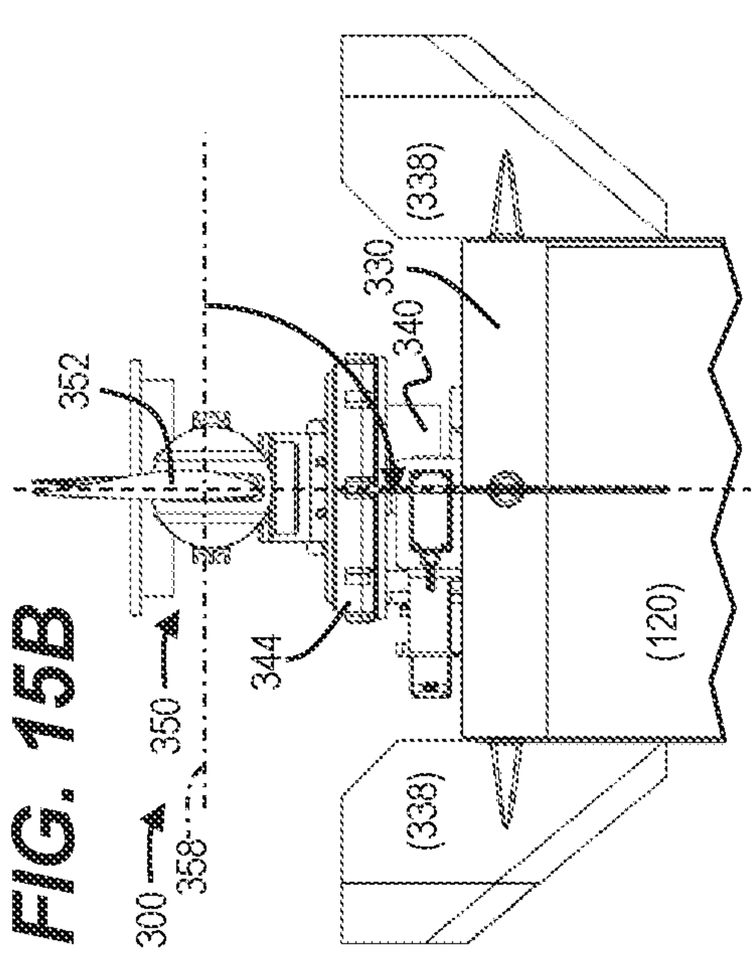


FIG. 15B
300
358
350
352
344
340
330
(338)
(120)
(338)

