US009366853B2

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

(10) **Patent No.: US 9,366,853 B2**
(45) **Date of Patent: Jun. 14, 2016**

(54) **MULTIPLE PETAL DEPLOYABLE TELESCOPE**

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(21) Appl. No.: **14/612,155**

(22) Filed: **Feb. 2, 2015**

(65) **Prior Publication Data**

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Related U.S. Application Data

(63) Continuation-in-part of application No. 13/885,140, filed as application No. PCT/US2012/026782 on Feb. 27, 2012, now Pat. No. 8,947,777.

(60) Provisional application No. 61/446,617, filed on Feb. 25, 2011.

(51) **Int. Cl.**
G02B 23/20 (2006.01)
B64G 1/22 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***G02B 23/20*** (2013.01); ***B64G 1/222*** (2013.01); ***B64G 1/66*** (2013.01); ***G02B 17/0808*** (2013.01); ***G02B 23/06*** (2013.01); *B64G 2001/1028* (2013.01)

(58) **Field of Classification Search**
CPC G02B 7/00; G02B 7/003; G02B 7/005; G02B 7/182; G02B 7/183; G02B 7/198; G02B 17/0808; G02B 23/00; G02B 23/02; G02B 23/16; G02B 23/20; G02B 23/2476; B64G 1/222; B64G 1/66; B64G 2001/1028; H04B 10/118
USPC 359/399, 405, 406, 408, 409, 817
See application file for complete search history.

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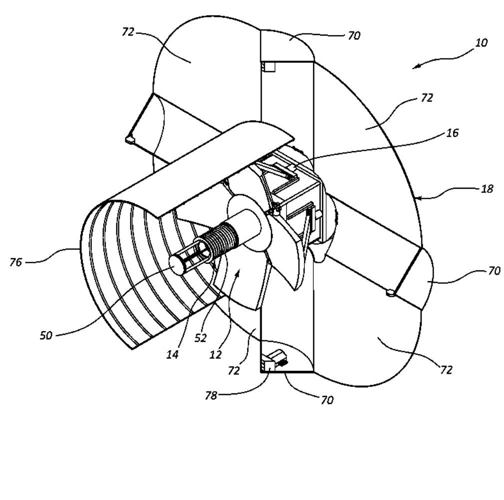
Primary Examiner — Frank Font

(57) **ABSTRACT**

An opto-mechanical deployable telescope includes a hub, at least one deployable multiple petal primary mirror mounted to the hub, a deployment assembly, a secondary optic assembly, and a deployment engine assembly. The deployment assembly is operable to move the at least one primary mirror between a stowed position and a deployed position. The deployment engine assembly is operable to power the deployment assembly using stored mechanical energy. The deployment assembly includes a kinematic or semi-kinematic interface between the hub and the at least one primary mirror to hold petals of the at least one primary mirror in alignment relative to each other in the deployed position. The secondary optic assembly comprising a secondary optical member and is operable to axially position the secondary optical member relative to the primary mirror.

20 Claims, 31 Drawing Sheets



(51) **Int. Cl.**

G02B 17/08	(2006.01)
G02B 23/06	(2006.01)
B64G 1/66	(2006.01)
B64G 1/10	(2006.01)

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U.S. Appl. No. 13/885,140 Applicant Arguments/Remarks Made in an Amendment, filed Sep. 16, 2014.

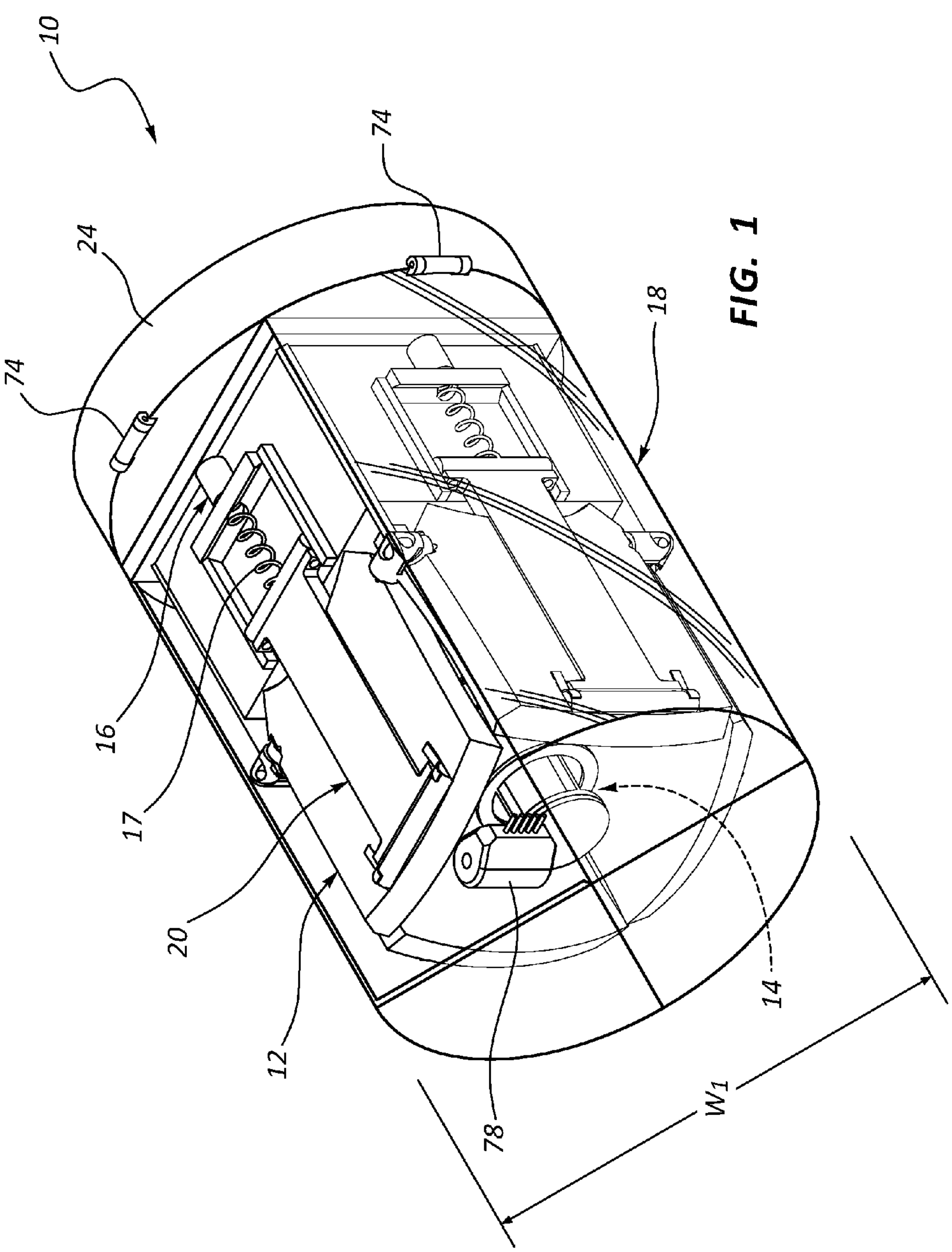

FIG. 1

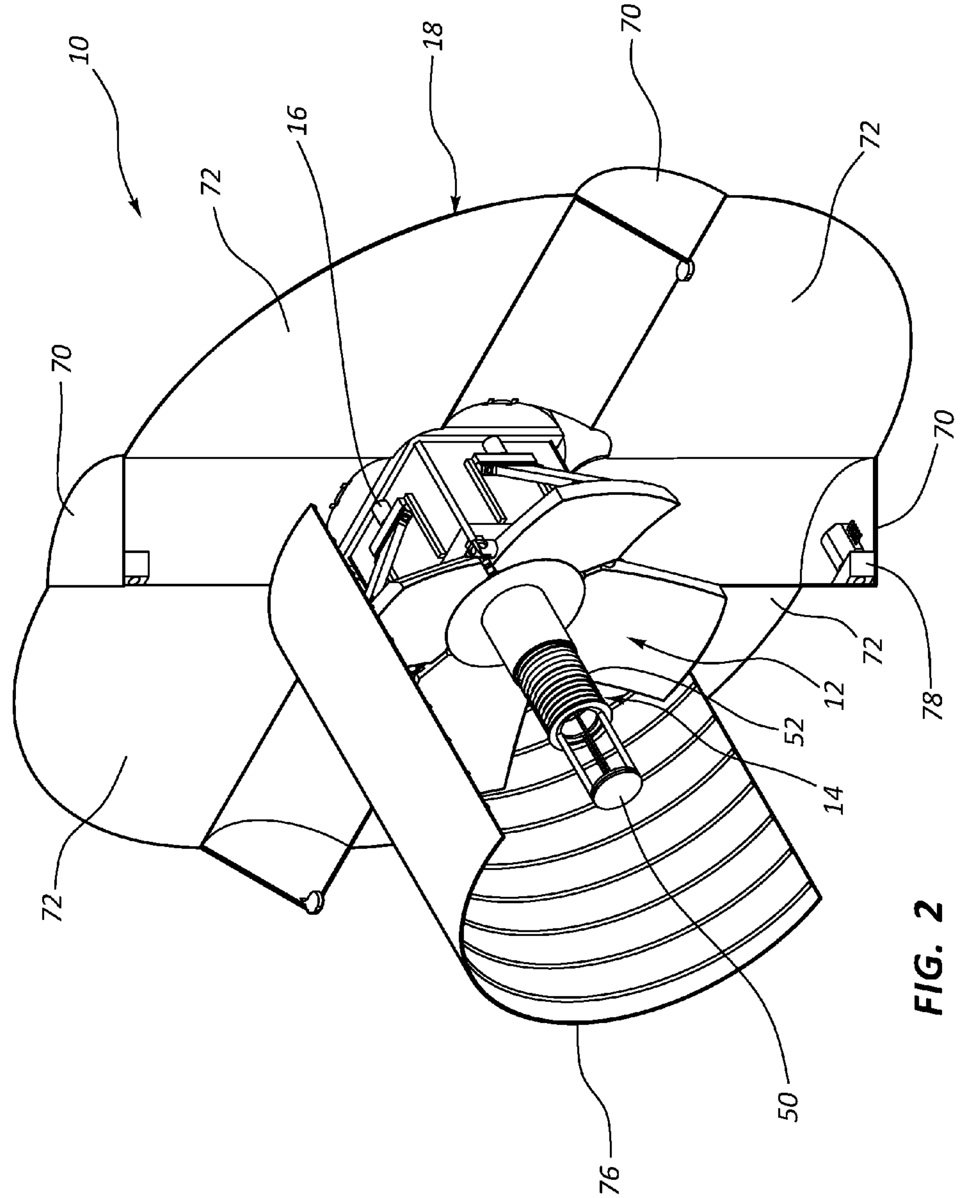

FIG. 2

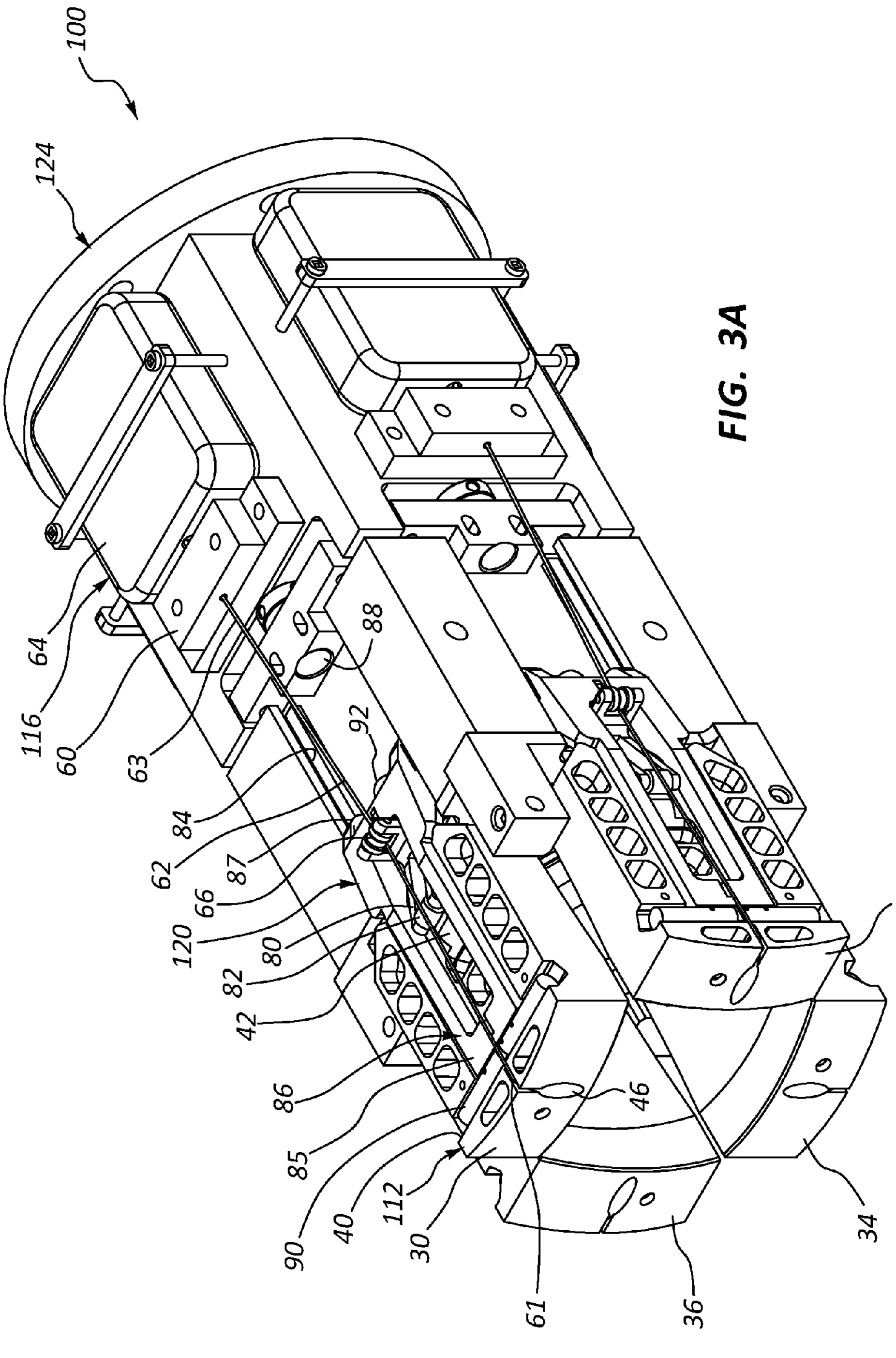
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FIG. 3A

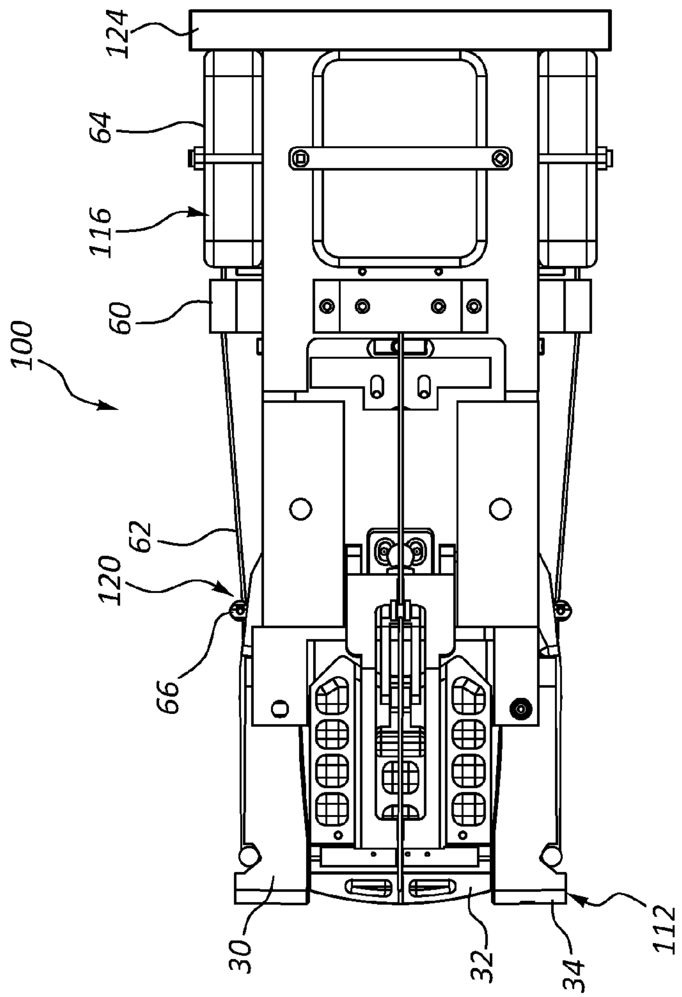
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FIG. 3B

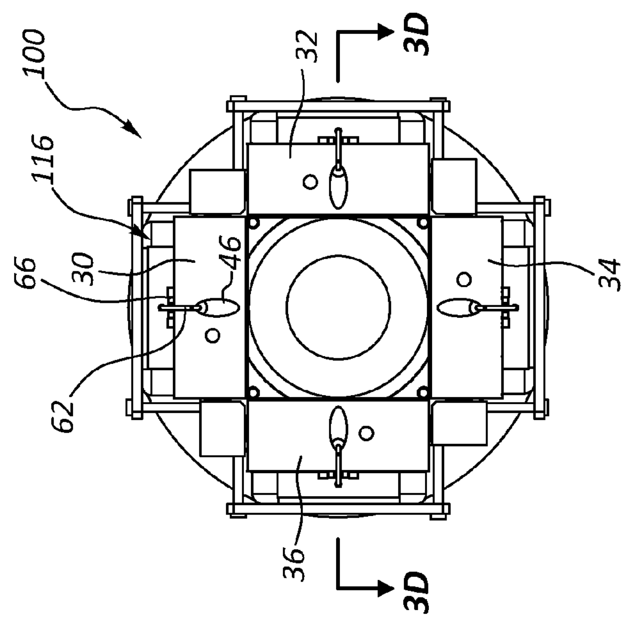
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FIG. 3C

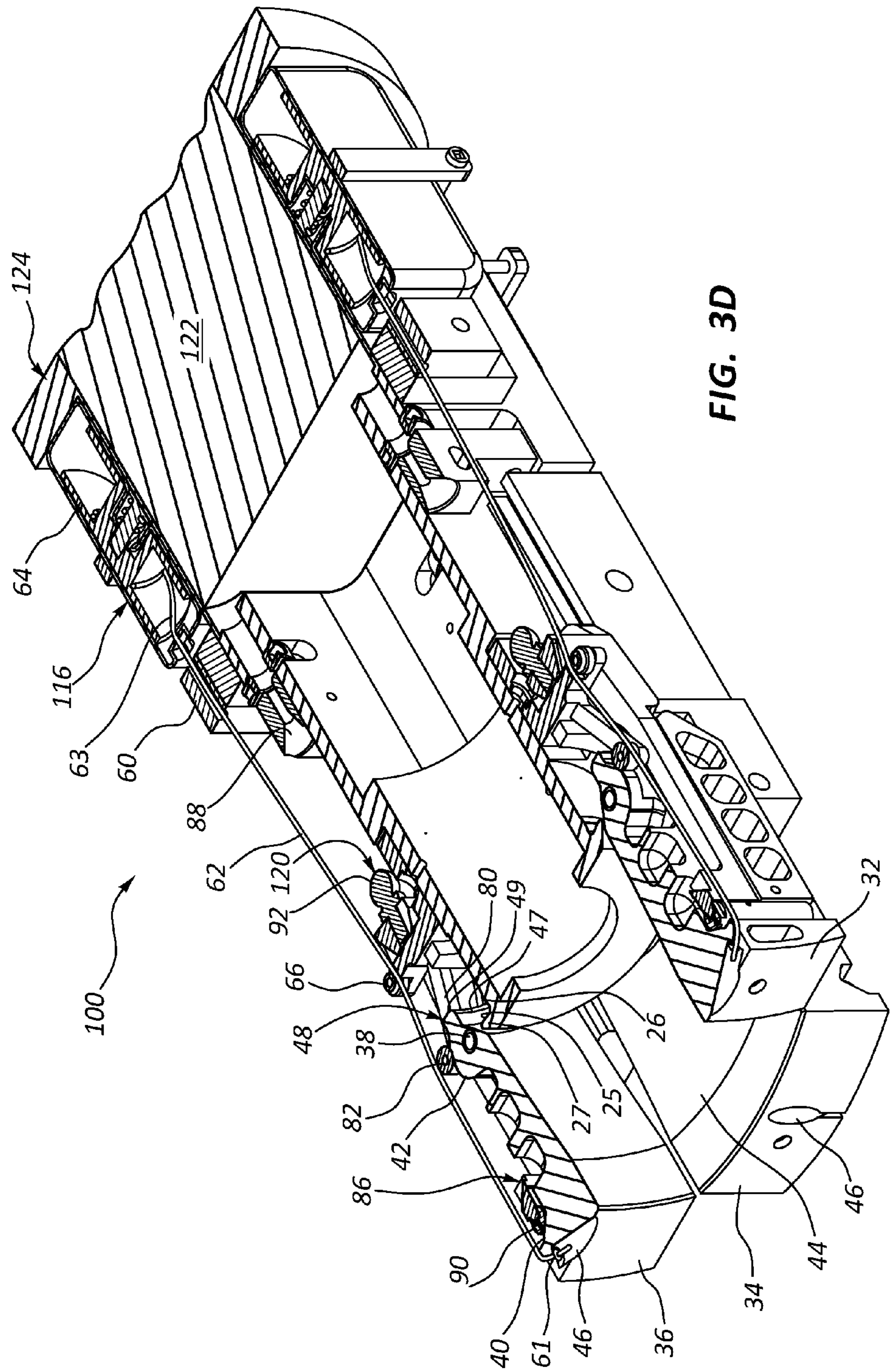
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FIG. 3D

