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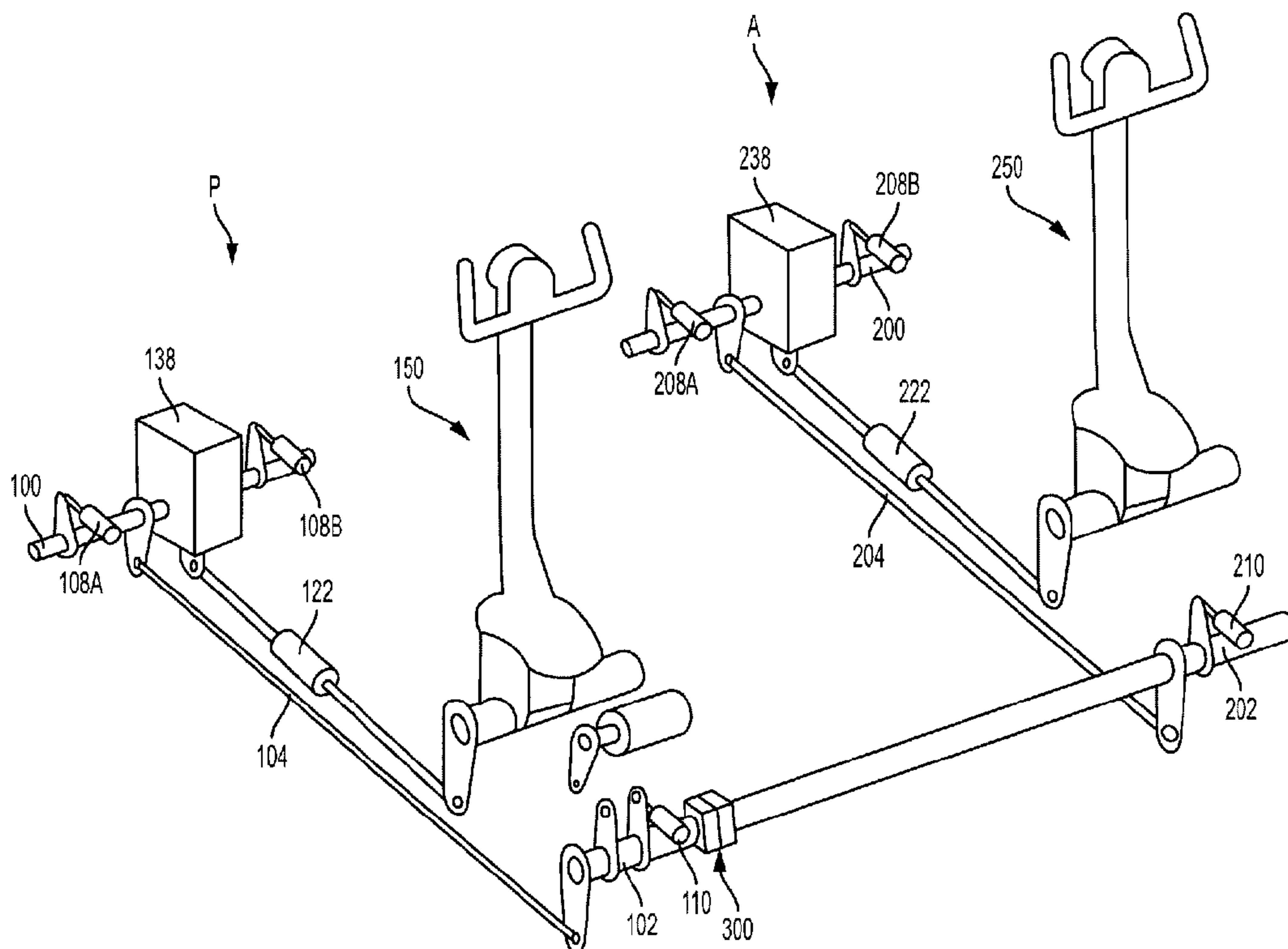
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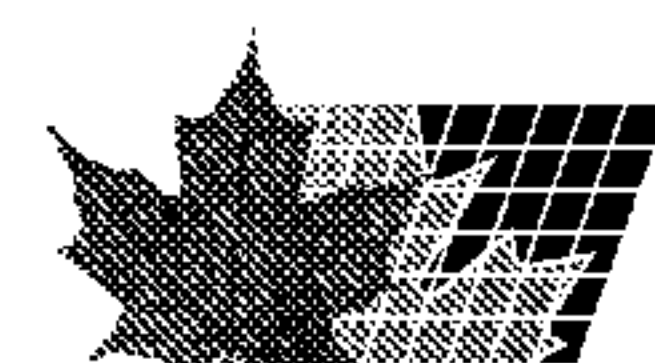
(54) Titre : METHODE ET APPAREIL DE DETECTION DE DEFAILLANCE LATENTE ET DE GESTION DE SYSTEME DE
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(54) Title: METHOD AND APPARATUS FOR LATENT FAULT DETECTION AND MANAGEMENT FOR FLY-BY-WIRE
FLIGHT CONTROL SYSTEMS



(57) Abrégé/Abstract:

An aircraft control system includes pilot and co-pilot flight control systems that each include a first shaft mechanically coupled to and displaced apart from a second shaft, the shafts defining and being rotatable about independent longitudinal axes. A



(57) **Abrégé(suite)/Abstract(continued):**

connecting link enables rotation of one of the first shafts to rotate a corresponding one of the second shafts. A position transducer is mechanically coupled to each shaft and configured to communicate an electrical signal corresponding to the rotation of the respective shaft. A flight control unit electrically communicates with the position transducers and is configured to (a) receive the electrical signal from each position transducer, (b) detect a failure of the flight control system by detecting differences in the position transducers' electrical signals, and (c) communicate the electrical signal from the position transducer to a flight control surface actuation system to compensate for the detected failure.

ABSTRACT

An aircraft control system includes pilot and co-pilot flight control systems that each include a first shaft mechanically coupled to and displaced apart from a second shaft, the shafts defining and being rotatable about independent longitudinal axes. A
5 connecting link enables rotation of one of the first shafts to rotate a corresponding one of the second shafts. A position transducer is mechanically coupled to each shaft and configured to communicate an electrical signal corresponding to the rotation of the respective shaft. A flight control unit electrically communicates with the position transducers and is configured to (a) receive the electrical signal from
10 each position transducer, (b) detect a failure of the flight control system by detecting differences in the position transducers' electrical signals, and (c) communicate the electrical signal from the position transducer to a flight control surface actuation system to compensate for the detected failure.

METHOD AND APPARATUS FOR LATENT FAULT DETECTION AND MANAGEMENT FOR FLY-BY-WIRE FLIGHT CONTROL SYSTEMS

BACKGROUND

5 Field of the Disclosure

The present disclosure relates generally to a fly-by-wire aircraft control system, and more particularly, to a flight control system configured to detect a failure of a pilot or co-pilot flight control system.

10 Description of Related Art

A majority of commercial aircraft utilize fly-by-wire flight control systems that no longer include direct mechanical linkages to physically connect flight deck controllers with aircraft flight control surfaces. Rather, a pilot provides an input to the flight deck controller, which is subsequently converted to an electrical signal. The
15 electrical signal is then electronically processed to generate commands to control units that appropriately orient the respective aircraft flight control surface.

Regulations governing the operation of certain aircraft require redundancies in flight control systems to satisfy safety requirements. Additionally, if a flight control system incurs a failure that is not detected (i.e., a latent failure), and a subsequent
20 failure in the flight control system would impact the aircraft safety, then a mandatory ground inspection and/or a series of inspection intervals may be required to check and resolve the latent failure. In some instances, entire flight control systems are removed and replaced with new systems when a latent failure cannot be detected, which increases operating costs and decreases operational tempo.

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SUMMARY

A fly-by-wire aircraft control system includes a pilot flight control system and a co-pilot flight control system. Each flight control system includes a first shaft that is mechanically coupled to a second shaft. Additionally, the first shaft is displaced
30 apart from the second shaft. Each shaft of the pilot and co-pilot flight control system

defines an independent longitudinal axis, and each shaft is configured to rotate about the longitudinal axis defined thereby. In some aspects, the pilot and co-pilot flight control systems each include a connecting link that enables rotation of one of the first shafts to rotate a corresponding one of the second shafts.

5 According to some aspects, the aircraft control system further includes a position transducer mechanically coupled to each shaft. The position transducers are configured to communicate an electrical signal corresponding to the rotation of the respective shaft. Additionally, the aircraft control system includes a flight control
10 control unit is configured to receive the electrical signal from each of the position transducers. The health of the position transducers affects the flight safety, and as such, the ability to predict and/or determine mechanical and/or electrical failures of the position transducers and other components of the flight control system significantly increases the safety of flight operations.

15 Additionally, the flight control unit is configured to detect a failure of the pilot or co-pilot flight control system by detecting differences in the electrical signals from the position transducers. In some aspects, the flight control unit is configured to communicate the electrical signal from the operational position transducer to a flight control surface actuation system to compensate for the detected failure.

20 Aspects of the present disclosure also provide a method of controlling a fly-by-wire aircraft control system. The method includes receiving an electrical signal from a plurality of position transducers. Each position transducer is coupled to one of a first shaft and a second shaft of a pilot flight control system and a first shaft and a second shaft of a co-pilot flight control system. The first and second shafts define
25 independent longitudinal axis and are rotatable about their respective independent longitudinal axes. Additionally, a connecting link enables rotation of one of the shafts to rotate a corresponding one of the connected shafts. The method further includes detecting a failure of the pilot or co-pilot flight control systems by detecting differences in the electrical signals received from each of the position transducers.

30 According to some aspects, the method includes communicating the electrical signal

from the position transducer to a flight control surface actuation system to compensate for the detected failure.