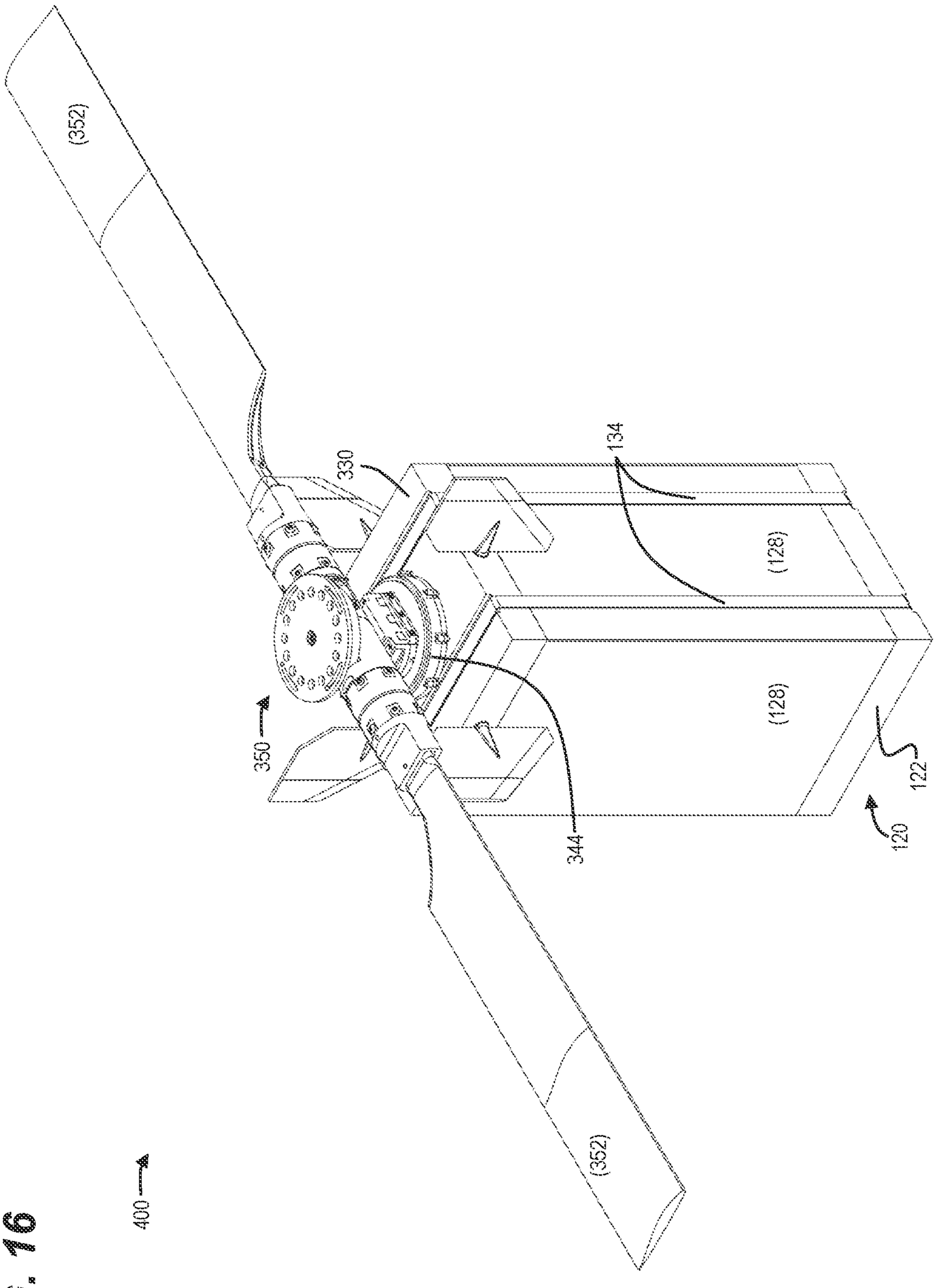


FIG. 16

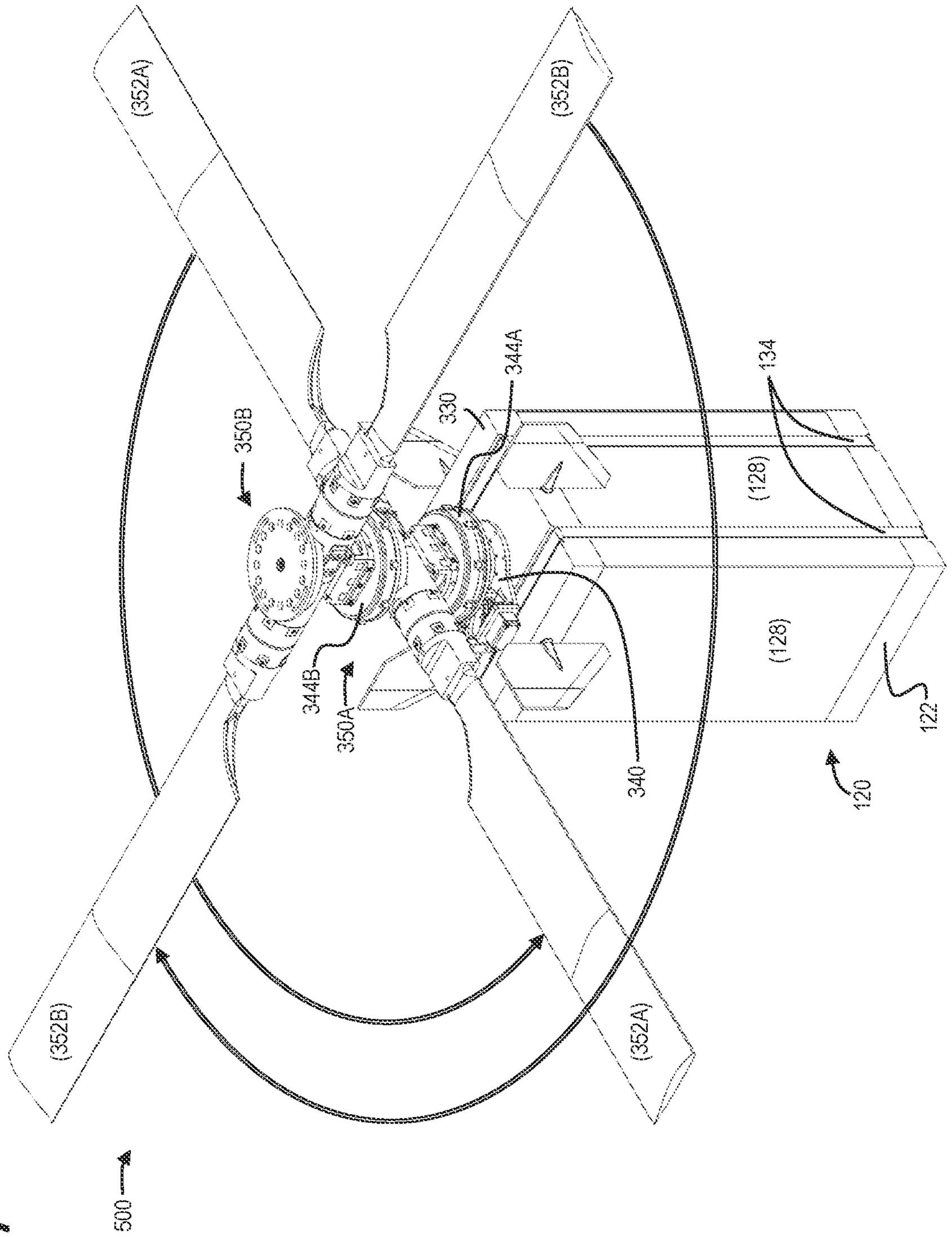

(352A)
(352B)
350B
330
344A
134
(128)
344B
350A
340
(128)
122
120
(352B)
(352A)
500

FIG. 17

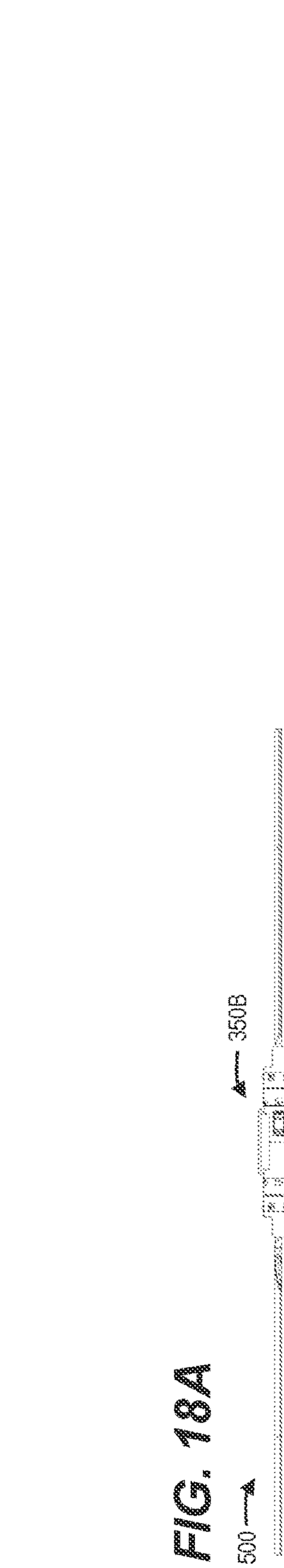


FIG. 18A

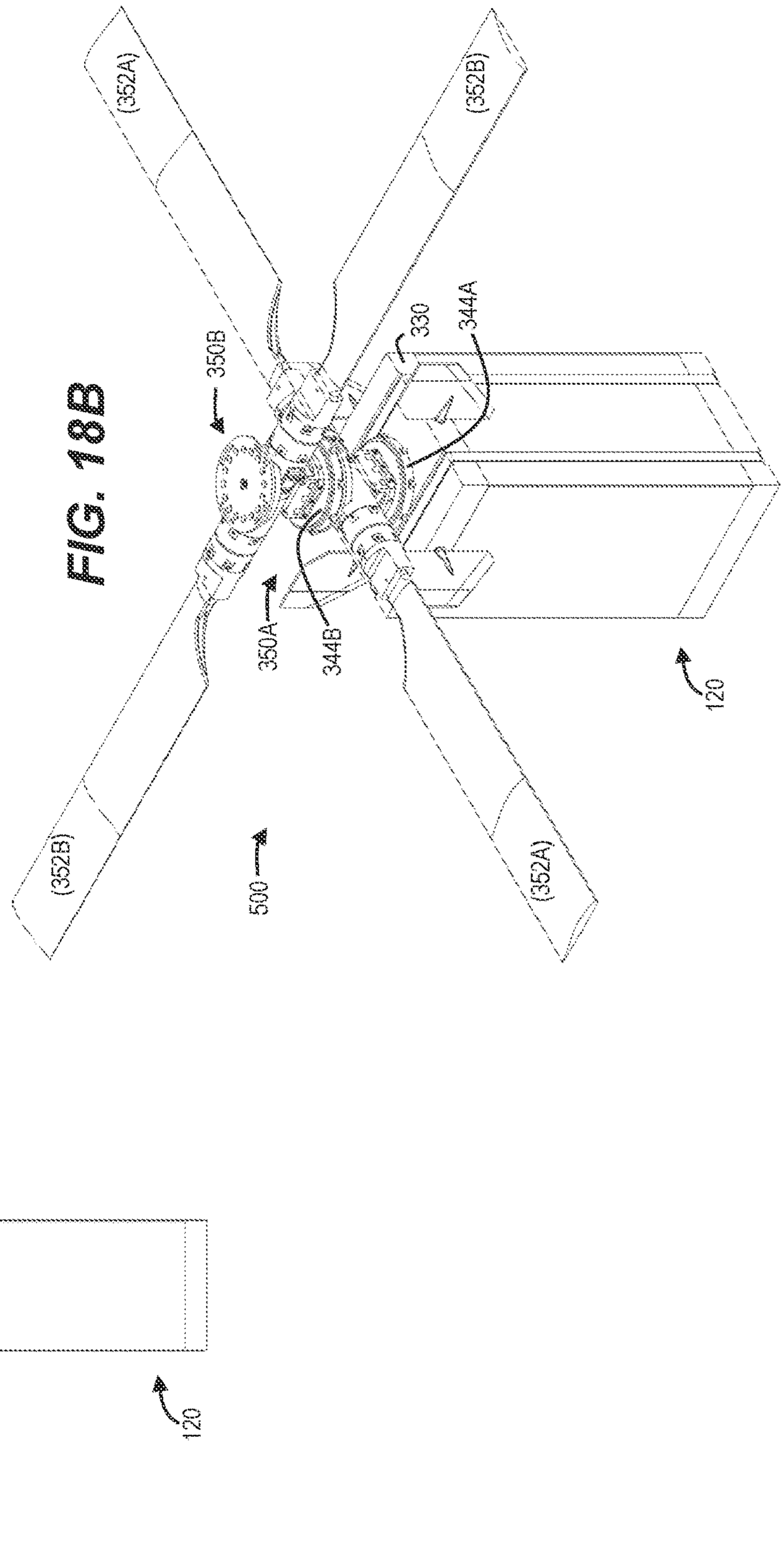


FIG. 18B

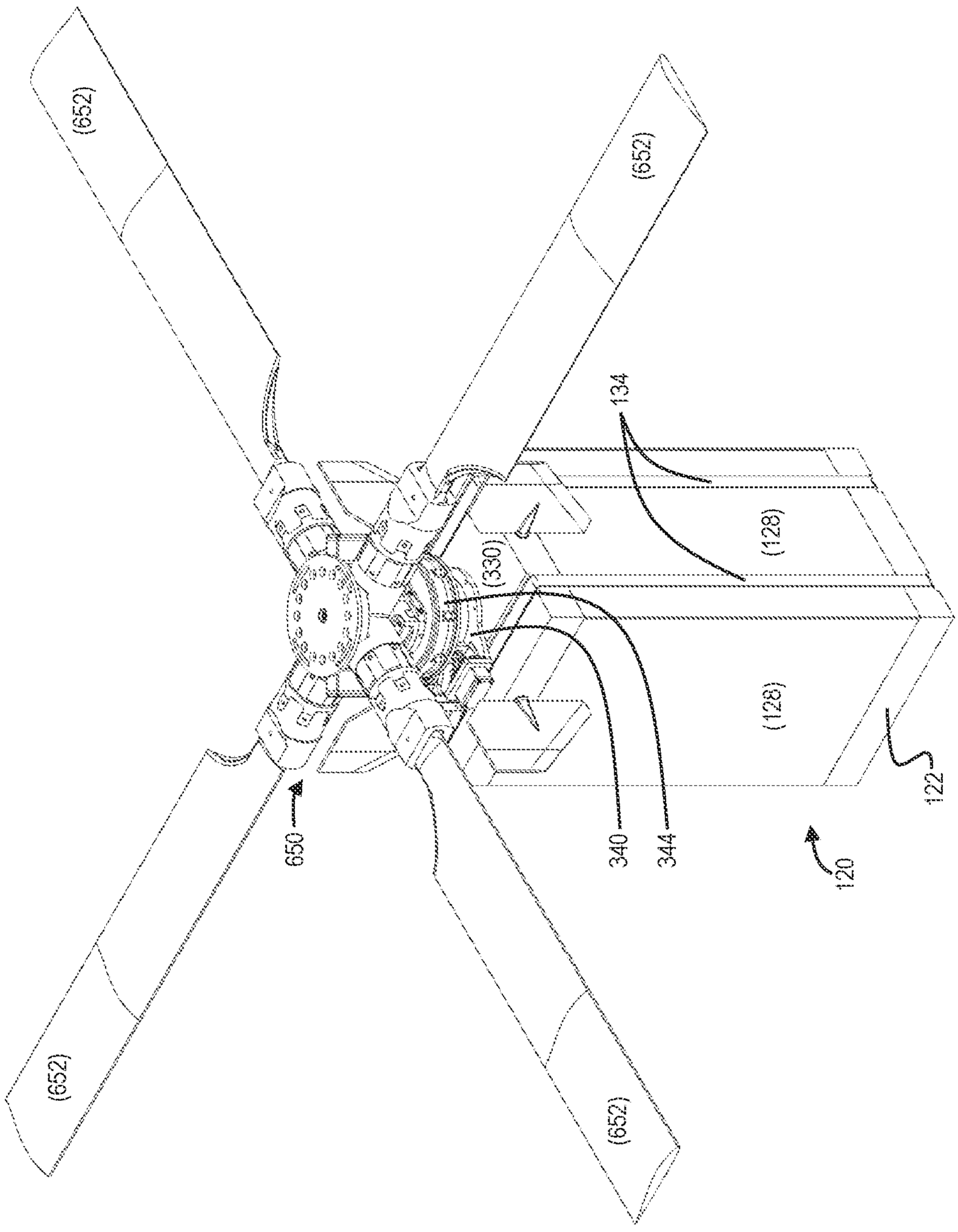


FIG. 19

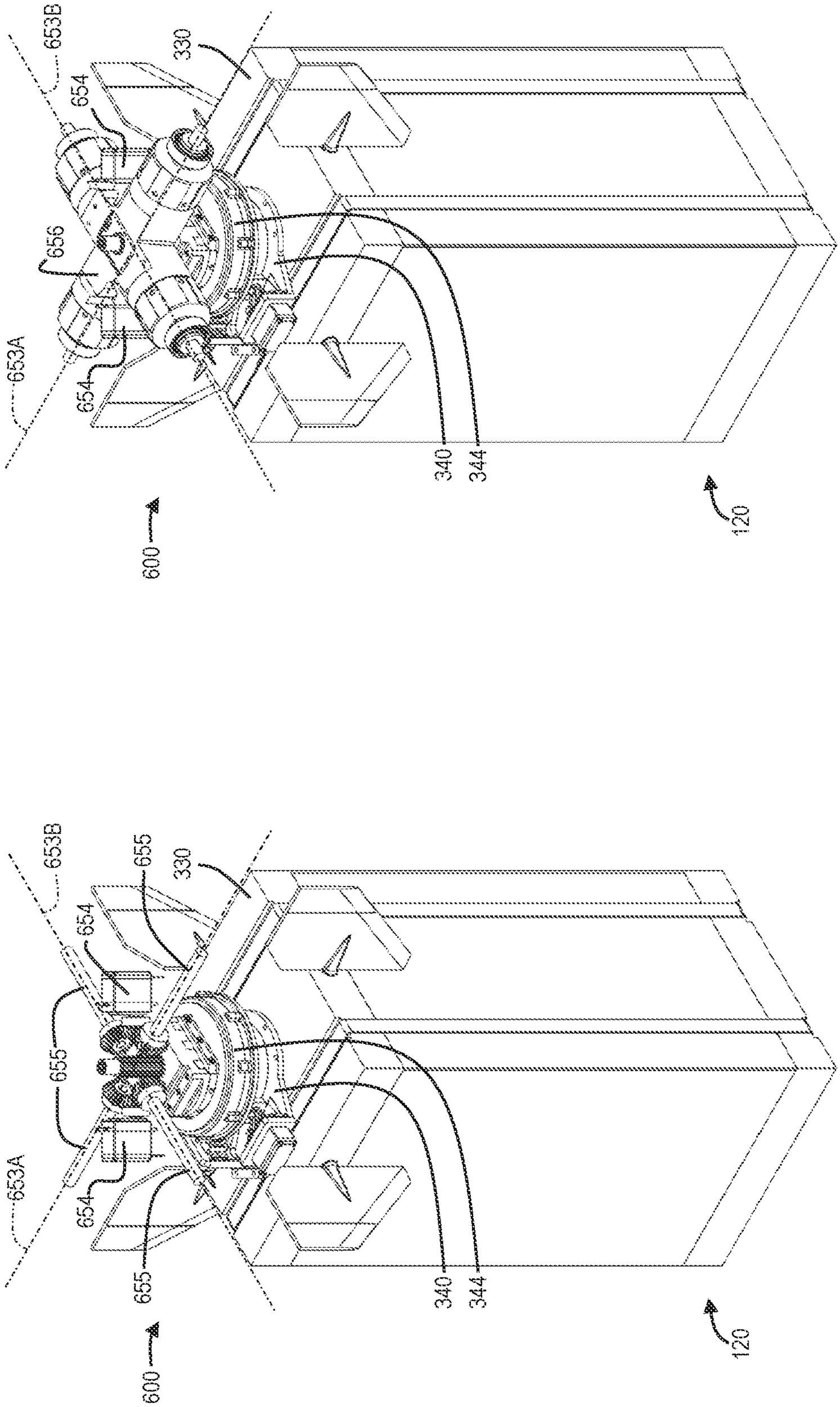


FIG. 20B

FIG. 20A

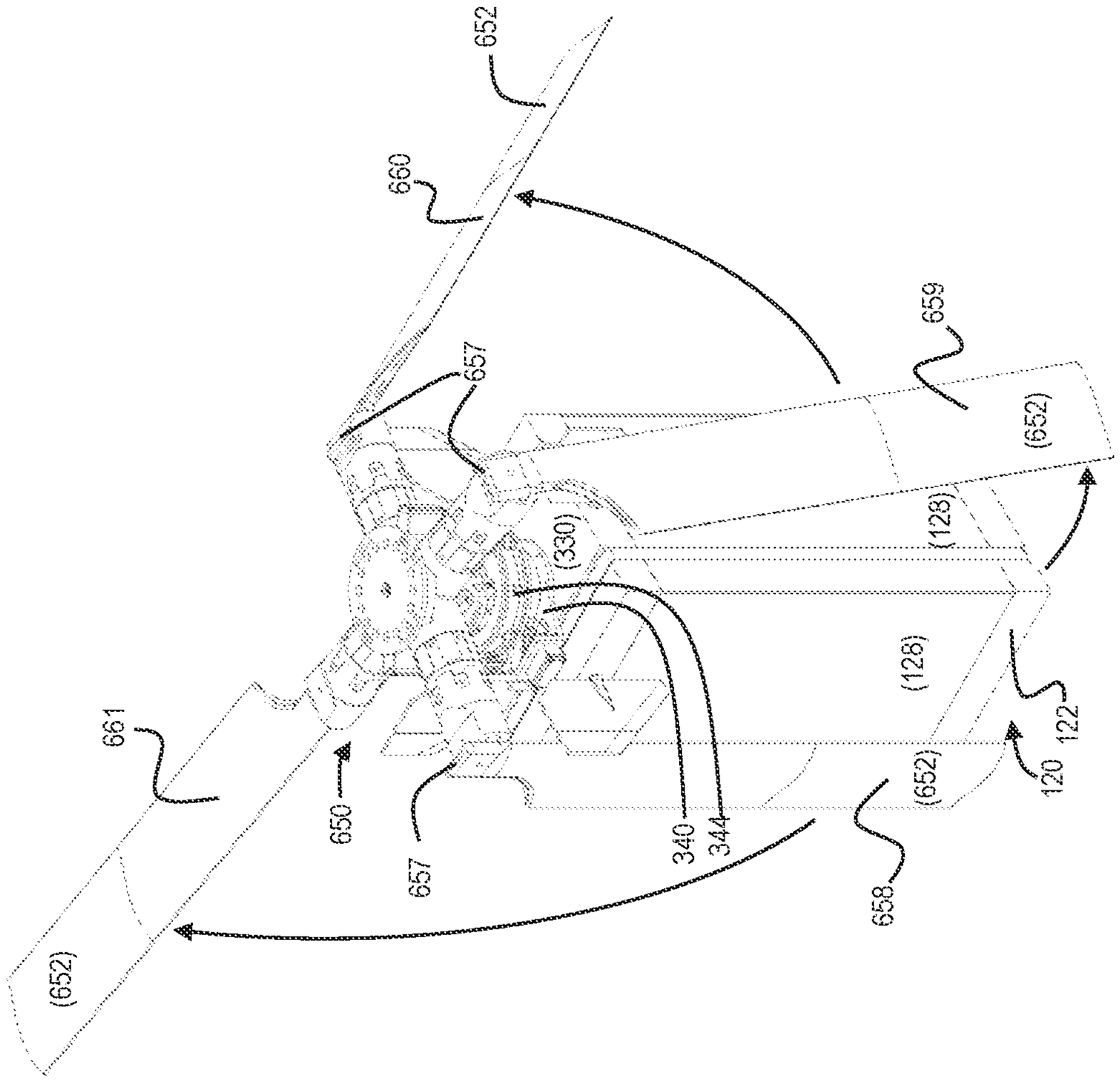


FIG. 21

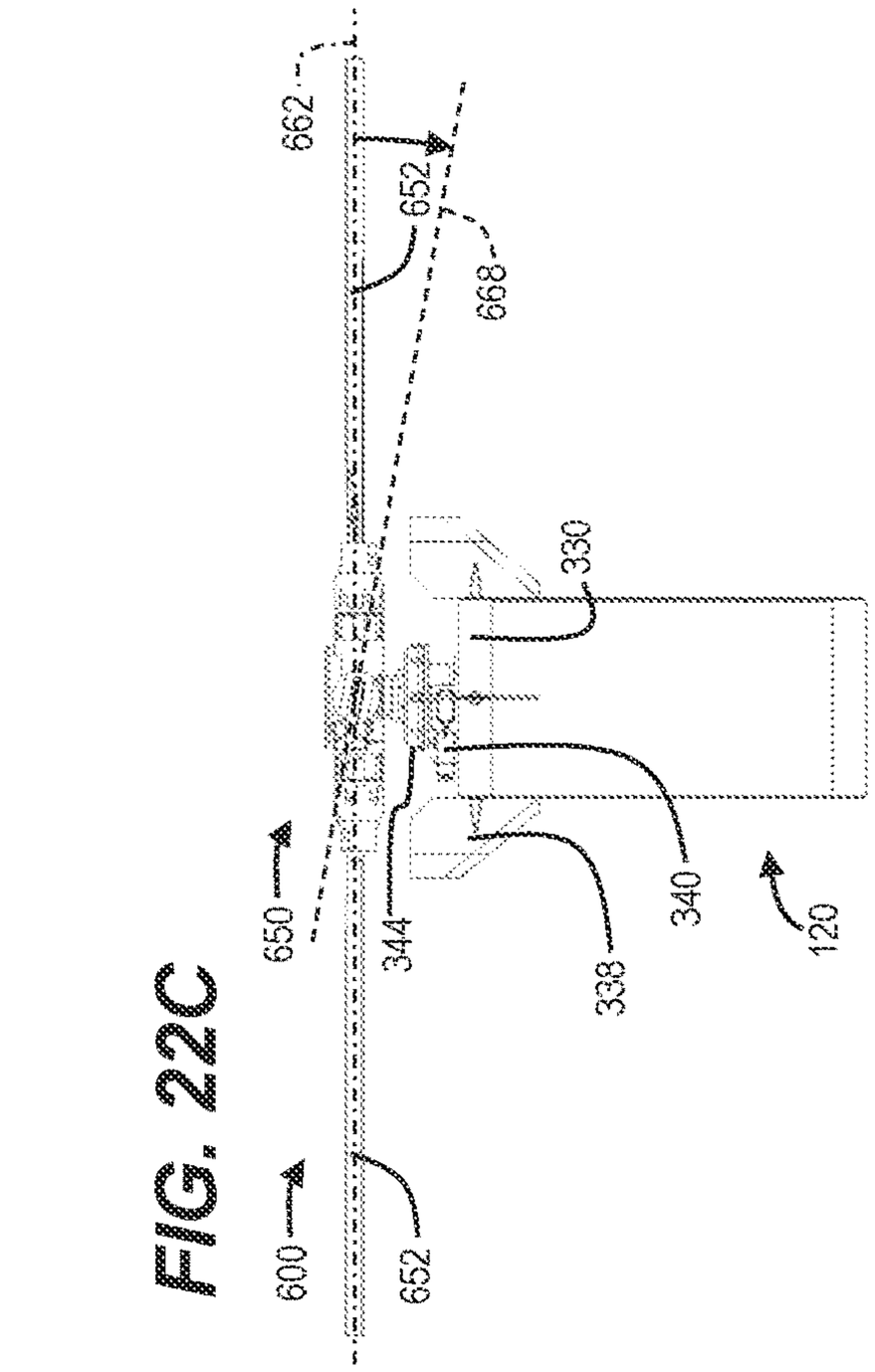


FIG. 22C

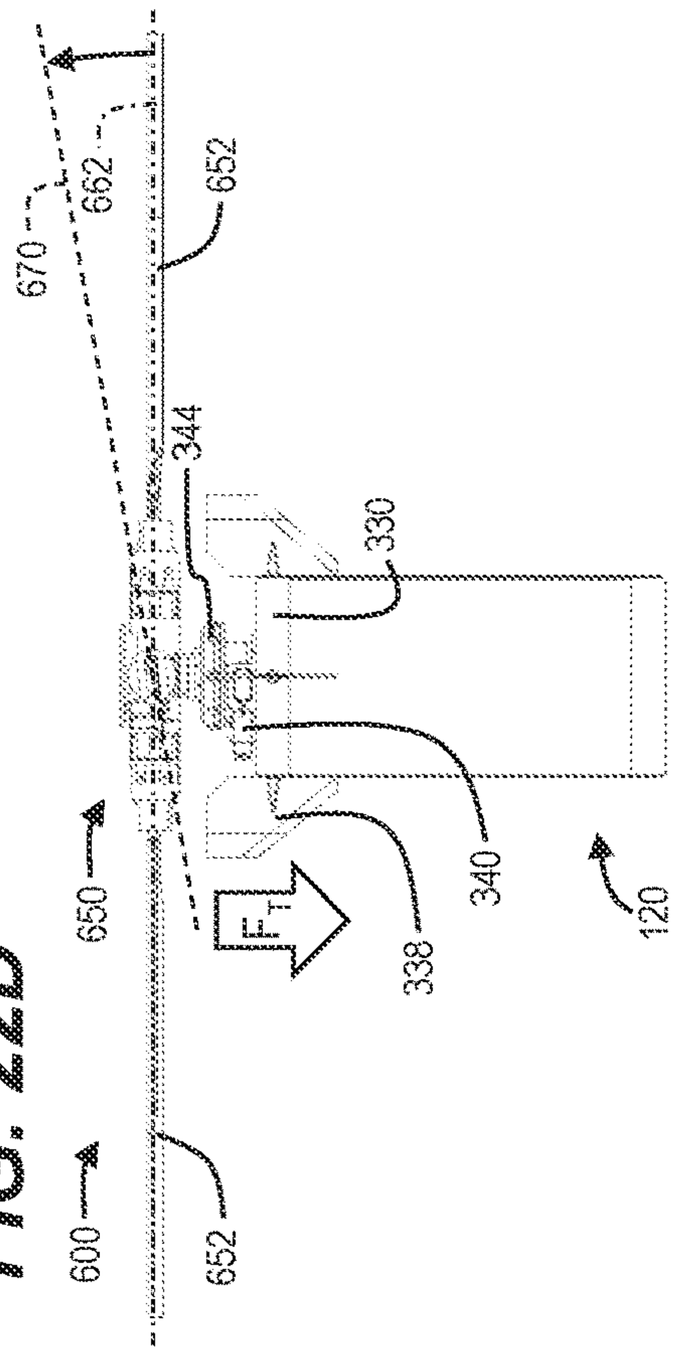


FIG. 22D

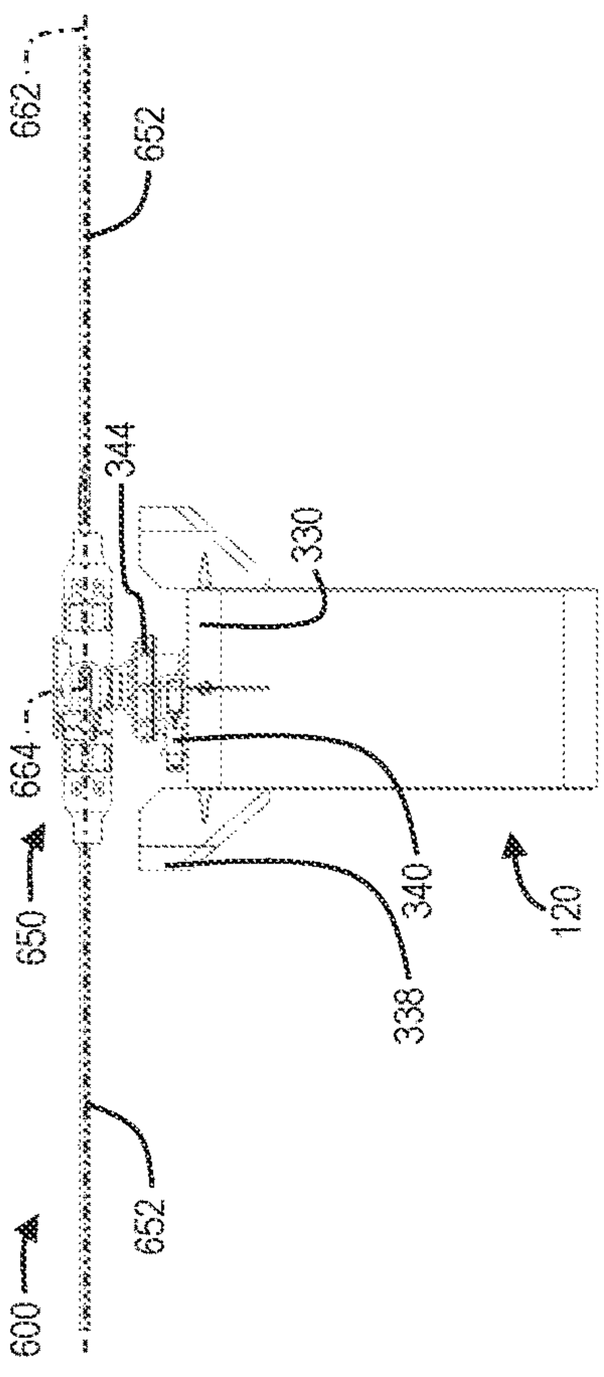


FIG. 22A

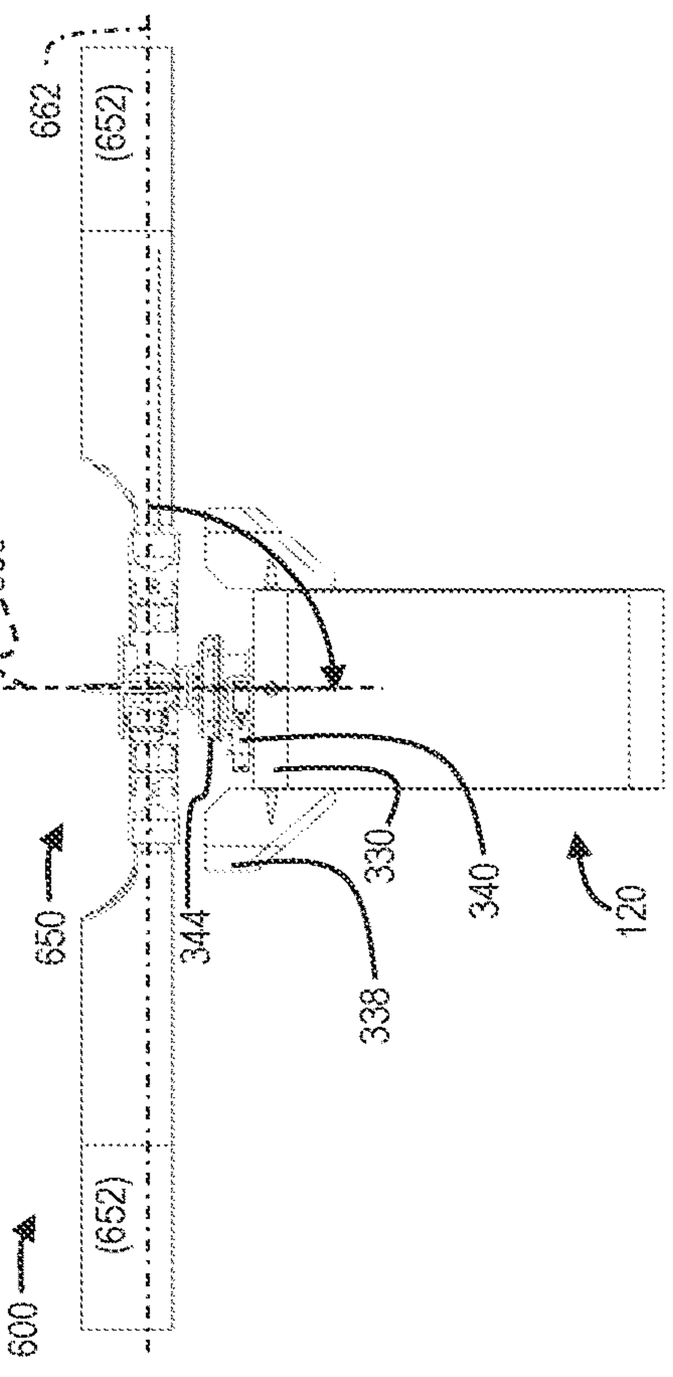


FIG. 22B

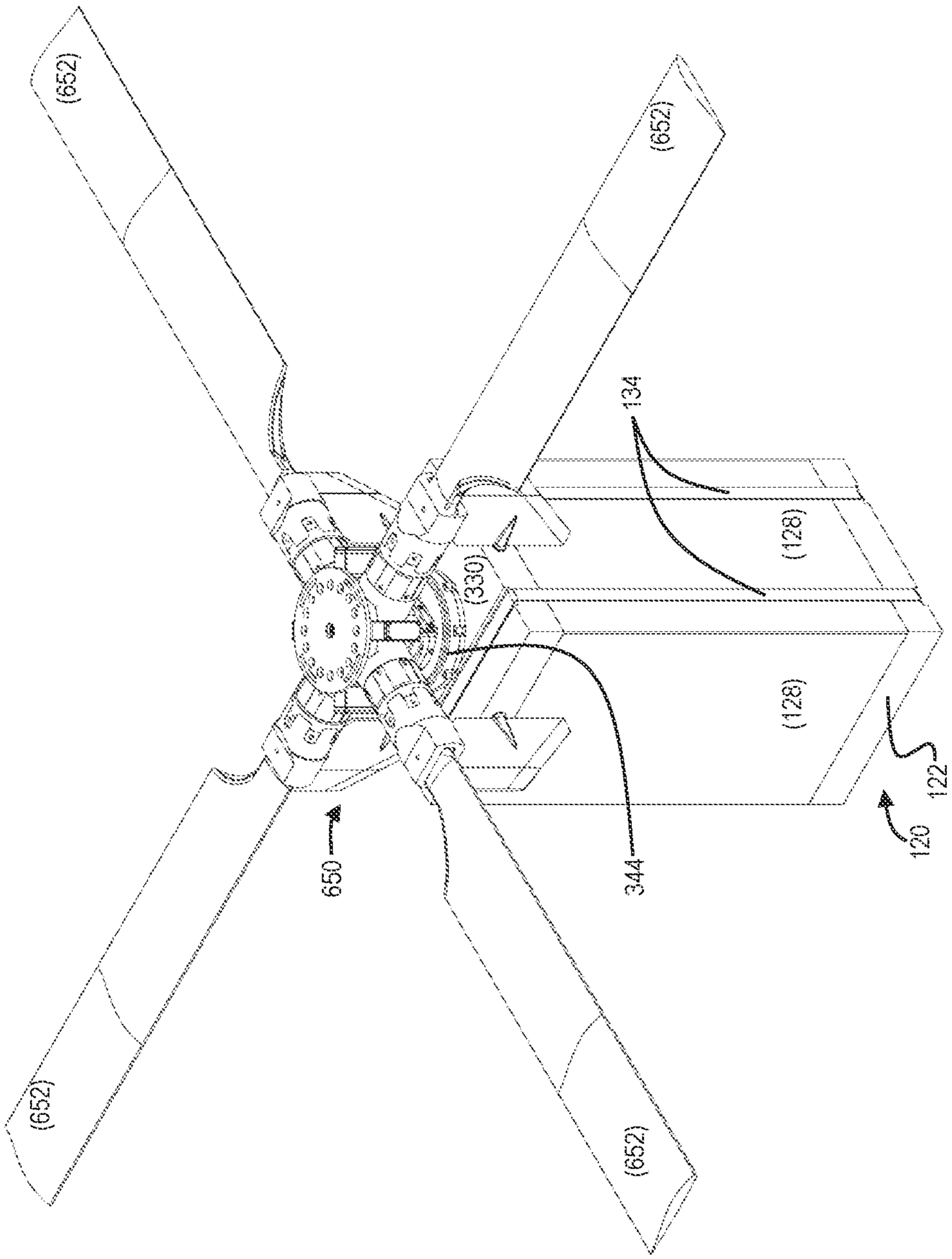


FIG. 23

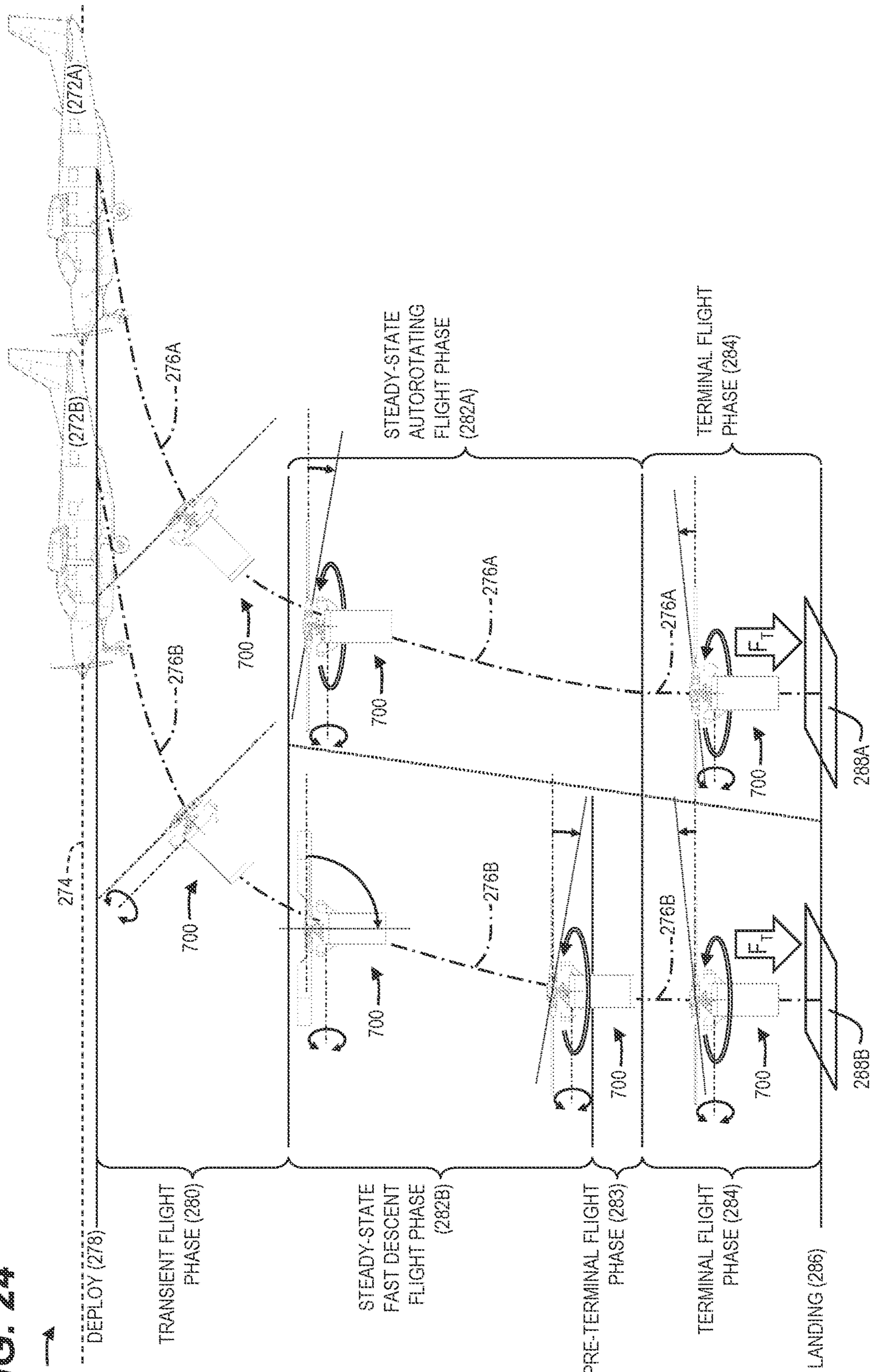

750
DEPLOY (278)
TRANSIENT FLIGHT PHASE (280)
STEADY-STATE FAST DESCENT FLIGHT PHASE (282B)
PRE-TERMINAL FLIGHT PHASE (283)
TERMINAL FLIGHT PHASE (284)
LANDING (286)
STEADY-STATE AUTOROTATING FLIGHT PHASE (282A)
TERMINAL FLIGHT PHASE (284)
(272A)
(272B)
274
276A
276B
700
F_T
288A
288B