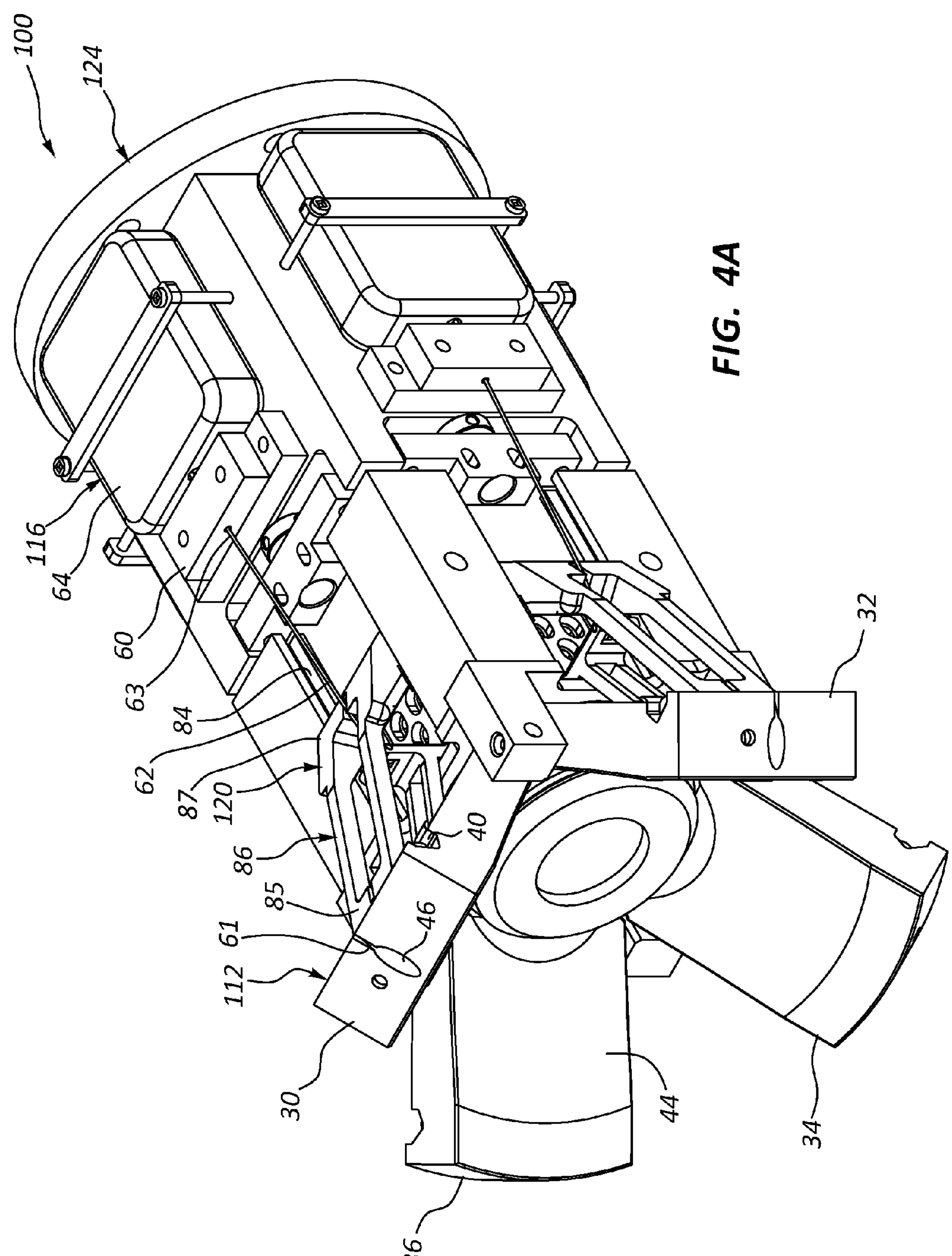
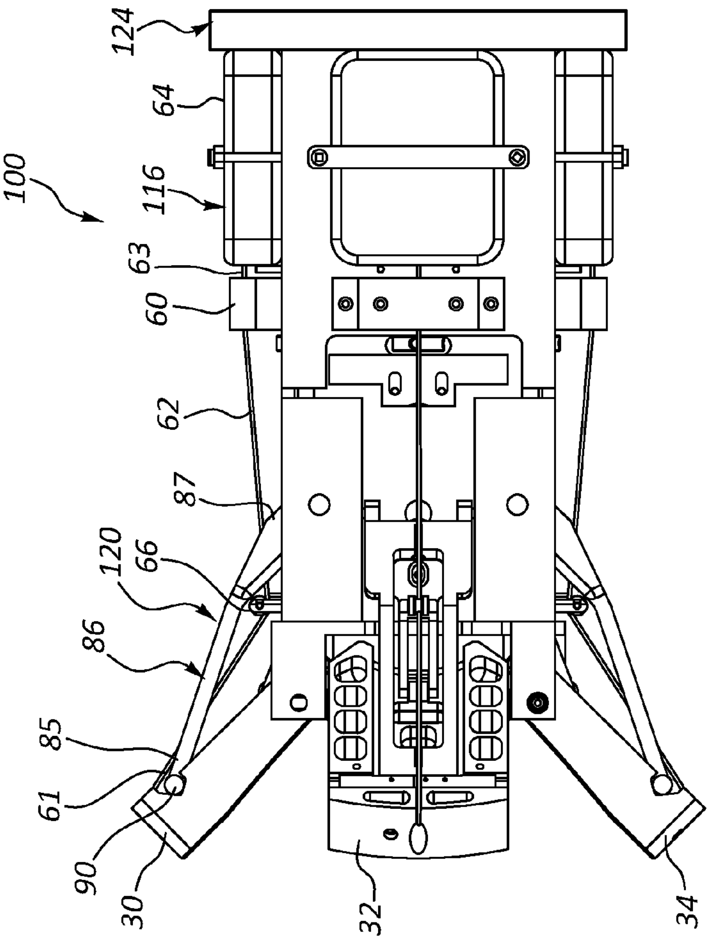


FIG. 4A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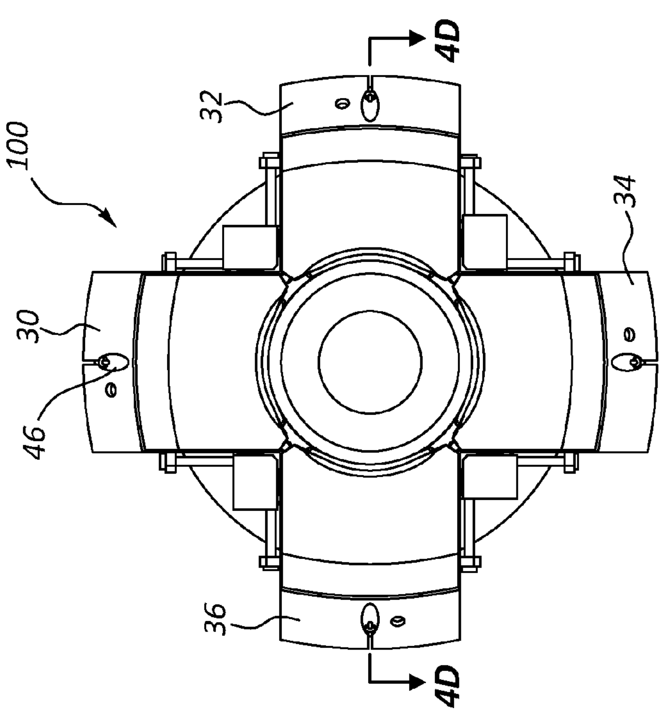
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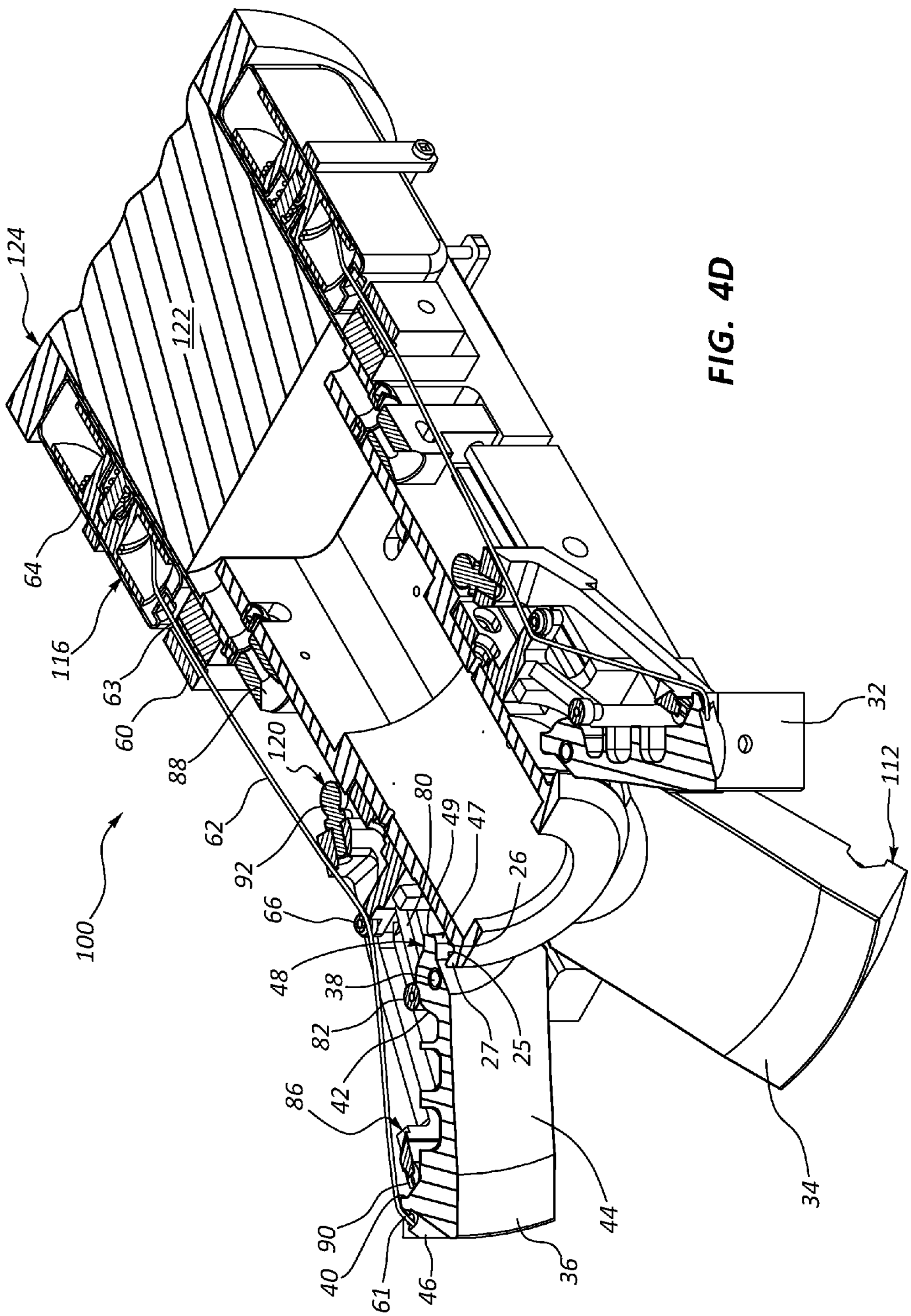
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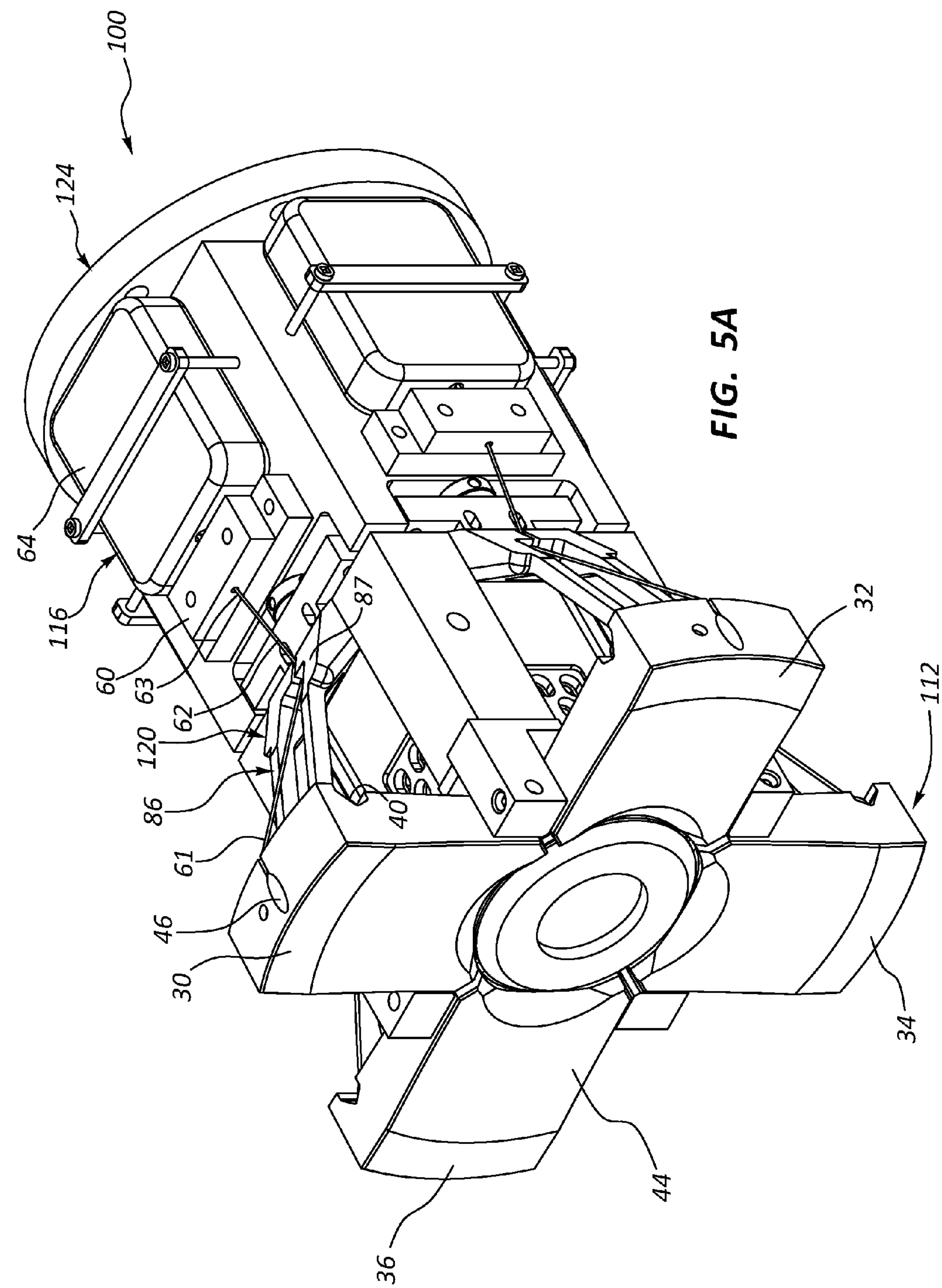
FIG. 4D



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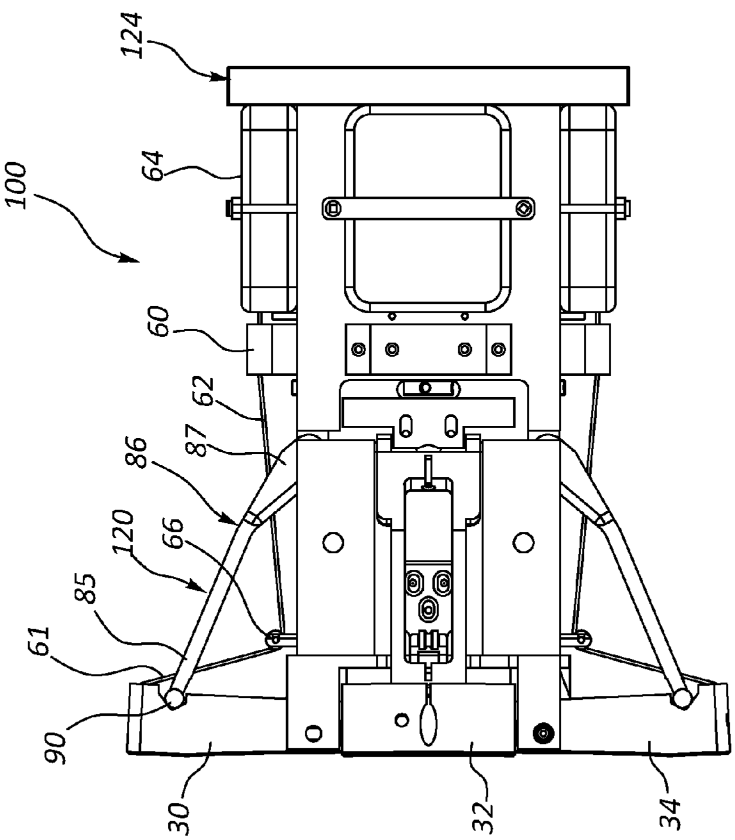
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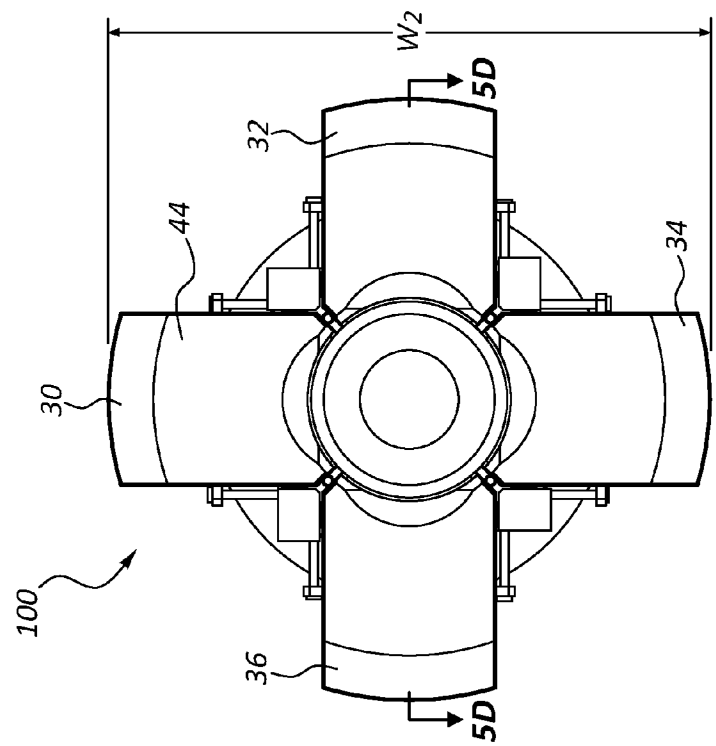
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FIG. 5C