According to some aspects, an aircraft control system is provided that includes a pilot and a co-pilot flight control system. Each flight control system
5 includes a first shaft mechanically coupled to and displaced apart from a second shaft. The shafts of the pilot and co-pilot flight control systems each define independent longitudinal axes and are rotatable about their respective longitudinal axes. Additionally, a pilot and a co-pilot connecting link respectively enable rotation of one of the first shafts to rotate a corresponding one of the second shafts of the
10 pilot and co-pilot flight control systems. The aircraft control system further includes a pilot and co-pilot flight deck controllers that are mechanically coupled to the respective first pilot and co-pilot shafts. Further, the system includes a position transducer mechanically coupled to each shaft. The position transducer is configured to communicate an electrical signal corresponding to the rotation of the
15 respective shaft. In some aspects, the system includes a pilot and a co-pilot wheel pulley mechanically coupled to the respective pilot and co-pilot flight deck controllers. The pilot and co-pilot wheel pulleys are configured to, in response to a failure of one of the connecting links, rotate the respective first shafts of the pilot and co-pilot flight control systems. According to some aspects, the system further
20 includes a flight control unit that is in communication with the position transducers. The flight control unit is configured to (a) receive the electrical signal from each of the position transducers, (b) detect a failure of the pilot or co-pilot flight control system by detecting differences in the electrical signals from the position transducers, and (c) communicate the electrical signal from the position transducer
25 to a flight control surface actuation system to compensate for the detected failure.

BRIEF DESCRIPTION OF THE DRAWING(S)

Having thus described example implementations of the disclosure in general terms, reference will now be made to the accompanying drawings, which are not necessarily drawn to scale, and wherein:

5 FIG. 1 illustrates a fly-by-wire aircraft control system that includes a pilot and co-pilot wheel flight deck controller according to one aspect of the present disclosure;

FIG. 2 illustrates a fly-by-wire aircraft control system that includes a pilot and co-pilot pedal flight deck controller according to one aspect of the present disclosure;

FIG. 3 illustrates a fly-by-wire aircraft control system that includes a pilot and co-pilot column flight deck controller according to one aspect of the present disclosure;

FIG. 4 illustrates a schematic block diagram of a fly-by-wire aircraft control system according to one aspect of the present disclosure;

FIG. 5 illustrates a block diagram of a method of manufacturing a fly-by-wire aircraft control system according to one aspect of the present disclosure; and

FIG. 6 illustrates a block diagram of a method of controlling a fly-by-wire aircraft control system according to one aspect of the present disclosure.

20 DETAILED DESCRIPTION

Some implementations of the present disclosure will now be described more fully hereinafter with reference to the accompanying drawings, in which some, but not all implementations of the disclosure are shown. Indeed, various implementations of the disclosure may be expressed in many different forms and should not be construed as limited to the implementations set forth herein; rather, these exemplary implementations are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the disclosure to those skilled in the art. As used herein, the term “and/or” and the “/” symbol includes any and all combinations of one or more of the associated listed items. Further, unless otherwise indicated, something being described as being a first, second or the like

should not be construed to imply a particular order. It should be understood that the terms first, second, etc. may be used herein to describe various steps, calculations, positions and/or the like, these steps, calculations or positions should not be limited to these terms. These terms are only used to distinguish one operation, calculation, 5 or position from another. For example, a first position may be termed a second position, and, similarly, a second step may be termed a first step, without departing from the scope of this disclosure. Additionally, something may be described as being above something else (unless otherwise indicated) may instead be below, and vice versa; and similarly, something described as being to the left of something else 10 may instead be to the right, and vice versa. As used in the specification, and in the appended claims, the singular forms “a”, “an”, “the”, include plural referents unless the context clearly dictates otherwise. Like reference numerals refer to like elements throughout.

Implementations of the present disclosure provide for a fly-by-wire aircraft 15 control system configured to control the operation of aircraft flight control surfaces and detect a failure of a flight control system. The fly-by-wire aircraft control system 5 can include a combination of mechanical and electrical components configured to control the operation of the aircraft flight control surfaces. Referring to FIGS. 1, 2 and 3, an aircraft control system 5 includes a pilot flight control system *P* (i.e., a 20 primary flight control system) and a co-pilot flight control system *A* (i.e., an alternate flight control system). In particular, the pilot flight control system *P* may be arranged with respect to the co-pilot flight control system *A* such that a pilot and co-pilot may operate the respective pilot and co-pilot flight control systems *P*, *A*. Additionally, the pilot flight control system *P* and the co-pilot flight control system *A* may each include 25 a respective flight deck controller (e.g., a pilot flight deck controller and a co-pilot flight deck controller). As shown in FIGS. 1, 2, and 3, the flight deck controllers may include a traditional wheel flight deck controller, column flight deck controller, and/or pedal flight deck controller configured to receive a user input to control the operation of the corresponding aircraft flight control surfaces.

According to some aspects, the pilot and co-pilot flight control systems **P**, **A** may each include a respective first shaft (e.g., a first pilot shaft **100** and a first co-pilot shaft **200**). Additionally, the first shafts of the respective pilot and co-pilot flight control systems may be mechanically coupled to the corresponding flight deck controller. For example, as shown in FIG. 1, a first pilot shaft **100** is mechanically coupled to the pilot wheel flight deck controller **106**, and a first co-pilot shaft **200** is mechanically coupled to the co-pilot wheel flight deck controller **206**. The first pilot shaft **100** defines a longitudinal axis **L1**, and the first pilot shaft **100** is configured to rotate about the longitudinal axis **L1**. Likewise, the first co-pilot shaft **200** defines a longitudinal axis **L3**, and the first co-pilot shaft **200** is configured to rotate about the longitudinal axis **L3**.

Additionally, the pilot and co-pilot flight control systems **P**, **A** each include a respective second shaft **102**, **202** that is mechanically coupled to the respective first pilot shaft **100** and the first co-pilot shaft **200**. The second pilot shaft **102** is displaced apart from the first pilot shaft **100**, and the second co-pilot shaft **202** is displaced apart from the first co-pilot shaft **200**. According to some aspects, the second pilot shaft **102** is displaced apart from the longitudinal axis **L1** defined by the first pilot shaft **100**. For example, a second pilot shaft **102** defines a longitudinal axis **L2** along which the second pilot shaft **102** extends. The longitudinal axis **L2** of the second pilot shaft **102** may be parallel to, but displaced from, the longitudinal axis **L1** of the first pilot shaft **100**. As shown in FIG. 1, the second pilot shaft **102** may be nonconcentrically displaced from the first pilot shaft **100**. According to another aspect, the respective longitudinal axes of the first and second pilot shaft may be coaxially arranged with respect to one another, but the first and second pilot shafts remain displaced apart from one another. Likewise, the second co-pilot shaft **202** may define a longitudinal axis **L4** along which the second co-pilot shaft **202** extends, and the second co-pilot shaft **202** may be displaced apart from the longitudinal axis **L3** defined by the first co-pilot shaft **200**. In some aspects, the first and second shafts of the respective pilot and co-pilot flight control systems are mass balanced

and are configured to not rotate without input from a flight deck controller and/or by induced dynamics.

According to some aspects, the pilot and co-pilot flight control systems *P*, *A* may further include a connecting link arranged such that for rotation of one of the first shafts of the pilot and co-pilot flight control systems correspondingly rotates the respective second shaft. For example, as shown in FIG. 1, a first pilot connecting rod **104** may have a first end mechanically coupled to the first pilot shaft **100** and an opposing second end mechanically coupled to the respective second pilot shaft **102**. Likewise, a first co-pilot connecting rod **204** may have a first end mechanically coupled to the first co-pilot shaft **200** and an opposing second end mechanically coupled to the second co-pilot shaft **202**.

In some aspects, the second pilot shaft **102** is mechanically coupled to the first pilot shaft **100** such that rotation of the first pilot shaft **100** about the longitudinal axis *L1* thereof causes corresponding rotation of the second pilot shaft **102** about the longitudinal axis *L2* defined thereby. As one of the first and second pilot shafts **100**, **102** rotates about its respective longitudinal axis, the first pilot connecting rod **104** is displaced and causes corresponding rotation of the other connected pilot shaft about the longitudinal axis defined thereby. Likewise, when one of the first and second co-pilot shafts **200**, **202** rotates about its respective longitudinal axis, the first co-pilot connecting rod **204** causes corresponding rotation of the other connected pilot shaft about the longitudinal axis defined thereby.

According to some aspects, each of the first and second pilot shafts **100**, **102** may be mechanically coupled to a respective position transducer **108A**, **108B**, **110A**, **110B**. In particular, the pilot flight control system *P* may include a pair of position transducers **108A**, **108B** mechanically coupled to the first pilot shaft **100** and a pair of position transducers **110A**, **110B** mechanically coupled to the second pilot shaft **102**. The first pilot position transducers **108A**, **108B** are configured to generate an electrical signal corresponding to the rotation of the first pilot shaft **100** about the longitudinal axis *L1* thereof and communicate the electrical signal to a flight control unit. The second pilot position transducers **110A**, **110B** are configured to generate

an electrical signal corresponding to the rotation of the second pilot shaft **102** about the longitudinal axis **L2** thereof and communicate the electrical signal to the flight control unit.

Likewise, each of the first and second co-pilot shafts **200**, **202** may be
 5 mechanically coupled to a respective position transducer **208A**, **208B**, **210A**, **210B**. The co-pilot flight control system **A** includes a pair of position transducers **208A**, **208B** mechanically coupled to the first co-pilot shaft **200** and a pair of position transducers **210A**, **210B** mechanically coupled to the second co-pilot shaft **202**. The transducers **208A**, **208B**, **210A**, **210B** are configured to generate an electrical signal
 10 corresponding to the rotation of the respective first and second co-pilot shafts **200**, **202** about their respective longitudinal axis **L3**, **L4** and communicate the respective electrical signals to the flight control unit, as described in greater detail herein.