FIG. 24

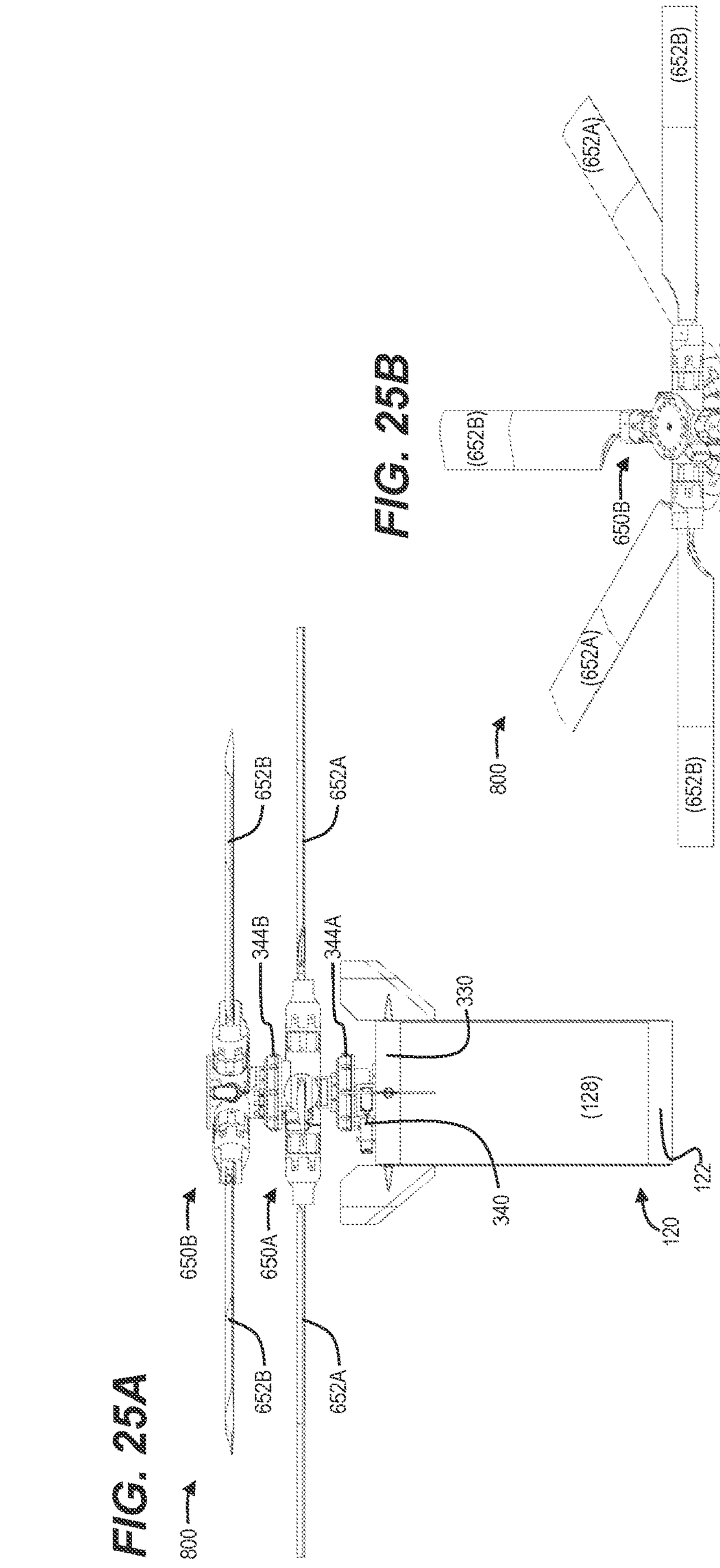


FIG. 25A

FIG. 25B

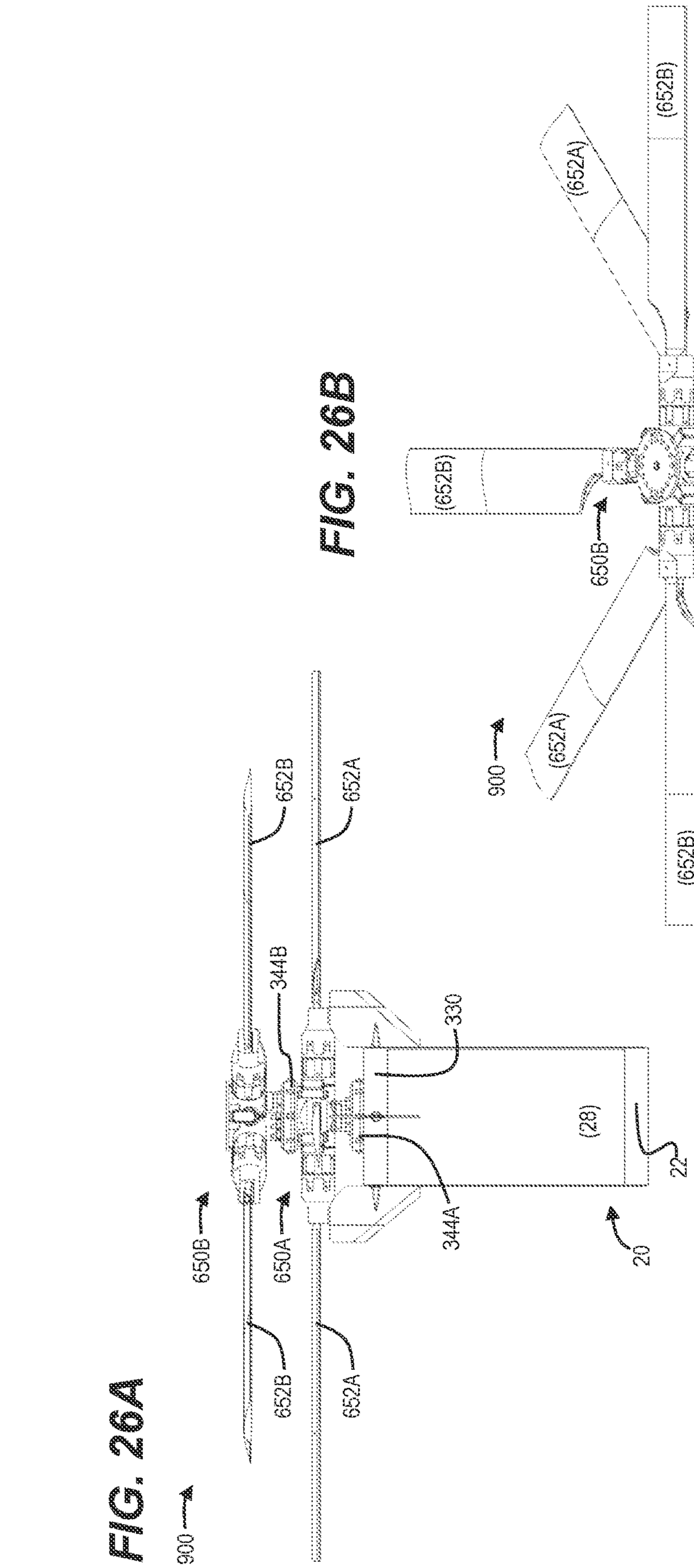


FIG. 26A

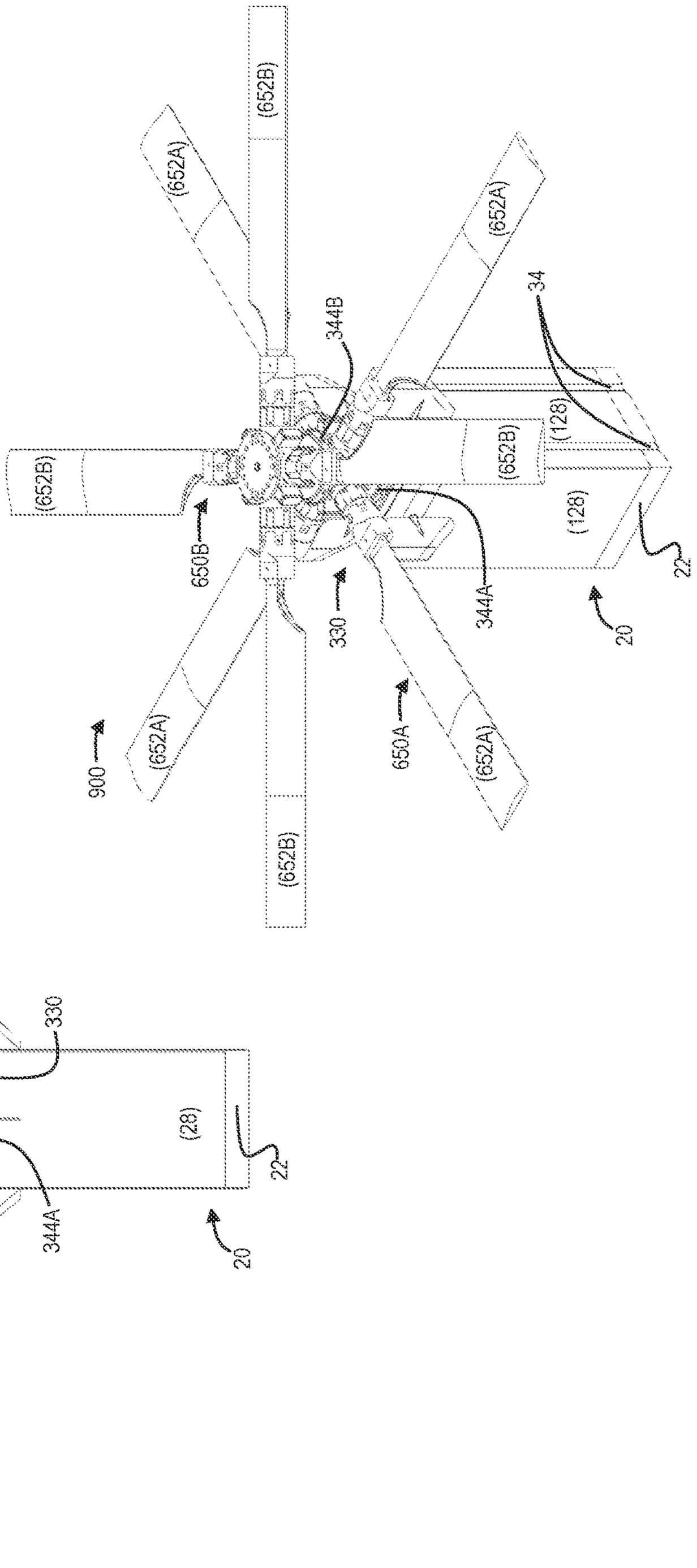


FIG. 26B

FIG. 27A

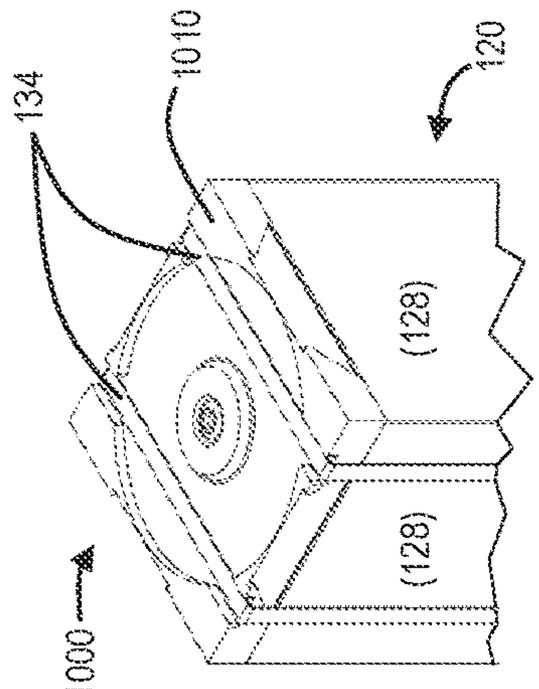


FIG. 27B

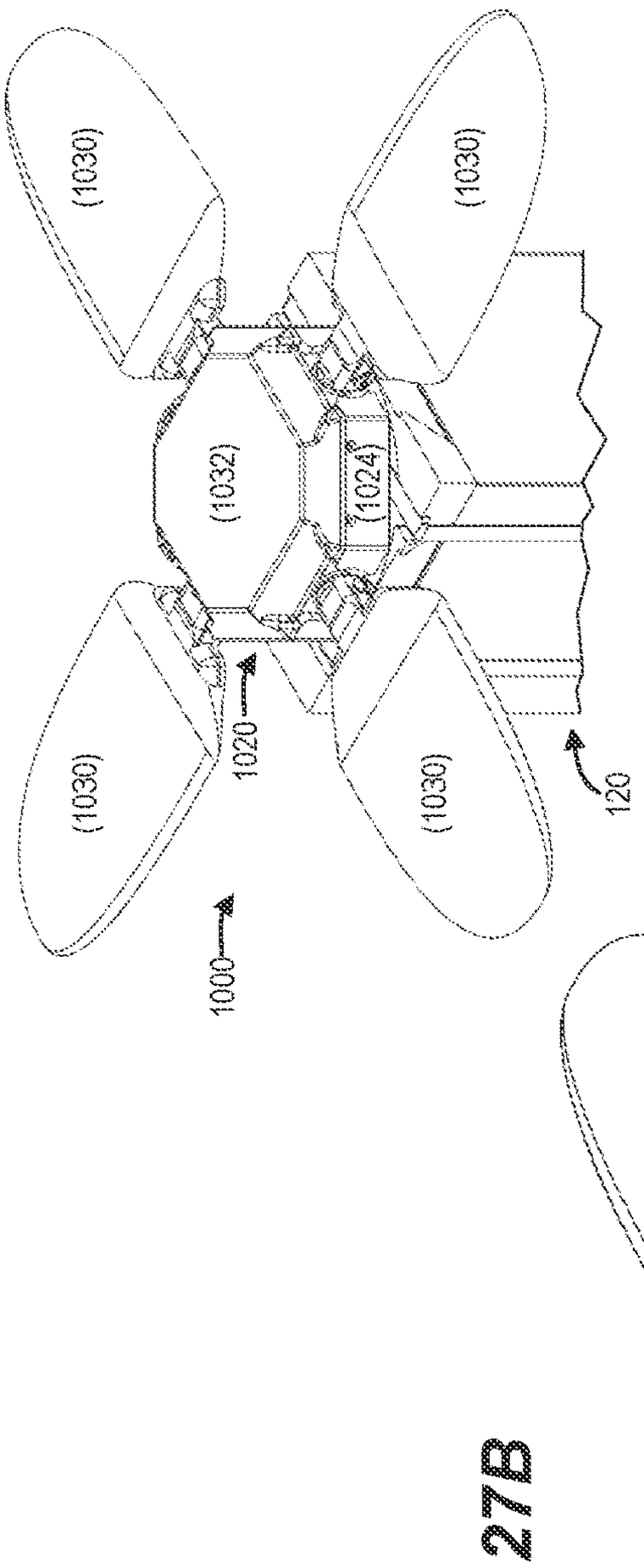
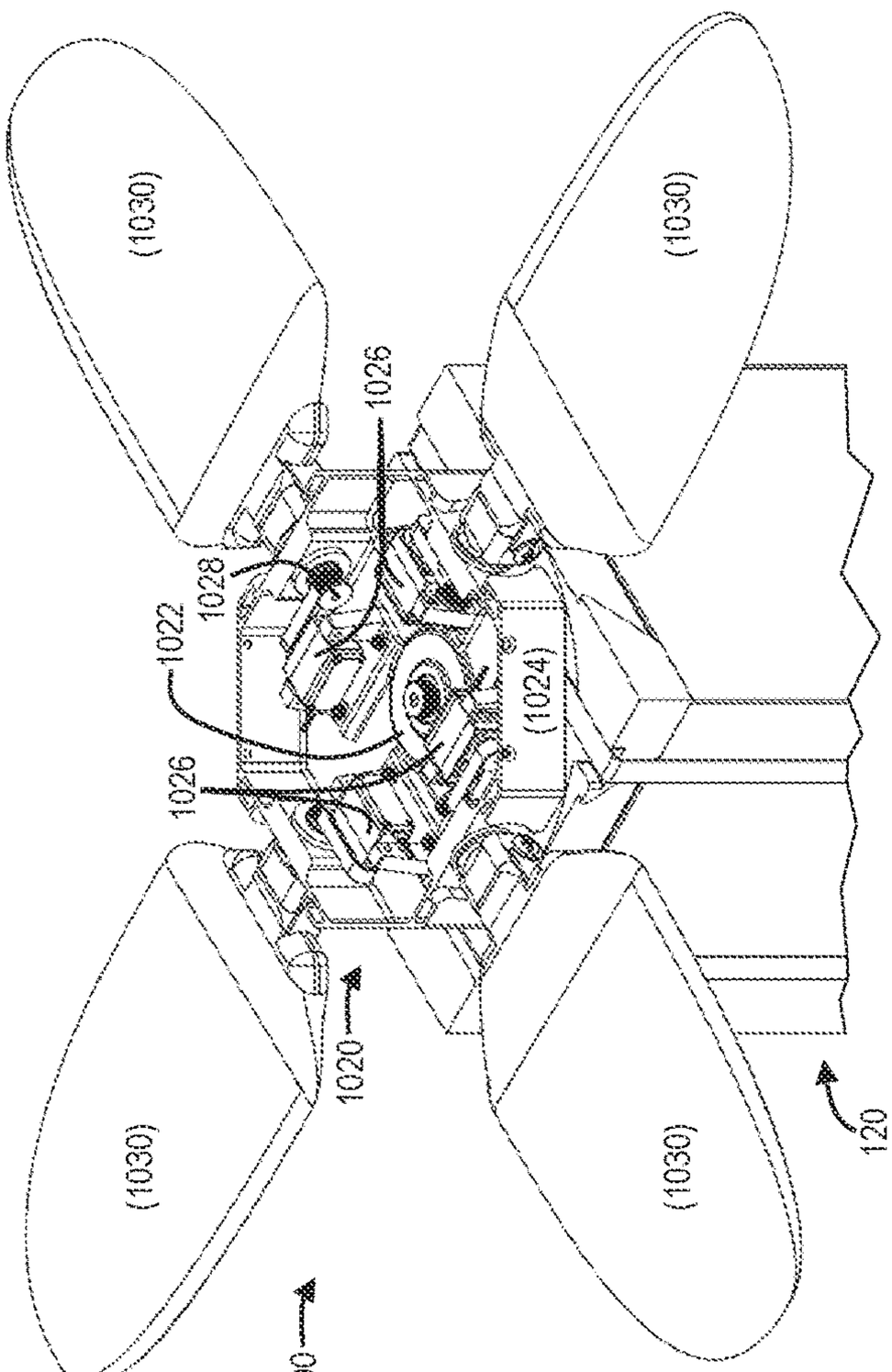