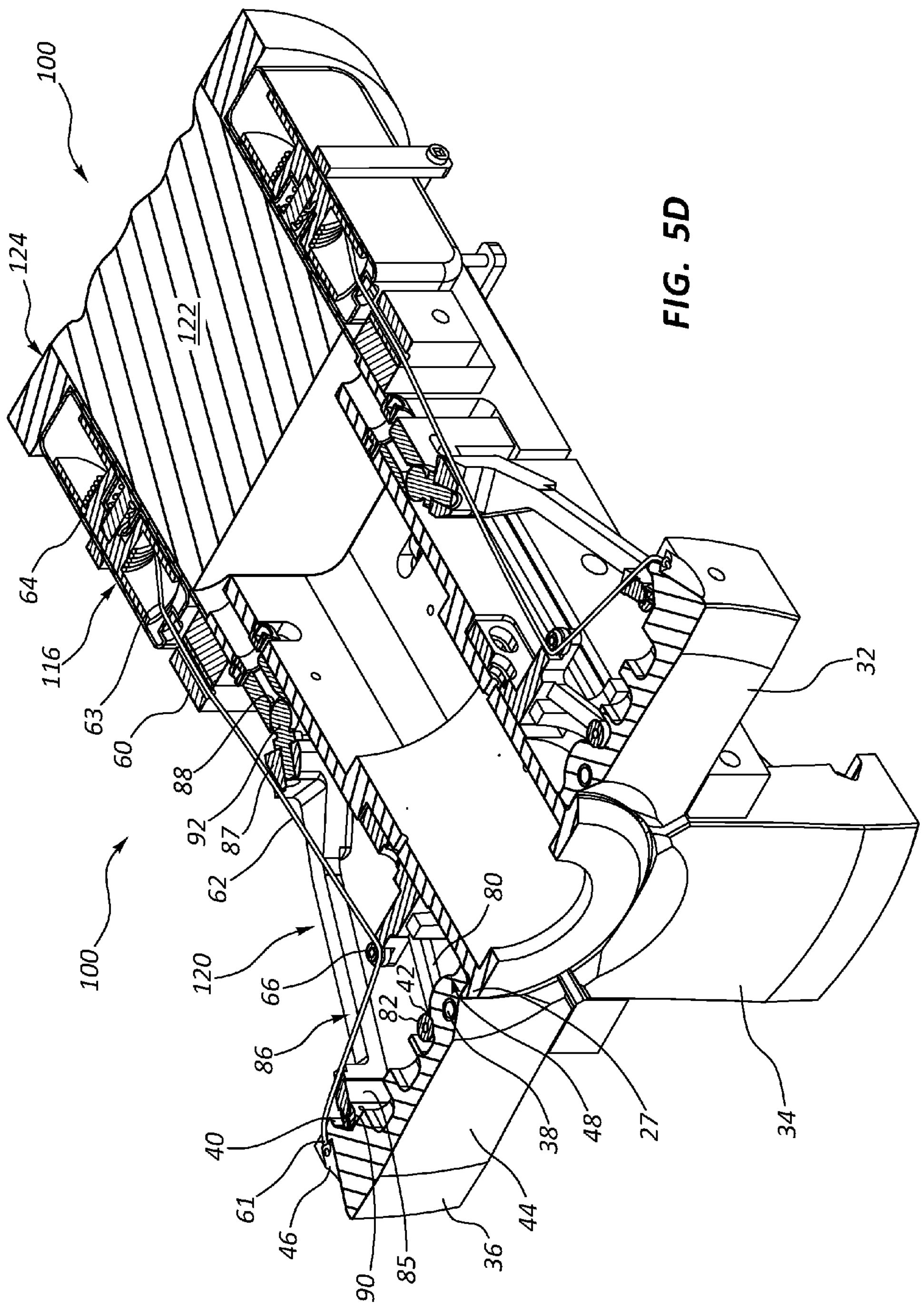
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FIG. 5D

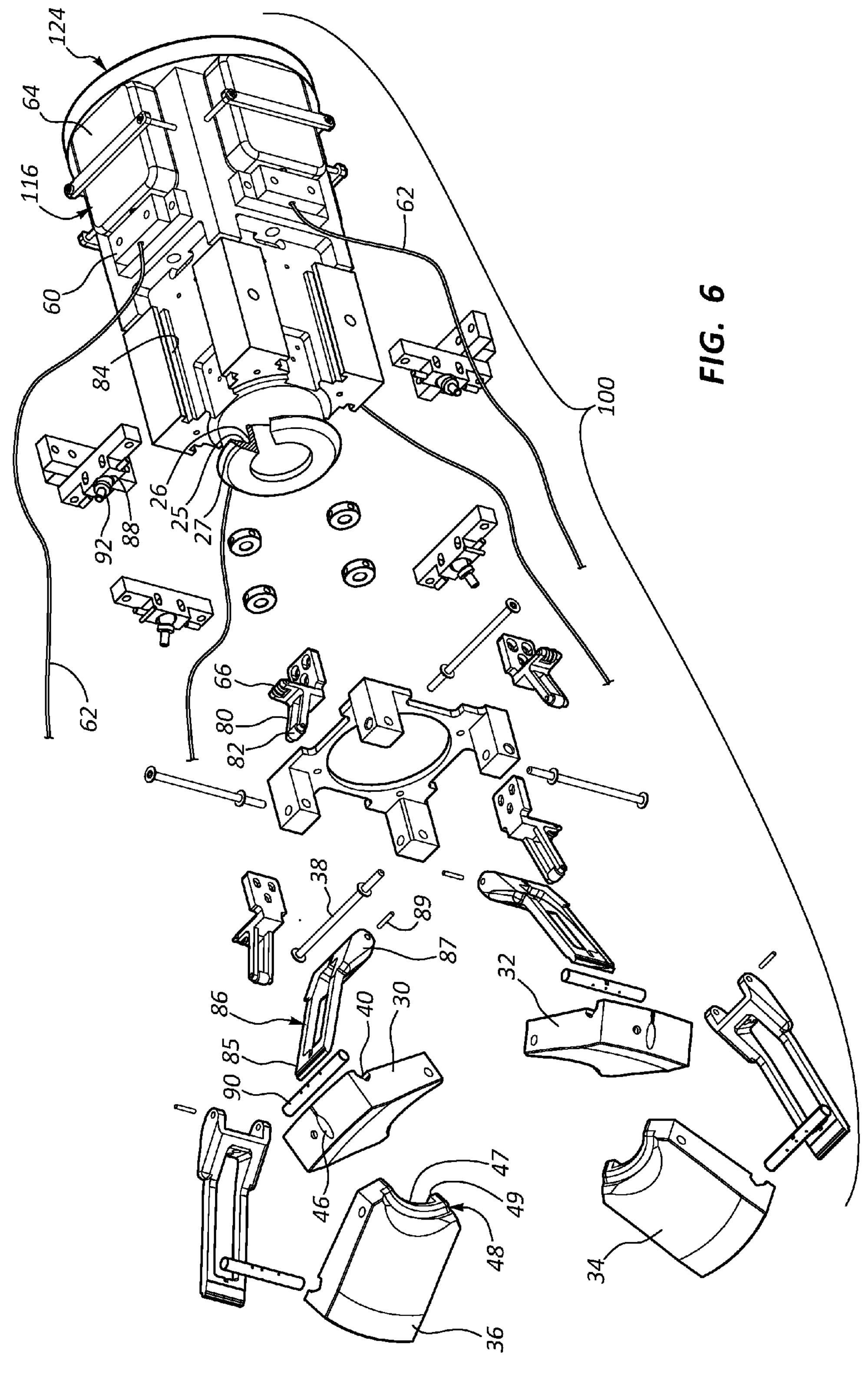
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FIG. 6

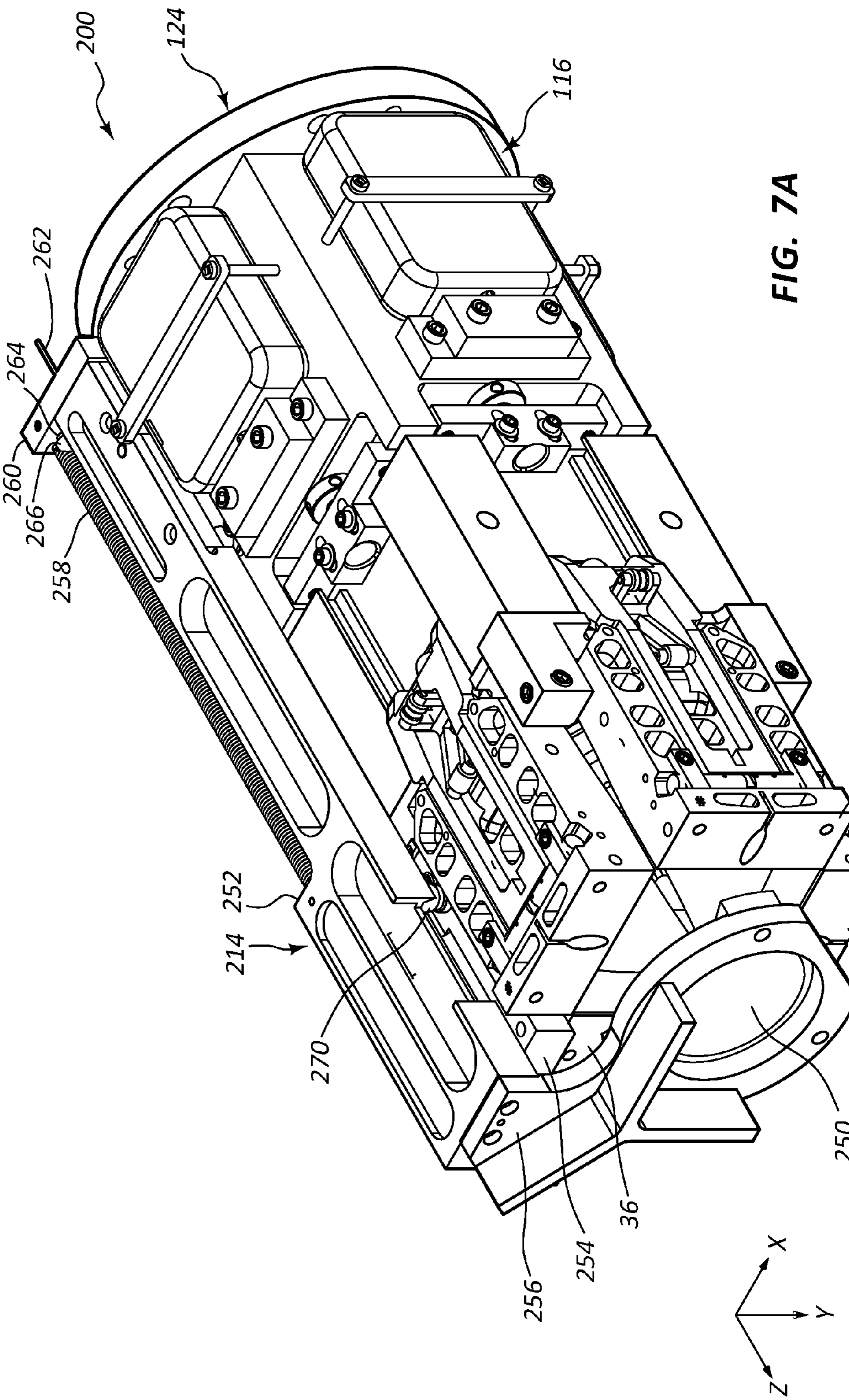
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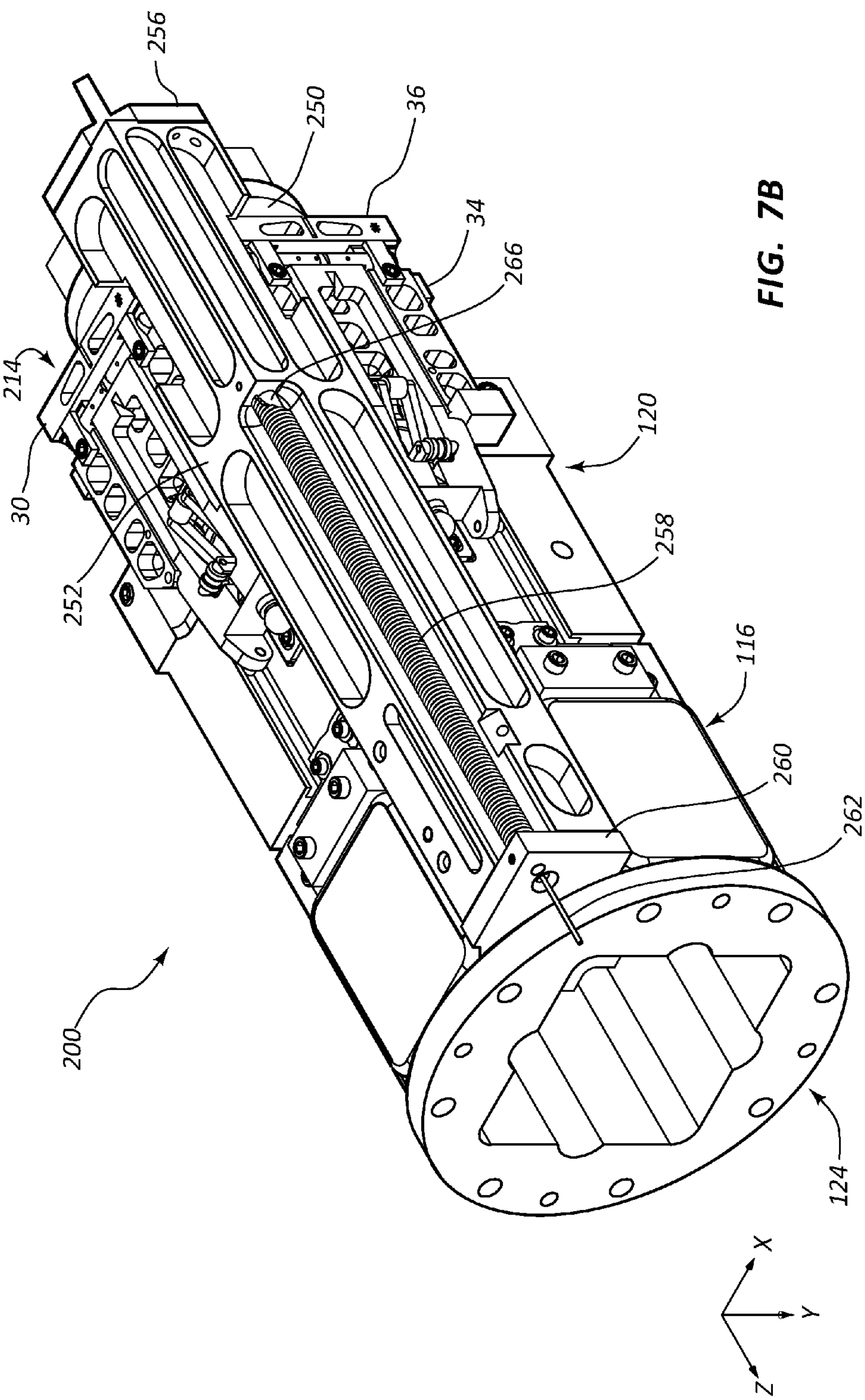
FIG. 7A



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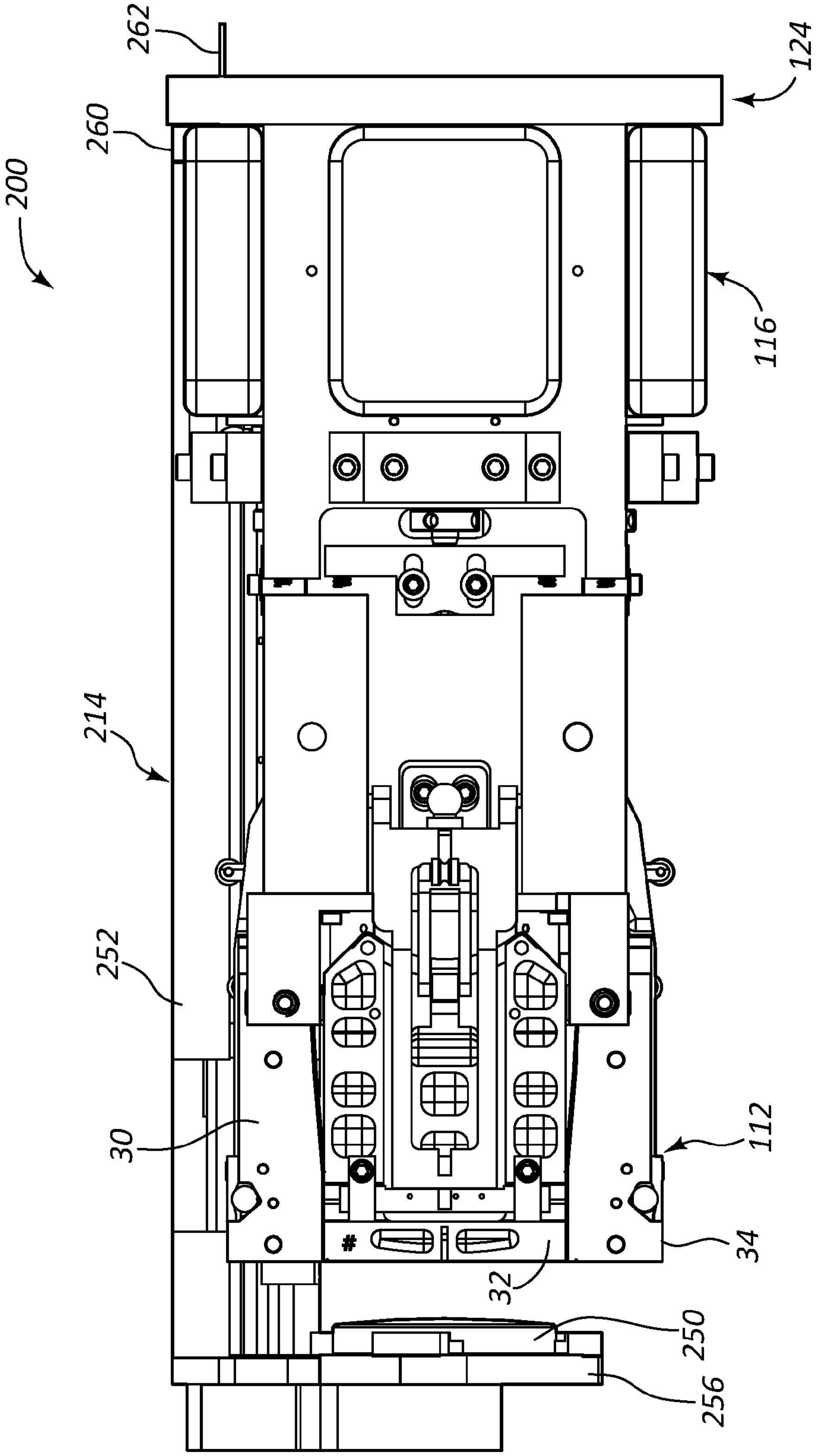