Referring to FIG. **4**, the fly-by-wire aircraft control system **5** further includes a flight control unit **400** that is in electrical communication with each of the position
 15 transducers **108**, **110**, **208**, **210**. Additionally, the flight control unit is configured to receive an electrical signal from any of the position transducers **108**, **110**, **208**, **210** for controlling the operation of a corresponding flight control surface actuation system **402** in accordance with the rotation of the corresponding shaft mechanically coupled to the respective position transducer. Additionally, the flight control unit **400**
 20 is configured to communicate the electrical signal from any of the position transducers **108**, **110**, **208**, **210** to the corresponding flight control surface actuation system **402** to compensate for the detected failure. In some aspects, the flight control unit **400** may be configured to process the electrical signal received from each of the position transducers and compare the electrical signals. Additionally, in
 25 response to a failure of the flight control unit **400**, any one of the operational position transducers **108**, **110**, **208**, **210** may be configured to provide an electrical signal to the flight control surface actuation system **402**. In some aspects, the flight control surface actuation system **402** may include actuator control electronics configured to control, for example, electro-hydraulic servo actuators that manipulate flight control

surfaces such as, for example, elevator control surfaces, ailerons, spoilerons, flaps, rudders and/or the like.

According to some aspects, the flight control unit **400** is further configured to detect a failure of the pilot flight control system **P** or the co-pilot flight control system **A**, based in part to the electrical signals received from the position transducers **108**, **110**, **208**, **210**. For example, the flight control unit **400** is configured to compare the electrical signals received from any one of the first pilot position transducer **108**, the second pilot position transducer **110**, the first co-pilot position transducer **208**, and the second co-pilot position transducer **210** with the electrical signals received from any of the other position transducers. In comparing the electrical signals received from the position transducers **108**, **110**, **208**, **210**, the flight control unit **400** detects a failure in the pilot flight control system **P** or the co-pilot flight control system **A** by detecting a difference between the electrical signals provided by any of the position transducers **108**, **110**, **208**, **210**.

Additionally, in response to detecting a failure of one of the pilot flight control system **P** or co-pilot flight control system **A**, the flight control unit **400** is configured to provide an electrical signal to a flight control surface actuation system **402** associated with the position transducers **108**, **110**, **208**, **210**. In particular, the flight control unit **400** is configured to communicate an electrical signal from at least one of the operational position transducers to the flight control surface actuation system **402** so as to compensate for the detected failure.

In some aspects, the wheel flight deck controllers **106**, **206** of the pilot and co-pilot flight control systems **P**, **A** may be configured to rotate the respective first pilot and co-pilot shafts **100**, **200**. For example, as shown in FIG. 1, the pilot wheel flight deck controller **106** may be configured to rotate the first pilot shaft **100** about the longitudinal axis **L1** defined thereby, and the co-pilot wheel flight deck controller **206** may be configured to rotate the first co-pilot shaft **200** about the longitudinal axis **L3**. For example, rotating the pilot wheel flight deck controller **106** in either the clockwise or counterclockwise direction provides for the first pilot shaft **100** to correspondingly rotate in a respective direction about the longitudinal axis **L1** defined thereby.

Likewise, rotating the co-pilot wheel flight deck controller **206** in either the clockwise or counterclockwise direction provides for the first co-pilot shaft **200** to correspondingly rotate in a respective direction about the longitudinal axis **L3**.

The aircraft control system **5** may further include a pilot flight data recorder force transducer **122** and a co-pilot flight data recorder force transducer **222**. The flight data recorder force transducers **122**, **222** may be mechanically coupled to the respective pilot and co-pilot flight deck controllers. For example, as shown in FIG. 3, the pilot flight data recorder force transducer **122** is directly coupled to the pilot column flight deck controller **150**, and the co-pilot flight data recorder force transducer **22** is directly coupled to the co-pilot column flight deck controller **250**. The flight data recorder force transducers **122**, **222** may be configured to provide an output, typically voltage or current, that is proportional to the input force provided to the pilot and co-pilot flight deck controllers by the pilot and the co-pilot respectively. As such, the flight data recorder force transducers **122**, **222** may be configured to measure the relative position of the magnetic core and windings, which is proportional to the force applied to the respective flight deck controllers (e.g., the pilot and co-pilot wheel flight deck controllers **106**, **206**; the pilot and co-pilot pedal flight deck controllers **144**, **244**; the pilot and co-pilot column flight deck controllers **150**, **250**). Additionally, the flight data recorder force transducers **122**, **222** may be configured to communicate an electrical signal to the flight control unit corresponding to the input force applied to the respective flight deck controllers.

In some aspects, the aircraft control system further includes at least one linkage mechanically coupling one of the pilot shafts **100**, **102** to one of the co-pilot shafts **200**, **202** such that rotation of one of the pilot shafts **100**, **102** about the longitudinal axis thereof **L1**, **L2** causes corresponding rotation of the coupled one of the co-pilot shafts **200**, **202** about the longitudinal axis thereof **L3**, **L4**. For example, as shown in FIG. 1, a first end of a first coupling rod **300** is mechanically coupled to the second pilot shaft **102** and an opposing second end of the first coupling rod **300** is mechanically coupled to the second co-pilot shaft **202**. As the second pilot shaft **102** rotates about its longitudinal axis **L2**, the first coupling rod **300** correspondingly

rotates the second co-pilot shaft **202** about its longitudinal axis **L4**. In particular, the ends of the first coupling rod **300** are directly coupled to the respective second pilot shaft **102** and second co-pilot shaft **202** such that any rotation of either second shaft **102**, **202** displaces the first coupling rod **300** and thereby causes the other coupled
 5 second shaft **102**, **202** to correspondingly rotate.

According to some aspects, the flight control system **5** may include a second coupling rod **302**. For example, as shown in FIG. 1, a first end of a second coupling rod **302** is mechanically coupled to the first pilot shaft **100**, and the opposing second end of the second coupling rod **302** is mechanically coupled to the first co-pilot shaft
 10 **200** via respective linkages. As the pilot shafts **100**, **102** and the co-pilot shafts **200**, **202** are mechanically coupled to one another by either the first or second coupling rods **300**, **302**, rotation in any one of the pilot shafts **100**, **102** provides for corresponding rotation in any one of the coupled co-pilot shafts **200**, **202**.

According to some embodiments, the aircraft control system **5** may further
 15 include a feel and centering unit **138**. As shown in FIG. 1, the feel and centering unit **138** may be mechanically coupled to the first pilot shaft **100**. The feel and centering unit **138** may be configured to provide a counterforce that progressively resists the rotation of the first pilot shaft **100** from a null or registration position as a force is applied to the pilot and/or co-pilot flight deck controllers to rotate the first pilot shaft
 20 **100** in either the clockwise or counterclockwise directions. Additionally, the registration position of the first pilot shaft **100** may correspond with the flight deck controllers being disposed in a null or registration position. In some aspects, the aircraft control system **5** may include a pilot feel and centering unit **138** mechanically coupled to the first pilot shaft **100** and a co-pilot feel and centering unit **238**
 25 mechanically coupled to the first co-pilot shaft **200**.

Referring back to FIG. 1, the aircraft control system **5** is configured to control angular displacement (i.e., roll) of the aircraft about a longitudinal axis defined thereby that extends from the nose to the tail of the aircraft. In particular, the pilot wheel flight deck controller **106** and the co-pilot wheel flight deck controller **206** are
 30 mechanically coupled to the first pilot and co-pilot shafts **100**, **200** respectively. In

some aspects, the pilot wheel flight deck controller **106** may be mechanically coupled to the first pilot shaft **100** via a pilot wheel pulley **112**. The pilot flight control system **P** may also include an endless cable **114** that is guided by the pilot wheel pulley **112** and a second pulley **116** associated with the pilot wheel flight deck controller **106**. The second pulley **116** may be configured to rotate correspondingly with the pilot wheel flight deck controller **106** in both of the clockwise and counterclockwise directions. Rotation of the pilot wheel pulley **112** about the longitudinal axis **L1** of the first pilot shaft **100** provides for the pilot wheel flight deck controller **106** to rotate correspondingly via the endless cable **114** and the pulley **116** associated with the pilot wheel flight deck controller **106**.

According to some aspects, the first pilot shaft **100** extends through the center of the pilot wheel pulley **112**, and the pilot wheel pulley **112** may be rotatable about the first pilot shaft **100**. Additionally, the pilot wheel pulley **112** may define an arcuate slot **118** proximate a peripheral portion of the pilot wheel pulley **112**.

According to some aspects, the pilot flight control system **P** may include a pilot flight data recorder linkage **120** having a first end securely attached to the pilot wheel pulley **112** and/or endless cable **114**. The pilot flight data recorder linkage **120** may also extend substantially radially from the first pilot shaft **100** and may extend from the first end, which is securely attached to the pilot wheel pulley **112** and/or endless cable **114**, to an opposing second end that is directly coupled to a first end of a pilot flight data recorder force transducer **122**.

In some aspects, the pilot flight control system may include a pilot force transducer linkage **124**. Like the pilot wheel pulley **112**, the pilot force transducer linkage **124** is also rotatable about the first pilot shaft **100**. Additionally, the pilot force transducer linkage **124** may also define an arcuate slot **128** (e.g., a kidney slot) that is aligned with the arcuate slot **118** of the pilot wheel pulley **112** along a direction parallel to the first pilot shaft **100**. For example, the pilot force transducer linkage **124** may be axially displaced from the pilot wheel pulley **112** along the first pilot shaft **100** such that the arcuate slot **128** of the pilot force transducer linkage **124** is aligned with the arcuate slot **118** of the pilot wheel pulley **112** along a direction parallel to the

first pilot shaft **100**. In some aspects, a second end of the pilot flight data recorder force transducer **122** is coupled to a pilot force transducer linkage **124**.