FIG. 27C



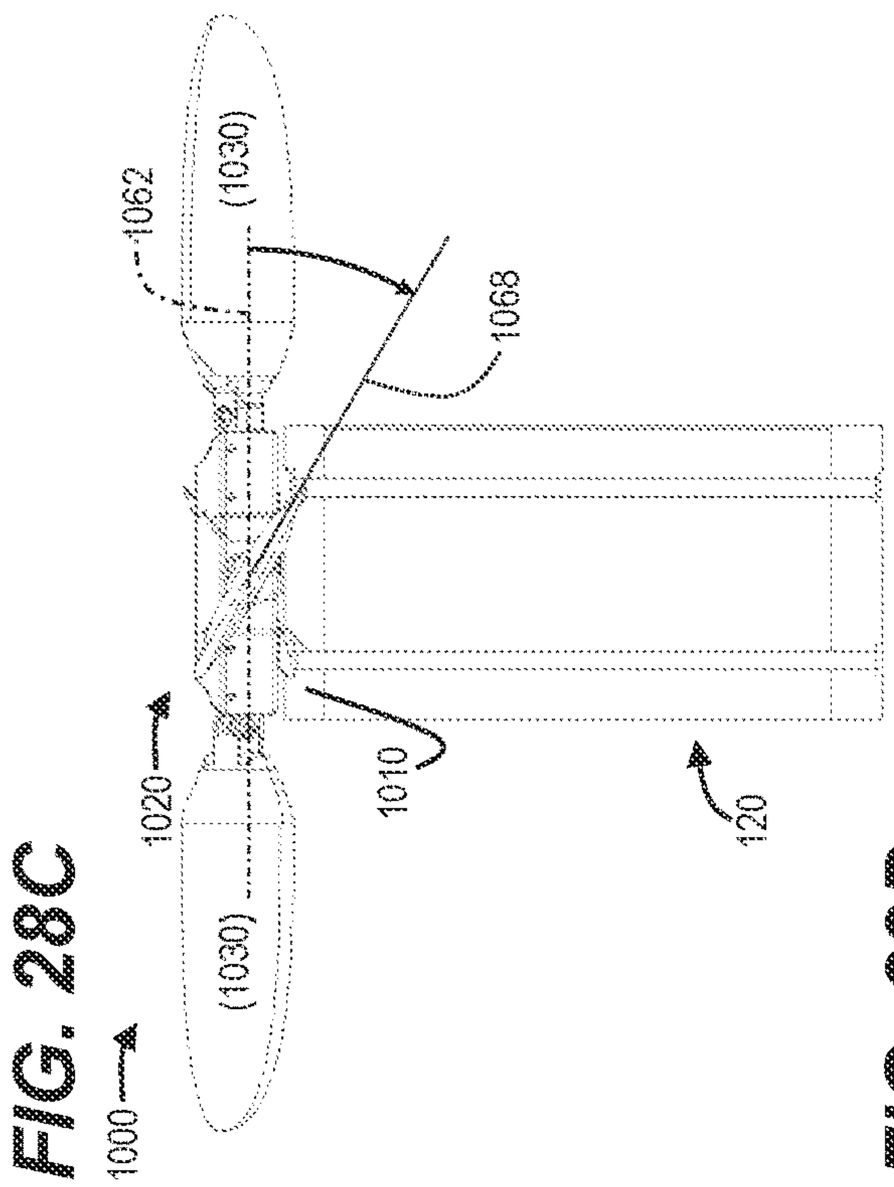


FIG. 28C

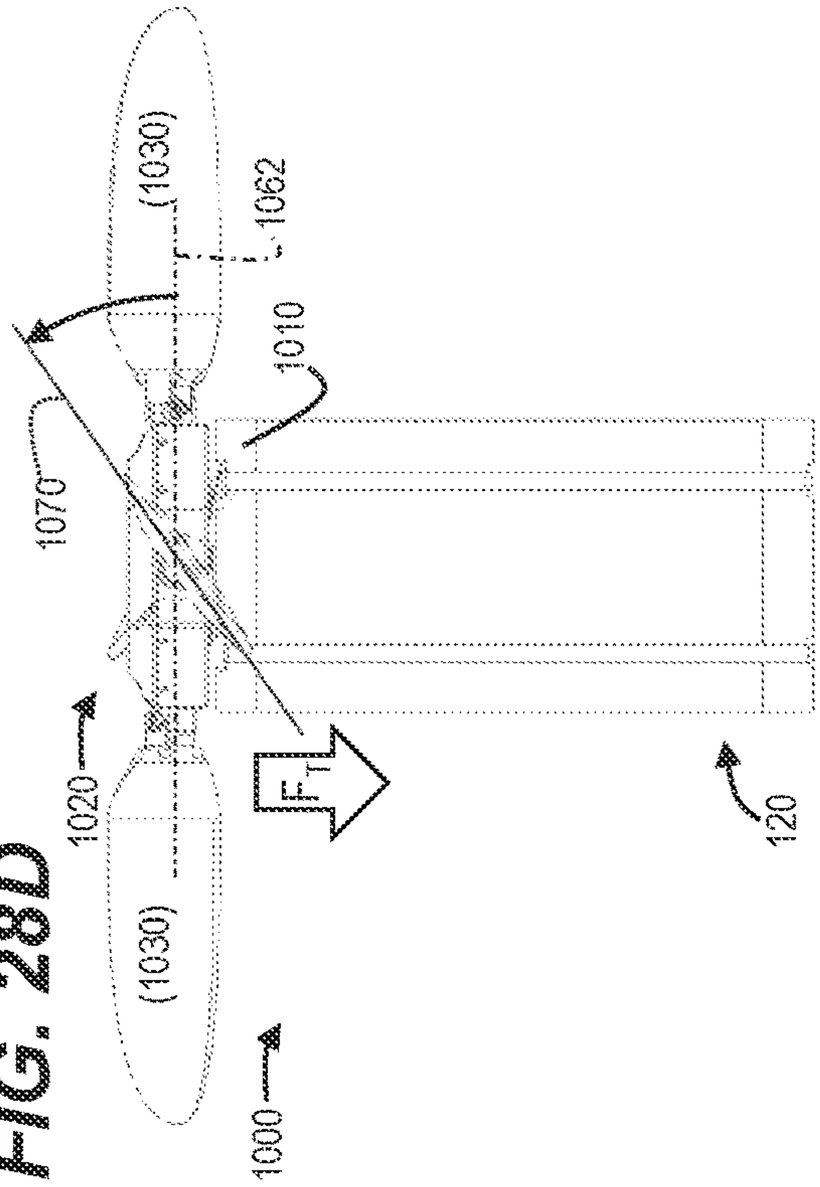


FIG. 28D

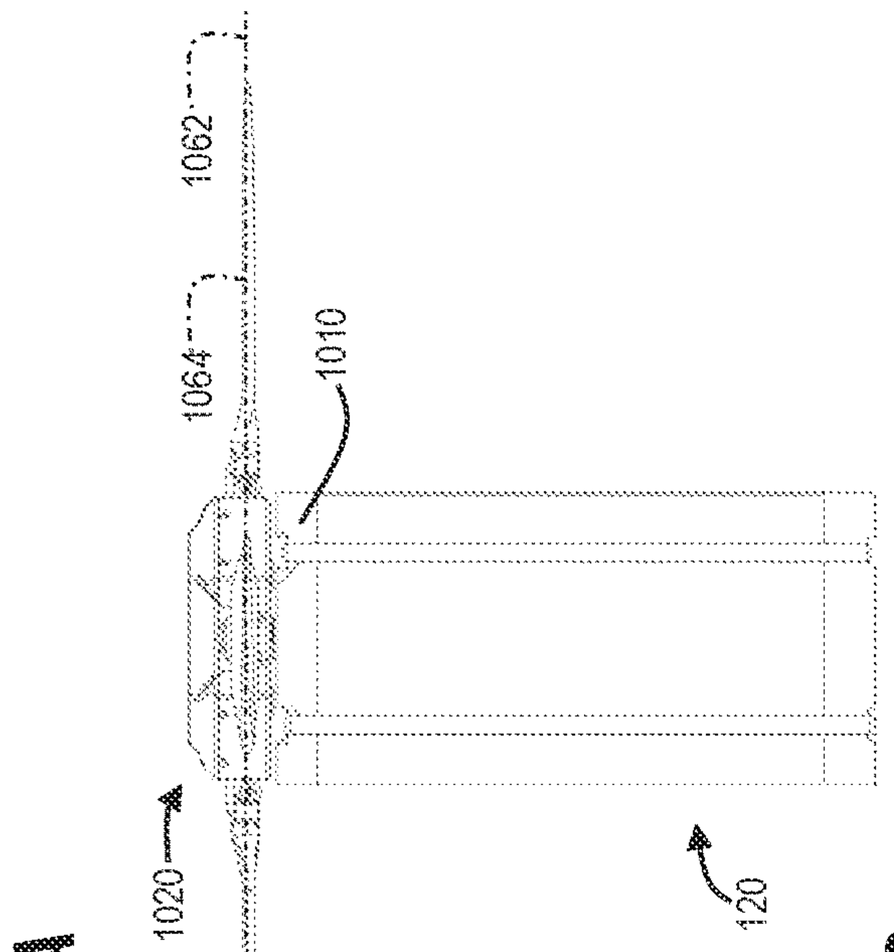


FIG. 28A

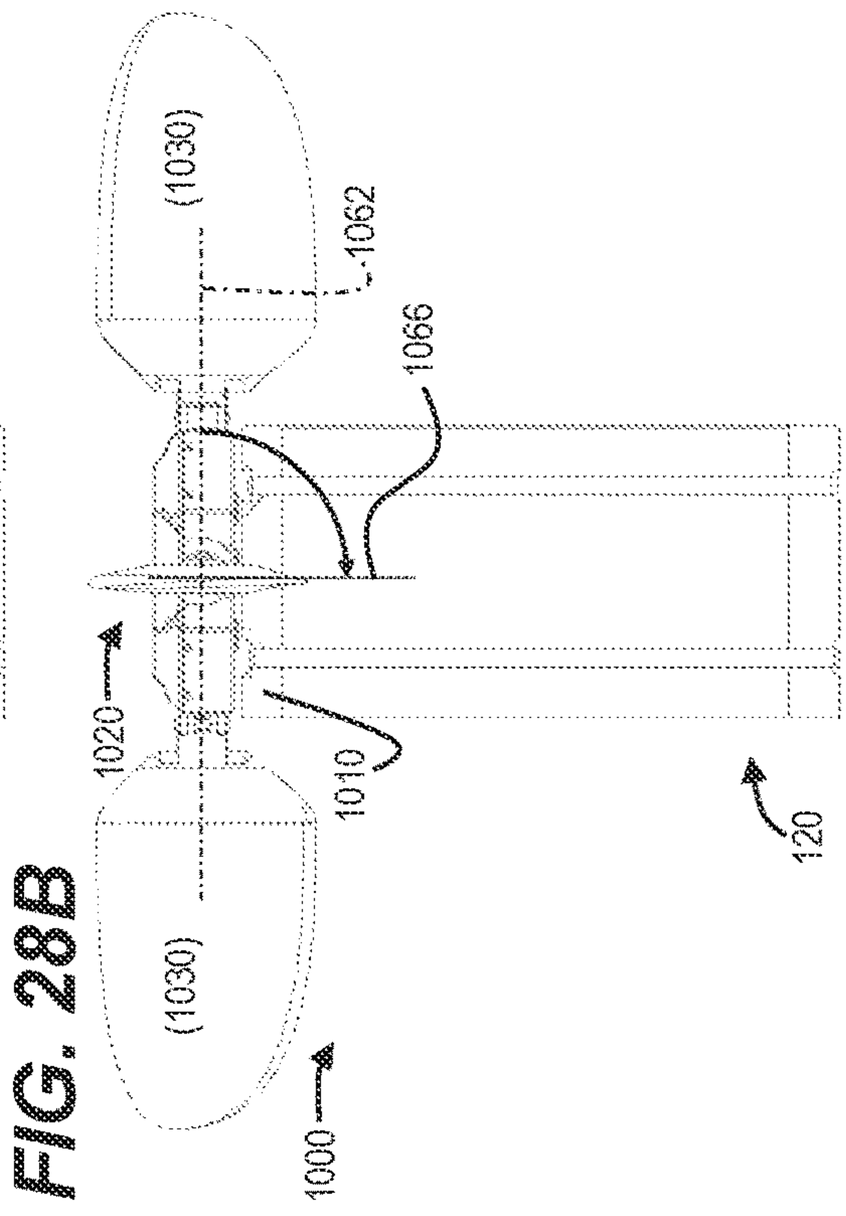


FIG. 28B

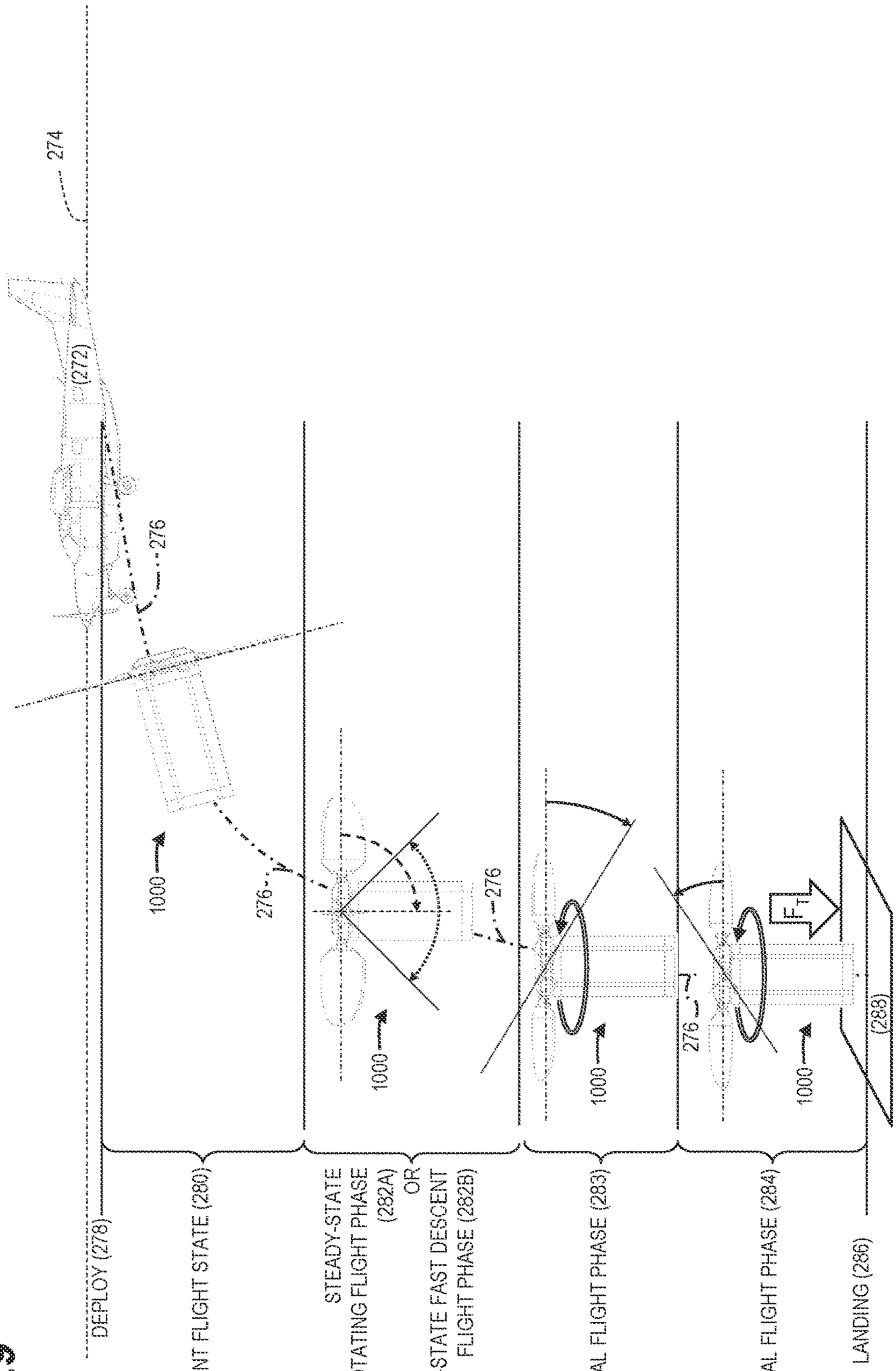

1050
DEPLOY (278)
TRANSIENT FLIGHT STATE (280)
STEADY-STATE
AUTOROTATING FLIGHT PHASE
(282A)
OR
STEADY-STATE FAST DESCENT
FLIGHT PHASE (282B)
PRE-TERMINAL FLIGHT PHASE (283)
TERMINAL FLIGHT PHASE (284)
LANDING (286)
274
(272)
276
1000
F_T
(288)

FIG. 29

FIG. 30A

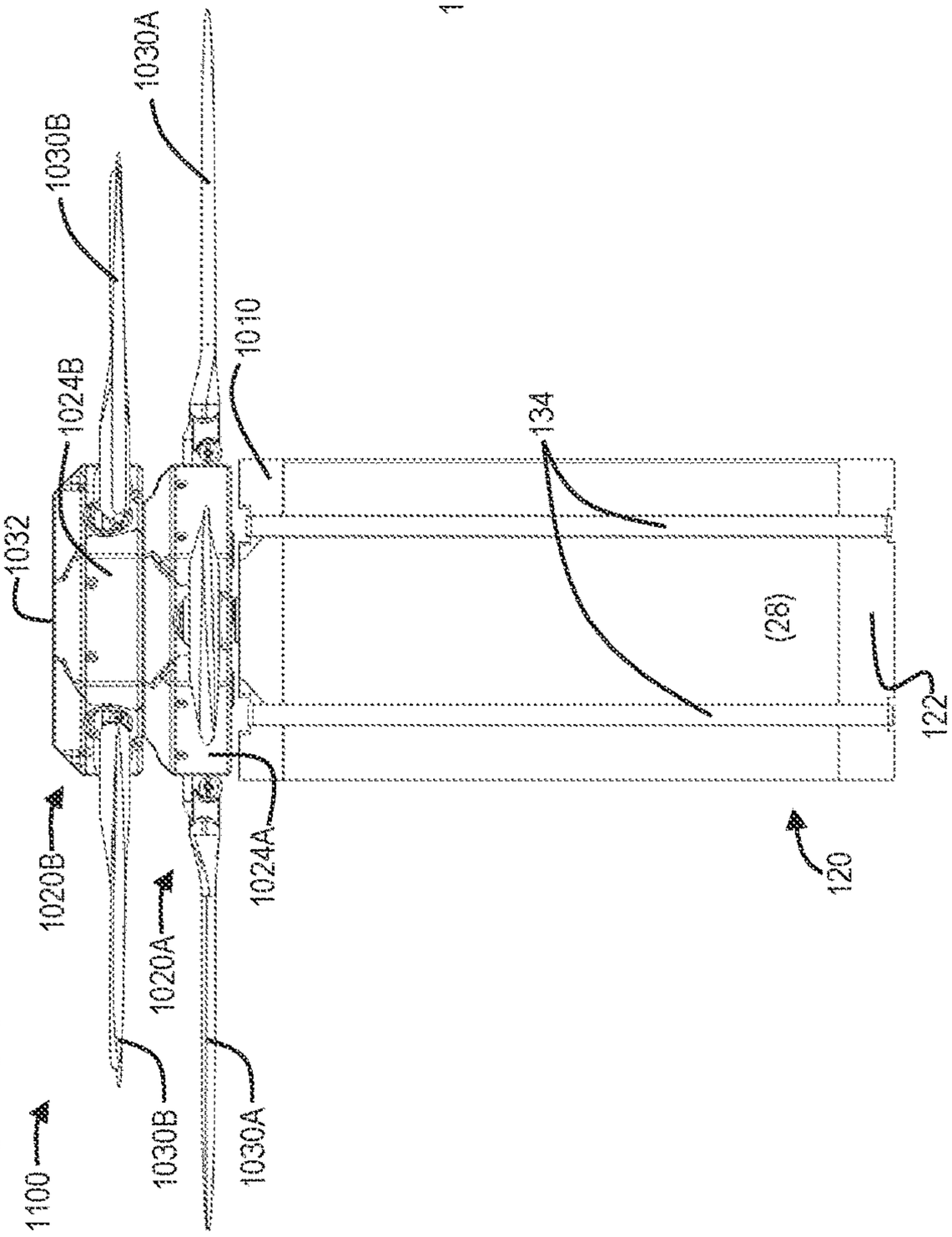
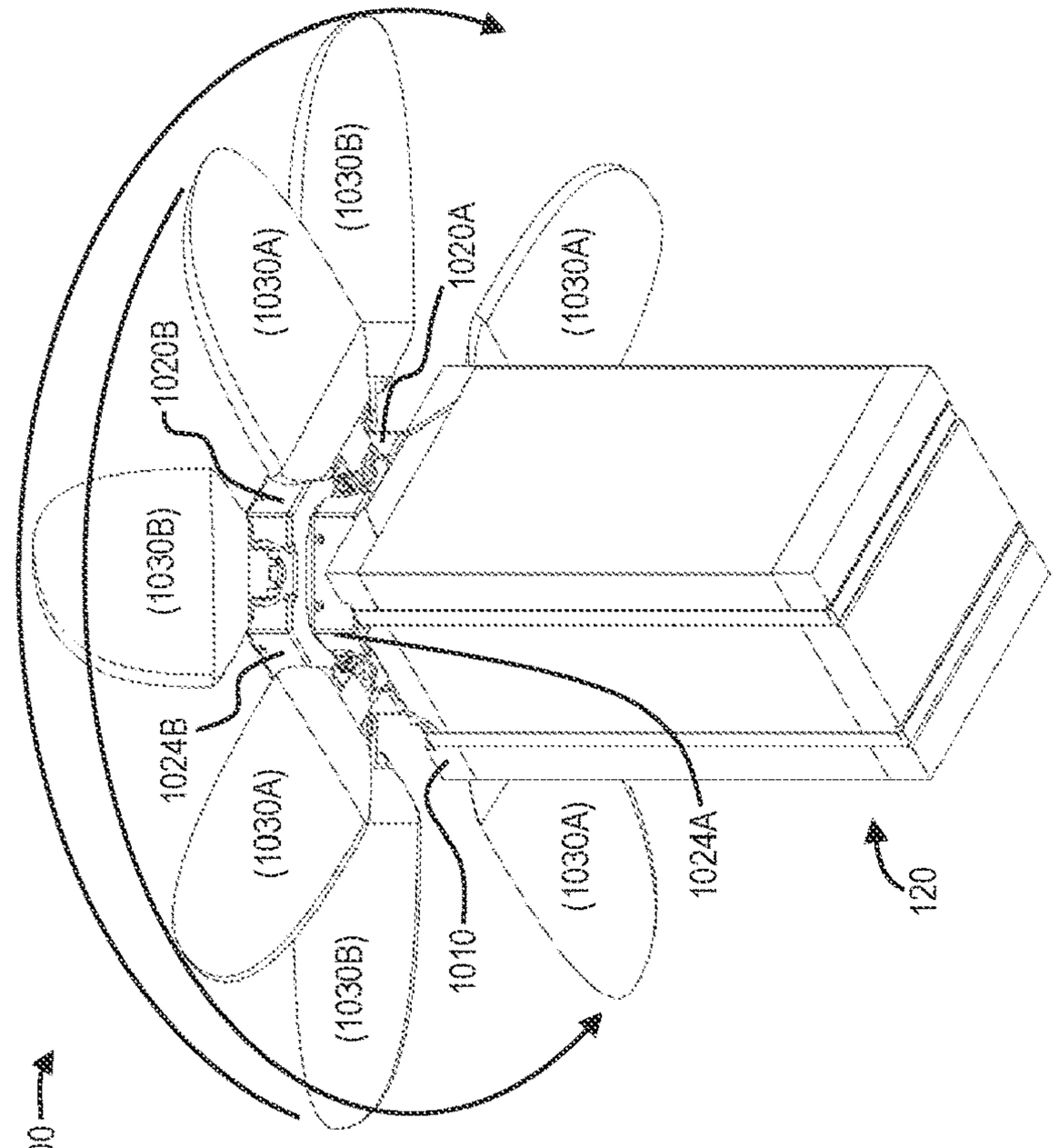


FIG. 30B



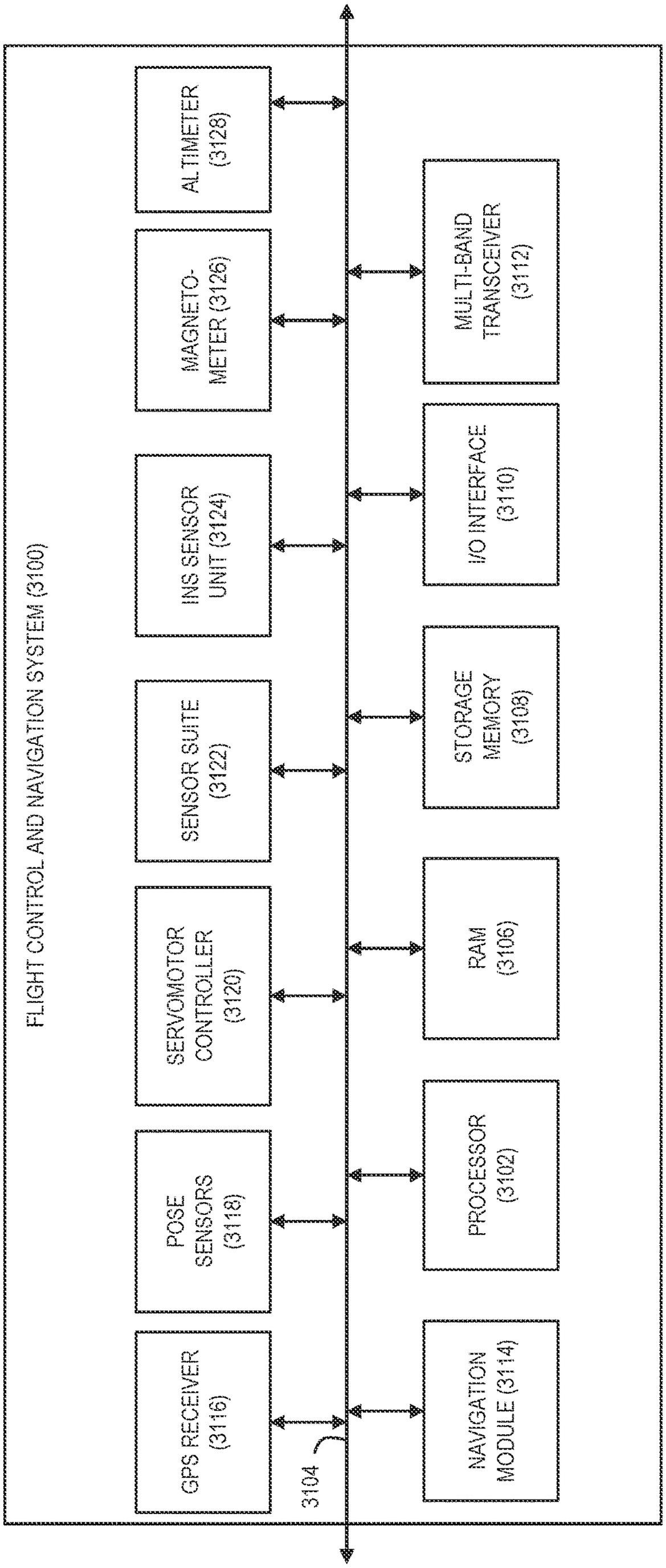

FLIGHT CONTROL AND NAVIGATION SYSTEM (3100)
ALTIMETER (3128)
MAGNETO-METER (3126)
MULTI-BAND TRANSCEIVER (3112)
INS SENSOR UNIT (3124)
I/O INTERFACE (3110)
SENSOR SUITE (3122)
STORAGE MEMORY (3108)
SERVOMOTOR CONTROLLER (3120)
RAM (3106)
POSE SENSORS (3118)
PROCESSOR (3102)
GPS RECEIVER (3116)
NAVIGATION MODULE (3114)
3104

FIG. 31

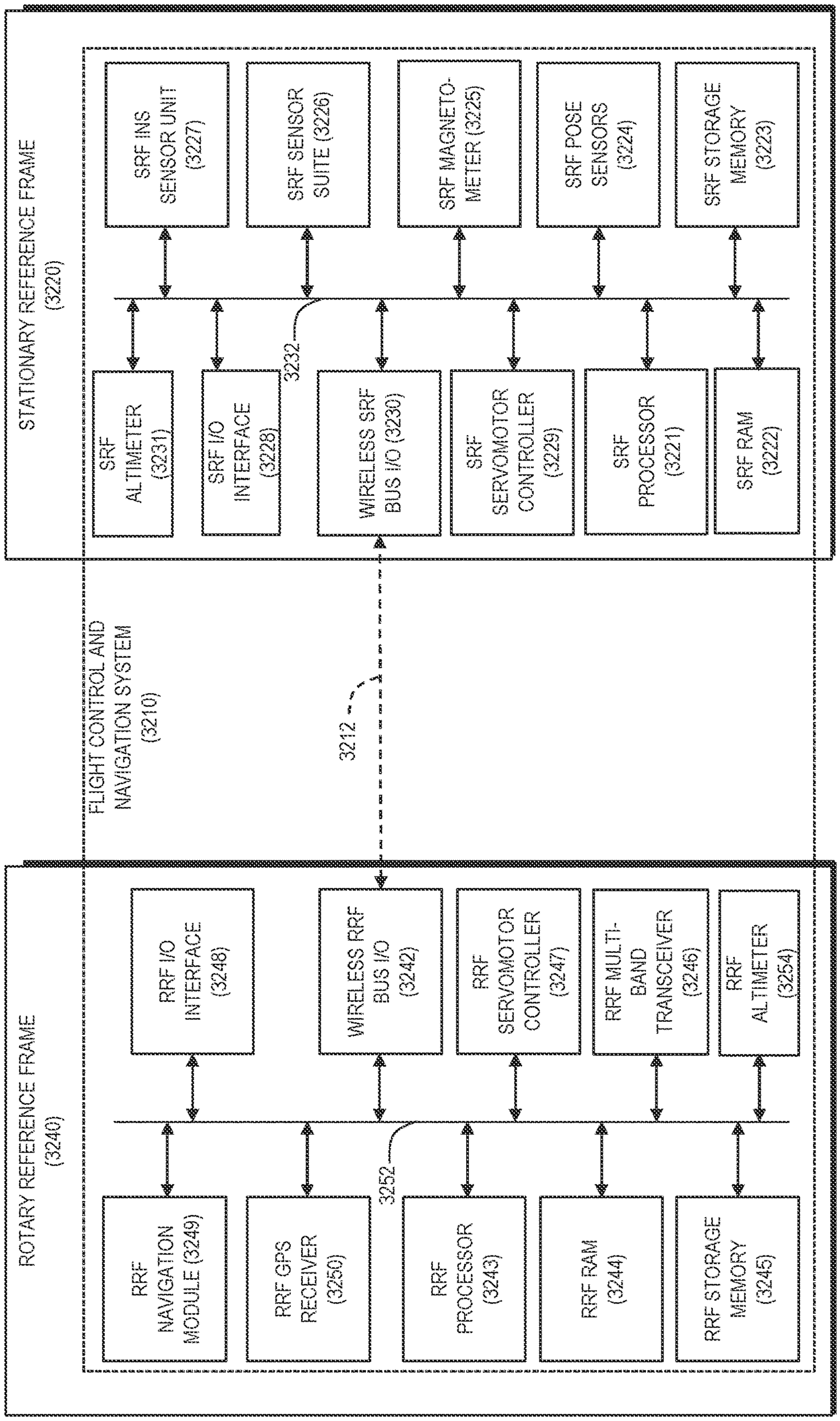

STATIONARY REFERENCE FRAME (3220)
SRF INS SENSOR UNIT (3227)
SRF SENSOR SUITE (3226)
SRF MAGNETO-METER (3225)
SRF POSE SENSORS (3224)
SRF STORAGE MEMORY (3223)
SRF ALTIMETER (3231)
SRF I/O INTERFACE (3228)
3232
WIRELESS SRF BUS I/O (3230)
SRF SERVOMOTOR CONTROLLER (3229)
SRF PROCESSOR (3221)
SRF RAM (3222)
FLIGHT CONTROL AND NAVIGATION SYSTEM (3210)
3212
ROTARY REFERENCE FRAME (3240)
RRF I/O INTERFACE (3248)
WIRELESS RRF BUS I/O (3242)
RRF SERVOMOTOR CONTROLLER (3247)
RRF MULTI-BAND TRANSCEIVER (3246)
RRF ALTIMETER (3254)
RRF NAVIGATION MODULE (3249)
RRF GPS RECEIVER (3250)
3252
RRF PROCESSOR (3243)
RRF RAM (3244)
RRF STORAGE MEMORY (3245)

FIG. 32

3200

AUTOROTATING PAYLOAD DELIVERY DEVICE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Patent Application Ser. No. 63/126,345 filed on Dec. 16, 2020, wherein the disclosure of the application listed above is incorporated herein by reference in its entirety.