FIG. 7C

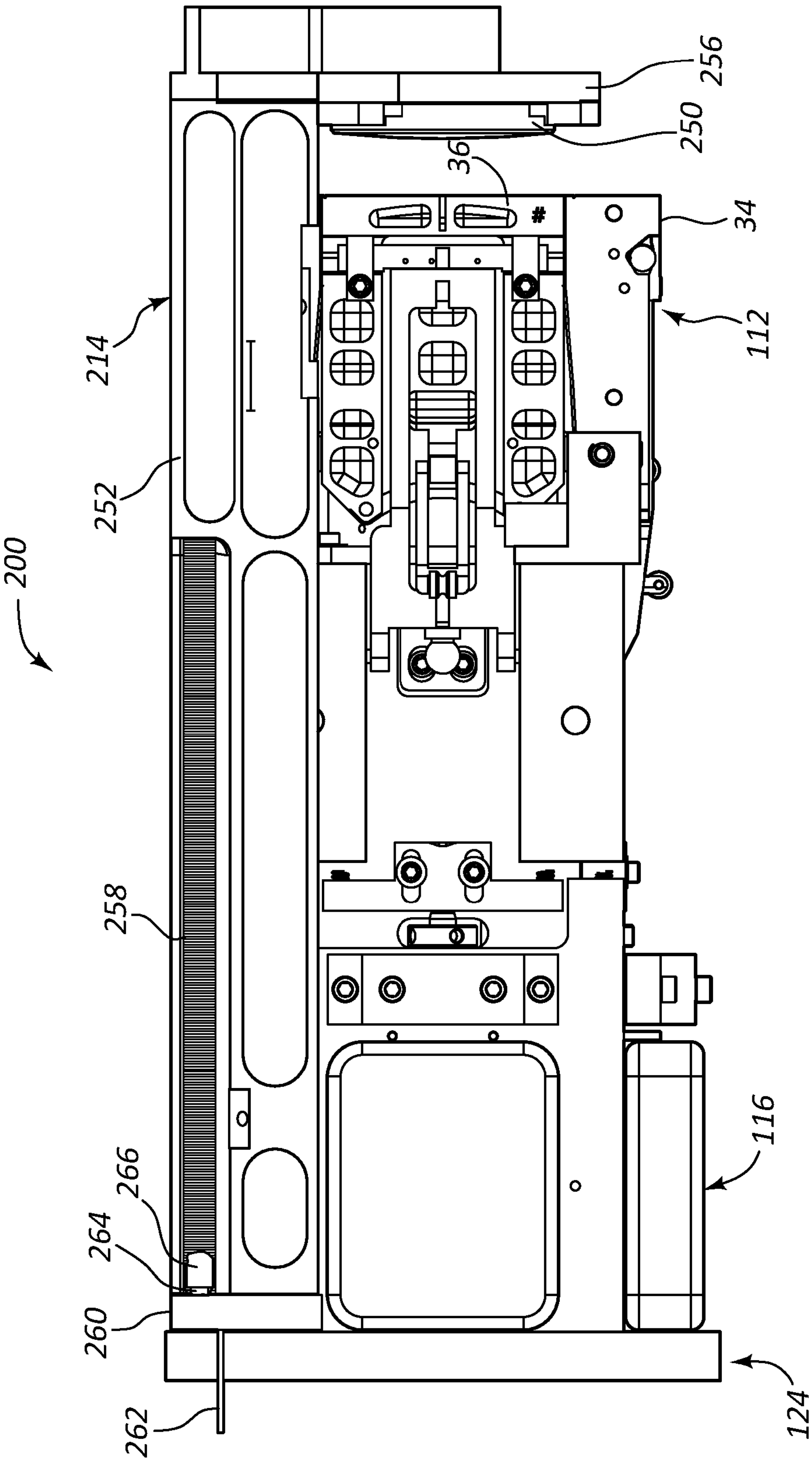


FIG. 7D

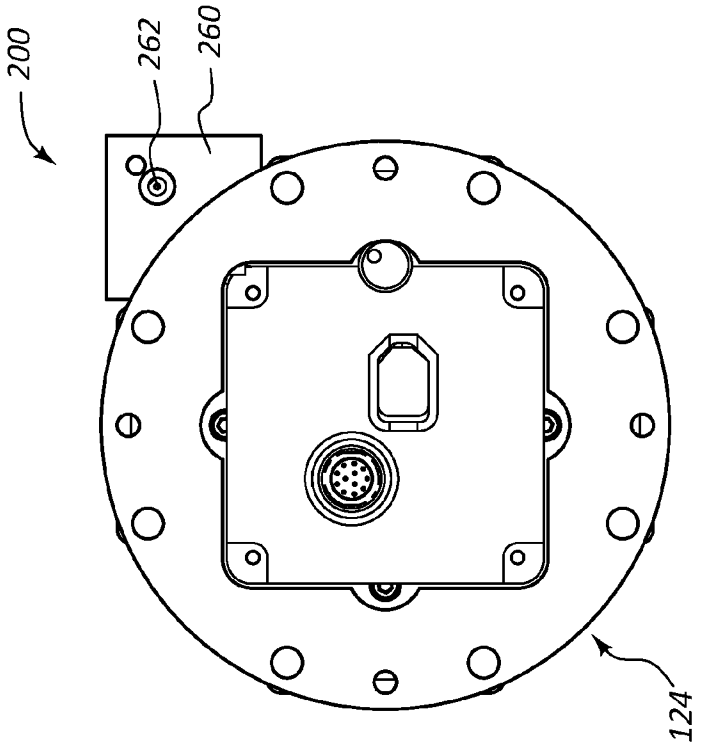
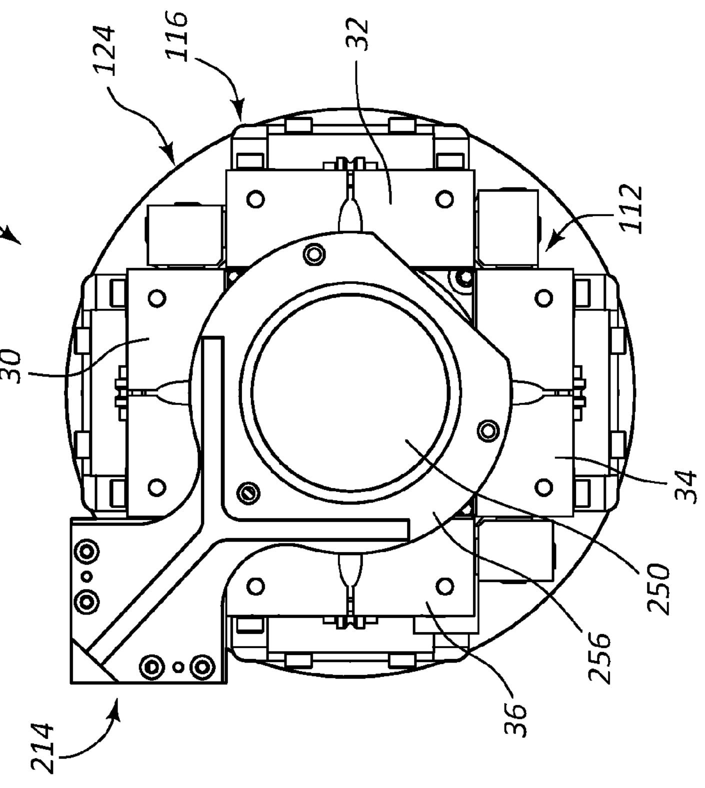


FIG. 7F



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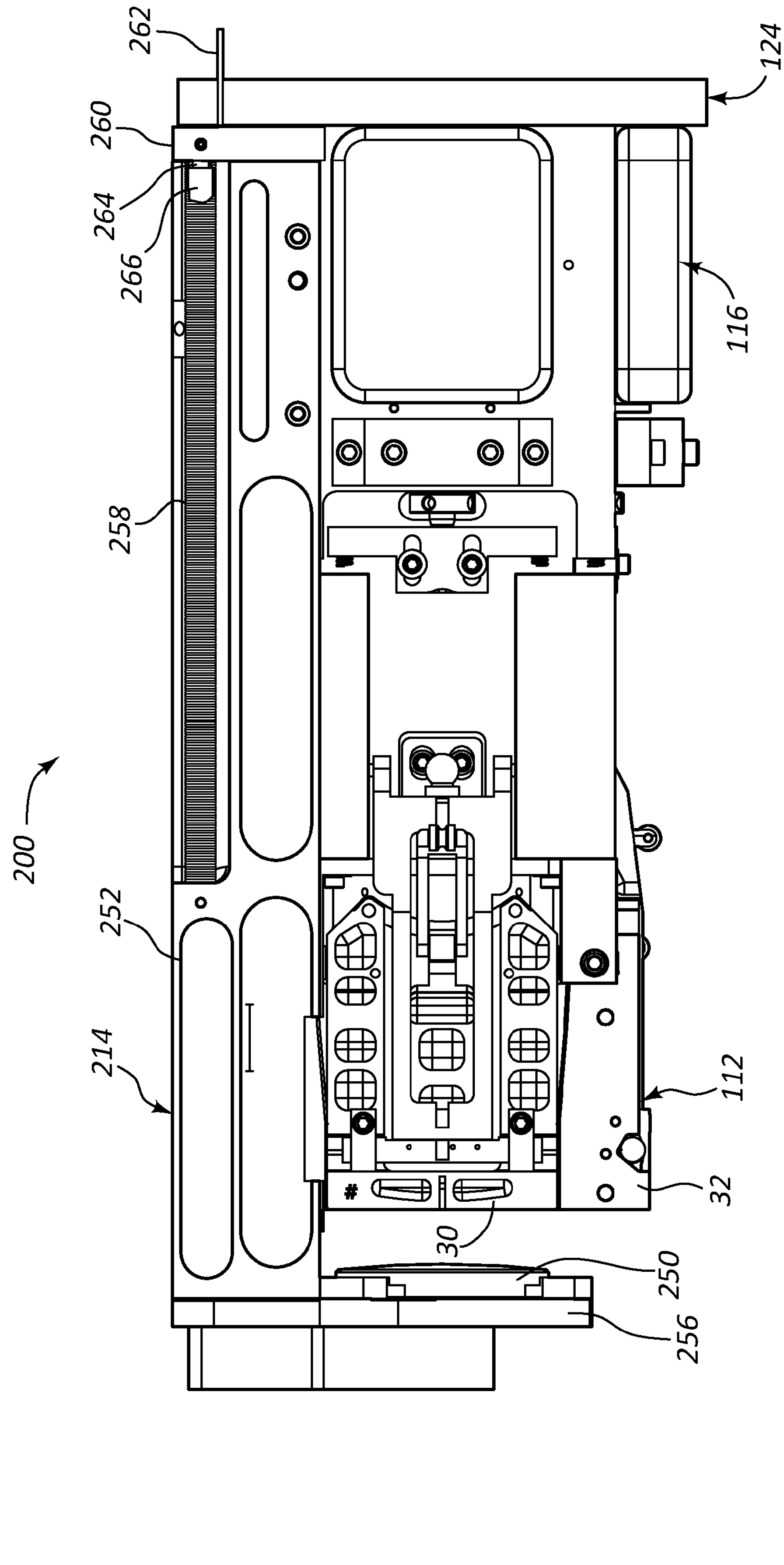

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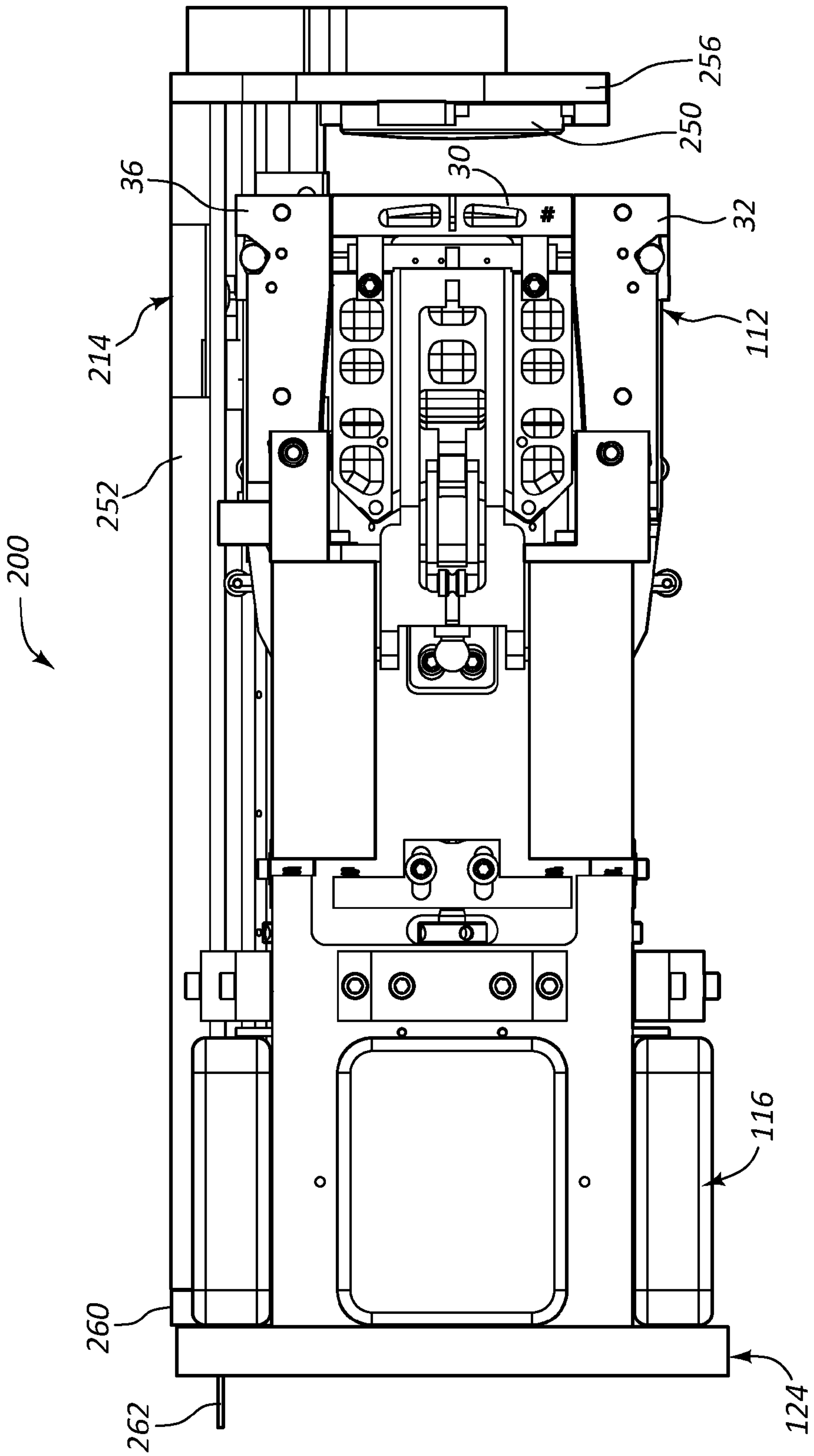

FIG. 7H

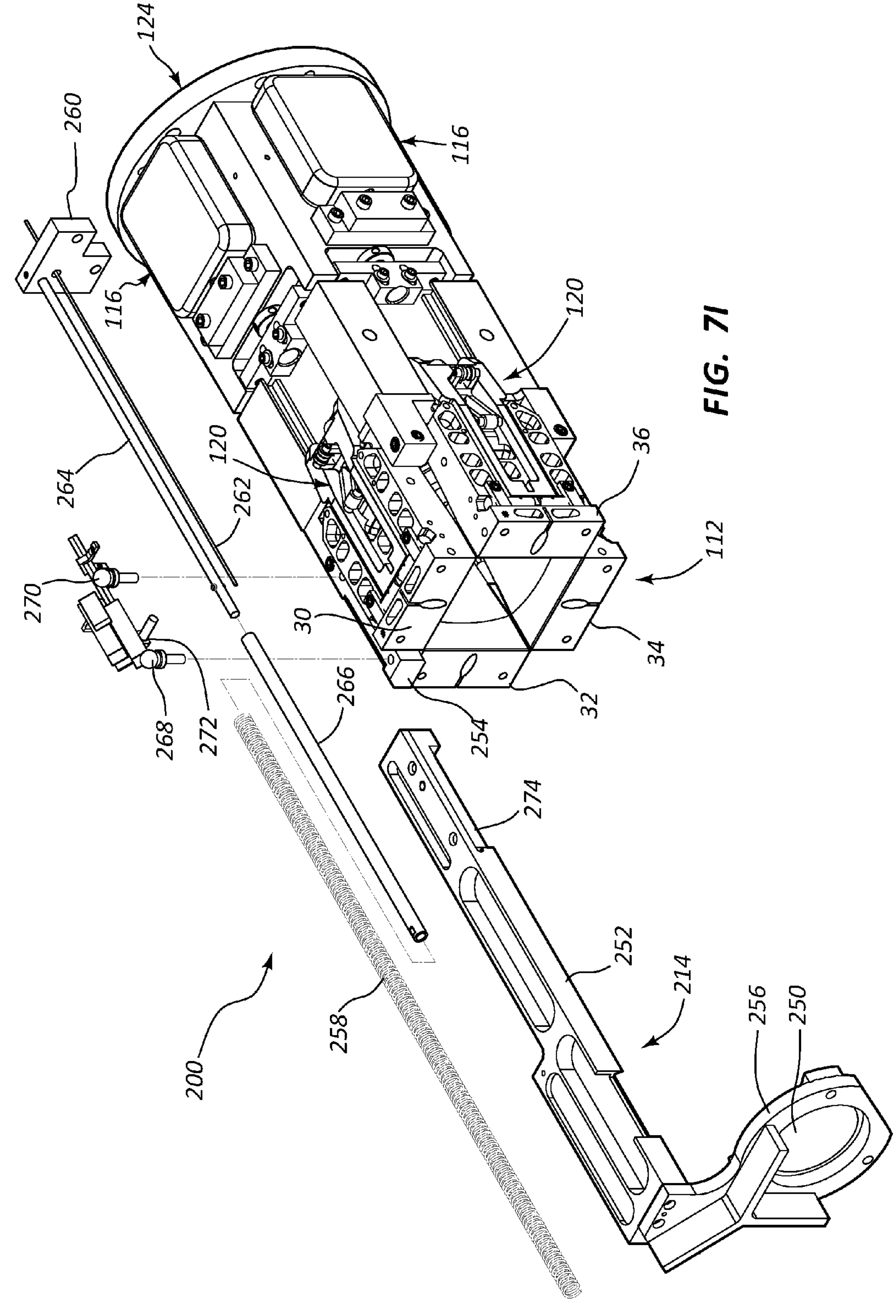
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FIG. 7I

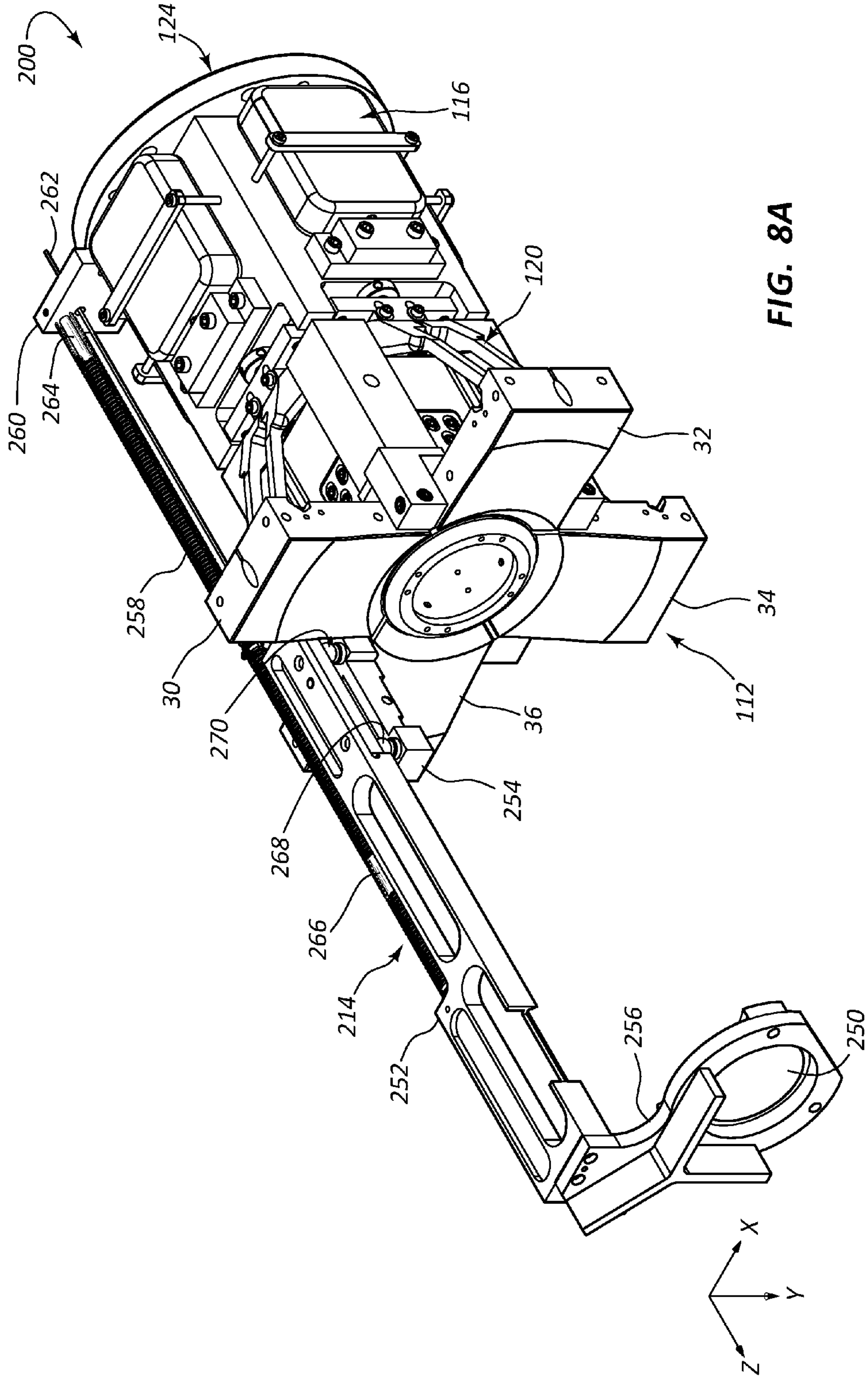
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FIG. 8A