As previously mentioned, the pilot wheel pulley **112** and the pilot force transducer linkage **124** are both rotatable about the first pilot shaft **100**. The coupling of the pilot flight data recorder force transducer **122** to the pilot flight data recorder linkage **120** at a first end and to the pilot force transducer linkage **124** at the opposing second end provides for the pilot wheel pulley **112** and the pilot force transducer linkage **124** to correspondingly rotate about the first pilot shaft **100**. According to some aspects, the pilot force transducer linkage **124** may also be mechanically coupled to a bank angle protection force transducer **126**. In particular, a first end of the bank angle protection (BAP) force transducer **126** may be securely attached to the pilot force transducer linkage **124**. The BAP force transducer **126** may also be configured as a LVDT like the pilot flight data recorder force transducer **122**.

An opposing second end of the BAP force transducer **126** may be securely attached to a first pilot deadzone linkage **130**. According to some aspects, the pilot flight control system **P** may include a first pilot deadzone linkage **130** and a second pilot deadzone linkage **134** that are both non-rotatably attached to the first pilot shaft **100**. Further, the first and second pilot deadzone linkages **130**, **134** may extend radially from the first pilot shaft **100**. In some aspects, each of the first and second pilot deadzone linkages **130**, **134** may include a first and second pilot deadzone engaging element **132**, **136** respectively that extends therefrom. In particular, the first pilot deadzone engaging element **132** and the second pilot deadzone engaging element **136** may extend from the first pilot deadzone linkage **130** and the second pilot deadzone linkage **134** respectively along a direction parallel to the longitudinal axis of the first pilot shaft **100**.

Additionally, the first pilot deadzone linkage **130** may be axially displaced from the pilot force transducer linkage **124** along the first pilot shaft **100**. The second pilot deadzone linkage **134** may also be axially displaced along the first pilot shaft **100** from the pilot wheel pulley **112**. According to some aspects, the first pilot deadzone

engaging element **132** may extend from the first pilot deadzone linkage **130** along a direction parallel to the longitudinal axis **L1** of the first pilot shaft **100** and through the arcuate slot **128** of the pilot force transducer linkage **124**. Further, the second pilot engaging element **136** may extend from the second pilot deadzone linkage **134** along a direction parallel to the longitudinal axis **L1** of the first pilot shaft **100** and through the arcuate slot **118** of the pilot wheel pulley **112**. As the arcuate slots **118**, **128** of the pilot wheel pulley **112** and the pilot force transducer linkage **124** are aligned with one another, the first and second deadzone engaging elements **132**, **136** may be coaxially aligned.

Accordingly, as the first pilot deadzone linkage **132** is non-rotatably attached to the first pilot shaft **100**, rotation of the first pilot shaft **100** provides for the first pilot deadzone engaging element **132** to orbit the first pilot shaft **100** in a direction corresponding with the rotation of the first pilot shaft **100**. Likewise, as the second pilot deadzone linkage **134** is also non-rotatably attached to the first pilot shaft **100**, rotation of the first pilot shaft **100** provides for the second pilot deadzone engaging element **136** to orbit the first pilot shaft **100** in a direction corresponding with the rotation of the first pilot shaft **100**. In some aspects, the first pilot deadzone engaging element **132** orbiting the first pilot shaft **100** may provide for the first pilot deadzone engaging element **132** to engage and/or contact an end of the arcuate slot **128** defined by the pilot force transducer linkage **124**. Additionally, the rotation of the first pilot shaft **100** may provide for the second pilot deadzone engaging element **136** to orbit the first pilot shaft **100** and to engage and/or contact an end of the arcuate slot **118** defined by the pilot wheel pulley **112**.

Likewise, the co-pilot flight control system **A** may include a co-pilot wheel pulley **212** that is mechanically coupled to the co-pilot wheel flight deck controller **206**. Additionally, the co-pilot wheel flight deck controller **206** may be mechanically coupled via the co-pilot wheel pulley **212**. Further, the co-pilot flight control system **A** includes an endless cable **214** that is guided by the co-pilot wheel pulley **212** and a second pulley **216** associated with the co-pilot wheel flight deck controller **206**. The second pulley **216** may be configured to rotate correspondingly with the co-pilot

wheel flight deck controller **206** in both the clockwise or counterclockwise directions. As discussed herein, rotation of the co-pilot wheel pulley **212** about the longitudinal axis **L3** of the first co-pilot shaft **200** provides for the co-pilot wheel flight deck controller **206** to rotate correspondingly via the endless cable **214** and the second pulley **216** associated with the co-pilot wheel flight deck controller **206**.

As the first pilot shaft **100** extends through the center of the pilot wheel pulley **112**, the first co-pilot shaft **200** extends through the center of the co-pilot wheel pulley **212**. Additionally, the co-pilot wheel pulley **212** may be rotatable about the first co-pilot shaft **200**. In some aspects, the co-pilot wheel pulley **212** may define an arcuate slot **218** proximate a peripheral portion of the co-pilot wheel pulley **212**.

According to some aspects, the co-pilot flight control system **A** may include a co-pilot flight data recorder linkage **220** having a first end securely attached to the co-pilot wheel pulley **212** and/or the endless cable **214**. The co-pilot flight data recorder linkage **220** may also extend radially from the first co-pilot shaft **200** and the first end, which is securely attached to the co-pilot wheel pulley **212**, to an opposing second end. The opposing second end of the co-pilot flight data recorder linkage **220** may be coupled to a first end of a co-pilot flight data recorder force transducer **222**.

In some aspects, the co-pilot flight control system **A** may include a co-pilot force transducer linkage **224**. Like the co-pilot wheel pulley **212**, the co-pilot force transducer linkage **224** may also be rotatable about the first co-pilot shaft **200**. Additionally, the co-pilot force transducer linkage **224** may also define an arcuate slot **228** that is aligned with the arcuate slot **218** of the co-pilot wheel pulley **212** along a direction parallel to the longitudinal axis **L3** of the first co-pilot shaft **200**. For example, the co-pilot force transducer linkage **224** may be axially displaced from the co-pilot wheel pulley **212** along the first co-pilot shaft **200** such that the arcuate slot **228** of the co-pilot force transducer linkage **224** is aligned with the arcuate slot **218** of the co-pilot wheel pulley **212** along a direction parallel to the longitudinal axis **L3** of the first co-pilot shaft **200**.

Additionally, a second end of the co-pilot flight data recorder force transducer **222**, which is opposed to the first end that is mechanically coupled to the co-pilot flight data recorder linkage **220**, may be coupled to the co-pilot force transducer linkage **224**. As previously mentioned, the co-pilot wheel pulley **212** and the co-pilot force transducer linkage **224** are both rotatable about the first co-pilot shaft **200**. In some aspects, the mechanical coupling of the co-pilot flight data recorder force transducer **222** to the co-pilot force transducer linkage **224** and the co-pilot flight data recorder linkage **220** provides for the co-pilot wheel pulley **212** and the co-pilot force transducer linkage **224** to correspondingly rotate about the first co-pilot shaft **200**. In particular, the co-pilot flight data recorder linkage **220** being securely attached to the co-pilot wheel pulley **212** at a first end and being mechanically coupled to the co-pilot flight data recorder force transducer **222** at the opposing second end provides for a rotation of the co-pilot wheel pulley **212** about the first co-pilot shaft **200** to translate to the co-pilot force transducer linkage **224** via the co-pilot flight data recorder force transducer **222**.

According to some aspects, the co-pilot flight control system **A** may include a first co-pilot deadzone linkage **230** and a second co-pilot deadzone linkage **234** that are both non-rotatably attached to the first co-pilot shaft **200**. Further, the first and second co-pilot deadzone linkages **230**, **234** may extend radially from the first co-pilot shaft **200**. In some aspects, each of the first and second co-pilot deadzone linkages **230**, **234** may include a first and second co-pilot deadzone engaging element **232**, **236** respectively that extends therefrom. In particular, the first co-pilot deadzone engaging element **232** may extend from the first co-pilot deadzone linkage **230**, and the second co-pilot deadzone engaging element **236** may extend from the second co-pilot deadzone linkage **234** along a direction parallel to the longitudinal axis **L3** of the first co-pilot shaft **200**.

Additionally, the first co-pilot deadzone linkage **230** may be axially displaced from the co-pilot force transducer linkage **224** along the first co-pilot shaft **200**. The second co-pilot deadzone linkage **234** may also be axially displaced along the first co-pilot shaft **200** from the co-pilot wheel pulley **212**. According to some aspects,

the first co-pilot deadzone engaging element **232** may extend from the first co-pilot deadzone linkage **230** along a direction parallel to the longitudinal axis **L3** of the first co-pilot shaft **200** and through the arcuate slot **228** of the co-pilot force transducer linkage **224**. Further, the second co-pilot engaging element **236** may extend from
 5 the second co-pilot deadzone linkage **234** along a direction parallel to the longitudinal axis **L3** of the first co-pilot shaft **200** and through the arcuate slot **218** of the co-pilot wheel pulley **212**. As the arcuate slots **218**, **228** of the co-pilot wheel pulley **212** and the co-pilot force transducer linkage **224** are aligned with one another, the first and second co-pilot deadzone engaging elements **232**, **236** may
 10 also be aligned with one another. In some aspects, the first and second co-pilot deadzone engaging elements **232**, **236** may be coaxially aligned with one another.

Accordingly, as the first co-pilot deadzone linkage **230** is non-rotatably attached to the first co-pilot shaft **200**, rotation of the first co-pilot shaft **200** causes the first co-pilot deadzone engaging element **232** to orbit the first co-pilot shaft **200** in
 15 a direction corresponding with the rotation of the first co-pilot shaft **200**. Likewise, as the second co-pilot deadzone linkage **234** is also non-rotatably attached to the first co-pilot shaft **200**, rotation of the first co-pilot shaft **200** causes the second co-pilot deadzone engaging element **236** to orbit the first co-pilot shaft **200** in a direction corresponding with the rotation of the first co-pilot shaft **200**. In some aspects, as
 20 the first co-pilot deadzone engaging element **232** orbits the first co-pilot shaft **200**, the first co-pilot deadzone engaging element **232** may engage and/or contact an end of the arcuate slot **228** defined by the co-pilot force transducer linkage **224**. Additionally, the rotation of the first co-pilot shaft **200** may cause for the second co-pilot deadzone engaging element **236** to orbit the first co-pilot shaft **200** and to
 25 engage and/or contact an end of the arcuate slot **218** defined by the co-pilot wheel pulley **212**.