BACKGROUND

[0002] The embodiments disclosed herein are directed toward air drop devices configured to be deployed from an aircraft with the purpose of safely delivering an attached payload to a predetermined target destination either on land, water or a structure on either land or water.

[0003] An unpowered pararotor assembly mounted on top of an air drop device is provided in at least two configurations disclosed herein. First, a pitch-link type rotor assembly may include a swashplate for collective pitch control of the rotor blades and cyclic pitch control of the rotors. A second type of a "swashplate-less" configuration may include greater control of collective and cyclic pitch of the rotor blades of a rotor assembly by directly controlling the rotor blades by servomotor actuators.

[0004] The pararotor is a biology-inspired decelerator device based on the autorotation of a rotary wing, whose main purpose is to guide a load descent into a certain planetary atmosphere. The pararotor is a device like an unpowered helicopter rotor that spins in an autorotation configuration when the attached payload is descending through an airstream impinging upon the pararotor. A drag force in the direction of the incident airstream flow is generated over the autorotating rotor, where the drag exerted over the rotor is greater if the rotor is spinning in an autorotating configuration. Thus, the rotational motion of the pararotor assembly is effective to slow down or exert a downwardly directed thrust vector relative to a falling body or payload in the airstream and also stabilize the payload's trajectory.

BRIEF SUMMARY

[0005] It should be appreciated that this Summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This Summary is not intended to be used to limit the scope of the claimed subject matter.

[0006] In one embodiment disclosed herein, a payload delivery device is configured to deliver an aircraft deployed payload along a payload flight path to a predetermined landing destination and include a support member configured to be removably attached to the payload, a flight control and navigation system module connected to the support member, a control surface assembly module including a plurality of control surfaces, the control surface assembly module connected to the support member and in communication with the flight control and navigation module to receive commands to control orientation of the plurality of control surfaces while the payload is travelling along the payload flight path to the predetermined landing destination, a rotor assembly including a plurality of rotor blades having a central axis of rotation, and a collective control assembly module including at least one collective servomotor, the collective control assembly module connected between the support member and the rotor assembly and in communication with the flight control and navigation module configured to control a plurality of control linkages connected to the plurality of rotor blades.

[0007] In another embodiment disclosed herein, a payload delivery device is configured to deliver an aircraft deployed payload along a payload flight path to a predetermined landing destination and include a support member configured to be removably attached to the payload, a flight control and navigation system module connected to the support member, a control surface assembly module including a plurality of control surfaces, the control surface assembly module connected to the support member and in communication with the flight control and navigation module to receive commands to control orientation of the plurality of control surfaces while the payload is travelling along the payload flight path to the predetermined landing destination, a gimbal assembly module including a plurality of gimbal servomotors, the gimbal assembly module connected to and configured to move relative to the support member and in communication with the flight control and navigation module to receive commands to control axial rotation of the gimbal assembly module with respect to the support member, a rotor assembly including a plurality of rotor blades having a central axis of rotation, and a collective control assembly module including at least one collective servomotor, the collective control assembly module connected between the gimbal assembly module and the rotor assembly and in communication with the flight control and navigation module configured to control a plurality of control linkages connected to the plurality of rotor blades.

[0008] In another embodiment disclosed herein, a payload delivery device configured to deliver an aircraft deployed payload along a payload flight path to a predetermined landing destination and include a support member configured to be removably attached to the payload, a flight control and navigation system module, a control surface assembly module including a plurality of control surfaces, the control surface assembly module connected to the support member and in communication with the flight control and navigation module to receive control surface commands to control orientation of the plurality of control surfaces, a rotation bearing assembly connected to the support member, and a rotor assembly including a plurality of rotor blades having a central axis of rotation and a plurality of rotor servomotors, the rotor assembly connected to the rotation bearing assembly and in communication with the flight control and navigation module to receive rotor rotation commands to control angular rotation of each of the plurality of rotor blades via co-planar aligned blade rotation shafts of each of the plurality of rotor blades, the co-planar aligned drive shafts coincident with a plane of rotation of the rotor assembly about the central axis of rotation.

[0009] In another embodiment disclosed herein, a method of assembling a delivery payload assembly configured to be deployed from an aircraft and travel along a payload flight path to a predetermined landing destination includes providing a payload configured to be delivered from the aircraft to the predetermined landing destination, attaching a tail-kit assembly to a first end of the payload thereby defining the delivery payload assembly, the tail-kit assembly including a rotor blade assembly including a plurality of rotor blades having a central axis of rotation proximate the first end of the

payload, and a flight control and navigation system configured to control a collective pitch angle of each of the plurality of rotor blades of the rotor blade assembly, control an axial thrust force of the rotor blade assembly, the axial thrust force being at an angle with respect to the central axis of rotation of the rotor blade assembly, and navigate the delivery payload assembly along the payload flight path to the predetermined landing destination. The method further includes removing the tail-kit assembly from the payload after the payload is delivered to the predetermined landing destination, wherein the flight control and navigation system is further configured to induce and control an autorotation motion of rotor blade assembly during a portion of the payload flight path of the delivery payload assembly from the aircraft to the predetermined landing destination, and produce and control a vertical thrust force by the rotor blade assembly during an end portion of the payload flight path of the delivery payload assembly from the aircraft to the predetermined landing destination.

[0010] In another embodiment disclosed herein, a method of delivering a payload to be deployed from an aircraft along a payload flight path to a predetermined landing destination includes attaching a tail-kit assembly to a first end of the payload thereby defining a delivery payload assembly, programming geographic coordinates of the predetermined landing destination into a flight control and navigation system in the tail-kit assembly, ejecting the delivery payload assembly from the aircraft, navigating, via the flight control and navigation system, the delivery payload assembly along a payload flight path configured to terminate at the predetermined landing destination, controlling, via the flight control and navigation system, an autorotation motion of a rotor blade assembly of the tail-kit assembly to enter a steady-state flight phase having a substantially constant first downward velocity, controlling, via the flight control and navigation system, the rotor blade assembly of the tail-kit assembly to enter a terminal flight phase before the predetermined landing destination, wherein the terminal flight phase has a second downward velocity less than the first downward velocity, wherein flight control and navigation system controls rotation of a leading-edge of each of the plurality of rotor blades of the rotor blade assembly in a positive direction to generate a vertical thrust force based on a moment of inertia of the rotor blade assembly in the autorotation motion, and removing the tail-kit assembly from the payload after the delivery payload assembly arrives at the predetermined landing destination, wherein the removed tail-kit assembly is configured to be attached to a second payload for delivery by an air vehicle to another predetermined landing destination.

[0011] In another embodiment disclosed herein, a method of delivering a payload to be deployed from an aircraft along a payload flight path to a predetermined landing destination includes attaching a tail-kit assembly to a first end of the payload thereby defining a delivery payload assembly, programming geographic coordinates of the predetermined landing destination into a flight control and navigation system in the tail-kit assembly, ejecting the delivery payload assembly from the aircraft, controlling, via the flight control and navigation system, a leading-edge of each rotor blade of a rotor blade assembly attached to the tail-kit assembly into a substantially downward disposed orientation, navigating, via the flight control and navigation system, the delivery payload assembly along a payload flight path terminating at the predetermined landing destination, inducing, via the flight control and navigation system, an autorotation motion of the rotor blade assembly by rotating the leading-edge of each rotor blade of the rotor blade assembly toward a plane of rotation of the rotor blade assembly, generating, via the flight control and navigation system, a vertical thrust force on the delivery payload assembly by rotating the leading-edge of each rotor blade of the rotor blade assembly above the plane of rotation of the rotor blade assembly, wherein the vertical thrust force is supplied by a moment of inertia of the rotor blade assembly in the autorotation motion before the predetermined landing destination, and removing the tail-kit assembly from the delivery payload assembly after the delivery payload assembly arrives at the predetermined landing destination, wherein the removed tail-kit assembly is configured to be attached to a second payload for delivery by an air vehicle to a second predetermined landing destination.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0012] The embodiments presented herein will be better understood from the following detailed description with reference to the drawings, which are not necessarily drawing to scale and in which:

[0013] FIG. **1** illustrates a top perspective view of a first embodiment of a pitch link type air drop device;

[0014] FIG. **2**A illustrates a top perspective view of a payload retained within the pitch link type air drop device of FIG. **1**;

[0015] FIG. **2**B illustrates a top perspective view of an enclosure surrounding the payload of FIG. **2**A retained withing the pitch link type air drop device of FIG. **1**;

[0016] FIG. **3**A illustrates a top perspective view of a stabilizer sub-assembly mounted on top of the enclosure of FIG. **2**B of the pitch link type air drop device of FIG. **1**;

[0017] FIG. **3**B illustrates a top perspective view of a stabilizer assembly mounted on top of the enclosure of FIG. **2**B of the pitch link type air drop device of FIG. **1**;

[0018] FIG. **4**A illustrates a top perspective view of a control system mounting plate mounted on top of the stabilizer assembly of FIG. **3**B of the pitch link type air drop device of FIG. **1**;

[0019] FIG. **4**B illustrates a top perspective view of a pitch link actuator sub-assembly mounted on top of the control system mounting plate of FIG. **4**A of the pitch link type air drop device of FIG. **1**;

[0020] FIG. **5**A illustrates a top perspective view of a pitch link assembly connected to the pitch link actuator sub-assembly of FIG. **4**B of the pitch link type air drop device of FIG. **1**;

[0021] FIG. **5**B illustrates a top perspective view of a pitch link-controlled rotor assembly connected to the pitch link assembly of FIG. **5**A of the pitch link type air drop device of FIG. **1**;

[0022] FIG. **6**A illustrates a bottom perspective view of a stored and an initial deployment configuration of the pitch link type air drop device of FIG. **1**;

[0023] FIG. **6**B illustrates a bottom perspective view of a rotor deployment configuration of the pitch link type air drop device of FIG. **1**;

[0024] FIG. **6**C illustrates a bottom perspective view of a fully rotor deployed configuration of the pitch link type air drop device of FIG. **1**;

[0025] FIG. **7**A illustrates a front view of stabilizer control surfaces in a first position of the pitch link type air drop device of FIG. **1**;

[0026] FIG. **7**B illustrates a bottom perspective view of the stabilizer control surfaces in the first position of FIG. **7**A of the pitch link type air drop device of FIG. **1**;

[0027] FIG. **7**C illustrates a front view of the stabilizer control surfaces in a second opposite position of the pitch link type air drop device of FIG. **1**;

[0028] FIG. **7**D illustrates a bottom perspective view of the stabilizer control surfaces in the second opposite position of FIG. **7**C of the pitch link type air drop device of FIG. **1**;

[0029] FIG. **8** illustrates a top perspective view of a second alternative embodiment of a pitch link type air drop device of FIGS. **1**-**7**D including a rotor dampening system;

[0030] FIG. **9**A illustrates a front view of the second alternative embodiment the pitch link type air drop device of FIG. **8** in an undampened state;

[0031] FIG. **9**B illustrates a front view of the second alternative embodiment the pitch link type air drop device of FIG. **8** in a dampening state;

[0032] FIG. **10** illustrates an air drop method of deploying the pitch link type air drop device of FIG. **1**;

[0033] FIG. **11** illustrates a schematic diagram of a system of communication of the pitch link type air drop device of FIG. **1**;

[0034] FIG. **12** illustrates a top perspective view of a first embodiment of a co-planar rotor control type air drop device;

[0035] FIG. **13**A illustrates a top perspective view of a payload, enclosure, stabilizer assembly, (similar to FIG. **3**), and a gimbal surface of the co-planar rotor control type air drop device of FIG. **12**;

[0036] FIG. **13**B illustrates a top perspective view of an actuated gimbal controller mounted on the gimbal surface of FIG. **13**A of the co-planar rotor control type air drop device of FIG. **12**;

[0037] FIG. **13**C illustrates a top perspective view of a gimbal rotor connector mounted on the gimbal actuated gimbal controller of FIG. **13**B of the co-planar rotor control type air drop device of FIG. **12**;

[0038] FIG. **14**A illustrates a top perspective view of a rotor pitch control actuator sub-assembly mounted on the gimbal rotor connector of FIG. **13**C of the co-planar rotor control type air drop device of FIG. **12**;

[0039] FIG. **14**B illustrates a top perspective view of a rotor sub-assembly covering and supporting the rotor pitch control actuator sub-assembly of FIG. **14**A of the co-planar rotor control type air drop device of FIG. **12**;

[0040] FIG. **15**A illustrates a front view of a rotor having a neutral/null angle mounted on the rotor sub-assembly of FIG. **14**B of the co-planar rotor control type air drop device of FIG. **12**;

[0041] FIG. **15**B illustrates a front view of the rotor of FIG. **15**A having a 90-degree negative angle mounted on the rotor sub-assembly of FIG. **14**B of the co-planar rotor control type air drop device of FIG. **12**;

[0042] FIG. **15**C illustrates a front view of the rotor of FIG. **15**A having a slight negative angle mounted on the rotor sub-assembly of FIG. **14**B of the co-planar rotor control type air drop device of FIG. **12**;

[0043] FIG. **15**D illustrates a front view of the rotor of FIG. **15**A having a slight positive angle mounted on the rotor sub-assembly of FIG. **14**B of the co-planar rotor control type air drop device of FIG. **12**;

[0044] FIG. **16** illustrates a top perspective view of a second alternative embodiment having no gimbal assembly components being similar to the co-planar rotor control type air drop device of FIG. **12**;

[0045] FIG. **17** illustrates a top perspective view of a third alternative embodiment having dual counter-rotating rotor assemblies mounted on a gimbal assembly being similar to the co-planar rotor control type air drop device of FIG. **12**;

[0046] FIG. **18**A illustrates a front view of the third alternative embodiment co-planar rotor control type air drop device of FIG. **17**;

[0047] FIG. **18**B illustrates a top perspective view of the third alternative embodiment co-planar rotor control type air drop device of FIG. **17**;

[0048] FIG. **19** illustrates a top perspective view of a fourth alternative embodiment having a four-blade rotor assembly mounted on a gimbal assembly being similar to the co-planar rotor control type air drop device of FIG. **12**;

[0049] FIG. **20**A illustrates a top perspective view of the fourth alternative embodiment having dual rotor rotational control actuators of the co-planar rotor control type air drop device of FIG. **19**;

[0050] FIG. **20**B illustrates a top perspective view of the fourth alternative embodiment having a rotor sub-assembly covering and supporting the dual rotor rotational control actuators of the co-planar rotor control type air drop device of FIG. **19**;

[0051] FIG. **21** illustrates a top perspective view of the fourth alternative embodiment having folding rotor blades illustrating a stowed, partially deployed and fully deployed states of the co-planar rotor control type air drop device of FIG. **19**;

[0052] FIG. **22**A illustrates a front view of a rotor having a neutral/null angle mounted on the rotor sub-assembly of FIG. **20**B of the co-planar rotor control type air drop device of FIG. **19**;

[0053] FIG. **22**B illustrates a front view of the rotor of FIG. **15**A having a **90**-degree negative angle mounted on the rotor sub-assembly of FIG. **20**B of the co-planar rotor control type air drop device of FIG. **19**;

[0054] FIG. **22**C illustrates a front view of the rotor of FIG. **15**A having a slight negative angle mounted on the rotor sub-assembly of FIG. **20**B of the co-planar rotor control type air drop device of FIG. **19**;

[0055] FIG. **22**D illustrates a front view of the rotor of FIG. **15**A having a slight positive angle mounted on the rotor sub-assembly of FIG. **20**B of the co-planar rotor control type air drop device of FIG. **19**;

[0056] FIG. **23** illustrates a top perspective view of a fifth alternative embodiment having a four-blade rotor assembly mounted without a gimbal assembly being similar to the co-planar rotor control type air drop device of FIG. **19**;

[0057] FIG. **24** illustrates two air drop methods of deploying the co-planar rotor control type air drop device of FIGS. **12**-**23**;

[0058] FIG. **25**A illustrates a front view of a sixth alternative embodiment having dual counter-rotating four-blade rotor assemblies mounted on a gimbal assembly being similar to the co-planar rotor control type air drop device of FIG. **19**;

[0059] FIG. **25**B illustrates a top perspective view of the dual counter-rotating four-blade rotor assemblies of FIG. **25**A of the co-planar rotor control type air drop device of FIG. **19**;

[0060] FIG. **26**A illustrates a front view of a seventh alternative embodiment having dual counter-rotating four-blade rotor assemblies with no gimbal assembly being similar to the co-planar rotor control type air drop device of FIGS. **18**A-**18**B;

[0061] FIG. **26**B illustrates a top perspective view of the dual counter-rotating four-blade rotor assemblies of FIG. **25**A of the co-planar rotor control type air drop device of FIG. **19**;

[0062] FIG. **27**A illustrates a top perspective view of an eighth alternative embodiment having no stabilizer assembly attached to an enclosure with a payload of a co-planar rotor control type air drop device;

[0063] FIG. **27**B illustrates a top perspective view of the eighth alternative embodiment of FIG. **27**A having independently controlled rotors of a quad rotor assembly of a co-planar rotor control type air drop device;

[0064] FIG. **27**C illustrates a top perspective view of the eighth alternative embodiment having a cover over the flight control portion of the co-planar rotor control type air drop device of FIG. **27**B;

[0065] FIG. **28**A illustrates a front view of a rotor having a neutral/null angle mounted on the rotor assembly of FIGS. **27**B-**27**C of the co-planar rotor control type air drop device of FIG. **27**B;

[0066] FIG. **28**B illustrates a front view of the rotor of FIGS. **27**B-**27**C having a **90**-degree negative angle mounted on the rotor assembly of FIGS. **27**B-**27**C of the co-planar rotor control type air drop device of FIG. **27**B;

[0067] FIG. **28**C illustrates a front view of the rotor of FIGS. **27**B-**27**C having a slight negative angle mounted on the rotor assembly of FIGS. **27**B-**27**C of the co-planar rotor control type air drop device of FIG. **27**B;

[0068] FIG. **28**D illustrates a front view of the rotor of FIGS. **27**B-**27**C having a slight positive angle mounted on the rotor assembly of FIGS. **27**B-**27**C of the co-planar rotor control type air drop device of FIG. **27**B;

[0069] FIG. **29** illustrates an air drop methods of deploying the co-planar rotor control type air drop device of FIGS. **27**B-**28**D;

[0070] FIG. **30**A illustrates a front view of a ninth alternative embodiment having dual counter-rotating four-blade rotor assemblies similar to the co-planar rotor control type air drop device of FIGS. **27**B-**28**D;

[0071] FIG. **30**B illustrates a top perspective view of the ninth alternative embodiment having dual counter-rotating four-blade rotor assemblies similar to the co-planar rotor control type air drop device of FIGS. **27**B-**28**D;

[0072] FIG. **31** illustrates a schematic diagram of a flight control and navigation system for the air drop devices of FIGS. **1**-**30**B; and

[0073] FIG. **32** illustrates a schematic diagram of a reference frame comparison between a rotary and a stationary reference frame for the air drop devices of FIGS. **1**-**30**B.

DETAILED DESCRIPTION

[0074] FIGS. **1**-**7**D illustrate a first embodiment of a pitch link type air drop device **100**.

[0075] FIG. **1** illustrates a top perspective view of the first embodiment of a pitch link type air drop device **100**, and FIGS. **2**A-**5**B illustrate a series of assembly views of the first embodiment of the pitch link type air drop device **100**.

[0076] FIG. **2**A illustrates a top perspective view of a payload retained within the pitch link type air drop device **100** of FIG. **1** illustrating a package or payload **110** having a length, width and depth where the shape of the payload **110** may be a rectangular cube shape having a central longitudinal axis therethrough defining a top portion **112** and a bottom portion **114**. The payload **110** may comprise any other shape that may be aerodynamically stable during a downward trajectory in an atmosphere after being deployed from an aircraft.

[0077] FIG. **2**B illustrates a top perspective view of an enclosure defining a containerized payload assembly **120** surrounding the payload **110** of FIG. **2**A retained withing the pitch link type air drop device **100** of FIG. **1**. The containerized payload assembly **120** may include a reinforced base **122** proximate the bottom portion **114** of the payload **110**, a plurality of intermediate side panels **124** that surround the exterior sides of the payload **110**, and reinforced corner members **126** projecting from reinforced base **122** to the top portion **112** of the payload **110**.

[0078] FIG. **3**A illustrates a top perspective view of the containerized payload assembly **120** and a stabilizer assembly **130** mounted on top of the payload **110** of FIG. **2**B of the pitch link type air drop device **100** of FIG. **1**. The containerized payload assembly **120** further includes a plurality of exterior panels **128** that overlap each side of the payload **110** and cover the plurality of intermediate side panels **124** surrounding the exterior sides of the payload **110** and the reinforced corner members **126**.

[0079] A flight stabilizer assembly **130** is mounted on the top portion **112** of the payload **110** and may include a stabilizer base **132** held in place on the top portion **112** of the payload **110** by an attachment mechanism **134**, here illustrated as a set of removeable straps or ties surrounding the stabilizer base **132**, two opposite sides of the payload **110** and the reinforced base **122**.