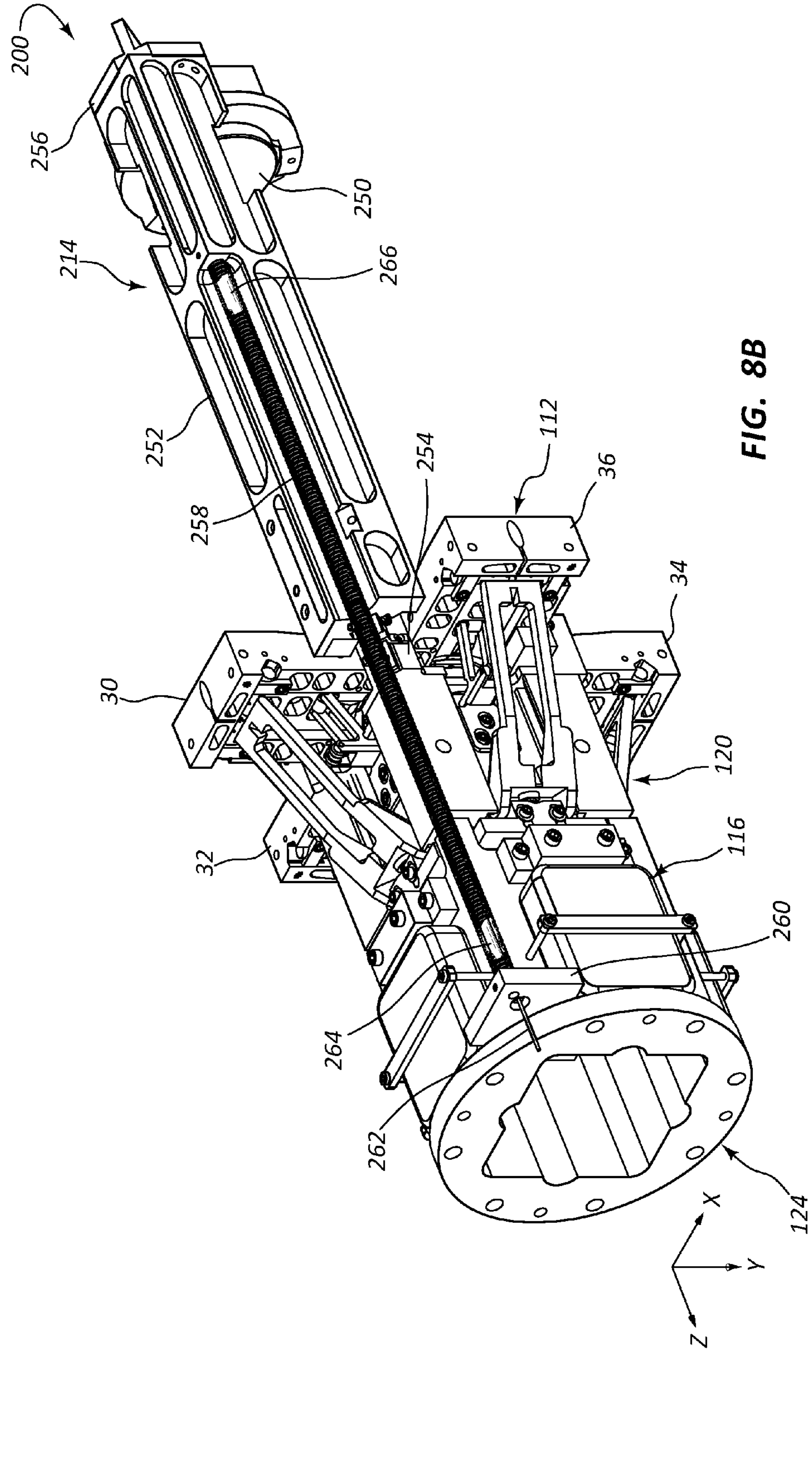
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FIG. 8B

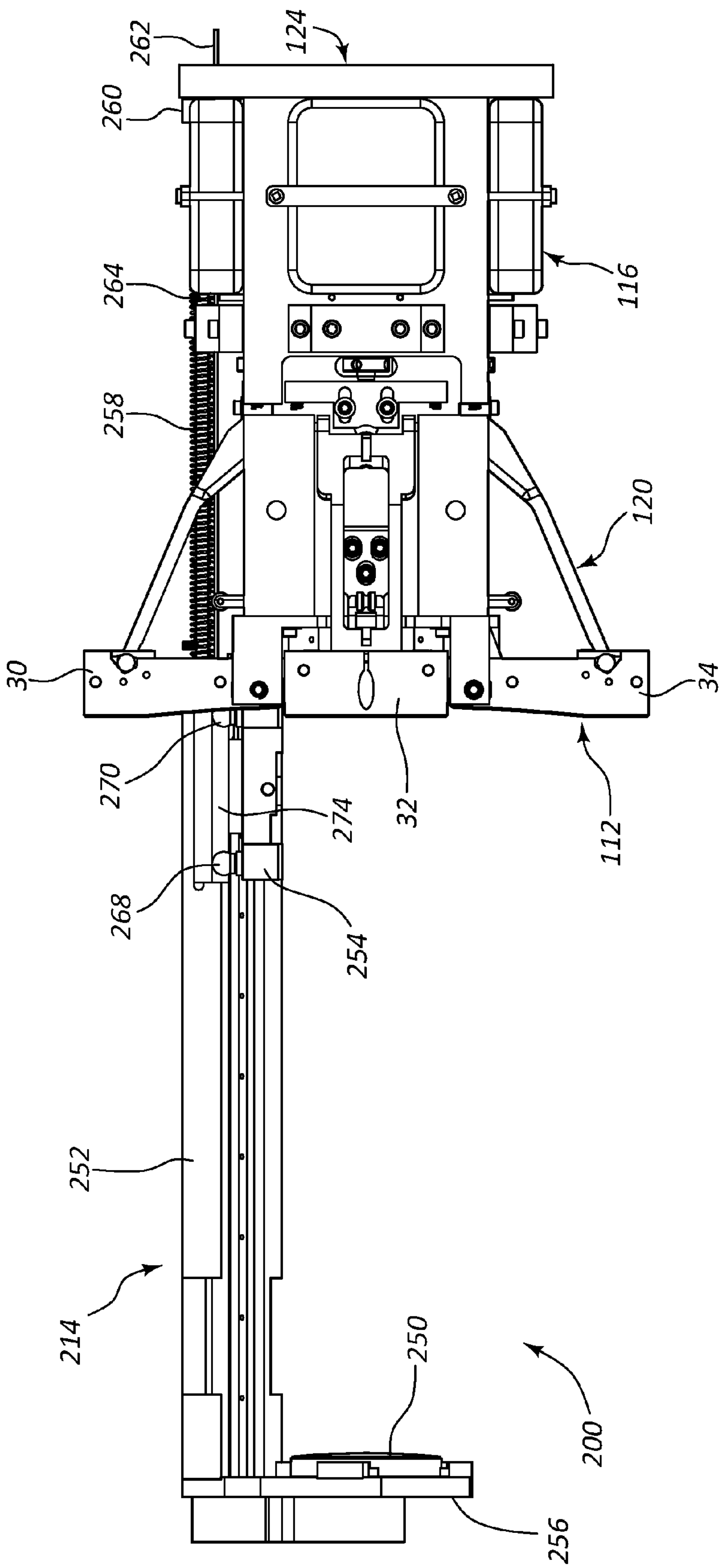
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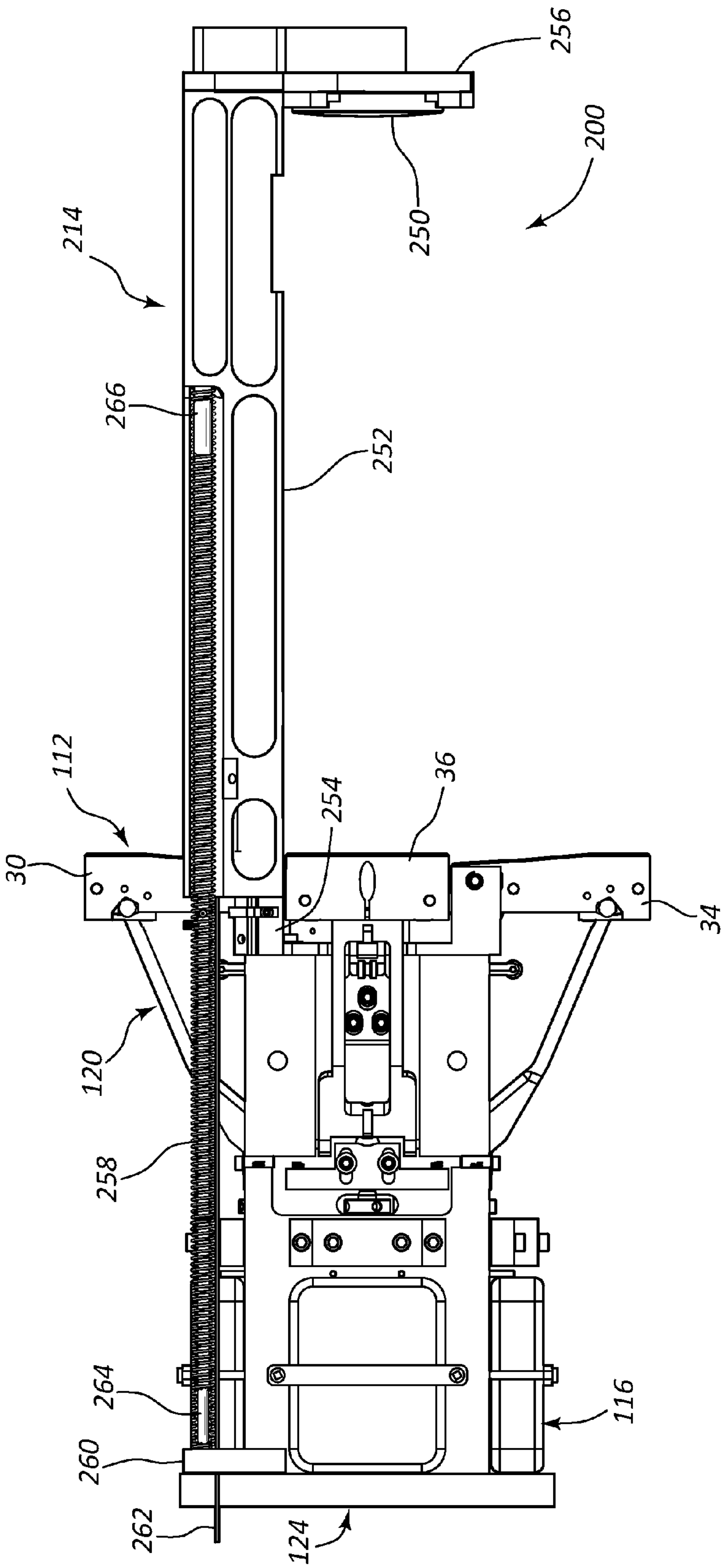
FIG. 8C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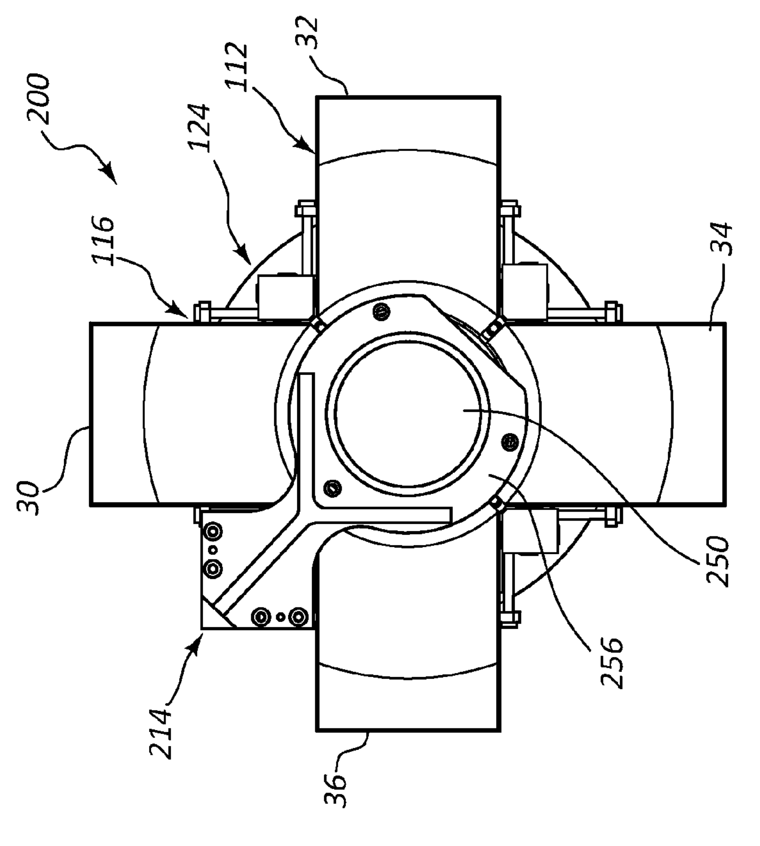
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FIG. 8E

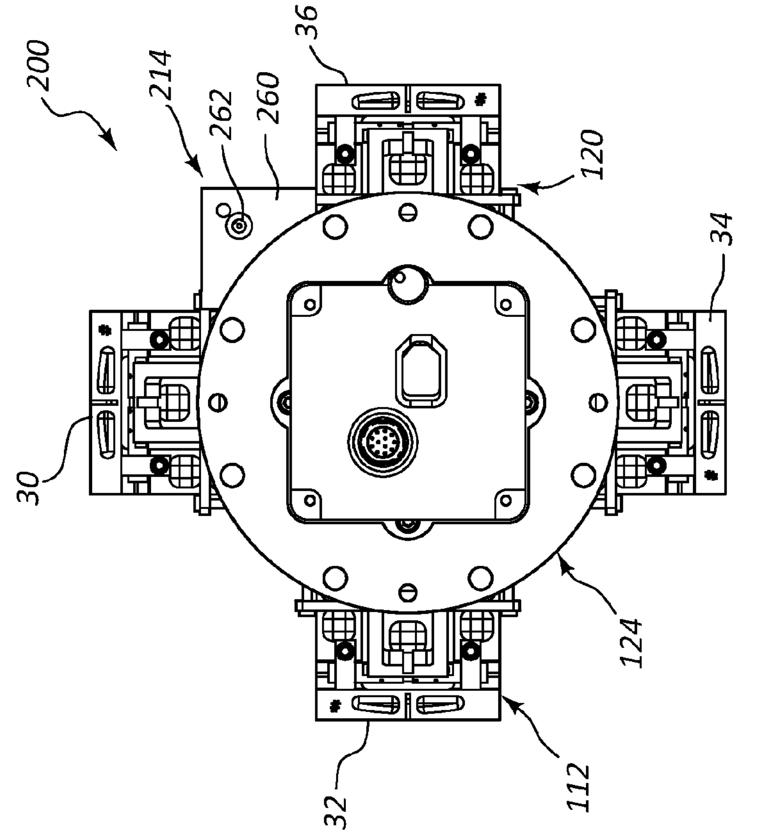
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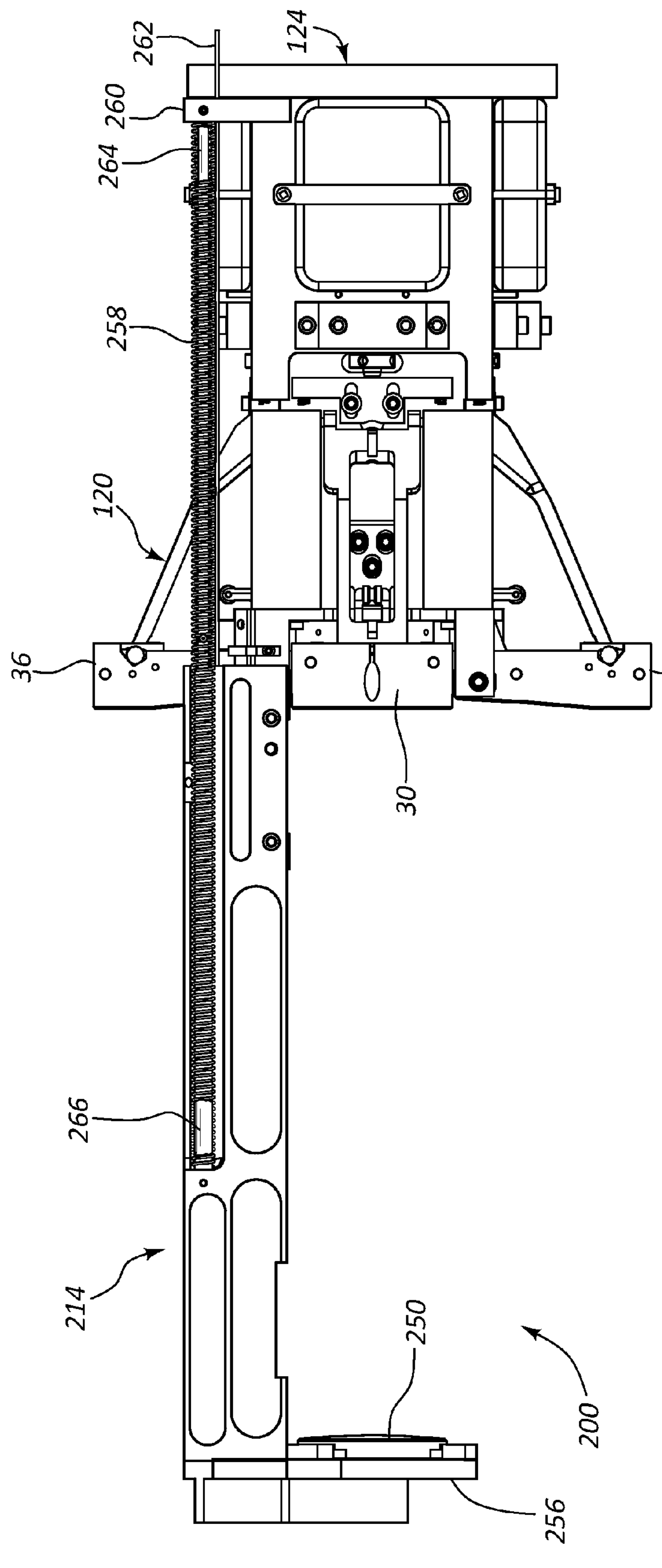
FIG. 8F