The pilot and co-pilot flight control systems **P**, **A** may also include at least one connecting link that causes rotation of one of the first shafts **100**, **200** of the pilot and co-pilot flight control systems to correspondingly rotate the respective second shaft
 30 **200**, **202**. When the first pilot shaft **100** rotates about its longitudinal axis **L1**, the first

pilot connecting rod **104** causes the second pilot shaft **102** to correspondingly rotate about its longitudinal axis **L2**. Accordingly, the pilot transducers **108A**, **108B** associated with the first pilot shaft **100** provide an electrical signal to the flight control unit that corresponds with the electrical signal provided by the pilot transducers **110A**, **110B** associated with the second pilot shaft **102**. Likewise, when the first co-pilot shaft **200** rotates about its longitudinal axis **L3**, the first co-pilot connecting rod **204** causes the second co-pilot shaft **202** to correspondingly rotate about its longitudinal axis **L4**. As such, the co-pilot transducers **208A**, **208B** associated with the first co-pilot shaft **200** provide an electrical signal to the flight control unit that corresponds with the electrical signal provided by the co-pilot transducers **210A**, **210B** associated with the second co-pilot shaft **202**.

In the event that the pilot flight data recorder force transducer **122** becomes decoupled from the pilot flight data recorder linkage **120** or the pilot force transducer linkage **124**, the pilot may experience a loss in fidelity when providing an input force to the pilot wheel flight deck controller **106**. In particular, the pilot rotates the pilot wheel flight deck controller **106** thereby causing the pilot wheel pulley **112** to rotate about the first pilot shaft **100** until an end of the arcuate slot **118** engages the second pilot deadzone engaging element **136**. Once an end of the arcuate slot **118** engages the second pilot deadzone engaging element **136**, the first pilot shaft **100** will then begin to rotate about the longitudinal axis **L1**. The flight control unit will receive electrical signals from each of the position transducers **108A**, **108B**, **110A**, **110B**, **208A**, **208B**, **210A**, **210B** that corresponds with the rotation of the respective shafts **100**, **102**, **200**, **202** that are substantially equal to one another. However, the flight control unit will also receive an electrical signal from the pilot flight data recorder force transducer **122** indicating that the pilot flight data recorder force transducer **122** has become decoupled, and the flight control unit will generate an electrical signal that corresponds to a corrected control command to operate to the respective aircraft flight control surfaces.

Likewise, should the co-pilot flight data recorder force transducer **222** become decoupled from either of the co-pilot flight data recorder linkage **220** and/or the co-

pilot force transducer linkage **224**, the copilot will experience a loss in fidelity when providing an input force to the co-pilot wheel flight deck controller **206**. The copilot rotates the co-pilot wheel flight deck controller **206** thereby causing the co-pilot wheel pulley **212** to rotate about the first co-pilot shaft **200** until an end of the arcuate slot **218** engages the second co-pilot deadzone engaging element **236**. Once an end of the arcuate slot **218** engages the second co-pilot deadzone engaging element **236**, the first co-pilot shaft **200** will then begin to rotate about the longitudinal axis **L3**. The flight control unit will receive electrical signals from each of the position transducers **108A**, **108B**, **110A**, **110B**, **208A**, **208B**, **210A**, **210B** that corresponds with the rotation of the respective shafts **100**, **102**, **200**, **202** that are substantially equal to one another. However, the flight control unit will also receive an electrical signal from the co-pilot flight data recorder force transducer **222** indicating that the co-pilot flight data recorder force transducer **222** has become decoupled, and the flight control unit will generate an electrical signal that corresponds to a corrected control command to operate to the respective aircraft flight control surfaces.

In the event that the BAP force transducer **126** becomes decoupled from the pilot force transducer linkage **124** and/or the first pilot deadzone linkage **130**, the pilot may experience a loss in fidelity when providing an input force to the pilot wheel flight deck controller **106**. In particular, the pilot rotates the pilot wheel flight deck controller **106** thereby causing the pilot wheel pulley **112** to rotate. Rotation of the pilot wheel pulley **112** causes the flight data recorder linkage **120**, which is mechanically coupled to a first end of the pilot flight data recorder force transducer **122**, to rotate. The opposing second end of the pilot flight data recorder force transducer **122** is mechanically coupled to the pilot force transducer linkage **124**, and thus the rotation of the pilot wheel pulley is translated to the pilot force transducer linkage **124** via the respective couplings. The pilot force transducer linkage **124** will rotate about the first pilot shaft **100** until an end of the arcuate slot **128** engages the first pilot deadzone engaging element **136**, thereby causing the first pilot shaft **100** to rotate about its longitudinal axis **L1**. The flight control unit will receive electrical signals from each of the position transducers **108A**, **108B**, **110A**, **110B**, **208A**, **208B**,

210A, 210B that corresponds with the rotation of the respective shafts **100, 102, 200, 202** that are substantially equal to one another. However, the flight control unit will also receive an electrical signal from the BAP force transducer **126** indicating that the BAP force transducer **122** has become decoupled, and the flight control unit will generate an electrical signal that corresponds to a corrected control command to operate to the respective aircraft flight control surfaces.

Should the first pilot shaft **100** fail by, for example, shearing into separate pieces, the first pilot shaft **100** may become unresponsive to any input force and will cease to rotate about the longitudinal axis **L1**. Consequently, the position transducers **108A, 108B** mechanically coupled to the first pilot shaft **100** will provide an electrical signal to the flight control unit that differs from the electrical signals provided to the flight control unit by the other position transducers **110A, 110B, 208A, 208B, 210A, 210B** mechanically coupled to the respective second pilot shaft **102**, first co-pilot shaft **200**, and second co-pilot shaft **202**. The co-pilot may still control the aircraft by rotating the co-pilot wheel flight deck controller **206**. In particular, the copilot rotates the co-pilot wheel flight deck controller **206** thereby causing the co-pilot wheel pulley **212** to rotate about the first co-pilot shaft **200** until an end of the arcuate slot **218** engages the second co-pilot deadzone engaging element **236**. Once an end of the arcuate slot **218** engages the second co-pilot deadzone engaging element **236**, the first co-pilot shaft **200** will then begin to rotate about the longitudinal axis **L3**. Rotation of the first co-pilot shaft **200** will cause the first co-pilot connecting rod **204** to rotate the second co-pilot shaft **202**. Additionally, rotation of the second co-pilot shaft **202** will cause the first coupling rod **300** to correspondingly rotate the second pilot shaft **102**. Accordingly, the position transducers **110A, 110B, 208A, 208B, 210A, 210B** mechanically coupled to the respective second pilot shaft **102**, first co-pilot shaft **200**, and second co-pilot shaft **202** will provide an electrical signal to the flight control unit that indicates the respective shafts are rotating in a corresponding manner, while the position transducers **108A, 108B** coupled to the first pilot shaft **100** will provide an electrical signal that indicates that the first pilot shaft **100** has failed (i.e., the first pilot shaft

100 is not rotating). In response, the flight control unit may be configured to communicate the electrical signals from the operational position transducer **110A**, **110B**, **208A**, **208B**, **210A**, **210B** to the respective aircraft flight control surfaces to compensate for the detected failure. In another aspect, the flight control unit may
 5 determine that the electrical signals generated by the position transducers **108A**, **108B** associated with the first pilot shaft **100** do not correspond with the electrical signals generated by the other position transducers **110A**, **110B**, **208A**, **208B**, **210A**, **210B**, and the flight control unit may be configured to generate an electrical signal that corresponds to a corrected control command to operate the respective aircraft
 10 control surfaces.

Likewise, if the first co-pilot shaft **200** were to fail, for example, by shearing into separate pieces, the position transducers **208A**, **208B** associated with the first co-pilot shaft **200** will communicate an electrical signal to the flight control unit that differs from the electrical signals provided to the flight control unit by the other
 15 position transducers **108A**, **108B**, **110A**, **110B**, **210A**, **210B** mechanically coupled to the respective first pilot shaft **100**, second pilot shaft **102**, and second co-pilot shaft **202**. In particular, the position transducers **108A**, **108B**, **110A**, **110B**, **210A**, **210B** mechanically coupled to the respective first pilot shaft **100**, second pilot shaft **102**, and second co-pilot shaft **202** will communicate an electrical signal to the flight
 20 control unit that indicates the respective shafts are rotating in a corresponding manner, while the position transducers **208A**, **208B** coupled to the first co-pilot shaft **200** will provide an electrical signal that indicates that the first co-pilot shaft **200** has failed (i.e., the first co-pilot shaft **200** is not rotating). In response, the flight control unit may be configured to communicate the electrical signals from the operational
 25 position transducer **108A**, **108B**, **110A**, **110B**, **210A**, **210B** to the respective aircraft flight control surfaces to compensate for the detected failure. In another aspect, the flight control unit may determine that the electrical signals generated by the position transducers **208A**, **208B** associated with the first co-pilot shaft **200** do not correspond with the electrical signals generated by the other position transducers
 30 **108A**, **108B**, **110A**, **110B**, **210A**, **210B**, and the flight control unit may be configured

to generate an electrical signal that corresponds to a corrected control command to operate the respective aircraft control surfaces.