[0080] FIG. **3**B illustrates a top perspective view of a stabilizer assembly **130** mounted on top of the containerized payload assembly **120** of FIG. **2**B of the pitch link type air drop device **100** of FIG. **1**. The flight stabilizer assembly **130** may further include and fixedly retain a plurality of stabilizer control surface servomotors **136** connected to respective rotational drive shafts to control surfaces **138** projecting outwardly from the stabilizer base **132**.

[0081] FIG. **4**A illustrates a top perspective view of a pitch link control base **142** of a pitch link control assembly **140** mounted on top of the stabilizer assembly **130** of FIG. **3**B of the pitch link type air drop device **100** of FIG. **1**. The pitch link control assembly **140** includes the pitch link control base **142** designed to support the electronic controls of the pitch link control assembly **140** and a later discussed rotor assembly **150**.

[0082] FIG. **4**B illustrates a top perspective view of a pitch link control assembly **140** mounted on top of the pitch link control base **142** of FIG. **4**A of the pitch link type air drop device **100** of FIG. **1**, where the pitch link control base **142** supports a plurality of pitch link control servomotors **144** configured to input a collective pitch control and a cyclic pitch control to a rotor assembly **150**, (later discussed).

[0083] FIG. **5**A illustrates a top perspective view of a pitch link control assembly **140** connected to the pitch link control base **142** of FIG. **4**B of the pitch link type air drop device

100 of FIG. **1** where pitch link controls **146** corresponding to each of the plurality of pitch link control servomotors **144**, respectively connect to a swashplate **148** for controlling the collective pitch control and cyclic pitch control for a rotor assembly **150**.

[0084] FIG. **5**B illustrates a top perspective view of a pitch link-controlled rotor assembly **150** connected to the pitch link assembly **140** of FIG. **5**A of the pitch link type air drop device **100** of FIG. **1**. The rotor assembly **150** includes a plurality of rotor blades **152** connected to the swashplate **148** by corresponding pitch link controls **146** to control the collective pitch and cyclic pitch for each of the rotor blades **152** of the rotor assembly **150**. FIG. **1** illustrates a rotor blade rotational axis **153** of a representative rotor blade **152** of the rotor assembly **150** denoting the axis of rotation about which the rotor blade **152** rotates under control of the swashplate **148** of the pitch link assembly **140**.

[0085] FIGS. **6**A-**6**C illustrate a rotor deployment sequence from an initial stowed rotor configuration to a fully deployed rotor configuration. FIG. **6**A illustrates a bottom perspective view of a stowed and an initial deployment configuration of the pitch link type air drop device **100** of FIG. **1**. In this stowed configuration, the pitch link air drop device **100** has each rotor blade **152** folded about a rotor blade folding joint **154** configured to bring the folded rotor blade **152** proximate to the outer edges of the containerized payload assembly **120** surrounding the payload **110**. In this stowed configuration, the pitch link air drop device **100** may be moved into an aircraft and stored with other similarly configured air drop devices the minimize the volumetric space taken by the air drop devices particularly when a number of the air drop devices need to be stored in and transported for deployment from an aircraft. FIG. **6**A further illustrates a folded rotor blade axis **156** denoting the configuration of the rotor blade **152** proximate to the containerized payload assembly **120**.

[0086] FIG. **6**B illustrates a bottom perspective view of a rotor deployment configuration of the pitch link type air drop device **100** of FIG. **1** in a subsequence sequence to FIG. **6**A where the rotor blades **152** are disposed in an intermediate configuration along an intermediate rotor blade axis **158** rotated an intermediate angle of rotation **159** from the stowed folded rotor blade axis **156**. In this intermediate configuration, the pitch link air drop device **100** may have been deployed from the aircraft and oriented in a downward disposition of an air drop payload flight path to a predetermined target destination and a force (F) of airflow upon the pitch link type air drop device **100** may begin acting upon each of the rotor blades **152** to rotate them into a fully deployed configuration. An alternative configuration may include a timing or trigger device that allows the rotor blades **152** to begin opening after a particular time from the initial aircraft deployment or a trigger condition, for example, a detected altitude or GPS coordinate location, while on the flightpath to the predetermined destination.

[0087] FIG. **6**C illustrates a bottom perspective view of a fully rotor deployed configuration of the pitch link type air drop device **100** of FIG. **1** where the rotor blades **152** are rotated into a fully deployed configuration about a fully deployed rotor blade axis **160** about a fully deployed angle of rotation **161**. The rotation may take place due to a force of wind F while the pitch link type air drop device **100** is traveling along a flightpath to the predetermined target destination. After deployment of the rotor blades **152** to the fully deployed configuration, the pitch link control assembly **140** may control the rotation of the rotor blades **152** for collective pitch control and/or cyclic pitch control purposes to cause the rotor blades to begin and maintain autorotation in a rotational direction R for the purposes of navigation and descent speed control of the pitch link type air drop device **100**.

[0088] While the rotor blades **152** may be efficiently packed and safely stowed alongside the containerized payload assembly **120** before deployment from an aircraft, a secondary system such as a tether or independent servomotor may release the rotor blades **152** from the initial stowed rotor blade condition as illustrated in FIG. **6**A. Once the rotor blades **152** are freed from their initial stowed position, the force (F) of airflow moving over the rotor blades **152** may rotate them into to an operational plane of rotation coincident with the fully deployed rotor blade axis **160** of FIG. **6**C. In the alternative, springs, linkages, servomotors, centripetal force or similar actuators may aid rotating the blades into the operational plane of rotation.

[0089] Once the rotor blades **152** are rotated into an operational plane of rotation, as in FIG. **6**C, a one-way locking mechanism, may lock the rotor blades **152** to prevent further rotor blade movement during the flightpath. An exemplary locking mechanism may consist of spring-loaded pins where a blade grip of the rotor blade **152** rotates to the operational plane of rotation and the spring-loaded pins line up with a corresponding hole and the springs force engagement of the pins in shear to prevent further rotation. Additionally, ball detents, ratchet and pawl or other mechanisms may be used to engage a mechanical lock from the rotating blade assembly **150** to a static hub.

[0090] Furthermore, a damping device, (as disclosed below in FIGS. **8**-**9**B), may be used to slow or modify the rate of initial blade rotation from the stowed to fully deployed configuration to prevent overstress due to cantilever loading of the rotor blades **152**. Dampening may consist of elastomer stops, gas shocks, springs, friction brakes or a crushable or compliant mechanism to arrest the movement of the rotor blade rotation into the fully deployed configuration.

[0091] FIGS. **7**A-**7**D illustrate movement of the control surfaces **138** of the flight stabilizer assembly **130** configured to provide directional control of the air drop device **100** while in a payload flight path to maintain the payload flight path to a predetermined landing destination. FIG. **7**A illustrates a front view and FIG. **7**B illustrates a bottom perspective view of the pitch link air drop device **100** of FIG. **1** with the containerized payload assembly **120**, the pitch link control assembly **140**, the rotor assembly **150** and the flight stabilizer assembly **130** having stabilizer control surfaces **138** rotated into a first position, for example, represented by reference number **138**A in FIG. **7**A, about corresponding control surface rotational axes **139**A and **139**B, as illustrated in FIG. **7**B.

[0092] FIG. **7**C illustrates a front view and FIG. **7**D illustrates a bottom perspective view of the pitch link air drop device **100** of FIG. **1** and FIGS. **7**A-**7**B with the containerized payload assembly **120**, the pitch link control assembly **140**, the rotor assembly **150** and the flight stabilizer assembly **130** having stabilizer control surfaces **138** rotated into a second position opposite that of the first position of FIGS. **7**A-**7**B, for example, represented by

reference number **138**B in FIG. **7**C, about corresponding control surface rotational axes **139**A and **139**B, as illustrated in FIG. **7**B.

[0093] FIGS. **8**-**9**D illustrate a second alternative embodiment of a pitch link type air drop device **200** similar to the pitch link air drop device **100** of FIGS. **1**-**7**D but further including a rotor dampening device **260** and an alternative flight stabilizer assembly **230**. FIG. **8** illustrates a top perspective view of the second alternative embodiment of a pitch link type air drop device **200** including a containerized payload assembly **220** having a reinforced base **222**, side panels **224**, and corner members **226**.

[0094] FIG. **8** further illustrates an alternative flight stabilizer assembly **230** of a single control surface having a stabilizer base **232** attached to the containerized payload assembly **220** via an attachment mechanism **234**, a stabilizer servomotor **236**, (not shown), housed in the stabilizer base **232**, and a control surface comprising an actuator controlled movable trailing edge control surface **238**A and a fixed leading edge control surface **238**B. The controlled movable control surface **238**A is configured to rotate about a control surface rotation axis **239** to provide rotational thrust about a longitudinal axis of the containerized payload assembly **220** of the pitch link air drop device **200**.

[0095] FIG. **8** further illustrates a pitch link control assembly **240**, (not shown), under a housing similar in configuration to the pitch link control assembly **140** of the pitch link air drop device **100** of FIGS. **1**-**7**D. A rotor assembly **250** includes rotor blades **252** with a rotor blade rotational axis **253** and a rotor blade folding joint **254** similar to the rotor assembly of **150** of FIGS. **1**-**7**D. A rotor dampening device **260** is disposed on each rotor blade **252** opposite the rotor blade folding joint **254** to allow each rotor blade **252** to flex in an upward direction, (as shown in FIG. **9**B), when the rotor blades **252** are deploying from a stowed position, (similar to FIG. **6**A), into a fully deployed position, (similar to FIG. **6**C).

[0096] FIG. **9**A illustrates a front view of the second alternative embodiment the pitch link type air drop device **200** of FIG. **8** in an undampened state where each rotor blade **252** is positioned in a fully deployed rotor blade rotation plane **258** after the rotor blades **252** fully rotate upwardly along the rotor blade deployment angle **257**.

[0097] FIG. **9**B illustrates a front view of the second alternative embodiment the pitch link type air drop device of FIG. **8** in a dampening state where the rotor dampening device **260** is compressed by a rotor blade dampening extension **262** positioned on the top portion of each respective rotor blade **252** when the rotor blades **252** rotate past about the folding rotor joint **254** the fully deployed rotor blade rotation plane **258** along a rotor blade dampening deflection angle **264** due to rotational inertial of the rotor blades **252** rotating from their stowed position under influence of the force of the upward airflow along the flightpath of the pitch link air drop device **200**.

[0098] FIG. **10** illustrates an air drop method in a pitch link deployment schematic diagram **270** of deploying the pitch link type air drop device **100** of FIG. **1**, or similarly the pitch link type air drop device **200** of FIG. **8**, to its predetermined target destination.

[0099] The pitch link deployment schematic diagram **270** illustrates an aircraft **272** travelling along an aircraft flight path **274** where upon a predetermined time and/or location of the aircraft **272**, an air drop device payload flight path **276** is calculated by a master flight controller of the aircraft and a payload launch controller in the aircraft **272** relative to predetermined target destination **288**. A when a launch trigger is executed by the master flight controller and the payload launch controller, the air drop device, e.g., **100**, is deployed **278** from the aircraft **272** and enters a transient flight phase **280** where the rotor blades **152**, **252** are maintained in a stowed position and the flight stabilizer assembly **130**, **230**, begins to rotate about their respective axes/axis to orient the air drop device into a downwardly disposed orientation.

[0100] A steady-state flight phase **282** is entered when the rotor blades **152**, **252** are fully deployed and begin autorotating to provide a thrust force Fl in a downward direction provided by autorotating rotor assembly **150**, **250**. During the steady-state flight phase, the flight stabilizer assembly **130**, **230** and/or the rotor assembly may provide directional control to the pitch link air drop device **100**, **200** to maintain the air drop device payload flight path **276**.

[0101] A terminal flight phase **284** is entered when the rotor blades **152**, **252** of the respective rotor assembly **150**, **250**, rotate the leading-edge of the blades into a positive direction, i.e., flaring the rotor blades, to generate a maximum amount of thrust force F**2** in a downward direction based on the rotational inertia of the rotor blades in the autorotation at the end of the steady-state flight phase **282**. The force of thrust F**2** is greater than the thrust force Fl in the steady-state flight phase **282** and is used immediately before the landing **286** at the predetermined target destination **288** or landing zone. Note that the flight stabilizer assembly **130**, **230** and/or the rotor assembly **150**, **250** continue to provide directional control to the pitch link air drop device **100**, **200** to maintain the air drop device payload flight path **276** during the terminal flight phase **284** immediately above and before the landing **286**.

[0102] FIG. **11** illustrates a schematic diagram **290** of a system of communication of the pitch link type air drop device **100** of FIG. **1** and similarly the air drop device **200** of FIG. **8**, however, all the air drop devices disclosed herein may subscribe to all or portions of the system of communication of schematic diagram **290**.

[0103] FIG. **11** illustrates a representative air drop device **100**A traveling along and being maintained in an air drop device payload flight path **276** having bi-directional communication **272**A with the aircraft master flight controller and payload launch controller **273** of the aircraft **272** from which it was launched. Bi-directional communication **272**A may include course correction information, course deviation information and other in-flight navigation telemetry parameters and controls.

[0104] The air drop device **100**A in the air drop device payload flight path **276** may alternatively or additionally be in bi-directional communication **292**A with a mid-to-high earth orbit satellite **292** which may be a GPS satellite or other non-GPS satellite.

[0105] The air drop device **100**A in the air drop device payload flight path **276** may alternatively or additionally be in bi-directional communication **294**A, **294**B with one or a network of low earth orbit satellites **294**. The bi-directional communication **294**A, **294**B may include tracking information and telemetry parameters.

[0106] The air drop device **100**A in the air drop device payload flight path **276** may alternatively or additionally be in bi-directional communication **296**A with a ground station

296 located proximate the predetermined landing destination **288** or landing zone. The bi-directional communication **296**A with a ground station **296** may include local wind speed and direction vectors and weather information of the ground station **296**. Bi-direction communication **296**A between the ground station **296** and air drop device **100**A may also be configured to provide flight control and navigation parameters from the ground station **296** to the air drop device **100**A when the aircraft **272** is no longer in communication range of the air drop device **100**A to provide such communication.

[0107] The air drop device **100**A in the air drop device payload flight path **276** may alternatively or additionally be in bi-directional communication **298** with a second air drop device **100**B that may be been launched before or after the airdrop device **100**A. The bi-direction communication between a second air drop device **100**B may include weather conditions at various altitudes or other communication parameters.

[0108] The representative air drop device **100**A' having landed at the predetermined target destination **288** may have bi-directional communication **272**B with the aircraft **272** from which is was launched. Bi-directional communication **272**B may include landing confirmation information or landing deviation information.

[0109] FIGS. **12**-**15**D illustrate a first embodiment of a co-planar rotor control type air drop device. A co-planar rotor control is defined herein to be rotor actuators that control the rotation of the rotor blades being disposed in or proximate to the plane of rotation of the rotor blades. (Similar reference numbers of similar elements from the air drop devices of FIGS. **1**-**7**D will be used in the subsequent air drop device embodiments where appropriate.)

[0110] FIG. **12** illustrates a top perspective view of the first embodiment of a co-planar rotor control type air drop device **300** used in the transportation of a payload, similar to payload **110** of FIG. **2**A, within a containerized payload assembly **120** having a flight stabilizer assembly **330** having flight control surfaces **338** and their respective control surface rotational axis **339**.

[0111] FIG. **12** further illustrates a rotor assembly **350** having a plurality of rotor blades **352** being co-aligned on a rotor blade rotational axis **353** where each rotor blade **352** includes a rotor blade folding joint **357** for the rotor blades **352** to be stowed in an initial pre-deployment and/or storage configuration similar to FIG. **6**A.

[0112] FIG. **13**A illustrates a top perspective view of the co-planar rotor control type air drop device **300** includes a gimbal assembly **340** and rotor assembly **350**, (described below in more detail in FIGS. **14**A-**14**B). The gimbal assembly **340** includes a gimbal mounting base **341** attached to the upper surface of the flight stabilizer assembly **330**, upon which are two gimbal servomotors **342** proximate a gimbal spherical surface **343**.

[0113] FIG. **13**B illustrates a top perspective view of the gimbal assembly **340** where a rotor base assembly **344** is mounted on and surrounds the gimbal spherical surface **343** and is connected to each of the two gimbal servomotors **342** to control an X and Y direction in a horizontal plane orthogonal to the rotational central axis **347** of the rotor blade assembly **350**, (disclosed below). The rotor base assembly **344** further includes a rotor assembly rotational bearing **345** directly mounted on the gimbal spherical surface **343** wherein the rotor base assembly **344** is controlled to move in a gimbal angular range of motion **346** about the rotational central axis **347** by the two gimbal servomotors **342**.

[0114] FIG. **13**C illustrates a top perspective view of a gimbal rotor assembly **340** mounted on the gimbal spherical surface **343** of FIG. **13**A further including a gimbal-rotor assembly connection **348** upon which the rotor assembly **350** is connect to.

[0115] FIG. **14**A illustrates a top perspective view of a rotor blade angular actuators **354** and rotor blade rotational shaft and bearing assembly **355** in alignment with the rotor blade rotational axis **353** being mounted on the gimbal-rotor assembly connection **348** of FIG. **13**C. Note the rotor blade angular actuators **354** may include rotor blade servomotors configured to control the angular direction of the leading edge of the rotor blades **352** with respect to a rotor blade rotation plane **358**, (see FIGS. **15**A-**15**D). The rotor blade servo motors **354** are located in a rotary reference frame defined by the rotor blade assembly **150** independent of a stationary or fixed reference frame defined by the stabilizer assembly **330** and the containerized payload assembly **120**.

[0116] FIG. **14**B illustrates a top perspective view of the rotor blade angular actuators **354** and the rotor blade rotational shaft and bearing assembly **355** in alignment with the rotor blade rotational axis **353** of FIG. **14**A being covered with a rotor blade actuator housing **356**.

[0117] FIG. **15**A illustrates a front view of a rotor blade **352** having a leading-edge neutral/null angle with respect to a rotor blade rotation plane **358** mounted on the rotor sub-assembly of FIG. **14**B of the co-planar rotor control type air drop device **300** of FIG. **12**.

[0118] FIG. **15**B illustrates a front view of a rotor blade **352** having a leading-edge 90-degree negative angle with respect to a rotor blade rotation plane **358** mounted on the rotor sub-assembly of FIG. **14**B of the co-planar rotor control type air drop device **300** of FIG. **12**. In this leading-edge angular orientation, the air drop device is able to travel at a maximum vertical descent speed with minimal resistance from the rotor blades **352** and, at the same time, use angular rotation of the rotor blades **352** to navigate either alone or in conjunction with the control surfaces **338** of the stabilizer assembly **330**.

[0119] FIG. **15**C illustrates a front view of a rotor blade **352** having a leading-edge slight negative angle with respect to a rotor blade rotation plane **358** mounted on the rotor sub-assembly of FIG. **14**B of the co-planar rotor control type air drop device **300** of FIG. **12**. In this leading-edge angular orientation, the rotor assembly is configured to achieve an autorotating motion and provide a downward thrust force due to the rotor blades **352** while providing collective and cyclic pitch control of the rotor blades to navigate toward the predetermined target destination.

[0120] FIG. **15**D illustrates a front view of a rotor blade **352** having a leading-edge slight positive angle with respect to a rotor blade rotation plane **358** mounted on the rotor sub-assembly of FIG. **14**B of the co-planar rotor control type air drop device **300** of FIG. **12**. In this leading-edge angular orientation, the rotor assembly is configured to achieve an increased downward thrust force, in comparison to the autorotation downward thrust force, due to the energy of rotational inertia of the rotor blades **352** in the previous autorotating state immediately before the air drop device lands at the predetermined target destination. This increased

thrust force further slows down the airdrop device in anticipation of impacting the landing zone.

[0121] FIG. **16** illustrates a top perspective view of a second alternative embodiment of a co-planar rotor control air drop device **400**, similar to the co-planar rotor control type air drop device **300** of FIG. **12**, but without a gimbal assembly **340** as illustrated in FIGS. **12-15**D. The second alternative embodiment of a co-planar rotor control air drop device **400** functions identically to the air drop device **300** with the gimbal assembly **340** but may have more powerful servomotors controlling the rotor blade pitch actuation to allow for increase maneuverability without a dedicated gimbal assembly.

[0122] FIG. **17** illustrates a top perspective view of a third alternative embodiment of a co-planar rotor control air drop device **500**, similar to the co-planar rotor control type air drop device **300** of FIG. **12**, further including a second rotor assembly **350**B connected via a second rotor base assembly **344**B to a first rotor assembly **350**A connected via a first rotor base assembly **344**A further attached to a gimbal assembly **340**. Each of the rotor assemblies **350**A, **350**B rotate in opposite counter-rotating directions.

[0123] FIGS. **18**A-**18**B illustrate front and top perspective views, respectively, of the third alternative embodiment co-planar rotor control type air drop device **500** of FIG. **17** in an alternate configuration without the gimbal assembly **340** as illustrated in FIG. **17**. This embodiment may include more powerful servomotors to control rotor blade pitch actuation to allow for increased maneuverability without a gimbal assembly.

[0124] FIGS. **19-22**D illustrate a fourth alternative embodiment of a co-planar air drop device **600** having a four-blade rotor assembly **650** mounted on the gimbal assembly **340** similar to the co-planar rotor control type air drop device **303** of FIG. **12**.

[0125] FIG. **19** illustrates a top perspective view of the fourth alternative embodiment of the co-planar air drop device **600** having a four-blade rotor assembly **650** with four rotor blades **652** each having rotor blade rotational axes, e.g., **653**A, **653**B, (see FIGS. **20**A-**20**B), a gimbal assembly **340**, a flight stabilizer assembly **330**, and a containerized payload assembly **120**.

[0126] FIG. **20**A illustrates a top perspective view of the fourth alternative embodiment of the co-planar air drop device **600** of FIG. **19** including two exemplary rotor blade angular actuators **654** each connected to two adjacent rotor blade rotational drive shafts **655** aligned on respective rotor blade rotational axes **653**A, **653**B.

[0127] FIG. **20**B illustrates a top perspective view of the fourth alternative embodiment of the co-planar air drop device **600** of FIG. **19** further including a rotor blade actuator housing **656** covering the rotor blade angular actuators **654** and the rotor blade rotational drive shafts **655**.

[0128] FIG. **21** illustrates a top perspective view of the fourth alternative embodiment of the co-planar air drop device **600** of FIG. **19**, for representative purposes, rotor blades **652** in each stage of deployment: a stowed or folded rotor blade **658**; an initial rotated rotor blade **659**; an intermediate rotated rotor blade **660**; and a fully deployed rotor blade **661** of the co-planar rotor control type air drop device **600** of FIG. **19**.

[0129] FIG. **22**A illustrates a front view of a rotor blade **652** having a leading-edge neutral/null angle **664** coincident with respect to a rotor blade rotation plane **662** mounted on the rotor assembly **650** of the co-planar rotor control type air drop device **600** of FIG. **12**.

[0130] FIG. **22**B illustrates a front view of a rotor blade **652** having a leading-edge 90-degree negative angle **666** with respect to a rotor blade rotation plane **662** mounted on the rotor assembly **650** of the co-planar rotor control type air drop device **600** of FIG. **12**. In this leading-edge angular orientation, the air drop device is able to travel at a maximum vertical descent speed with minimal resistance from the rotor blades **652** and, at the same time, use angular rotation of the rotor blades **652** to navigate either alone or in conjunction with the control surfaces **338** of the stabilizer assembly **330**.

[0131] FIG. **22**C illustrates a front view of a rotor blade **652** having a leading-edge slight negative angle **668** with respect to a rotor blade rotation plane **662** mounted on the rotor assembly **650** of the co-planar rotor control type air drop device **600** of FIG. **12**. In this leading-edge angular orientation, the rotor assembly is configured to achieve an autorotating motion and provide a downward thrust force due to the rotor blades **652** while providing collective and cyclic pitch control of the rotor blades to navigate toward the predetermined target destination.

[0132] FIG. **22**D illustrates a front view of a rotor blade **652** having a leading-edge slight positive angle **670** with respect to a rotor blade rotation plane **662** mounted on the rotor assembly **650** of the co-planar rotor control type air drop device **600** of FIG. **12**. In this leading-edge angular orientation, the rotor assembly is configured to achieve an increased downward thrust force, in comparison to the autorotation downward thrust force, due to the energy of rotational inertia of the rotor blades **352** in the previous autorotating state immediately before the air drop device lands at the predetermined target destination. This increased thrust force F_T further slows down the airdrop device in anticipation of impacting the landing zone.