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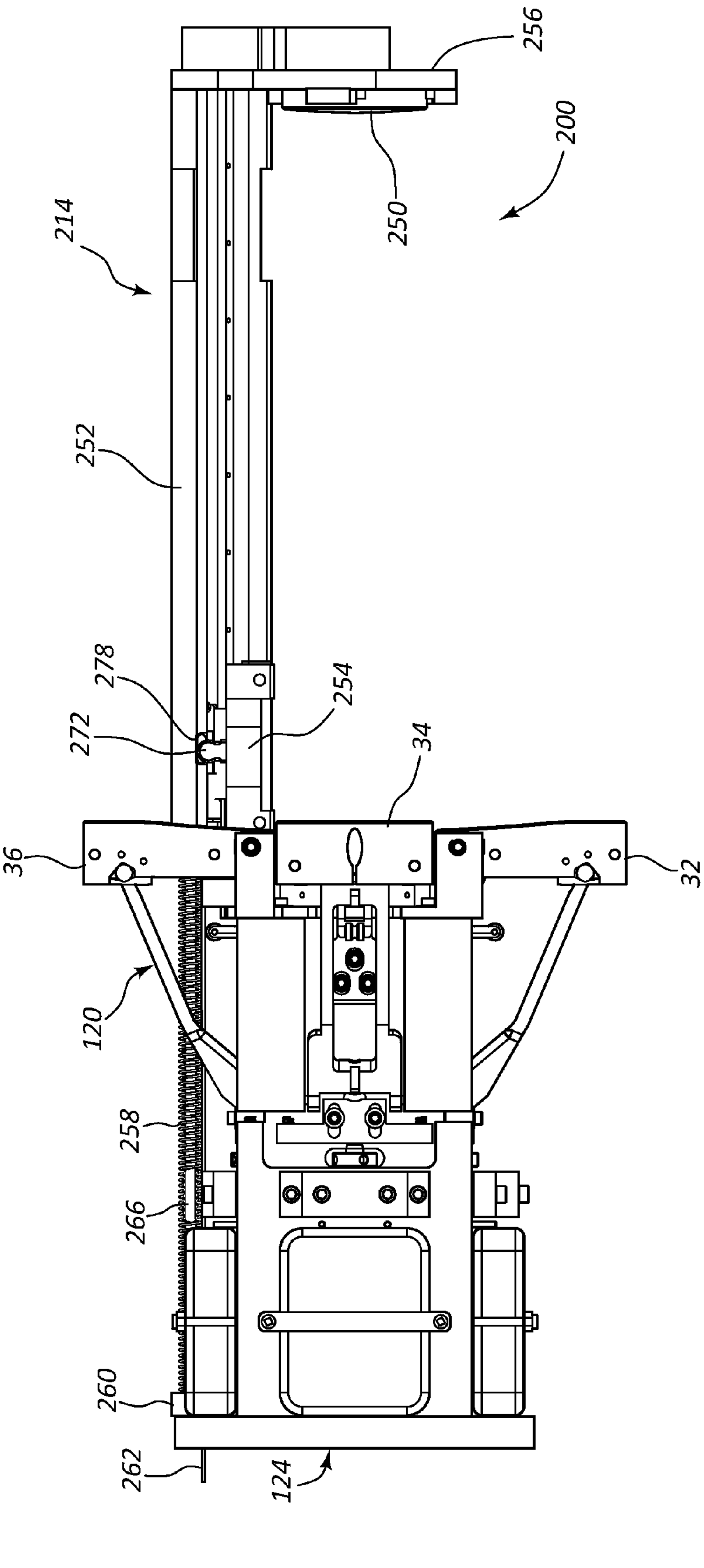

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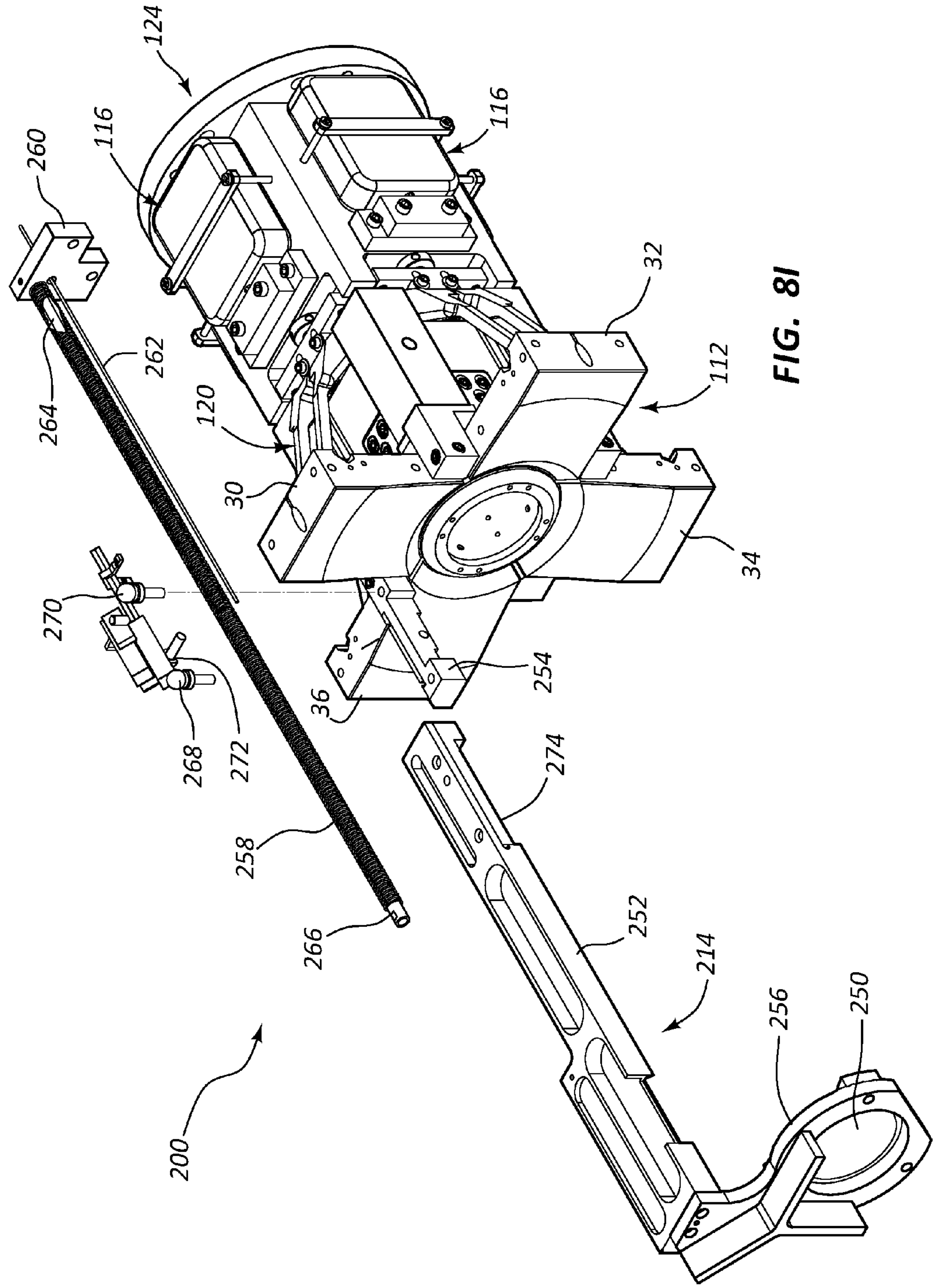
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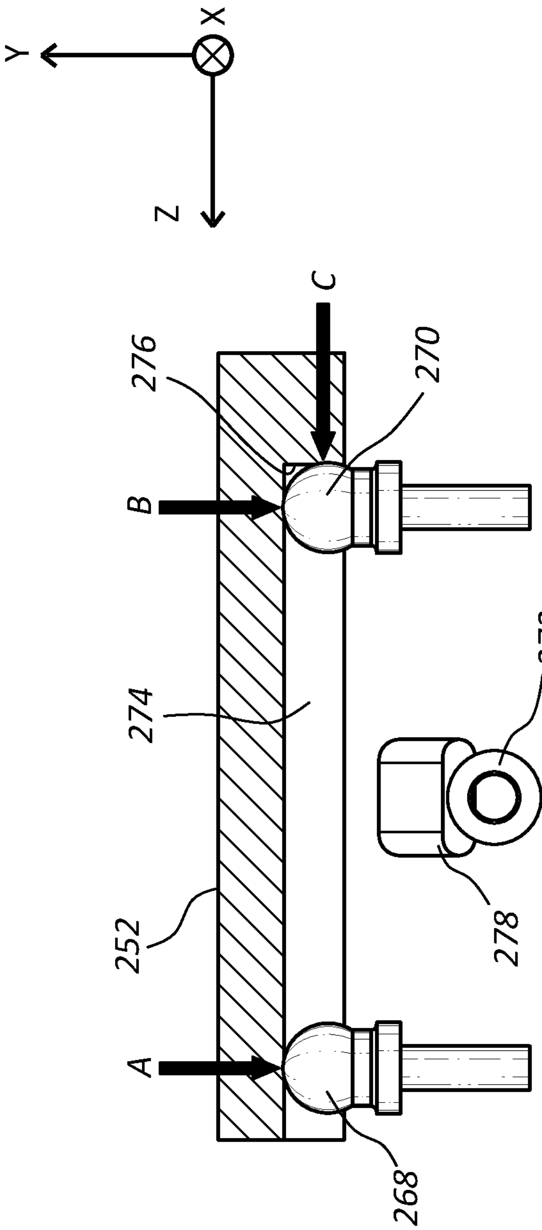
FIG. 8I



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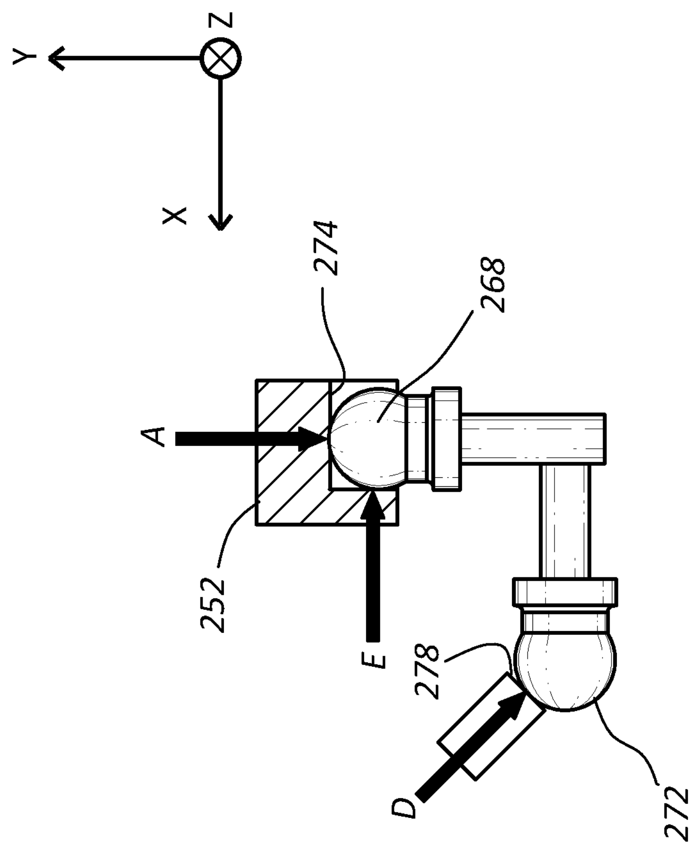

FIG. 10

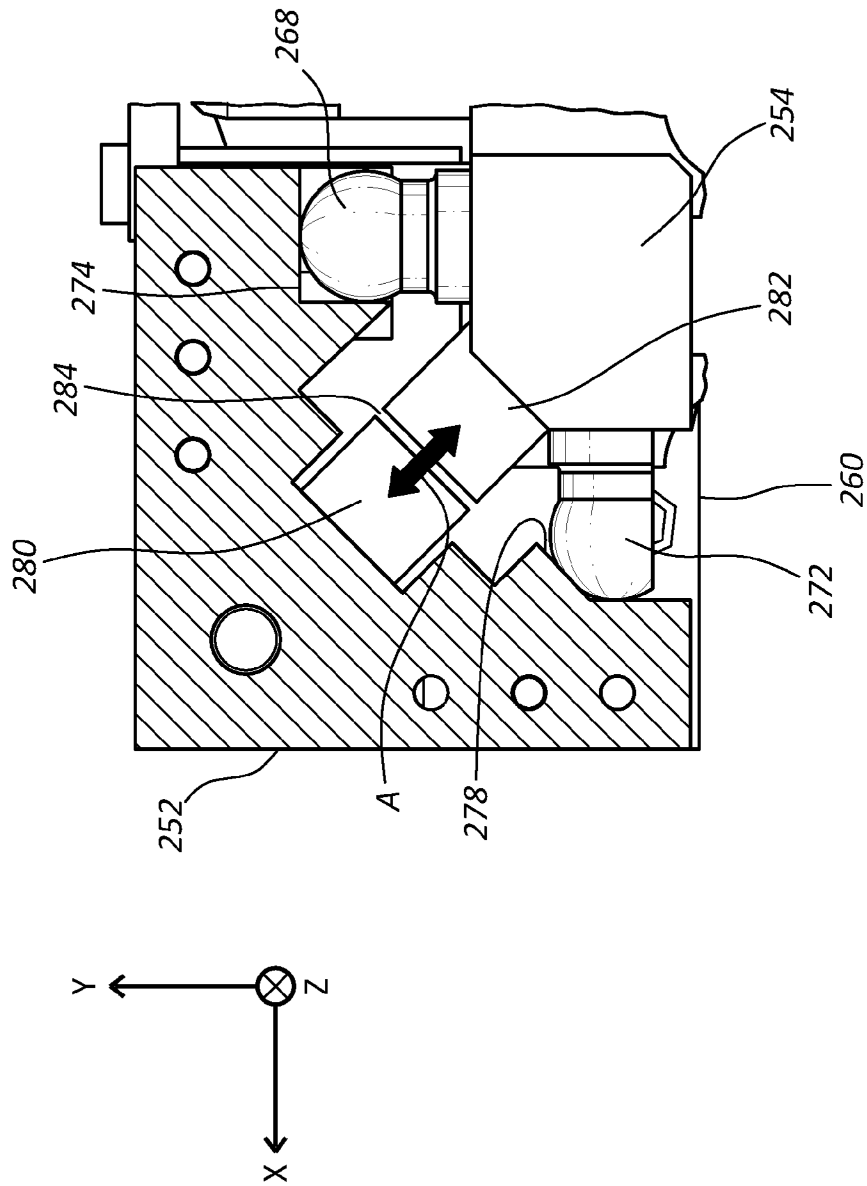

FIG. 11

MULTIPLE PETAL DEPLOYABLE TELESCOPE

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part of U.S. patent application Ser. No. 13/885,140, filed on May 13, 2015, and entitled MULTIPLE PETAL DEPLOYABLE TELESCOPE, which claims priority to PCT Application No. PCT/US2012/026782, filed Feb. 27,2102, and entitled MULRIPLE PETAL DEPLOYABLE TELESCOPE, which in turn claims priority to U.S. Provisional Patent Application No. 61/446,617, filed Feb. 25, 2011, and entitled MULTIPLE PETAL DEPLOYABLE TELESCOPE, the disclosures of which are incorporated by reference herein, in their entireties.

TECHNICAL FIELD

The present application relates generally to constrained volume optical systems, and more particularly relates to small package opto-mechanical telescope designs that provide relatively high signal levels and resolutions.

BACKGROUND

Small satellites offer promise for increased instrument presence in space as well as for tactical quick turn missions. However, small satellites fall short in optical performance due to their relatively small aperture size. Even the most precision optical instruments are limited by basic physics. With small aperture optical sensors in space, diffraction often limits the imaging resolution. For a circular aperture, this diffraction blur angle may be estimated using the following equation:

$$\text{blur angle}=(1.22\lambda)/D$$

Where λ is the wavelength and D is the diameter of the optical aperture. The diffraction limited imaging resolution is directly proportional to wavelength and inversely proportional to aperture extent or diameter regardless of the shape of the aperture.

In addition to the assumption of diffraction limitation, this simple relationship of resolution and optical aperture assumes that the viewed object radiance is sufficient for adequate signal to noise ratio. Grainy images and insufficient contrast, caused by a lack of signal or too much noise, are common manifestations of the lack of signal to noise ratio.

The same reasoning can be applied to sensors that are required to be transported when mass or volume is an important system driver. An optical system used for surveillance or communication may need to be transported by a human being, small vehicle, etc. The same physics discussed above concerning space sensors and aperture applies to resolution and signal in these and other situations.

A need exists for systems and methods that can overcome diffraction limitations and signal to noise limitations with improved optical performance.

SUMMARY OF THE INVENTION

One aspect of the present disclosure relates to an opto-mechanical deployable telescope that includes a hub, at least one deployable multiple petal primary mirror mounted to the hub, a deployment assembly, a deployment engine assembly, and a secondary optic assembly. The deployment assembly is operable to move the at least one primary mirror between a stowed position and a deployed position. The deployment engine assembly is operable to power the deployment assembly using stored mechanical energy. The secondary optic assembly includes a secondary optical member. The secondary optic assembly is mounted to the hub and operable to axially position the secondary optical member relative to the at least one primary mirror. The deployment assembly also includes a kinematic or semi-kinematic interface between the hub and the at least one primary mirror to hold petals of the at least one primary mirror in alignment relative to each other in the deployed position. Each petal of the at least one primary mirror is separately attached to the hub with a hinge connection. The hinge connection provides radial movement of the petals when in the deployed position that permits the deployment assembly rather than the hinge connection to control alignment of the petals.

In some examples, the secondary optic assembly may include a stationary base mounted to the hub, and an extension member mounted to the stationary base, wherein the secondary optical member is positionable by the extension member axially relative to the at least one primary mirror to optimize optical imaging on a focal plane. The telescope may include a plurality of locating members positioned between the stationary base and the extension member, wherein the plurality of locating members provide translational and rotational alignment between the stationary base and the extension member. The telescope may include at least one magnetic member operable to apply a magnetic connection between the stationary base and the extension member. The at least one magnetic member may include a first magnetic member carried by the stationary base and a second magnetic member carried by the extension member. The first and second magnetic members may be operable when the extension member is in an extended position relative to the hub. The telescope may include at least one guide track configured to interface with the plurality of locating members. The plurality of locating members may each comprise a spherical portion.

The telescope may include a guide rod coupled between the stationary base and the extension member, wherein the guide rod provides constrained movement of the extension member relative to the stationary base to relative axial movement. The telescope may include a guide cylinder receptive of the guide rod, wherein the guide cylinder is mounted to one of the stationary base and the extension member, and the guide rod is mounted to the other of the stationary base and the extension member. The telescope may include a compression spring operable to apply a biasing force between the extension member and the stationary base to move the extension member into an extended position relative to the stationary base, wherein the compression spring is arranged coaxially with and overlapping the guide rod and guide interface between the hub and the plurality of petals. The secondary optic assembly includes a secondary optical member and is mounted to the hub and operable to axially position the secondary optical member relative to the primary mirror. Each petal of the primary mirror is separately attached to the hub with a hinge connection. The hinge connection provides radial movement of the plurality of petals when in the deployed position that permits the deployment assembly rather than the hinge connection to control alignment of the plurality of petals.

In one example, the secondary optic assembly includes a stationary base mounted to the hub, and an extension member mounted and movable relative to the stationary base, wherein the secondary optical member is carried by the extension member. The telescope may include an alignment rod mounted to one of the stationary base and the extension member, and an alignment cylinder receptive of the alignment rod and mounted to the other of the stationary base and the extension member. The telescope may include a plurality of locating members operable between the stationary base and the extension member when the extension member is in a fully extended position to constrain movement between the extension member and the stationary base in multiple directions of movement.

A further aspect of the present disclosure relates to a method of deploying an opto-mechanical deployable telescope. The method includes providing a hub, at least one primary mirror mounted to the hub, a deployment assembly, and a secondary optic assembly mounted to the hub and comprising a secondary optical member, wherein the at least one primary mirror includes a plurality of petals. The method includes moving the plurality of petals from a stowed position to a deployed position with the deployment assembly, aligning the plurality of petals relative to each other with the deployment assembly while moving the plurality of petals into the deployed position, wherein aligning the plurality of petals includes providing a semi-kinematic interface between the plurality of petals and the hub, and operating the secondary optic assembly to adjust an axial position of the secondary optical member relative to the at least one primary mirror. Each petal of the at least one primary mirror is separately attached to the hub with a hinge connection, wherein the hinge connection provides radial movement of the plurality of petals when in the deployed position that permits the deployment assembly rather than the hinge connection to control alignment of the plurality of petals.

The secondary optic assembly may further include a extension member, a stationary base, and a plurality of alignment members, and the method may further include extending the extension member axially relative to the stationary base, and constraining movement of the extension member relative to the stationary base with the plurality of alignment members to align the secondary optical member relative to the at least one primary mirror. The plurality of alignment members may include a guide cylinder, a guide rod extending into the guide cylinder, at least one locating surface, a plurality of locating members configured to interface with the at least one locating surface, and at least one magnetic member operable to apply a magnetic force to draw the extension member toward the stationary base.

Features from any of the above-mentioned embodiments may be used in combination with one another in accordance with the general principles described herein. These and other embodiments, features, and advantages will be more fully understood upon reading the following detailed description in conjunction with the accompanying drawings and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings illustrate a number of exemplary embodiments and are a part of the specification. Together with the following description, these drawings demonstrate and explain various principles of the instant disclosure.

FIG. **1** is a perspective view of an example opto-mechanical deployable telescope in a stowed position in accordance with the present disclosure.

FIG. **2** is a perspective view of the opto-mechanical deployable telescope of FIG. **1** in a deployed position.

FIG. **3**A is a perspective view of a portion of another example opto-mechanical deployable telescope in a stowed position in accordance with the present disclosure.

FIG. **3**B is a side view of the opto-mechanical deployable telescope of FIG. **3**A.