In the event that the first pilot connecting rod **104** becomes decoupled, the position transducers **108A**, **108B** mechanically coupled to the first pilot shaft **100** may communicate an electrical signal to the flight control unit that indicates the first pilot shaft **100** is not rotating in a corresponding manner with the second pilot shaft **102**, the first co-pilot shaft **200**, and/or the second co-pilot shaft **202**. Accordingly, the pilot may provide an input to the pilot wheel flight deck controller **106** that causes the first pilot shaft **100** to rotate about the longitudinal axis **L1**, thereby causing the position transducers **108A**, **108B** coupled to the first pilot shaft **100** to communicate an electrical signal to the flight control unit corresponding to the rotation of the first pilot shaft **100**. With the decoupling of the first pilot connecting rod **104**, the second pilot shaft **102** will not correspondingly rotate with respect to the first pilot shaft **100**. Rather, the rotation of the first pilot shaft **100** will cause the second coupling rod **302** to rotate the co-pilot force transducer linkage **224** about the first co-pilot shaft **200** until an end of the arcuate slot **228** defined by the co-pilot force transducer linkage **224** engages the first co-pilot deadzone engaging element **232**. After the first co-pilot deadzone engaging element **232** engages an end of the arcuate slot **228**, the first co-pilot shaft **200** will then begin to rotate about its longitudinal axis **L3**. Accordingly, the position transducers **208A**, **208B** will provide an electrical signal to the flight control unit that corresponds with the rotation of the first co-pilot shaft **200**, which is offset from the rotation of the first pilot shaft **100**. The flight control unit thereby determines that the midpoint values of the position transducers **108A**, **108B**, **110A**, **110B** of the pilot flight control system **P** are not equivalent to one another, and the flight control unit may be configured to generate an electrical signal that corresponds to a corrected control command to operate the respective aircraft control surfaces.

Likewise, if the first co-pilot connecting rod **204** were to become decoupled, the position transducers **208A**, **208B** mechanically coupled to the first co-pilot shaft **200** may communicate an electrical signal to the flight control unit that indicates the

first co-pilot shaft **200** is not rotating in a corresponding manner with the second co-pilot shaft **202**, the first pilot shaft **100**, and/or the second pilot shaft **102**. That is, the position transducers **210A**, **210B**, **108A**, **108B**, **110A**, **110B** associated with the respective second co-pilot shaft **202**, first pilot shaft **100**, and second pilot shaft **102** will communicate an electrical signal to the flight control unit that indicates the respective second co-pilot shaft **202**, first pilot shaft **100**, and second pilot shaft **102** are rotating differently from the first co-pilot shaft **200**. In particular, rotation of the first pilot shaft **100** will cause the first pilot connecting rod **104** to correspondingly rotate the second pilot shaft **102**. Additionally, the second pilot shaft **102** being mechanically coupled to the second co-pilot shaft **202** through the first coupling rod **300** will cause the second co-pilot shaft **202** to rotate in a corresponding manner with respect to the second pilot shaft **102**. Further, the rotation of the first pilot shaft **100** will cause the second coupling rod **302** to rotate the co-pilot force transducer linkage **224** about the first co-pilot shaft **200** until an end of the arcuate slot **228** defined by the co-pilot force transducer linkage **224** engages the first co-pilot deadzone engaging element **232**. After the first co-pilot deadzone engaging element **232** engages an end of the arcuate slot **228**, the first co-pilot shaft **200** will then begin to rotate about its longitudinal axis **L3**. Accordingly, the position transducers **208A**, **208B** will provide an electrical signal to the flight control unit that corresponds with the rotation of the first co-pilot shaft **200**, which is offset from the rotation of the first pilot shaft **100**. The flight control unit thereby determines that the midpoint values of the co-pilot position transducers **208A**, **208B**, **210A**, **210B** of the co-pilot flight control system **A** are not equivalent to one another, and the flight control unit may be configured to generate an electrical signal that corresponds to a corrected control command to operate the respective aircraft control surfaces.

In the event that the second pilot shaft **102** fails, for example, by shearing into separate pieces, the position transducers **110A**, **110B** mechanically coupled to the second pilot shaft **102** may communicate an electrical signal to the flight control unit that differs from the electrical signals provided to the flight control unit by the other position transducers **108A**, **108B**, **208A**, **208B**, **210A**, **210B** mechanically coupled to

the respective first pilot shaft **100**, first co-pilot shaft **200**, and second co-pilot shaft **202**. For example, as the first pilot shaft **100** rotates about the longitudinal axis **L1**, the second coupling rod **302** causes the co-pilot force transducer linkage **224** to rotate about the first co-pilot shaft **200** until an end of the arcuate slot **228** defined by the co-pilot force transducer linkage **224** engages the first co-pilot deadzone engaging element **232**. After the first co-pilot deadzone engaging element **232** engages an end of the arcuate slot **228**, the first co-pilot shaft **200** will then begin to rotate about its longitudinal axis **L3**. Subsequently, rotation of the first co-pilot shaft **200** will cause the first co-pilot connecting rod **204** to correspondingly rotate the second co-pilot shaft **202**. Thus, the electrical signals generated by the position transducers **108A**, **108B** associated with the first pilot shaft **100** will differ from the electrical signals generated by the co-pilot position transducers **208A**, **208B**, **210A**, **210B**, and the position transducers **108A**, **108B** associated with the first pilot shaft **100** and the co-pilot position transducers **208A**, **208B**, **210A**, **210B** will all communicate electrical signals to the flight control unit that differ from the electrical signals communicated by the position transducers **110A**, **110B** associated with the second pilot shaft **102**. In response to the detected failure, the flight control unit may be configured to generate and communicate an electrical signal to the respective aircraft control surfaces that corresponds to a corrected control command.

Likewise, if failure of the second co-pilot shaft **202** were to occur, the position transducers **210A**, **210B** mechanically coupled thereto may communicate an electrical signal to the flight control unit that differs from the electrical signals provided to the flight control unit by the other position transducers **108A**, **108B**, **110A**, **110B**, **208A**, **208B** mechanically coupled to the respective first pilot shaft **100**, second pilot shaft **102**, and first co-pilot shaft **200**. For example, as the first pilot shaft **100** rotates about the longitudinal axis **L1**, the second coupling rod **302** causes the co-pilot force transducer linkage **224** to rotate about the first co-pilot shaft **200** until an end of the arcuate slot **228** defined by the co-pilot force transducer linkage **224** engages the first co-pilot deadzone engaging element **232**. After the first co-pilot deadzone engaging element **232** engages an end of the arcuate slot **228**, the

first co-pilot shaft **200** will then begin to rotate about its longitudinal axis **L3**. Additionally, as the first pilot shaft **100** rotates about the longitudinal axis **L1**, the second pilot shaft **102** will rotate in a corresponding manner as the pilot shafts **100**, **102** are mechanically coupled to one another by the first pilot connecting rod **104**.

Thus, the electrical signals generated by the pilot position transducers **108A**, **108B**, **110A**, **110B** will differ from the electrical signals generated by the position transducers **208A**, **208B** associated with the first co-pilot shaft **200**. In response to the detected failure, the flight control unit may be configured to communicate an electrical signal to the respective aircraft control surfaces that corresponds to a corrected control command.

According to one possible scenario, the first coupling rod **300** may become decoupled from other components in the aircraft control system **5**. In such a case, the position transducers **108A**, **108B**, **110A**, **110B** associated with the first and second pilot shafts **100**, **102** will communicate electrical signals to the flight control unit that indicate the shafts are rotating in a corresponding manner through the first pilot connecting rod **104**. Likewise, the co-pilot position transducers **208A**, **208B**, **210A**, **210B** will communicate respective electrical signals to the flight control unit that indicate the co-pilot shafts **200**, **202** are rotating in a corresponding manner with respect to one another through the first co-pilot connecting rod **204**. However, the failure of the first coupling rod **300** will cause the pilot position transducers **108A**, **108B**, **110A**, **110B** to communicate electrical signals to the flight control unit that differ from the electrical signals communicated by the co-pilot position transducers **208A**, **208B**, **210A**, **210B**. In particular, rotation of the first pilot shaft **100** about the longitudinal axis **L1** will cause the second coupling rod **302** to rotate the co-pilot force transducer linkage **224** about the first co-pilot shaft **200** until an end of the arcuate slot **228** defined by the co-pilot force transducer linkage **224** engages the first co-pilot deadzone engaging element **232**. After the first co-pilot deadzone engaging element **232** engages an end of the arcuate slot **228**, the first co-pilot shaft **200** will then begin to rotate about its longitudinal axis **L3**. The second co-pilot shaft **202** will rotate in a corresponding manner with respect to the first co-pilot shaft **200**

as the first and second co-pilot shafts **200**, **202** are directly and mechanically coupled to one another through the first co-pilot connecting rod **204**. Thus, the electrical signals generated by the pilot position transducers **108A**, **108B**, **110A**, **110B** will differ from the electrical signals generated by the co-pilot position transducers **208A**, **208B**, **210A**, **210B**. In response to the detected failure, the flight control unit may be configured to communicate an electrical signal to the respective aircraft control surfaces that corresponds to a corrected control command.

In another possible scenario, the second coupling rod **302** may become decoupled from other components in the aircraft control system **5**. For example, when the second coupling rod **302** fails and/or becomes decoupled while the aircraft is flying, the flight control unit will receive electrical signals from each of the position transducers **108A**, **108B**, **110A**, **110B**, **208A**, **208B**, **210A**, **210B** that corresponds with the rotation of the respective shafts **100**, **102**, **200**, **202** that are substantially equal to one another. However, when the aircraft has landed and/or prior to takeoff, the pilot and/or copilot may perform a post-flight and/or pre-flight check, which may include providing opposite inputs to the pilot wheel flight deck controller **106** and the co-pilot wheel flight deck controller **206**. The pilot and co-pilot flight data recorder force transducers **122**, **222** may be configured to provide an electrical signal to the flight control unit corresponding to the opposing input forces provided to the respective pilot wheel flight deck controller **106** and the co-pilot wheel flight deck controller **206**. Under normal operating conditions, the second coupling rod **302** will resist the opposing input forces, and the flight data recorder force transducers **122**, **222** will communicate an electrical signal to the flight control unit indicating as such. However, when the second coupling rod **302** has failed, the flight data recorder force transducers **122**, **222** will communicate an electrical signal to the flight control unit that corresponds with the second coupling rod **302** providing subthreshold resistance to the opposing input forces to the respective wheel flight deck controllers **106**, **206**, and in response, the flight control unit may communicate an electrical signal indicating such failure to a control panel.