[0133] FIG. **23** illustrates a top perspective view of a fifth alternative embodiment co-planar rotor control type air drop device **700** having a four-blade rotor assembly **650**, similar to the co-planar rotor control type air drop device of FIG. **19**, mounted without a gimbal assembly. This embodiment may include more powerful servomotors to control rotor blade pitch actuation to allow for increased maneuverability without a gimbal assembly.

[0134] FIG. **24** illustrates two air drop methods of deploying a representative co-planar rotor control type air drop device illustrated in FIGS. **12-23**.

[0135] FIG. **24** illustrates two types of air drop methods in a co-planar control-type deployment schematic diagram **750** of deploying a representative co-planar control-type air drop device, e.g., **700**, of FIG. **23**, or similarly any co-planar air drop devices **300**, **400**, **500** and **600** of FIGS. **12-22**D, to its predetermined target destination.

[0136] The co-planar control-type deployment schematic diagram **750** illustrates an aircraft, e.g., aircraft **272**A, travelling along an aircraft flight path **274** where upon a predetermined time and/or location of the aircraft, an air drop device payload flight path **276**A is calculated by a master flight controller of the aircraft and a payload launch controller in the aircraft relative to predetermined target destination, e.g., **288**A. When a launch trigger is executed by the master flight controller and the payload launch controller, the air drop device, e.g., **700**, is deployed **278** from the

aircraft **272**A and enters a transient flight phase **280** where the rotor blades **652** begin to be deployed from their stowed position and the flight stabilizer assembly **330** begins to rotate about their respective axes to orient the air drop device **700** into a downwardly disposed orientation.

[0137] A steady-state flight phase **282**A is entered when the rotor blades **652** are fully deployed and begin autorotating to provide a thrust force in a downward direction provided by autorotating rotor assembly **650**. During the steady-state flight phase **282**A, the flight stabilizer assembly **330** and/or the rotor assembly **650** provide directional control to the air drop device **700** to maintain the air drop device payload flight path **276**A.

[0138] A terminal flight phase **284** is entered when the rotor blades **652** of the respective rotor assembly **650**, rotate the leading-edge of the blades into a positive direction, i.e., flaring the rotor blades, to generate a maximum amount of thrust force F_T in a downward direction based on the rotational inertia of the rotor blades in the autorotation at the end of the steady-state flight phase **282**A. The force of thrust F_T is greater than the thrust force generated in the steady-state flight phase **282**A and is used immediately before the landing **286** at the predetermined target destination **288** or landing zone. Note that the flight stabilizer assembly **330** and/or the rotor assembly **650** continue to provide directional control to the air drop device **700** to maintain the air drop device payload flight path **276**A during the terminal flight phase **284** immediately above and before the landing **286**.

[0139] The co-planar control-type deployment schematic diagram **750** further illustrates an aircraft, e.g., aircraft **272**B travelling along an aircraft flight path **274** where upon a predetermined time and/or location of the aircraft, an alternative air drop device payload flight path **276**B is calculated by a master flight controller of the aircraft and a payload launch controller in the aircraft relative to predetermined target destination, e.g., **288**B. A when a launch trigger is executed by the master flight controller and the payload launch controller, the air drop device, e.g., **700**, is deployed **278** from the aircraft **272**B and enters a transient flight phase **280** where the rotor blades **652** begins to be deployed from their stowed position and the flight stabilizer assembly **330** begins to rotate about their respective axes to orient the air drop device **700** into a downwardly disposed orientation.

[0140] A steady-state flight fast descent phase **282**B is entered when the rotor blades **652** are fully deployed and the leading edges of the rotor blades are pointed straight down. No autorotation begins in the fast descent flight phase **282**B, as in the previous example. During the steady-state fast descent flight phase **282**B, the flight stabilizer assembly **330** and/or the rotor assembly **650** provide directional control to the air drop device **700** to maintain the air drop device payload flight path **276**B.

[0141] A pre-terminal flight phase **283** is entered when the rotor blades **652** rotate to a negative rotor rotation angle **668**, (see FIG. **22**C), and the rotor assembly **650** begins to autorotate, thus providing a downward thrust from the autorotation of the rotor blades **652**.

[0142] A terminal flight phase **284** is entered when the rotor blades **652** of the respective rotor assembly **650**, rotate the leading-edge of the blades, i.e., flaring the rotor blades, into a positive direction to generate a maximum amount of thrust force F_T in a downward direction based on the rotational inertia of the rotor blades in the autorotation at the end of the pre-terminal flight phase **283**. The force of thrust F_T is greater than the thrust force generated in the pre-terminal flight phase **283** and is used immediately before the landing **286** at the predetermined target destination **288**B or landing zone. Note that the flight stabilizer assembly **330** and/or the rotor assembly **650** may continue to provide directional control to the air drop device **700** to maintain the air drop device payload flight path **276**B during the terminal flight phase **284** immediately above and before the landing **286**.

[0143] FIGS. **25**A-**25**B illustrate a front view a top perspective view, respectively, of a sixth alternative embodiment of a co-planar air drop device **800** having dual counter-rotating four-rotor blade assemblies **650**A, **650**B mounted on a gimbal assembly **340** being similar to the co-planar rotor control type air drop device **600** of FIG. **19**. Each rotor assembly **650**A and **650**B and their respective rotor blades **652**A and **652**B rotate in opposite directions of each other when the rotor assemblies **650**A and **650**B are in autorotation or providing a flaring thrust force in the terminal flight phase **284** immediately before landing **286** in the predetermined target destination **288**, **288**A, **288**B.

[0144] FIGS. **26**A-**26**B illustrate a front view a top perspective view, respectively, of a seventh alternative embodiment of a co-planar air drop device **900** having dual counter-rotating four-rotor blade assemblies **650**A and **650**B, similar to the co-planar air drop device **800** of FIGS. **25**A-**25**B, with no gimbal assembly.

[0145] FIGS. **27**A-**28**D illustrate an eighth alternative embodiment of a co-planar rotor control type air drop device **1000** having no independent stabilizer assembly attached to a payload containing enclosure. FIG. **27**A illustrates a top perspective view of the co-planar rotor control type air drop device **1000** including a rotor assembly attachment base **1010** attached to a containerized payload assembly **120**, similar to FIG. **1**,

[0146] FIG. **27**B illustrates a top perspective view of the co-planar rotor control type air drop device **1000** of FIG. **27**A having a rotor assembly **1020** containing independently controlled rotors blades **1030** including a rotor bearing **1022** located in a central portion of a rotor assembly housing **1024** supporting a plurality of rotor actuators **1026** connected to rotor drive shafts **1028** of respective rotor blades **1030**.

[0147] FIG. **27**C illustrates a top perspective view of the co-planar rotor control type air drop device **1000** of FIG. **27**B further including a rotor assembly cover **1032**.

[0148] FIG. **28**A illustrates a front view of a rotor blades **1030** of the co-planar rotor control type air drop device **1000** of FIGS. **27**B-**27**C having a leading edge of the rotor blades **1030** rotated to a neutral/null angle **1064** mounted on the rotor assembly **1020** of the co-planar rotor control type air drop device **1000** of FIGS. **27**B-**27**C.

[0149] FIG. **28**B illustrates a front view of a rotor blades **1030** of the co-planar rotor control type air drop device **1000** of FIGS. **27**B-**27**C having a leading edge of the rotor blades **1030** rotated to a **90**-degree negative angle **1066** mounted on the rotor assembly **1020** of the co-planar rotor control type air drop device **1000** of FIGS. **27**B-**27**C. In this leading-edge angular orientation, the air drop device is able to travel at a maximum vertical descent speed with minimal resistance from the rotor blades **1030** and, at the same time, use angular rotation of the rotor blades **1030** to navigate to the predetermined target destination without any independent stabilizer assembly.

[0150] FIG. **28**C illustrates a front view of a rotor blades **1030** of the co-planar rotor control type air drop device **1000** of FIGS. **27**B-**27**C having a leading edge of the rotor blades **1030** rotated to a slight negative angle **1068** mounted on the rotor assembly **1020** of the co-planar rotor control type air drop device **1000** of FIGS. **27**B-**27**C. In this leading-edge angular orientation, the rotor assembly **1020** is configured to achieve an autorotating motion and provide a downward thrust force due to the rotor blades **1030** while providing collective and cyclic pitch control of the rotor blades to navigate toward the predetermined target destination.

[0151] FIG. **28**D illustrates a front view of a rotor blades **1030** of the co-planar rotor control type air drop device **1000** of FIGS. **27**B-**27**C having a leading edge of the rotor blades **1030** rotated to a slight positive angle **1070** mounted on the rotor assembly **1020** of the co-planar rotor control type air drop device **1000** of FIGS. **27**B-**27**C. In this leading-edge angular orientation, the rotor assembly **1020** is configured to achieve an increased downward thrust force F_T, in comparison to the autorotation downward thrust force, e.g., of FIG. **28**C, due to the energy of rotational inertia of the rotor blades **1030** in the previous autorotating state immediately before the air drop device lands at the predetermined target destination. This increased thrust force F_T further slows down the airdrop device in anticipation of impacting the landing zone.

[0152] FIG. **29** illustrates an air drop methods of deploying the co-planar rotor control type air drop device **1000** of FIGS. **27**B-**28**D and FIGS. **30**A-**30**B, discussed below. FIG. **29** illustrates an air drop method in a co-planar control-type deployment schematic diagram **1050** of deploying a representative co-planar control-type air drop device, e.g., **1000**, of FIG. **27**B-**28**D to its predetermined target destination **288**.

[0153] The co-planar control-type deployment schematic diagram **1050** illustrates an aircraft **272** travelling along an aircraft flight path **274** where upon a predetermined time and/or location of the aircraft, an air drop device payload flight path **276** is calculated by a master flight controller of the aircraft and a payload launch controller in the aircraft relative to predetermined target destination, e.g., **288**. A when a launch trigger is executed by the master flight controller and the payload launch controller, the air drop device **1000** is deployed **278** from the aircraft **272** and enters a transient flight phase **280** where the rotor blades **1030** may be flared in a neutral position indicated by FIG. **28**A or a fast-descent position indicated by FIG. **28**B to orient the containerized payload **120** into a downward orientation to enter the next steady-state flight phase.

[0154] A steady-state autorotating flight phase **282**A or a steady-state fast descent flight phase **282**B is entered when the rotor blades **652** either begin autorotating to provide a thrust force in a downward direction provided by rotor assembly **650**, or are trimmed to accelerate the air drop device **1000** to a maximum downward velocity. In either steady-state flight phase, the rotor blades may provide directional control to the air drop device **1000** to maintain the air drop device payload flight path **276**.

[0155] If the air drop device **1000** enters the steady-state fast descent flight phase **282**B, a pre-terminal flight phase **283** is entered when the rotor blades **1030** rotate to a negative rotor rotation angle **1068**, (see FIG. **28**C), and the rotor assembly begin to autorotate, thus providing a downward thrust from the autorotation of the rotor blades **1052**.

[0156] A terminal flight phase **284** is entered when the rotor blades **1052** of the rotor assembly **1020**, rotate the leading-edge of the blades, i.e., flaring the rotor blades, into a positive direction to generate a maximum amount of thrust force F_T in a downward direction based on the rotational inertia of the rotor blades in the autorotation at the end of the steady-state flight phase **282**A or the pre-terminal flight phase **283**. The force of thrust F_T is greater than the autorotating thrust force generated in the steady-state flight phase **282**A or the pre-terminal flight phase **283** and is used immediately before the landing **286** at the predetermined target destination **288** or landing zone. Note that the rotor assembly **1020** continues to provide directional control to the air drop device **1000** to maintain the air drop device payload flight path **276** during the terminal flight phase **284** immediately above and before the landing **286** at the landing zone **288**.

[0157] FIGS. **30**A-**30**B illustrate a ninth alternative embodiment of a co-planar rotor control type air drop device **1100** similar to the co-planar rotor control type air drop device **1000** of FIGS. **27**B-**28**D including dual counter-rotating four-blade rotor assemblies **1020**A and **1020**B.

[0158] FIGS. **30**A-**30**B illustrates a front view and a top perspective view, respectively, of the ninth alternative embodiment having dual counter-rotating four-blade rotor assemblies **1020**A and **1020**B similar to the co-planar rotor control type air drop device **1000** of FIGS. **27**B-**28**D. Both rotor assemblies **1020**A and **1020**B rotate in opposite directions and may provide all the controls and feature of the above described embodiments in FIGS. **27**A-**29** but have more control surfaces for navigation and providing control during descent along the flight path for heavier payloads.

[0159] FIG. **31** illustrates a schematic diagram of a flight control and navigation system **3100** for the air drop devices of FIGS. **1**-**30**B. The flight control and navigation system **3100** may include a processor **3102** connected to a common communication bus **3104** that provides bi-direction communication between the remaining components of the flight control and navigation system **3100**. The processor **3102** via the communication bus is further in communication with random access memory (RAM) **3106**, a storage memory **3108**, an input/output (I/O) interface **3110**, a multi-band transceiver **3112**, a navigation module **3114**, a GPS receiver **3116**, position and orientation, or pose, sensors **3118**, a plurality of servomotor controllers **3120**, a sensor suite **3122**, an inertial navigation system (INS) sensor unit **3124**, a magnetometer **3126** and altimeter **3128** that may include at least a barometer, a radar and/or a LiDAR sensor.

[0160] FIG. **32** illustrates a schematic diagram **3200** of a flight control and navigation system **3210** for any of the air drop devices of FIGS. **1**-**30**B relative to a stationary reference frame **3220** and a rotary reference frame **3240** of the air drop device.

[0161] A stationary reference frame **3220** of an air drop device may include all the components that are distinct from the rotor assembly, for example, the containerized payload assembly, the stabilizer assembly and/or the rotor linkages in a pitch-link type air drop device. A rotary reference frame of the air drop device may include all the components of the rotor assembly that rotate in consonance with the rotor blades during autorotation and/or navigation operation.

[0162] The stationary reference frame (SRF) **3220** may include a SRF processor **3221**, communicating via a common communication bus **3232** with SRF random access

memory (RAM) **3222**, SRF storage memory **3223**, SRF position and orientation, or pose, sensor **3224**, SRF magnetometer **3225**, SRF sensor suite **3226**, SRF inertial navigation system (INS) sensor unit(s) **3227**, SRF input/output (I/O) interface **3228**, SRF servomotor controller(s) **3229**, SRF altimeter **3231**, and a wireless SRF bus input/output (I/O) communication device **3230** configured to communicate via a near-field wireless communication protocol **3212**, for example, an RF signal or an optical link, with a corresponding rotary reference frame (RRF) wireless RRF bus input/output (I/O) communication device **3242**.

[0163] In the rotary reference frame **3240**, wireless RRF bus input/output (I/O) communication device **3242** may communicate with a RRF common communication bus **3252** to an RRF processor **3243** that communicates with an RRF RAM **3244**, an RRF storage memory **3245**, an RRF multi-band transceiver **3246**, an RRF servomotor controller (s) **3247**, an RRF I/O interface **3248**, a payload course RRF navigation module **3249**, an RRF GPS receiver **3250** and/or an RRF altimeter **3254**.

[0164] The rotary reference frame **3240**, typically including the rotor assembly, may have identical sensors as that of a traditional UAV helicopter or gyrocopter for example: GPS, accelerometers/IMU, barometer, magnetometer etc. If a sample rate of the sensors are configured to be capable of measuring attitude, (e.g., via magnetometer, or gyroscope), is not high enough for direct sensing of the rotational rate and position, the addition of a rotary encoder and/or RPM sensor may allow the controller to determine its location relative to the stationary reference frame, (either truly inertial, or relative to the non-rotating payload), such that location information and position can be translated to a non-rotational frame.

[0165] This auxiliary sensor could be as simple as a simple optical proximity sensor (LED and photodiode) that would sense a light change when a simple pattern on the non-rotating payload passed by it—given the change in rotation rate per rotation would be, by definition, small, even a simple pattern would provide for more than enough angular resolution for the coordinate transform.

[0166] The primary position sensing using GPS should not be compromised at all by the rotation of the system, (provided the GPS sensing antenna may be located at or near the center of rotation of the rotary reference frame).

[0167] To affect the required pitch changes, the system may command mechanical actuators, (servomotors, voice coil actuators, etc.), to vary the effective pitch of the blades through either rotation of the entire blade or varying the angle of trailing edge. The system may utilize directed airflow through holes in the blade to vary the effective lift coefficient and control such airflow with valving in the hub. The servos may directly or indirectly drive each blade or blade flap with the additional benefit of being able to take a profile that is not sinusoidal or possible with traditional swash plates which generally limit a given blade pitch to an approximately 90 degree quadrant and limit the speed and acceleration by which they change pitch angle.

[0168] In summary, a system for delivering a payload to the ground from an aerial vehicle may include a payload to be delivered, an outer delivery payload container configured to house the payload, and a flight controller located inside the aerial vehicle. The outer delivery payload container may contain a removable and/or detachable tail kit allowing separation from a cardboard, plastic or similar shipping box.

[0169] The tail kit assembly may contain a rotary blade system that is free to rotate and generate autorotation-based aerodynamic lift forces, aerodynamic fin control surfaces to provide attitude control and a flight controller to provide guidance navigation and control intelligence, where the aerodynamic fins may be used to further control vehicle attitude during flight.

[0170] The rotor blade system may be folded and stowed prior to launch to increase packing volume, protect the blade surfaces and ease stowage requirements both before and during loading into an aircraft.

[0171] The rotor blade root may include a self-locking feature allowing aerodynamic forces to translate the blade to a 90-degree locked orientation in the plane of rotation. An NACA 8H12 or similar rotor blade system is designed to maximize autorotative efficiency and thrust forces to add in mid-flight phase guidance and the terminal landing phase.

[0172] A collective pitch system may be used to change blade pitch during various phases of flight, and cyclic pitch mechanism is used to translational control authority to guide the vehicle mid-flight to a predetermined target landing position or coordinates.

[0173] A self-contained flight computer provides guidance navigation and control as well as two-way telemetry communication with ground or mothership/aircraft-based transmitters.

[0174] The rotating blade system may be modular or detachable from the payload to allow different blade configurations corresponding to payload, weather or altitude parameters. The modular system may be self-contained and/or isolated within a rotating reference frame allowing collective control via motors located within the rotor blade assembly and may thereby eliminate a need for a "swash plate mechanism."

[0175] A battery, RX transmitter, microcontroller and servos provide two-way data with the flight controller located in the non-rotating vehicle body.

[0176] A bearing assembly allows three rotational degrees of freedom: one rotational perpendicular to the blade tip plane allowing rotation of the blade assembly; and two gimballing degrees of freedom to allow rotation of the blade plane and thus thrust vectoring/cyclic control.

[0177] A "flair" maneuver may be performed to arrest vertical descent speed and allow safe and slow touchdown of contents within the payload where the rotor blades of the rotor assembly rotate the leading edges of the rotors into a positive direction with respect to the plane of rotation to provide a downward directed thrust force based on the rotational inertial generated from the autorotation motion.

[0178] To eliminate the need to translate motion from the static body reference frame to the rotor hub rotational frame, the flight controller, batteries, sensors and all associated control hardware on the rotating rotor assembly are located in the rotor assembly such that they spin along with the rotor blades. To control the rotor blades themselves, servo motors or linear actuators may be placed at the root of each rotor blade and directly drive the blade pitch angle per rotational cycle. No power, data, or other electrical connections would need to be made to the stationary body allowing, in theory, a hub assembly to be quickly attached to a travel case via straps or other fastening methods to include even a clip-on swivel to an existing cable-attachment point and allow controlled descent or glide.

[0179] A "hybrid" approach may include certain components put into the rotating reference frame such as servos, batteries and an RX receiver transmitter while the flight computer and other components be located in the stationary reference frame. This may allow for use of a gimbal assembly to control the rotor blade plane similar to a gyrocopter and the collective pitch controls to be performed in the rotating frame, easing requirements on fast acting per-cycle servos.

[0180] In summary, one embodiment of the disclosed payload delivery device being configured to deliver an aircraft deployed payload along a flight path to a predetermined landing destination, includes a support member configured to be removably attached to the payload, a flight control and navigation system module connected to the support member, a control surface assembly module including a plurality of control surfaces, the control surface assembly module connected to the support member and in communication with the flight control and navigation module to receive commands to control orientation of the plurality of control surfaces while the payload is travelling along the flight path to the predetermined landing destination.

[0181] The above embodiment further includes a rotor assembly including a plurality of rotor blades having a central axis of rotation, and a collective control assembly module including at least one collective servomotor, the collective control assembly module connected between the support member and the rotor assembly and in communication with the flight control and navigation module configured to control a plurality of control linkages connected to the plurality of rotor blades.

[0182] The payload delivery device may further include the flight control and navigation system module having at least a GPS receiver, at least one servomotor controller, an inertial navigation system (INS) sensor, a magnetometer, a navigation module, and a multi-band transceiver configured to communicate with at least one of a master flight computer in the aircraft, a satellite communications network, a ground-based telemetry station and a weather station.

[0183] The payload delivery device may further include at least a first portion of components of the flight control and navigation system module being disposed in a rotating frame of the rotor assembly.

[0184] The payload delivery device may further include the flight control and navigation system module being fully disposed in a rotating frame of the rotor assembly.

[0185] The payload delivery device may further include the control surfaces, under control of the flight control and navigation system module, being configured to one of vertically stabilize and impart an axial moment of rotation about a longitudinal axis of the payload during a portion of the flight path.

[0186] The payload delivery device may further include the plurality of control surfaces, under control of the flight control and navigation system module, being configured to navigate the payload along a portion of the flight path to the predetermined landing destination.

[0187] The payload delivery device may further include the collective control assembly module, under control of the flight control and navigation system module, controlling a collective motion imparted the rotor assembly to rotate the leading-edge of each blade of the plurality of rotor blades of the rotor assembly to a negative leading-edge angle with respect to the rotational plane of the rotor assembly in a fully deployed rotor position, where the rotor assembly enters an autorotating motion to produce an upward vertical force on the payload during at least a portion of the flight path.

[0188] The payload delivery device may further include the collective control assembly module, under control of the flight control and navigation system module, controlling the collective motion imparted to the rotor assembly to rotate a leading-edge of each of the rotor blades of the rotor assembly to a positive leading-edge angle with respect to a rotational plane of the rotor assembly in the fully deployed rotor position, where the rotor assembly produces a positive vertical thrust force on the payload based on a moment of inertia of an autorotating motion during at least a portion of the flight path before the payload arrives at the predetermining landing destination.

[0189] The payload delivery device may further include the rotor assembly being further configured to rotate the plurality of rotor blades to a folded position proximate a side of the payload, an initial deployed position rotated away from the side of the payload, and a fully deployed and locked position further rotated away from the side of the payload and perpendicular to the central axis of rotation of the rotor assembly.

[0190] The payload delivery device may further include the rotor assembly being further configured to dampening the plurality of rotor blades during a blade deployment operation when each of the plurality of rotor blades nears the fully deployed and locked position.

[0191] Another embodiment of the payload delivery device being configured to deliver an aircraft deployed payload along a flight path to a predetermined landing destination, where the payload delivery device may include a support member configured to be removably attached to the payload, a flight control and navigation system module connected to the support member, and a control surface assembly module including a plurality of control surfaces, the control surface assembly module connected to the support member and in communication with the flight control and navigation module to receive commands to control orientation of the plurality of control surfaces while the payload is travelling along the flight path to the predetermined landing destination.

[0192] The above embodiment may further include a gimbal assembly module including a plurality of gimbal servomotors, the gimbal assembly module connected to and configured to move relative to the support member and in communication with the flight control and navigation module to receive commands to control axial rotation of the gimbal assembly module with respect to the support member, a rotor assembly including a plurality of rotor blades having a central axis of rotation, and a collective control assembly module including at least one collective servomotor, the collective control assembly module connected between the gimbal assembly module and the rotor assembly and in communication with the flight control and navigation module configured to control a plurality of control linkages connected to the plurality of rotor blades.