FIG. **3**C is a front view of the opto-mechanical deployable telescope of FIG. **3**A.

FIG. **3**D is a cross-sectional perspective view of the opto-mechanical deployable telescope of FIG. **3**C taken along cross-section indicators **3**D-**3**D.

FIG. **4**A is a perspective view of the opto-mechanical deployable telescope of FIG. **3**A in a partially deployed position in accordance with the present disclosure.

FIG. **4**B is a side view of the opto-mechanical deployable telescope of FIG. **4**A.

FIG. **4**C is a front view of the opto-mechanical deployable telescope of FIG. **4**A.

FIG. **4**D is a cross-sectional perspective view of the opto-mechanical deployable telescope of FIG. **4**C taken along cross-section indicators **4**D-**4**D.

FIG. **5**A is a perspective view of the opto-mechanical deployable telescope of FIG. **3**A in a deployed position in accordance with the present disclosure.

FIG. **5**B is a side view of the opto-mechanical deployable telescope of FIG. **5**A.

FIG. **5**C is a front view of the opto-mechanical deployable telescope of FIG. **5**A.

FIG. **5**D is a cross-sectional perspective view of the opto-mechanical deployable telescope of FIG. **5**C taken along cross-section indicators **5**D-**5**D.

FIG. **6** is an exploded perspective view of the opto-mechanical deployable telescope of FIGS. **3**A-**5**D.

FIG. **7**A is a front perspective view of the opto-mechanical deployable telescope of FIG. **3**A with a secondary optic assembly in a stowed position in accordance with the present disclosure.

FIG. **7**B is a rear perspective view of the opto-mechanical deployable telescope of FIG. **7**A.

FIG. **7**C is a right side view of the opto-mechanical deployable telescope of FIG. **7**A.

FIG. **7**D is a left side view of the opto-mechanical deployable telescope of FIG. **7**A.

FIG. **7**E is a front view of the opto-mechanical deployable telescope of FIG. **7**A.

FIG. **7**F is a rear view of the opto-mechanical deployable telescope of FIG. **7**A.

FIG. **7**G is a top view of the opto-mechanical deployable telescope of FIG. **7**A.

FIG. **7**H is a bottom view of the opto-mechanical deployable telescope of FIG. **7**A.

FIG. **7**I is an exploded perspective view of the opto-mechanical deployable telescope of FIG. **7**A.

FIG. **8**A is a perspective view of the opto-mechanical deployable telescope of FIG. **7**A with the secondary optic assembly in a deployed position in accordance with the present disclosure.

FIG. **8**B is a rear perspective view of the opto-mechanical deployable telescope of FIG. **8**A.

FIG. **8**C is a right side view of the opto-mechanical deployable telescope of FIG. **8**A.

FIG. **8**D is a left side view of the opto-mechanical deployable telescope of FIG. **8**A.

FIG. **8**E is a front view of the opto-mechanical deployable telescope of FIG. **8**A.

FIG. **8**F is a rear view of the opto-mechanical deployable telescope of FIG. **8**A.

FIG. **8**G is a top view of the opto-mechanical deployable telescope of FIG. **8**A.

FIG. **8**H is a bottom view of the opto-mechanical deployable telescope of FIG. **8**A.

FIG. **8**I is an exploded perspective view of the opto-mechanical deployable telescope of FIG. **8**A.

FIG. **9** is a side view of a portion of the alignment assembly of the opto-mechanical deployable telescope of FIG. **8**A.

FIG. **10** is an end view of a portion of the alignment assembly of the opto-mechanical deployable telescope of FIG. **8**A.

FIG. **11** is a another end view of a portion of the alignment assembly of the opto-mechanical deployable telescope of FIG. **8**A.

While the embodiments described herein are susceptible to various modifications and alternative forms, specific embodiments have been shown by way of example in the drawings and will be described in detail herein. However, the exemplary embodiments described herein are not intended to be limited to the particular forms disclosed. Rather, the instant disclosure covers several modifications, equivalents, and alternatives falling within the scope of the appended claims.

BEST MODE(S) FOR CARRYING OUT THE INVENTION

Detailed Description

The present disclosure is directed to deployable telescopes, and more specifically related to opto-mechanical deployable telescopes. One aspect of the present disclosure relates to deployment and alignment systems for a multiple petal primary mirror of the telescope. The alignment system may use a kinematic or semi-kinematic (also referred to as "quasi-kinematic") constraint system to align the petals relative to each other when the primary mirror is in a deployed position. The primary mirror may have a passive alignment and deployment system that uses stored mechanical energy to deploy the petals and orient the petals relative to each other. The stored mechanical energy may concurrently deploy the petals and align the petals relative to each other. The alignment system for the primary mirror may include a plurality of precision-machined interfaces that define the kinematic or semi-kinematic constraints that provide positioning of the petals of the primary mirror in a deployed position that is repeatable each time the primary mirror is deployed.

Another aspect of the present disclosure relates to a telescope system that provides a larger entrance aperture than the package in which the telescope is initially housed. For example, the deployable telescope described herein may support persistent space-based imaging by enabling the use of larger imaging systems that rely on active structures and mechanisms. Pico-size cube satellites containing the deployable telescopes described herein may support tactically responsive missions. Doubling the aperture size may provide at least twice the diffraction limited performance and may produce increased radiometric sensitivity for viewing extended sources. Alternatively, the deployable telescope may support free space laser communications by achieving a larger aperture and hence increased signal levels that may otherwise be realized from a small package volume.

Another aspect of the present disclosure relates to a secondary optic assembly mounted to a hub of the telescope. The secondary optic assembly includes a secondary optical member that is positionable axially relative to the primary mirror to optimize optical imaging on a focal plane of the telescope. The secondary optic assembly includes an extension feature that provides the axial positioning of the secondary optical member relative to the primary mirror. The secondary optic assembly further includes a plurality of alignment features that assist in establishing a fixed positioning of the secondary optical member relative to the primary mirror when the secondary optical member is arranged in a fully extended position relative to the primary mirror. One alignment feature includes a guide rod insertable and slidable within an elongate guide cylinder. Another alignment feature includes a plurality of locating members that mate with alignment surfaces (e.g., V-shaped tracks, etc.) that constrain movement in various translational and rotational directions. Other alignment features include one or more magnetic members that apply magnetic forces that draw features of the secondary optic assembly toward each other, such as when the secondary optical member is in a fully extended position. In some embodiments, the one or more magnetic members hold the locating members in contact with the alignment surfaces when the secondary optical member is in a fully extended position.

In one example, the deployable telescope designs disclosed herein may provide a means for achieving higher signal levels and resolution in a smaller stowed package size. In one example, the deployable telescope may be launched on a 10 cm size cube satellite and provide a partial aperture primary mirror having a deployed size of about 23 cm. This ratio of stowed versus deployed size may be accomplished by incorporating multiple foldout primary mirror petals as part of the primary mirror. The deployable telescope size may be scaled with the package size so that the deployable telescope design may be applied to larger telescopes such as meter-class apertures stowed in 40 cm cube packages.

Referring to FIGS. **1** and **2**, an example opto-mechanical deployable telescope **10** is shown in stowed and deployed positions, respectively. The telescope **10** includes a primary mirror **12**, a support structure **14**, an engine assembly **16**, baffling **18**, an alignment system **20**, and a chassis hub **24**. Various features included in the support structure **14**, engine assembly **16**, alignment system **20** and hub **24** may be included in a deployment assembly or an alignment assembly of the telescope **10** that operates to move the primary mirror **12** between stowed and deployed positions. The telescope **10** in the stowed position of FIG. **1** may have a maximum width W_1. The telescope in the deployed position (e.g., see FIG. **5**C) may have an effective opening size of W_2. The deployed width W_2 is typically at least twice as great as the stowed width W_1.

The primary mirror **12** includes a plurality of petal members that move between stowed (see FIG. **1**) and deployed (see FIG. **2**) positions. The support structure **14** includes a secondary mirror **50** that moves from a stowed position (see FIG. **1**) to a deployed position (see FIG. **2**) by operation of an extension member **52**. The engine assembly **16** includes at least one stored energy engine operable to move the petals of the primary mirror between the stowed and deployed positions, and operate the support structure **14** to move the secondary mirror **50** into the deployed position shown in FIG. **2**.

In one example, the engine assembly **16** includes a separate engine that operates each individual petal of the primary mirror. The engine assembly may also include a separate engine that operates the support structure **14**. In some examples, the engine assembly may also include at least one engine that operates the baffling **18** from the stowed to the deployed positions shown in FIGS. **1** and **2**, respectively. The engines of the engine assembly **16** may comprise at least one biasing member or spring **17** (see FIG. **1**). The biasing member may be, for example, a compression, extension or coil spring. The engines of the engine assembly may be actuated automatically upon release of the primary mirror **12** or baffling **18** (e.g., when the baffling **18** is released, the primary mirrors **12** are free to move to the deployed position under power of the engine assembly **16**).

Other types of stored energy engines (also referred to as stored energy motors or power devices) may be used to deploy various features of telescope **10**. For example, individual devices driven by actuation of a shape memory material such as a shape memory alloy may be used to deploy petals of the primary mirror **12** or portions of the baffling **18**. The actuator devices may be complex or simply a shape memory alloy or shape memory composite material that when heated with an electrical current moves to a pre-memorized form or shape releasing or pulling the deployment feature with it. In one concept (not shown), a folded nitinol rod is attached to the petal spar and base hub structure. This nitinol has been conditioned to straighten when heated. Deployment of the petal is actuated by an electrical current heating the nitinol rod causing the rod to straighten pulling the spar and the petal into the deployed position.

The baffling **18** may include a plurality of baffling cover members **70** (one of which is removed in FIG. **1** for visualization purposes), an expandable baffling portion **72**, baffling hinges **74**, a cylindrical baffle **76**, and an actuator **78**. The expandable baffling portion **72** may extend between each of the baffling cover members **70** (see FIG. **2**). The baffling cover members **70** may be pivotally mounted to the hub **24** with the baffle hinges **74**. The cylindrical baffle **76** may expand axially and radially upon release of the baffling cover members **70**. In one example, the cylindrical baffle **76** extends further distally than a position of the secondary mirror **50** in the deployed position shown in FIG. **2**. The actuator **78** may be remotely operated to release the baffling cover members **70**. In one example, the actuator **78** comprises a bolt cutter or release mechanism, which when actuated permits the baffling cover members to open into the deployed position shown in FIG. **2**.

The petal members of the primary mirror **12** provide an aperture larger than the size of the initial stowed package of FIG. **1**. This approach makes possible a sparse aperture that approximates a full circle aperture, which, in this example, is a cross-shaped aperture that has full diffraction performance in both tangential and saggital planes, but reduced resolution on the diagonals.

The primary mirror petals may utilize positive deploying and locking clamp hinges and other alignment features. In one example, at the extent of hinge rotation in a deployed position, out of ramp features push the deployed petal inward and downward into a precision, kinematic or semi-kinematic alignment interface. Precision locating seats and diameters may be manufactured flat and perpendicular with high accuracy. A compressed spring engine or other stored energy device may provide positive pressure to hold the mirror petals in a final deployed position wherein each petal is aligned relative to the others without the need for additional adjustment using alternative adjustment means. The secondary mirror may deploy in a similar fashion with the mechanism providing positive pressure through a precision kinematic or a semi-kinematic alignment interface.

The cylindrical baffle **76** may be referred to as a cylindrical sun-shade baffle membrane that surrounds the primary mirror petals. The cylindrical baffle **76** may reduce stray light from reaching a radiation detector position within the hub **24**. The cylindrical baffle **76** may also provide thermal radiation shielding in orbit, thus minimizing thermal irradiants. The baffling **18** may include a spring-loaded collapsible structure, thermal blankets, and high emissivity materials with flexible rigid supports providing longitudinal stiffness. Portions of the baffling **18** (e.g., the cylindrical baffle **76**) may spring into a cylindrical shape when released. The flexible rigid supports may utilize a tape-measure type cross-section that is flexible when bent or buckled, but provides substantial stiffness when extended. In other embodiments, the baffle **18** comprises a polymeric membrane without a defined form in the stowed position. Upon release and exposure to ultraviolet radiation, at least the cylindrical baffle **76** forms a trans-cylindrical shape.

In satellite applications, precision alignment and stability of the deployable telescope may be reliably attained in the spacecraft environment under severe launch vibration and shock, exposure to thermal environments, and lengthy stowed storage. For terrestrial free-space laser communications and surveillance applications, the same precision alignment and stability may be attained after rough transportation, uncertain thermal conditions, and storage. The optical imaging performance of the deployable telescope is typically sensitive to the alignment of the primary mirror petals and the secondary mirror alignment. Precision mechanism alignment of these elements is usually an important objective of the design. Precision features on the primary and secondary mirrors **12**, **50** may include, for example, precision machined features that provide precision alignment. Positive force acting through mating interfaces using minimal lubrication may provide improved reliable precision mating.

In one example, the radiation detector (not shown) may have a detector focus that is set in the lab prior to launch. In other embodiments, the detector is focused in initial systems set up using a focus adjustment system. In some optical designs, a primary mirror and secondary mirror may use additional mirrors and/or refractive lenses for improved performance and possible reduced tolerance sensitivity.

The opto-mechanical deployable telescope designs disclosed herein may allow the radiation detector to view the primary mirror voids and associated background irradiance. This background irradiance may then be compensated for in the image utilizing progressive non-uniformity compensation (NUC). This NUC procedure may include taking frames of data interspersed with periodic acquisition of NUC frames. The NUC frames present a local average irradiance within the frame and may be subtracted from the data frames, thereby moving most of the contrast inhibiting background. Multiple methods to acquire the NUC image exist, including, but not limited to, moving an optical element, changing the optical pathway, and inserting a diffraction or scatter element.

The rear baffle of the baffling **18** (e.g., the combination of baffling cover members **70** and expandable baffling portion **72**) may contribute to the background flux, which may reduce sensor sensitivity. The primary mirror petals may scatter light, which may also contribute to the background flux. In other embodiments, the optical design includes an intermediate focus and a Lyot stop to prevent the detector from seeing the rear baffle through the petal gaps. The Lyot stop may block a portion of the stray light. The Lyot stop may be an aperture stop placed at an exit pupil of the telescope, which in some embodiments is the image of the primary mirror aperture. The Lyot stop shape may match the shape of the primary mirror and block the radiation detector from viewing the primary mirror voids and the structure exposed behind it. The Lyot stop may be cooled to further reduce the background irradiants viewed by the detector.

The chassis hub **24** is part of a base structure in the examples disclosed herein. The base fulfills many functions, only one of which is a hub (e.g., chassis hub) for the mirror. In some arrangements, the chassis hub **24** may be a separate piece from the rest of the base. In some examples, portions of the chassis hub **24** may include a polished mirror surface providing an additional (5^{th}) segment of the mirror.

The terms kinematic and semi-kinematic are used herein to describe constraints for at least the purpose of aligning the petals of the telescope mirrors. Kinematic constraints allow a body to be held with the highest precision, exactly constraining each of the six degrees of freedom. Semi-kinematic constraints allow a small amount of over constraint while providing high precision.

Any object in three-dimensional space may be defined with six independent coordinates: X, Y, and Z (three translation), and yaw, pitch, and roll (three rotation). When each of these degrees of freedom is constrained fully and none are over constrained, the system is considered to be kinematically constrained. The theory of kinematic design requires perfectly rigid bodies that touch only at a point or points (e.g., point contacts). When slight over constraints are allowed, the constraint is considered semi-kinematic. The kinematic constraint requires six point contacts that contain all six degrees of freedom. A hard sphere typically provides a good point contact when it meets another hard surface, which is why spheres are typically used in kinematic constraints. Whenever there is a degree of freedom that is not constrained, the system is under constrained. This happens when there are less than six point contacts, but it can still occur with six or more points. An example of a kinematically constrained system includes three balls that interface with a cone, a V-channel and a flat, or with three V-channels. The ball/cone interface has three point contacts, thus effectively constraining all three translations. The ball/groove contact has two point contacts, thus constraining roll and yaw. The ball/flat contact has one point contact, thus constraining pitch. Typically, the balls are positioned at corners of a triangle.

A semi-kinematic scenario may include replacing any one of the balls with a cylinder, or in some way replacing one of the point contacts with a line contact or flat surface. Kinematic and semi-kinematic systems may provide holding of a body with high precision, motion with little or no backlash or play, and repeatable, removable and replacement of a part in the same location. As discussed further herein, the kinematic and/or semi-kinematic features included in the example telescopes disclosed herein may assist in optical alignment. In a semi-kinematic mount, stresses may be significantly lower than in a kinematic mount. Further details concerning kinematic and semi-kinematic constraint is described in "*Kinematic and Quasi-Kinematic Constraints: What They Are and How They Work*," Fellowes, David, December 2006, which is incorporated herein in its entirety by this reference.

Referring now to FIGS. **3A-6**, another example opto-mechanical deployable telescope **100** is shown and described. The telescope **100** includes a primary mirror **112**, an engine assembly **116**, an alignment system **120**, a radiation detector **122**, and a hub **124**. The telescope **100** may also include a support structure for a secondary mirror and baffling similar to those features shown in FIGS. **1** and **2**, which have been removed for purposes of more clearly describing the alignment system **120**.

Referring first to FIGS. **3A** and **6**, the primary mirror **112** (also referred to as a multiple petal primary or segmented mirror) includes first, second, third and fourth petals **30**, **32**, **34**, **36** that are equally spaced apart circumferentially. The petals **30**, **32**, **34**, **36** may each be attached to the hub **124** with a hinge member **38** and may each include a first alignment seat **40**, a clamp surface **42**, a mirror surface **44** (see FIG. **5A**), a cable connector **46**, and an alignment protrusion **48**. The first alignment seat **40** may be constructed as a V-groove. The alignment protrusion **48** (see FIG. **6**) may include an axial alignment surface **47** and a radial alignment surface **49**. The axial and radial alignment surfaces **47**, **49** may be constructed as toroidal bumps or protrusions that interface with related alignment features on the hub **124** when the primary mirror **112** is in the deployed position shown in FIGS. **5A-5D** to hold the petals of the primary mirror **112** in a predetermined aligned position. The alignment protrusion **48** may be part of a semi-kinematic mounting of the petals of the primary mirror **112** to the hub **124**. The first alignment seat **40** may also be part of a semi-kinematic mounting of the petals of the primary mirror **112** to the hub **124**. In at least some arrangements, the first alignment seat **40** and alignment protrusion **48** may be part of an alignment system of the telescope **100**.

The engine assembly **116** includes a cable alignment member **60**, a cable **62**, and engine **64**, and a cable support **66** for each of the petals **30**, **32**, **34**, **36** of the primary mirror **112**. The cable may have distal and proximal ends **61**, **63**. The distal end **61** is connected to one of the petals of the primary mirror **112** with a cable connector **46**. The proximal end **63** extends through the cable alignment member **60** into the engine **64** where the engine **64** applies tension in cable **62** to move the petal from the stowed position of FIG. **3A** to the deployed position of FIG. **5A**. The engine **64** may be a stored energy engine or related stored energy device. In one example, the engine **64** includes a spring or other biasing member. The engine **64** may spool or collect the cable **62**. Many types of stored energy devices may be used for engine **64**. Preferably, the engine **64** may be configured to operate without a source of electrical power such as a battery.

In some arrangements, the engine assembly **116** includes a single engine that operates a plurality of the petals of primary mirror **112**. The engine assembly **116** may also operate a support structure and associated secondary mirror, an additional primary mirror, and baffling of the telescope (not shown). Separate engines, motors, or desired stored energy devices may be used to operate each mirror, mirror petal deployment feature, and baffling feature of the telescope, or in other arrangements may operate multiple features of the telescope.

The alignment system **120** is shown and described with reference to FIGS. **3A**, **4A**, **5A** and **6**. The alignment system **120** includes a clamp support **80**, a clamp **82**, a track **84**, a spar **86**, a spar locating seat **88**, and first and second spar alignment members **90**, **92**. The clamp support **80** positions the clamp **82** on the clamp surface **42** of a petal of the primary mirror **112**. When the petal is in the deployed position of FIGS. **5A-5D**, the clamp **82** applies a radially inward directed force on the petal to hold the alignment protrusion **48** of the petals against the alignment features of the chassis hub **124** as described in further detail below.