Referring to FIG. 2, the pilot and co-pilot flight control systems **P**, **A** may also include a pilot pedal flight deck controller **144** and a co-pilot pedal flight deck controller **244**. Additionally, the aircraft control system **5** may include a pilot jackshaft assembly **140** and a co-pilot jackshaft assembly **240**. Each jackshaft assembly **140**, **240** may include a jackshaft **142**, **242** respectively. Each of the jackshafts **142**, **242** may be configured to rotate about a longitudinal axis **Y1**, **Y2** defined by the pilot and co-pilot jackshafts **142**, **242** respectively. In particular, the pilot jackshaft **142** may rotate about its longitudinal axis **Y1** in response to a force exerted on the pilot pedal flight deck controller **144**. Likewise, the co-pilot jackshaft **242** may rotate about its longitudinal axis **Y2** in response to a force exerted on the co-pilot pedal flight deck controller **244**.

A first pilot connecting rod **104A** may have a first end mechanically coupled to the first pilot shaft **100** and an opposing second end mechanically coupled to the pilot jackshaft **142**. According to some aspects, a second pilot connecting rod **104B** may include a first end mechanically coupled to the second pilot shaft **102** and an opposing second end mechanically coupled to the pilot jackshaft **142**. Likewise, the co-pilot flight control system **A** may include a first co-pilot connecting rod **204A** and a second co-pilot connecting rod **204B**. The first co-pilot connecting rod **204A** may include a first end mechanically coupled to the first co-pilot shaft **200** and an opposing second end mechanically coupled to the co-pilot jackshaft **242**. The second co-pilot connecting rod **204B** may include a first end mechanically coupled to the second co-pilot shaft **202** and an opposing second end mechanically coupled to the co-pilot jackshaft **242**. As such, when the pilot jackshaft **142** rotates about its longitudinal axis **Y1**, the first and second pilot connecting rods **104A**, **104B** are displaced accordingly and cause the first and second pilot shafts **100**, **102** to rotate about their respective longitudinal axis **L1**, **L2**. Likewise, rotation of the co-pilot jackshaft **242** about its longitudinal axis **Y2** displaces the first and second co-pilot connecting rods **204A**, **204B** such that the first co-pilot shaft **200** rotates about its longitudinal axis **L3** and the second co-pilot shaft **202** rotates correspondingly about its longitudinal axis **L4**.

Additionally, the first coupling rod **300** may have a first end mechanically coupled to the pilot jackshaft **142** and an opposing second end of the first coupling rod **300** may be mechanically coupled to the co-pilot jackshaft **242**. According to some aspects, the aircraft control system may include a second coupling rod **302** that includes a first end mechanically coupled to the pilot jackshaft **142**. An opposing second end of the second coupling rod may be mechanically coupled to the co-pilot jackshaft **242**. As such, rotation of the pilot jackshaft **142** about its longitudinal axis **Y1** may cause either of the first and second coupling rods **300**, **302** to displace and cause the co-pilot jackshaft **242** to correspondingly rotate about its longitudinal axis **Y2**. Likewise, rotation of the co-pilot jackshaft **242** about its longitudinal axis **Y2** may cause either of the first and second coupling rods **300**, **302** to displace and cause the pilot jackshaft **142** to correspondingly rotate about its longitudinal axis **Y1**.

The pilot and co-pilot flight control systems **P**, **A** include a plurality of position transducers **108**, **110**, **208**, **210** mechanically coupled to the first pilot shaft **100**, second pilot shaft **102**, first co-pilot shaft **200**, and second co-pilot shaft **202** respectively. The position transducers **108**, **110**, **208**, **210** are configured to generate an electrical signal corresponding to the rotation of the respective first pilot shaft **100**, second pilot shaft **102**, first co-pilot shaft **200**, and second co-pilot shaft **202**. Additionally, the position transducers **108**, **110**, **208**, **210** are configured to communicate the electrical signal to the flight control unit.

In one possible scenario, the pilot flight data recorder force transducer **122** may become decoupled from the pilot jackshaft **142** and/or the pilot pedal flight deck controller **144**. When the pilot flight data recorder force transducer **122** becomes decoupled from either of the pilot jackshaft **142** and/or the pilot pedal flight deck controller **144**, the pilot may experience a loss in fidelity when providing an input force to the pilot pedal flight deck controller **144**. The flight control unit will receive electrical signals from each of the position transducers **108**, **110**, **208**, **210** corresponding with the rotation of the respective shafts **100**, **102**, **200**, **202** that are substantially equal to one another. However, the flight control unit will also receive

an electrical signal from the pilot flight data recorder force transducer **122** indicating that the pilot flight data recorder force transducer **122** has become decoupled, and the flight control unit may communicate an electrical signal to the respective aircraft control surfaces that corresponds to a corrected control command.

5 Likewise, if the co-pilot flight data recorder force transducer **222** were to become decoupled from either of the co-pilot jackshaft **242** and/or the co-pilot pedal flight deck controller **244**, the copilot will experience a loss in fidelity when providing an input force to the co-pilot pedal flight deck controller **244**. The flight control unit will receive electrical signals from each of the position transducers **108**, **110**, **208**,
10 **210** corresponding with the rotation of the respective shafts **100**, **102**, **200**, **202** that are substantially equal to one another. However, the flight control unit will also receive an electrical signal from the co-pilot flight data recorder force transducer **222** indicating that the co-pilot flight data recorder force transducer **222** has become decoupled, and the flight control unit may be configured to communicate an electrical
15 signal to the respective aircraft control surfaces that corresponds to a corrected control command.

In yet another possible scenario, the first pilot shaft **100** may fail by, for example, shearing into separate pieces. Additionally or alternatively, the first pilot connecting rod **104A** may fail and/or become decoupled from the first pilot shaft **100**.

20 In either possible failure mode, the first pilot shaft **100** will become unresponsive to any rotation of the pilot jackshaft **142**, and the first pilot shaft **100** will cease to rotate about the longitudinal axis **L1**. Consequently, the position transducer **108** mechanically coupled to the first pilot shaft **100** will communicate an electrical signal to the flight control unit that differs from the electrical signals provided to the flight
25 control unit by the other position transducers **110**, **208**, **210** mechanically coupled to the respective second pilot shaft **102**, first co-pilot shaft **200**, and second co-pilot shaft **202**. In response, the flight control unit may be configured to communicate the electrical signals from the operational position transducer **110**, **208**, **210** to the respective aircraft flight control surfaces to compensate for the detected failure. In
30 another aspect, the flight control unit thereby determines that the electrical signal

communicated by the position transducer **108** mechanically coupled to the first pilot shaft **100** does not correspond with the electrical signals communicated by the other position transducers **110**, **208**, **210**, and the flight control unit may be configured to communicate an electrical signal that corresponds to a corrected control command to operate the respective aircraft control surfaces.

Likewise, if the first co-pilot shaft **200** and/or the first co-pilot connecting rod **204A** were to fail and/or become decoupled, the position transducer **208** mechanically coupled to the first co-pilot shaft **200** will communicate an electrical signal to the flight control unit that differs from the electrical signals communicated to the flight control unit by the other position transducers **108**, **110**, **210** mechanically coupled to the respective first pilot shaft **100**, second pilot shaft **102**, and second co-pilot shaft **202**. When either the first co-pilot shaft **200** and/or the first co-pilot connecting rod **204A** fails, the first co-pilot shaft **200** will become unresponsive to any rotation of the co-pilot jackshaft **242**, and the first co-pilot shaft **200** will cease to rotate about the longitudinal axis **L3**. In particular, the position transducers **108**, **110**, **210** mechanically coupled to the respective first pilot shaft **100**, second pilot shaft **102**, and second co-pilot shaft **202** will communicate an electrical signal to the flight control unit that indicates the respective shafts are rotating in a corresponding manner, while the position transducer **208** coupled to the first co-pilot shaft **200** will provide an electrical signal that indicates that the first co-pilot shaft **200** and/or the first co-pilot connecting rod **204A** has failed. In response, the flight control unit may be configured to communicate the electrical signals from the operational position transducer **108**, **110**, **210** to the respective aircraft flight control surfaces to compensate for the detected failure. In another aspect, the flight control unit may determine that the electrical signal communicated by the position transducer **208** mechanically coupled to the first co-pilot shaft **200** does not correspond with the electrical signals communicated by the other position transducers **108**, **110**, **210**, and the flight control unit may be configured to generate an electrical signal that corresponds to a corrected control command to operate the respective aircraft control surfaces.

According to another example scenario, the second pilot shaft **102** may fail by, for example, shearing into separate pieces. Additionally or alternatively, the second pilot connecting rod **104B** may fail and/or become decoupled from the second pilot shaft **200** and/or the pilot jackshaft **142**. In either possible failure mode, the second pilot shaft **102** will become unresponsive to any rotation of the pilot jackshaft **142**, and the second pilot shaft **102** will cease to rotate about the longitudinal axis **L2**. Consequently, the position transducer **110** mechanically coupled to the second pilot shaft **102** will provide an electrical signal to the flight control unit that differs from the electrical signals provided to the flight control unit by the other position transducers **108**, **208**, **210** mechanically coupled to the respective first pilot shaft **100**, first co-pilot shaft **200**, and second co-pilot shaft **202**. In response, the flight control unit may be configured to communicate the electrical signals from the operational position transducers **108**, **208**, **210** to the respective aircraft flight control surfaces to compensate for the detected failure. In another aspect, the flight control unit may determine that the electrical signal communicated by the position transducer **110** mechanically coupled to the second pilot shaft **102** does not correspond with the electrical signals communicated by the other position transducers **108**, **208**, **210**, and the flight control unit may be configured to generate an electrical signal that corresponds to a corrected control command to operate the respective aircraft control surfaces.