[0193] The payload delivery device may further provide the gimbal assembly module, under control of the flight control and navigation system module, pivoting the central axis of rotation the rotor assembly via at least one servomotor about a point located on a longitudinal axis of the

payload to impart an axial thrust force away from the longitudinal axis of the payload.

[0194] The payload delivery device may further provide the collective control assembly module, under control of the flight control and navigation system module, controlling, via at least one servomotor mounted on the gimbal assembly module, a collective motion imparted to the rotor assembly configured to simultaneously rotate a leading-edge of each blade of the plurality of rotor blades of the rotor assembly.

[0195] Another embodiment of the payload delivery device configured to deliver an aircraft deployed payload along a flight path to a predetermined landing destination, may include a support member configured to be removably attached to the payload, a flight control and navigation system module, a control surface assembly module including a plurality of control surfaces, the control surface assembly module connected to the support member and in communication with the flight control and navigation module to receive control surface commands to control orientation of the plurality of control surfaces, a rotation bearing assembly connected to the support member, and a rotor assembly including a plurality of rotor blades having a central axis of rotation and a plurality of rotor servomotors, the rotor assembly connected to the rotation bearing assembly and in communication with the flight control and navigation module to receive rotor rotation commands to control angular rotation of each of the plurality of rotor blades via co-planar aligned blade rotation shafts of each of the plurality of rotor blades, the co-planar aligned drive shafts coincident with a plane of rotation of the rotor assembly about the central axis of rotation.

[0196] The payload delivery device may further include the gimbal assembly module having a plurality of gimbal servomotors, the gimbal assembly module connected to and configured to move relative to the support member and in communication with the flight control and navigation module to receive gimbal rotation commands to control axial rotation of the gimbal assembly module with respect to the support member.

[0197] The payload delivery device may further include the gimbal assembly module, under control of the flight control and navigation system module, to pivot the central axis of rotation of the rotor assembly via at least one gimbal servomotor about a point located on a longitudinal axis of the payload to impart an axial thrust force produced by the rotor assembly away from the longitudinal axis of the payload.

[0198] The payload delivery device may further include a quick-release coupler connected between the rotation bearing assembly and the rotor assembly configured to allow detaching of the rotor assembly from the payload delivery assembly and attaching a second rotor assembly.

[0199] The payload delivery device may further include the flight control and navigation system module to have at least a GPS receiver, at least one servomotor controller, an inertial navigation system (INS) sensor, a magnetometer, a navigation module, and a multi-band transceiver configured to communicate with at least one of a master flight computer in an aircraft, a satellite communications network, a ground-based telemetry station and a weather station.

[0200] The payload delivery device may further include at least one component of the flight control and navigation system module is disposed in a rotating frame of the rotor assembly.

[0201] The payload delivery device may further include the flight control and navigation system module being disposed in a rotating frame of the rotor assembly.

[0202] The payload delivery device may further include the plurality of control surfaces, under control of the flight control and navigation system module, at least one of vertically stabilizing and imparting an axial moment of rotation about a longitudinal axis of the payload during a portion of the flight path to the predetermined landing destination.

[0203] The payload delivery device may further include the plurality of control surfaces, under control of the flight control and navigation system module, being configured to navigate the payload along a portion of the flight path to the predetermined landing destination.

[0204] The payload delivery device may further include the rotor assembly, under control of the flight control and navigation system module, being configured to simultaneously rotate leading edges of each of the plurality of rotor blades of the rotor assembly.

[0205] The payload delivery device may further include the rotor assembly, under control of the flight control and navigation system module, being configured to independently rotate leading edges of each of the plurality of rotor blades of the rotor assembly.

[0206] The payload delivery device may further include the rotor assembly, under control of the flight control and navigation system module, being configured impart a cyclic thrust force to the rotor assembly by cyclically rotating a leading-edge of at least one of the plurality of rotor blades of the rotor assembly.

[0207] The payload delivery device may further include the rotor assembly, under control of the flight control and navigation system module, rotating leading-edges of the plurality of rotor blades of the rotor assembly to a negative leading-edge angle with respect to a rotational plane of the rotor assembly in a fully deployed rotor position, where the rotor assembly is configured to produce an autorotation motion to produce a vertical thrust force on the payload during a portion of the flight path to the predetermined landing destination.

[0208] The payload delivery device may further include the rotor assembly, under control of the flight control and navigation system module, rotating leading-edges of the plurality of rotor blades of the rotor assembly to a positive leading-edge angle with respect to a plane of rotation of the rotor assembly in a fully deployed rotor position, where the rotor assembly produces a vertical thrust force on the payload based on a moment of inertia produced from the autorotation motion during a second portion of the flight path before the payload arrives at the predetermining landing destination.

[0209] The payload delivery device may further include the rotor assembly, under control of the flight control and navigation system module, rotating leading-edges of the plurality of rotor blades of the rotor assembly perpendicular to a plane of rotation of the rotor assembly in a fully deployed rotor position, where the rotor assembly minimizes an aerodynamic profile of the rotor assembly along a portion of the flight path to the predetermined landing destination.

[0210] The payload delivery device may further include the rotor assembly, under control of the flight control and navigation system module, rotating a leading-edge of at least one of the plurality of rotor blades of the rotor assembly

away from being perpendicular to the plane of rotation of the rotor assembly in the fully deployed rotor position to navigate the payload delivery device along a portion of the flight path to the predetermined landing destination.

[0211] The payload delivery device may further include the rotor assembly being further configured to rotate the plurality rotor blades to a folded position proximate at least one side of the payload, to an initial deployed position rotated away from the at least one side of the payload, and to a fully deployed and locked position further rotated away from the at least one side of the payload and perpendicular to the central axis of rotation of the rotor assembly.

[0212] In another embodiment a method of assembling a delivery payload assembly configured to be deployed from an aircraft and travel along a flight path to a predetermined landing destination includes providing a payload configured to be delivered from the aircraft to the predetermined landing destination, attaching a tail-kit assembly to a first end of the payload thereby defining the delivery payload assembly, the tail-kit assembly including a rotor blade assembly including a plurality of rotor blades having a central axis of rotation proximate the first end of the payload, and a flight control and navigation system configured to control a collective pitch angle of each of the plurality of rotor blades of the rotor blade assembly, control an axial thrust force of the rotor blade assembly, the axial thrust force being at an angle with respect to the central axis of rotation of the rotor blade assembly, and navigate the delivery payload assembly along the flight path to the predetermined landing destination.

[0213] The above method further includes removing the tail-kit assembly from the payload after the payload is delivered to the predetermined landing destination, where the flight control and navigation system is further configured to induce and control an autorotation motion of rotor blade assembly during a portion of the flight path of the delivery payload assembly from the aircraft to the predetermined landing destination, and produce and control a vertical thrust force by the rotor blade assembly during an end portion of the flight path of the delivery payload assembly from the aircraft to the predetermined landing destination.

[0214] The method may further include controlling, the flight control and navigation system, an axial thrust force of the rotor blade assembly by further controlling a cyclic pitch angle of each of the plurality of rotor blades of the rotor blade assembly.

[0215] The method may further include controlling, via the flight control and navigation system, an axial thrust force orientation of the rotor blade assembly with respect to a longitudinal axis of the delivery payload assembly.

[0216] The method may further include attaching the tail-kit assembly removed from the payload to a first end of a second payload configured to be delivered to a second landing destination.

[0217] The method may further include providing a plurality of vertical control surfaces on the tail-kit assembly, the plurality of vertical control surfaces configured to orient the delivery payload assembly during a second portion the flight path of the delivery payload assembly from the aircraft to the predetermined landing destination, controlling, via the flight control and navigation system, the plurality of vertical control surfaces to stabilize and orient the delivery payload assembly into a downwardly disposed attitude during a transient phase of the flight path immediately after the delivery payload assembly is deployed from the aircraft, and navigate the delivery payload assembly along the flight path to the predetermined landing destination.

[0218] The method may further include providing a reinforcing structure to at least one exterior surface of the payload, and wherein the attaching the tail-kit assembly to the payload further includes attaching the tail-kit assembly to the reinforcing structure.

[0219] Another embodiment of a method of delivering a payload to be deployed from an aircraft along a flight path to a predetermined landing destination may include attaching a tail-kit assembly to a first end of the payload thereby defining a delivery payload assembly, programming geographic coordinates of the predetermined landing destination into a flight control and navigation system in the tail-kit assembly, ejecting the delivery payload assembly from the aircraft, navigating, via the flight control and navigation system, the delivery payload assembly along a flight path configured to terminate at the predetermined landing destination, controlling, via the flight control and navigation system, an autorotation motion of a rotor blade assembly of the tail-kit assembly to enter a steady-state flight phase having a substantially constant first downward velocity, controlling, via the flight control and navigation system, the rotor blade assembly of the tail-kit assembly to enter a terminal flight phase before the predetermined landing destination, wherein the terminal flight phase has a second downward velocity less than the first downward velocity, wherein flight control and navigation system controls rotation of a leading-edge of each of the plurality of rotor blades of the rotor blade assembly in a positive direction to generate a vertical thrust force based on a moment of inertia of the rotor blade assembly in the autorotation motion, and removing the tail-kit assembly from the payload after the delivery payload assembly arrives at the predetermined landing destination, wherein the removed tail-kit assembly is configured to be attached to a second payload for delivery by an air vehicle to another predetermined landing destination.

[0220] The method may further include controlling, via the flight control and navigation system while navigating the delivery payload assembly along the flight path, a plurality of control surfaces on the tail-kit assembly.

[0221] The method may further include providing at least one servomotor connected to a rotational control structure configured to control rotation of the leading-edge of at least one rotor blade of the rotor blade assembly.

[0222] The method may further include providing a plurality of servo-motors each configured to control rotation of a plurality of rotational rotor blade shafts aligned with a longitudinal axis of at least a pair of rotor blades of the rotor blade assembly, and controlling, by the plurality of servo-motors, rotation of the leading-edge of at least the pair of rotor blades.

[0223] The method may further include providing a plurality of servo-motors each configured to control rotation of a plurality of rotational rotor blade shafts aligned with a rotational plane of the rotor blade assembly, and controlling, by the plurality of servo-motors, rotation of the leading-edge of a plurality of rotor blades of the rotor blade assembly.

[0224] The method may further include controlling, via the flight control and navigation system while navigating the delivery payload assembly along the flight path, an axial thrust force direction of the rotor blade assembly by rotating

the rotor blade assembly about a point on a longitudinal axis of the delivery payload assembly.

[0225] The method may further include where the navigating, via the flight control and navigation system, the delivery payload assembly along the flight path further includes controlling, via the flight control and navigation system while navigating the delivery payload assembly along the flight path, to impart a cyclic thrust force with the rotor blade assembly by cyclically rotating respective rotor blades in the rotor blade assembly to create the cyclic thrust force.

[0226] Another embodiment of a method of delivering a payload to be deployed from an aircraft along a flight path to a predetermined landing destination including attaching a tail-kit assembly to a first end of the payload thereby defining a delivery payload assembly, programming geographic coordinates of the predetermined landing destination into a flight control and navigation system in the tail-kit assembly, ejecting the delivery payload assembly from the aircraft, controlling, via the flight control and navigation system, a leading-edge of each rotor blade of a rotor blade assembly attached to the tail-kit assembly into a substantially downward disposed orientation, navigating, via the flight control and navigation system, the delivery payload assembly along a flight path terminating at the predetermined landing destination, inducing, via the flight control and navigation system, an autorotation motion of the rotor blade assembly by rotating the leading-edge of each rotor blade of the rotor blade assembly toward a plane of rotation of the rotor blade assembly, generating, via the flight control and navigation system, a vertical thrust force on the delivery payload assembly by rotating the leading-edge of each rotor blade of the rotor blade assembly above the plane of rotation of the rotor blade assembly, wherein the vertical thrust force is supplied by a moment of inertia of the rotor blade assembly in the autorotation motion before the predetermined landing destination, and removing the tail-kit assembly from the delivery payload assembly after the delivery payload assembly arrives at the predetermined landing destination, wherein the removed tail-kit assembly is configured to be attached to a second payload for delivery by an air vehicle to a second predetermined landing destination.

[0227] The method may further include controlling, the flight control and navigation system while navigating the delivery payload assembly along the flight path, a plurality of control surfaces on the tail-kit assembly.

[0228] The method may further include controlling, by at least one servomotor connected to respective rotational rotor shafts of the each of rotor blade of the rotor blade assembly, the leading-edge of the rotor blades of the rotor blade assembly.

[0229] The method may further include providing two counter-rotating rotor blade sub-assemblies aligned on a common central rotational axis of each of the rotor blade sub-assemblies.

[0230] The method may further include providing a plurality of servo-motors each controlling a rotation of each of a plurality of rotational rotor blade shafts aligned with at least one of a longitudinal axis of at least a pair of rotor blades of the rotor blade assembly, wherein the plurality of servo-motors control rotation of the leading-edge of at least the pair of rotor blades, and a rotational plane of the rotor blade assembly, wherein the plurality of servo-motors control rotation of the leading-edge of the rotor blades of the rotor blade assembly.

[0231] The method may further include controlling, via the flight control and navigation system while navigating the delivery payload assembly along the flight path, an axial thrust force orientation of the rotor blade assembly by rotating the rotor blade assembly about a point on a longitudinal axis of the delivery payload assembly.

[0232] The method may further include controlling, via the flight control and navigation system while navigating the delivery payload assembly along the flight path, to impart a cyclic thrust force with the rotor blade assembly by cyclically rotating respective rotor blades in the rotor blade assembly to create the cyclic thrust force.

[0233] The foregoing description, for purpose of explanation, has been described with reference to specific arrangements and configurations. However, the illustrative examples provided herein are not intended to be exhaustive or to limit embodiments of the disclosed subject matter to the precise forms disclosed. Many modifications and variations are possible in view of the disclosure provided herein. The embodiments and arrangements were chosen and described in order to explain the principles of embodiments of the disclosed subject matter and their practical applications. Various modifications may be used without departing from the scope or content of the disclosure and claims presented herein.

What is claimed is:

1. A payload delivery device configured to deliver an aircraft deployed payload along a flight path to a predetermined landing destination, the payload delivery device comprising:

a support member configured to be removably attached to the payload;

a flight control and navigation system module connected to the support member;

a control surface assembly module including a plurality of control surfaces, the control surface assembly module connected to the support member and in communication with the flight control and navigation module to receive commands to control orientation of the plurality of control surfaces while the payload is travelling along the flight path to the predetermined landing destination;

a rotor assembly including a plurality of rotor blades having a central axis of rotation; and

a collective control assembly module including at least one collective servomotor, the collective control assembly module connected between the support member and the rotor assembly and in communication with the flight control and navigation module configured to control a plurality of control linkages connected to the plurality of rotor blades.

2. The payload delivery device according to claim **1**, wherein the flight control and navigation system module comprises at least

a GPS receiver,

at least one servomotor controller,

an inertial navigation system (INS) sensor,

a magnetometer,

a navigation module, and

a multi-band transceiver configured to communicate with at least one of a master flight computer in the aircraft,

a satellite communications network, a ground-based telemetry station and a weather station.

3. The payload delivery device according to claim **2**, wherein at least a first portion of components of the flight control and navigation system module are disposed in a rotating frame of the rotor assembly.

4. The payload delivery device according to claim **2**, wherein the flight control and navigation system module is fully disposed in a rotating frame of the rotor assembly.

5. The payload delivery device according to claim **1**, wherein the control surfaces, under control of the flight control and navigation system module, are configured to one of vertically stabilize and impart an axial moment of rotation about a longitudinal axis of the payload during a portion of the flight path.

6. The payload delivery device according to claim **1**, wherein the plurality of control surfaces, under control of the flight control and navigation system module, are configured to navigate the payload along a portion of the flight path to the predetermined landing destination.

7. The payload delivery device according to claim **1**, wherein the collective control assembly module, under control of the flight control and navigation system module, controls a collective motion imparted the rotor assembly to rotate the leading-edge of each blade of the plurality of rotor blades of the rotor assembly to a negative leading-edge angle with respect to the rotational plane of the rotor assembly in a fully deployed rotor position,

wherein the rotor assembly enters an autorotating motion to produce an upward vertical force on the payload during at least a portion of the flight path.

8. The payload delivery device according to claim **1**, wherein the collective control assembly module, under control of the flight control and navigation system module, controls the collective motion imparted to the rotor assembly to rotate a leading-edge of each of the rotor blades of the rotor assembly to a positive leading-edge angle with respect to a rotational plane of the rotor assembly in the fully deployed rotor position,

wherein the rotor assembly produces a positive vertical thrust force on the payload based on a moment of inertia of an autorotating motion during at least a portion of the flight path before the payload arrives at the predetermining landing destination.

9. The payload delivery device according to claim **1**, wherein the rotor assembly is further configured to rotate the plurality of rotor blades to

a folded position proximate a side of the payload,

an initial deployed position rotated away from the side of the payload, and

a fully deployed and locked position further rotated away from the side of the payload and perpendicular to the central axis of rotation of the rotor assembly.

10. The payload delivery device according to claim **9**, wherein the rotor assembly is further configured to dampen the plurality of rotor blades during a blade deployment operation when each of the plurality of rotor blades nears the fully deployed and locked position.

11. A payload delivery device configured to deliver an aircraft deployed payload along a flight path to a predetermined landing destination, the payload delivery device comprising:

a support member configured to be removably attached to the payload;

a flight control and navigation system module connected to the support member;

a control surface assembly module including a plurality of control surfaces, the control surface assembly module connected to the support member and in communication with the flight control and navigation module to receive commands to control orientation of the plurality of control surfaces while the payload is travelling along the flight path to the predetermined landing destination;

a gimbal assembly module including a plurality of gimbal servomotors, the gimbal assembly module connected to and configured to move relative to the support member and in communication with the flight control and navigation module to receive commands to control axial rotation of the gimbal assembly module with respect to the support member;

a rotor assembly including a plurality of rotor blades having a central axis of rotation; and

a collective control assembly module including at least one collective servomotor, the collective control assembly module connected between the gimbal assembly module and the rotor assembly and in communication with the flight control and navigation module configured to control a plurality of control linkages connected to the plurality of rotor blades.

12. The payload delivery device according to claim **11**, wherein the gimbal assembly module, under control of the flight control and navigation system module, pivots the central axis of rotation the rotor assembly via at least one servomotor about a point located on a longitudinal axis of the payload to impart an axial thrust force away from the longitudinal axis of the payload.

13. The payload delivery device according to claim **11**, wherein the collective control assembly module, under control of the flight control and navigation system module, controls, via at least one servomotor mounted on the gimbal assembly module, a collective motion imparted to the rotor assembly configured to simultaneously rotate a leading-edge of each blade of the plurality of rotor blades of the rotor assembly.

14. A payload delivery device configured to deliver an aircraft deployed payload along a flight path to a predetermined landing destination, the payload delivery device comprising:

a support member configured to be removably attached to the payload;

a flight control and navigation system module;

a control surface assembly module including a plurality of control surfaces, the control surface assembly module connected to the support member and in communication with the flight control and navigation module to receive control surface commands to control orientation of the plurality of control surfaces;

a rotation bearing assembly connected to the support member; and

a rotor assembly including a plurality of rotor blades having a central axis of rotation and a plurality of rotor servomotors, the rotor assembly connected to the rotation bearing assembly and in communication with the flight control and navigation module to receive rotor rotation commands to control angular rotation of each of the plurality of rotor blades via co-planar aligned blade rotation shafts of each of the plurality of rotor

blades, the co-planar aligned drive shafts coincident with a plane of rotation of the rotor assembly about the central axis of rotation.

15. The payload delivery device according to claim **14**, further comprising a gimbal assembly module including a plurality of gimbal servomotors, the gimbal assembly module connected to and configured to move relative to the support member and in communication with the flight control and navigation module to receive gimbal rotation commands to control axial rotation of the gimbal assembly module with respect to the support member.

16. The payload delivery device according to claim **15**, wherein the gimbal assembly module, under control of the flight control and navigation system module, pivots the central axis of rotation of the rotor assembly via at least one gimbal servomotor about a point located on a longitudinal axis of the payload to impart an axial thrust force produced by the rotor assembly away from the longitudinal axis of the payload.

17. The payload delivery device according to claim **14**, further comprising a quick-release coupler connected between the rotation bearing assembly and the rotor assembly configured to allow detaching of the rotor assembly from the payload delivery assembly and attaching a second rotor assembly.

18. The payload delivery device according to claim **14**, wherein the flight control and navigation system module comprises at least

a GPS receiver,

at least one servomotor controller,

an inertial navigation system (INS) sensor,

a magnetometer,

a navigation module, and

a multi-band transceiver configured to communicate with at least one of a master flight computer in an aircraft, a satellite communications network, a ground-based telemetry station and a weather station.

19. The payload delivery device according to claim **14**, wherein at least one component of the flight control and navigation system module is disposed in a rotating frame of the rotor assembly.

20. The payload delivery device according to claim **14**, wherein the flight control and navigation system module is disposed in a rotating frame of the rotor assembly.

21. The payload delivery device according to claim **14**, wherein the plurality of control surfaces, under control of the flight control and navigation system module, at least one of vertically stabilize and impart an axial moment of rotation about a longitudinal axis of the payload during a portion of the flight path to the predetermined landing destination.

22. The payload delivery device according to claim **14**, wherein the plurality of control surfaces, under control of the flight control and navigation system module, are configured to navigate the payload along a portion of the flight path to the predetermined landing destination.

23. The payload delivery device according to claim **14**, wherein the rotor assembly, under control of the flight control and navigation system module, is configured to simultaneously rotate leading edges of each of the plurality of rotor blades of the rotor assembly.

24. The payload delivery device according to claim **14**, wherein the rotor assembly, under control of the flight control and navigation system module, is configured to independently rotate leading edges of each of the plurality of rotor blades of the rotor assembly.

25. The payload delivery device according to claim **24**, wherein the rotor assembly, under control of the flight control and navigation system module, is configured impart a cyclic thrust force to the rotor assembly by cyclically rotating a leading-edge of at least one of the plurality of rotor blades of the rotor assembly.

26. The payload delivery device according to claim **14**, wherein the rotor assembly, under control of the flight control and navigation system module, rotates leading-edges of the plurality of rotor blades of the rotor assembly to a negative leading-edge angle with respect to a rotational plane of the rotor assembly in a fully deployed rotor position,

wherein the rotor assembly is configured to produce an autorotation motion to produce a vertical thrust force on the payload during a portion of the flight path to the predetermined landing destination.

27. The payload delivery device according to claim **26**, wherein the rotor assembly, under control of the flight control and navigation system module, rotates leading-edges of the plurality of rotor blades of the rotor assembly to a positive leading-edge angle with respect to a plane of rotation of the rotor assembly in a fully deployed rotor position,

wherein the rotor assembly produces a vertical thrust force on the payload based on a moment of inertia produced from the autorotation motion during a second portion of the flight path before the payload arrives at the predetermining landing destination.

28. The payload delivery device according to claim **14**, wherein the rotor assembly, under control of the flight control and navigation system module, rotates leading-edges of the plurality of rotor blades of the rotor assembly perpendicular to a plane of rotation of the rotor assembly in a fully deployed rotor position,

wherein the rotor assembly minimizes an aerodynamic profile of the rotor assembly along a portion of the flight path to the predetermined landing destination.

29. The payload delivery device according to claim **28**, wherein the rotor assembly, under control of the flight control and navigation system module, rotates a leading-edge of at least one of the plurality of rotor blades of the rotor assembly away from being perpendicular to the plane of rotation of the rotor assembly in the fully deployed rotor position to navigate the payload delivery device along a portion of the flight path to the predetermined landing destination.

30. The payload delivery device according to claim **14**, wherein the rotor assembly is further configured to rotate the plurality rotor blades

to a folded position proximate at least one side of the payload,

to an initial deployed position rotated away from the at least one side of the payload, and

to a fully deployed and locked position further rotated away from the at least one side of the payload and perpendicular to the central axis of rotation of the rotor assembly.

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