The spar **86** includes distal and proximal ends **85**, **87**. The first spar alignment member **90** is mounted to the distal end **85** and positioned within the first alignment seat **40** of the petals. The second spar alignment member **92** is mounted to the proximal end **87** of spar **86**. The proximal end **87** travels within track **84** to move the second spar alignment member **92** from a position spaced apart from the spar locating seat **88** (see FIGS. **3A-4D**) to a position in contact with the spar locating seat **88** (see FIGS. **5A-5D**). The spar **86** may include at least one follower member **89** (see FIG. **6**) that retains spar **86** in contact with and moving along track **84**.

The hub **124** may include a support surface **27** and axial and radial alignment members **25**, **26** (see FIGS. **3D**, **4D**, **5D** and **6**). The axial alignment member **25** is mounted to the support surface **27**. The support surface **27** may be positioned in a rotational path of movement of the alignment protrusion **48** on the petals of primary mirror **112**. The axial and radial alignment members **25**, **26** are positioned at a location in which the axial and radial alignment surfaces **47**, **49** of the alignment protrusion **48** contact the axial and radial alignment members **25**, **26** to provide a final deployed position for the mirror petals. The axial and radial alignment members **25**, 26 may be referred to as axial and radial seats or toroidal bumps. The axial and radial alignment members 25, 26 may provide a point contact for the alignment protrusion 48 in axial and radial directions. The axial and radial alignment members 25, 26 may have a small flat feature formed thereon at a location in which the alignment protrusion 48 contacts the axial and radial alignment members 25, 26.

In operation, the telescope 100 moves from a stowed position shown in FIGS. 3A-3D, to an intermediate deployed position shown in FIGS. 4A-4D, to a fully deployed position shown in FIGS. 5A-5D. The engine assembly 116 operates to pull the petals of primary mirror 112 from the stowed position shown in FIGS. 3A-3D through a rotation angle to the deployed position shown in FIGS. 5A-5D. The spar 86 moves along track 84 while the petals rotate about hinge member 38. An interface between hinge member 38 and an aperture of the petal within which the hinge member 38 resides has a gap that provides some "slop" or radial movement between the hinge member 38 and the aperture. The hinge member 38 guides the petal through the pivot rotation toward the deployed position so that the precision surfaces of the alignment protrusion 48 and the axial and radial alignment members 25, 26 and support surface 27 can interface and control a final position of the petal without the hinge member 38 controlling in a non-precise manner.

In a deployed position, the position of each of the petals of primary mirror 112 are controlled by the interface between the first spar alignment member 90 and the first alignment seat 40, the second spar alignment member 92 and the spar locating seat 88, the axial alignment surface 47 of alignment protrusion 48 and the axial alignment member 25, and the radial alignment surface 49 of the alignment protrusion 48 and the radial alignment member 26. This semi-kinematic mount of the petals of primary mirror 112 to the hub 124 is provided, at least in part, by the alignment system 120 and other features of the petals of primary mirror 112 and hub 124.

The features of telescope 100 shown in FIGS. 5A-5D provide concurrent deployment of the primary mirror 112 and alignment of each of the petals of the primary mirror 112 relative to each other using a semi-kinematic mounting of the petals to hub 124. Once the petals of primary mirror 112 are in the deployed position, no further adjustment of the petals may be required in order to provide relatively precise alignment of the petals relative to each other. As such, the need for secondary adjustment features such as actuators and small motors that require additional power and remote control can be eliminated from the telescope. Also, feedback mechanisms such as wavefront sensors that control the aforementioned actuators or motors can be eliminated. Further, in one embodiment, the clamp 82 provides a radially inward directed force that holds the petals of primary mirror 112 against the axial and radial alignment members 25, 26 so that the alignment of the petals of primary mirror 112 is maintained during operation of telescope 100 in the deployed position.

Other types of features and structures for the telescope may be used to provide the desired kinematic or semi-kinematic mounting of the petals of primary mirror 112 to the hub 124. The examples described herein are merely exemplary of the application of the principles of applying semi-kinematic mounting for an opto-mechanical deployable telescope are embodied in the examples disclosed herein. Furthermore, various components of the telescopes disclosed herein may be rearranged to provide a similar outcome. In one example, the first and second spar alignment members are carried by the petals of the primary mirror and the hub, respectively, and the spar carries a V-groove and conical recess to receive the first and second spar alignment members.

FIGS. 7A-11 illustrate another example opto-mechanical deployable telescope 200 in stowed and deployed positions. Opto-mechanical deployable telescope 200 may be an example of the opto-mechanical deployable telescope 100 described with reference to FIGS. 1-6.

FIGS. 7A-7I show the opto-mechanical deployable telescope 200 with a secondary optic assembly 214 in a stowed or retracted position, and the pedals 30, 32, 34, 36 of the primary mirror 112 in stowed or retracted positions. FIGS. 8A-8I show the opto-mechanical deployable telescope 200 with the secondary optic assembly 214 in a deployed or extended position, and the pedals 30, 32, 34, 36 of the primary mirror 112 in deployed or extended positions. At least some features and functionality of the opto-mechanical deployable telescope 200 include the same or similar features and functionality of the opto-mechanical deployable telescope 100 described above with reference to FIGS. 3A-6. The secondary optic assembly 214 may be one example of and/or be used in place of the support structure 14 (including secondary mirror 50 with extension member 52) described above with reference to FIGS. 1 and 2.

FIGS. 7A-7H show the opto-mechanical deployable telescope 200 with the secondary optic assembly 214 in a stowed or retracted position. The secondary optic assembly 214 includes a secondary optical member 250, an extension member 252, and a base (e.g., stationary base) 254. FIG. 7I is an exploded view showing all of the components of secondary optic assembly 214. Only some of the components of secondary optic assembly 214 are visible in the various views of FIGS. 7A-7H.

Referring to FIG. 7I, the secondary optic assembly 214 further includes an optical mount 256, a compression spring 258, a spring mount 260, a dragline 262 (also referred to as a release member 262), a guide rod 264, and a guide cylinder 266. The guide rod 264 extends into and/or through guide cylinder 266. Guide rod 264 is mounted directly to spring mount 260. Guide cylinder 266 is mounted to extension member 252. The guide rod 264 and guide cylinder 266 extend through compression spring 258. Compression spring 258 may be connected to one or both of extension member 252 and spring mount 260. In other embodiments, the guide rod 264 may be mounted to extension member 252 and guide cylinder 266 may be mounted to spring mount 260.

Compression spring 258 is shown in a compressed state in FIGS. 7A-7H. The compression spring 258 is maintained in the compressed state by maintaining tension in drag line 262, which extends through spring mount 260 and is secured to extension member 252. One end of dragline 262 may be connected to extension member 252, or a component that is directly connected to extension member 252. An opposite end of dragline 262 may be attached to a dampening mechanism such as, for example, a friction clamp, a decurrent damper, or the like. In some examples, the free end of drag line 262 may be connected to another type of release mechanism, which when actuated releases the drag line to permit the compression spring 258 to apply a biasing force that moves the extension member 252 axially away from the primary mirror 112 and hub 124.

An interface between guide rod 264 and guide cylinder 266 limits movement of extension member 252 relative to primary mirror 112 in an axial translational movement relative to the primary mirror 112. Other alignment features of the secondary optic assembly 214 may constrain movement of extension member 252 relative to the primary mirror 112 in other directions or types of movement (e.g., rotational movement or translational movement in other directions besides along a Z axis direction).

FIGS. **8A-8H** show the extension member **252** in a fully extended or deployed position relative to the primary mirror **112**. The extension member **252** may maintain the extended position due at least in part to the biasing forces applied by compression spring **258**. The extension member **252** may be retracted into the fully stowed or retracted position shown in FIGS. **7A-7H** by applying tension in dragline **262**. Applying tension in drag line **262** moves the guide cylinder **266** along the guide rod **264** until, for example, a proximal end of extension member **252** contacts spring mount **260**.

FIGS. **8I-11** show additional alignment features for secondary optic assembly **214**. The additional alignment features include, for example, first, second and third locating members **268**, **270**, **272**, a guide track **274** having an end surface **276** (see FIG. **9**), a further alignment surface **278**, and first and second magnetic preload members **280**, **282** (see FIG. **11**). The additional alignment members may be particularly useful in providing a fixed position for the secondary optical member **250** relative to the stationary base **254** (which maintains a fixed position relative to the primary mirror **112**) when the extension member **252** is in a fully extended position, as shown in FIGS. **8A-8H**.

FIG. **9** is a side view showing contact between the first and second locating members **268**, **270** and the guide track **274** at points A and B, respectively, when the extension member **252** is in a fully extended position. FIG. **9** also shows the third locating member **272** in contact with alignment surface **278**. FIG. **9** shows contact between the first and second locating members **268**, **270** and the guide track **274** in the Y direction and contact between the second locating member **270** and the end surface **276** at a point C in the Z direction to constrain movement of the extension member **252** in the Y and Z directions. FIG. **10** shows contact between the first locating member **268** and surfaces of the guide track **274** to constrain movement in the X and Y directions.

The motion constraint shown for first locating member **268** in FIG. **10** also applies to second locating member **270**. FIG. **10** shows motion constraint provided by third locating member **272** at a point D in the XY direction against alignment surface **278**. FIG. **10** shows the guide track **274** having a V-shape, which may be referred to as a trough, a track shape, or a V-channel. The interface between first and second locating members **268**, **270** and the guide track **274** may provide two points of contact for each of the first and second locating members **268**, **270** (i.e., in the X direction at point E (see FIG. **10**) and Y direction at points A (see FIGS. **9** and **10**) and B (see FIG. **9**)). Second locating member **270** may have a third contact point C with the guide track **274** at end surface **276** (in the Z direction as shown in FIG. **9**). The contact between second locating member **270** and end surface **276** may provide an end stop for relative axial movement between the stationary base **254** (and the primary mirror **112**) and extension member **252** (which carries secondary optical member **250**). The third locating member **272** may be positioned relative to second locating member **270** so that third locating member **272** is aligned with and contacts alignment surface **278** when second locating member **270** contacts end surface **276**.

In other arrangements, less than three locating members may be used to provide the desired movement constraints that limit translational and/or rotational movement of extension member **252** relative to stationary base **254**. In still further embodiments, more than three locating members may be used with associated guide tracks and/or surfaces to provide the desired amount of movement constraint in various translational and rotational movements.

Various shapes may be possible for the locating members besides the generally spherical shape of the first, second and third locating members **268**, **270**, **272** and the generally planar contact surfaces provided by the guide track **274**, end surface **276**, and alignment surface **278**. For example, any one of the guide track **274**, end surface **276** and alignment surface **278** may include a multi-surface construction, a concave or convex shape, or other contoured or curvilinear shape. Any one of the first, second and third locating member **268**, **270**, **272** may have other shapes such as planar surfaces that interface with mating surfaces of the guide track **274**, end surface **276**, and/or alignment surface **278**.

The spherical contact surfaces of the first, second and third locating members **268**, **270**, **272** may provide limited friction at the interface with extension member **252** and/or other surfaces (e.g., alignment surface **278**) that provides improved ease in moving the extension member **252** between retracted and extended positions. Reducing friction forces at these interfaces may provide energy conservation, particularly in applications where telescope **200** is being used in environments (e.g., outer space) that have a limited power supply allocated for operating the telescope features between stowed and deployed positions.

Referring now to FIG. **11**, an end view of a portion of secondary optic assembly **214** shows the first and second magnetic preload member **280**, **282**, aligned with and facing each other when the extension member **252** is in the fully extended position of FIGS. **8A-8H**. The magnetic preload members **280**, **282** apply a magnetic force to each other in the direction A shown in FIG. **11** to draw the extension member **252** in a lateral direction towards stationary base **254**. These magnetic forces in the direction A help maintain contact between the first, second and third locating member **268**, **270**, **272** and the respective guide track **274**, end surface **276** and/or alignment surface **278**. Maintaining contact of these alignment features may provide improved stability and maintenance of the aligned orientation of secondary optical member **250** relative to the primary mirror **112** when the secondary optic assembly **214** is in the fully extended position shown in FIGS. **8A-8H** and/or in various partially extended positions.

In at least some examples, an air gap **284** exists between the magnetic preload members **280**, **282** (see FIG. **11**). The air gap **284** may provide a bearing surface between the magnetic preload members **280**, **282** with limited and/or reduced friction. The air gap **284** may provide for a frictionless preload applied between extension member **252** and stationary base **254**. The magnetic preload members **280**, **282** may be replaced with, for example, springs, flexures, pistons, clamps, and other devices and/or components that apply a load and/or force that maintains contact between the locating members **268**, **270**, **272** and the guide track **274**, end surface **276**, and alignment surface **278**, and/or other alignment features of the secondary optic assembly **214** when in the extended position.

In some embodiments, the magnetic preload members **280**, **282** may provide sufficient preload forces to hold the extension member **252** in a predetermined axial position relative to stationary base **254** without providing a positive stop interface in the axial direction (e.g., contact between second locating member **270** and end surface **276**). The magnetic forces applied between magnetic preload members **280**, **282** may be sufficiently small that the forces can be overcome by applying a predetermined tension force in drag line **262** when operating the extension member **252** from the extended position shown in FIGS. **8A-8H** to the retracted position shown in FIGS. **7A-7H**.

FIGS. **7**A and **8**A show mounting of the secondary optic assembly **214** to hub **124** without obstructing movement of the pedals **30**, **32**, **34**, **36** between the stowed position of FIG. **7**A and the extended or deployed positions of FIG. **8**A. The secondary optic assembly **214** is shown positioned between the pedals **30**, **36** at one location around the circumference of hub **124**. In other arrangements, secondary optic assembly **214** may be secured to hub **124** at other and/or additional locations around a circumference of hub **124**.

A distance at which secondary optical member **250** may be positioned axially away from primary mirror **112** may be defined substantially by a length L of extension member **252** (see FIG. **7**I). In at least some arrangements, the guide rod **264** may disengage from the guide cylinder **266** when the extension member **252** is in the fully extended position shown in FIGS. **8**A-**8**H. At least some of the other alignment members (e.g. first, second and third locating members **268**, **270**, **272**, guide track **274**, end surface **276**, alignment surface **278**, and first and second magnetic preload members **280**, **282**) may provide all alignment and connection functions for the secondary optic assembly **214** when extension member **252** is in the fully extended position.

The foregoing description, for purpose of explanation, has been described with reference to specific embodiments. However, the illustrative discussions above are not intended to be exhaustive or to limit the invention to the precise forms disclosed. Many modifications and variations are possible in view of the above teachings. The embodiments were chosen and described in order to best explain the principles of the present systems and methods and their practical applications, to thereby enable others skilled in the art to best utilize the present systems and methods and various embodiments with various modifications as may be suited to the particular use contemplated.

Unless otherwise noted, the terms "a" or "an," as used in the specification and claims, are to be construed as meaning "at least one of." In addition, for ease of use, the words "including" and "having," as used in the specification and claims, are interchangeable with and have the same meaning as the word "comprising."

What is claimed is:

1. An opto-mechanical deployable telescope, comprising:
a hub;
at least one deployable multiple petal primary mirror mounted to the hub;
a deployment assembly operable to move the at least one primary mirror between a stowed position and a deployed position;
a deployment engine assembly operable to power the deployment assembly using stored mechanical energy; and
a secondary optic assembly comprising a secondary optical member, the secondary optic assembly being mounted to the hub and operable to axially position the secondary optical member relative to the at least one primary mirror;
wherein:
the deployment assembly includes a kinematic or semi-kinematic interface between the hub and the at least one primary mirror to hold petals of the at least one primary mirror in alignment relative to each other in the deployed position; and
each petal of the at least one primary mirror is separately attached to the hub with a hinge connection, the hinge connection providing radial movement of the petals when in the deployed position that permits the deployment assembly rather than the hinge connection to control alignment of the petals.

2. The telescope of claim **1**, wherein the secondary optic assembly comprises:
a stationary base mounted to the hub; and
an extension member mounted to the stationary base;
wherein the secondary optical member is positionable by the extension member axially relative to the at least one primary mirror to optimize optical imaging on a focal plane.

3. The telescope of claim **2**, further comprising:
a plurality of locating members positioned between the stationary base and the extension member;
wherein the plurality of locating members provide translational and rotational alignment between the stationary base and the extension member.

4. The telescope of claim **3**, further comprising:
at least one magnetic member operable to apply a magnetic connection between the stationary base and the extension member.

5. The telescope of claim **4**, wherein the at least one magnetic member includes a first magnetic member carried by the stationary base and a second magnetic member carried by the extension member.

6. The telescope of claim **5**, wherein the first and second magnetic members are operable when the extension member is in an extended position relative to the hub.

7. The telescope of claim **3**, further comprising:
at least one guide track configured to interface with the plurality of locating members.

8. The telescope of claim **3**, wherein the plurality of locating members each comprise a spherical portion.

9. The telescope of claim **2**, further comprising:
a guide rod coupled between the stationary base and the extension member, the guide rod providing constrained movement of the extension member relative to the stationary base to relative axial movement.

10. The telescope of claim **9**, further comprising:
a guide cylinder receptive of the guide rod, the guide cylinder being mounted to one of the stationary base and the extension member, and the guide rod being mounted to the other of the stationary base and the extension member.

11. The telescope of claim **10**, further comprising:
a compression spring operable to apply a biasing force between the extension member and the stationary base to move the extension member into an extended position relative to the stationary base, the compression spring being arranged coaxially with and overlapping the guide rod and guide cylinder.

12. The telescope of claim **2**, further comprising:
a release member operable to hold the extension member in a retracted position relative to the stationary base, wherein releasing the release member permits the extension member to move into an extended position relative to the stationary base.

13. The telescope of claim **2**, further comprising:
a compression spring operable to apply a biasing force between the extension member and the stationary base to move the extension member into an extended position relative to the stationary base.

14. An opto-mechanical deployable telescope, comprising:
a hub;
a deployable primary mirror positioned on the hub and comprising a plurality of petals, the plurality of petals being pivotable from a stowed position to a deployed position;

a deployment assembly configured to operate the plurality of petals between the stowed and deployed positions and hold the plurality of petals in alignment relative to each other in the deployed position using a kinematic or semi-kinematic interface between the hub and the plurality of petals; and

a secondary optic assembly comprising a secondary optical member, the secondary optic assembly being mounted to the hub and operable to axially position the secondary optical member relative to the primary mirror;

wherein each petal of the primary mirror is separately attached to the hub with a hinge connection, the hinge connection providing radial movement of the plurality of petals when in the deployed position that permits the deployment assembly rather than the hinge connection to control alignment of the plurality of petals.

15. The telescope of claim **14**, wherein the secondary optic assembly comprises:

a stationary base mounted to the hub; and

an extension member mounted and movable relative to the stationary base, the secondary optical member being carried by the extension member.

16. The telescope of claim **15**, further comprising:

a guide rod mounted to one of the stationary base and the extension member; and

a guide cylinder receptive of the guide rod and mounted to the other of the stationary base and the extension member.

17. The telescope of claim **15**, further comprising:

a plurality of locating members operable between the stationary base and the extension member when the extension member is in a fully extended position to constrain movement between the extension member and the stationary base in multiple directions of movement.

18. A method of deploying an opto-mechanical deployable telescope, comprising:

providing a hub, at least one primary mirror mounted to the hub, a deployment assembly, and a secondary optic assembly mounted to the hub and comprising a secondary optical member, the at least one primary mirror including a plurality of petals;

moving the plurality of petals from a stowed position to a deployed position with the deployment assembly;

aligning the plurality of petals relative to each other with the deployment assembly while moving the plurality of petals into the deployed position, wherein aligning the plurality of petals includes providing a semi-kinematic interface between the plurality of petals and the hub; and

operating the secondary optic assembly to adjust an axial position of the secondary optical member relative to the at least one primary mirror;

wherein each petal of the at least one primary mirror is separately attached to the hub with a hinge connection, the hinge connection providing radial movement of the plurality of petals when in the deployed position that permits the deployment assembly rather than the hinge connection to control alignment of the plurality of petals.

19. The method of claim **18**, wherein the secondary optic assembly further comprises an extension member, a stationary base, and a plurality of alignment members, the method further comprising:

extending the extension member axially relative to the stationary base; and

constraining movement of the extension member relative to the stationary base with the plurality of alignment members to align the secondary optical member relative to the at least one primary mirror.

20. The method of claim **19**, wherein the plurality of alignment members includes a guide cylinder, a guide rod extending into the guide cylinder, at least one locating surface, a plurality of locating members configured to interface with the at least one locating surface, and at least one magnetic member operable to apply a magnetic force to draw the extension member toward the stationary base.

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