Likewise, should the second co-pilot shaft **200** and/or the second co-pilot connecting rod **204B** fail and/or become decoupled, the position transducer **210** mechanically coupled to the second co-pilot shaft **202** will communicate an electrical signal to the flight control unit that differs from the electrical signals provided to the flight control unit by the other position transducers **108**, **110**, **208** mechanically coupled to the respective first pilot shaft **100**, second pilot shaft **102**, and first co-pilot shaft **200**. Should either the second co-pilot shaft **200** and/or the second co-pilot connecting rod **204B** fails, the second co-pilot shaft **202** will become unresponsive to any rotation of the co-pilot jackshaft **242**, and the second co-pilot shaft **202** will cease to rotate about the longitudinal axis **L4**. In particular, the position transducers

108, 110, 208 mechanically coupled to the respective first pilot shaft **100**, second pilot shaft **102**, and first co-pilot shaft **202** will communicate an electrical signal to the flight control unit that indicates the respective shafts are rotating in a corresponding manner, while the position transducer **210** coupled to the second co-pilot shaft **202** will provide an electrical signal that indicates that the second co-pilot shaft **202** and/or the second co-pilot connecting rod **204B** has failed. In response, the flight control unit may be configured to communicate the electrical signals from the operational position transducer **108, 110, 208** to the respective aircraft flight control surfaces to compensate for the detected failure. In another aspect, the flight control unit may determine that the electrical signal communicated by the position transducer **210** mechanically coupled to the second co-pilot shaft **202** does not correspond with the electrical signals communicated by the other position transducers **108, 110, 208**, and the flight control unit may be configured to communicate an electrical signal that corresponds to a corrected control command to operate the respective aircraft control surfaces.

In the event that the first coupling rod **300** becomes decoupled and/or fails, rotation of the pilot jackshaft **142** about its longitudinal axis **Y1** will cause the second coupling rod **302** to correspondingly rotate the co-pilot jackshaft **242** about its longitudinal axis **Y2**. Likewise, rotation of the co-pilot jackshaft **242** about its longitudinal axis **Y2** will cause the second coupling rod **302** to correspondingly rotate the pilot jackshaft **142** about its longitudinal axis **Y1**. As such, failure of the first coupling rod **300** will still be mitigated by the second coupling rod **302** while the aircraft is in flight, and the pilot and co-pilot position transducers **108, 110, 208, 210** mechanically coupled to the respective first and second shafts **100, 102, 200, 202** will communicate electrical signals to the flight control unit that indicate the shafts **100, 102, 200, 202** are rotating in a corresponding manner with respect to one another. Likewise, should the second coupling rod **302** were to fail and/or become decoupled from one or both of the pilot and co-pilot jackshafts **142, 242**, the first coupling rod **300** will mitigate the failure and the position transducers **108, 110, 208, 210** mechanically coupled to the respective first and second shafts **100, 102, 200,**

202 will communicate electrical signals to the flight control unit that indicate the shafts **100, 102, 200, 202** are rotating in a corresponding manner with respect to one another. However, when the aircraft has landed and/or prior to takeoff, the pilot and/or copilot may perform a post-flight and/or pre-flight check, which may include
 5 providing opposite inputs to the pilot pedal flight deck controller **144** and the co-pilot pedal flight deck controller **244**.

If either of the first and/or second coupling rods **300, 302** has become decoupled and/or failed, during the opposite input force test, the pilot position transducers **108, 110** will communicate an electrical signal to the flight control unit
 10 that differs from the electrical signals communicated by the co-pilot position transducers **208, 210**. Further, the flight control unit may be configured to communicate an electrical signal that corresponds to a corrected control command to operate the respective aircraft control surfaces.

Referring to FIG. 3, the pilot flight control system **P** and the co-pilot flight
 15 control system **A** may include a pilot column flight deck controller **150** and a co-pilot column flight deck controller **250** that are each coupled to the respective first pilot and co-pilot shafts **100, 200**. In particular, a first end of a pilot flight data recorder force transducer **122** may be mechanically coupled to the pilot column flight deck controller **150**, and the opposing second end of the pilot flight data recorder force
 20 transducer **122** may be mechanically coupled to the first pilot shaft **100**. In some aspects, the opposing second end of the pilot flight data recorder force transducer **122** may be coupled to a pilot feel and centering unit **138** that is mechanically coupled to the first pilot shaft **100**. Likewise, a co-pilot flight data recorder force transducer **222** may include a first end mechanically coupled to the co-pilot column
 25 flight deck controller **250** and an opposing second end that is mechanically coupled to a co-pilot feel and centering unit **238** that is mechanically coupled to the first co-pilot shaft **200**.

The pilot flight control system **P** includes a pair of first pilot position transducers **108A, 108B** mechanically coupled to the first pilot shaft **100**. Likewise,
 30 the co-pilot flight control system **A** includes a pair of position transducers **208A,**

208B mechanically coupled to the first co-pilot shaft **200**. The second pilot shaft **102** is mechanically coupled to a second pilot position transducer **110**, and the second co-pilot shaft **202** is mechanically coupled to a second co-pilot position transducer **210**. The position transducers **108A**, **108B**, **110**, **208A**, **208B**, **210** are configured to generate an electrical signal corresponding to the rotation of the respective first pilot shaft **100**, second pilot shaft **102**, first co-pilot shaft **200**, and second co-pilot shaft **202**, and are further configured to communicate the respective electrical signals to the flight control unit.

In one possible scenario, the pilot flight data recorder force transducer **122** may become decoupled from the first pilot shaft **100** and/or the pilot column flight deck controller **150**. When the pilot flight data recorder force transducer **122** becomes decoupled from either of the first pilot shaft **100** and/or the pilot column flight deck controller **150**, the pilot may experience a loss in fidelity when providing an input force to the pilot column flight deck controller **150**. In particular, the decoupling and/or failure of the pilot flight data recorder force transducer **122** may cause the pilot column flight deck controller **150** to fall forward and become completely unresponsive. The flight control unit will receive electrical signals from each of the position transducers **108A**, **108B**, **110**, **208A**, **208B**, **210** corresponding with the rotation of the respective shafts **100**, **102**, **200**, **202** that are substantially equal to one another. However, the flight control unit will also receive an electrical signal from the pilot flight data recorder force transducer **122** indicating that the pilot flight data recorder force transducer **122** has become decoupled, and the flight control unit may be configured to communicate an electrical signal that corresponds to a corrected control command to operate the respective aircraft control surfaces.

Likewise, should the co-pilot flight data recorder force transducer **222** become decoupled from either of the first co-pilot shaft **200** and/or the co-pilot column flight deck controller **250**, the copilot will experience a loss in fidelity when providing an input force to the co-pilot column flight deck controller **250**. The flight control unit will receive electrical signals from each of the position transducers **108A**, **108B**, **110**, **208A**, **208B**, **210** corresponding with the rotation of the respective shafts **100**, **102**,

200, 202 that are substantially equal to one another. However, the flight control unit will also receive an electrical signal from the co-pilot flight data recorder force transducer **222** indicating that the co-pilot flight data recorder force transducer **222** has become decoupled, and the flight control unit may be configured to communicate an electrical signal that corresponds to a corrected control command to operate the respective aircraft control surfaces.

In yet another example possible scenario, the first pilot shaft **100** may fail by, for example, shearing into separate pieces. Thus, the first pilot shaft **100** will become unresponsive to any input force and will cease to rotate about the longitudinal axis **L1**. In another possible failure mode, the pilot connecting rod **104** mechanically coupling the first pilot shaft **100** to the second pilot shaft **102** may fail and/or become decoupled at either end. In response to the failure of the first pilot shaft **100** and/or the pilot connecting rod **104**, the position transducers **108A, 108B** mechanically coupled to the first pilot shaft **100** will provide an electrical signal to the flight control unit that differs from the electrical signals provided to the flight control unit by the other position transducers **110, 208A, 208B, 210** mechanically coupled to the respective second pilot shaft **102**, first co-pilot shaft **200**, and second co-pilot shaft **202**. The co-pilot may still control the aircraft with the co-pilot column flight deck controller **206**. Accordingly, the position transducers **110, 208A, 208B, 210** mechanically coupled to the respective second pilot shaft **102**, first co-pilot shaft **200**, and second co-pilot shaft **202** will provide an electrical signal to the flight control unit that indicates the respective shafts are rotating in a corresponding manner, while the position transducers **108A, 108B** coupled to the first pilot shaft **100** will provide an electrical signal that indicates that the first pilot shaft **100** has failed (i.e., the first pilot shaft **100** is not rotating). In response, the flight control unit may be configured to communicate the electrical signals from the operational position transducer **110, 208A, 208B, 210** to the respective aircraft flight control surfaces to compensate for the detected failure. In another aspect, the flight control unit may determine that the electrical signals generated by the position transducers **108A, 108B** associated with the first pilot shaft **100** do not correspond with the electrical signals generated by the

other position transducers **110**, **208A**, **208B**, **210**, and the flight control unit may be configured to communicate an electrical signal that corresponds to a corrected control command to operate the respective aircraft control surfaces.

Likewise, if the first co-pilot shaft **200** were to fail, the position transducers
5 **208A**, **208B** associated with the first co-pilot shaft **200** will communicate an electrical signal to the flight control unit that differs from the electrical signals provided to the flight control unit by the other position transducers **108A**, **108B**, **110**, **210** mechanically coupled to the respective first pilot shaft **100**, second pilot shaft **102**, and second co-pilot shaft **202**. Additionally, the first co-pilot shaft **200** will become
10 unresponsive to any input force provided to the co-pilot column flight deck controller **250** and will cease to rotate about the longitudinal axis **L2**. Additionally or alternatively, the co-pilot connecting rod **204** mechanically coupling the first co-pilot shaft **200** to the second co-pilot shaft **202** may fail and/or become decoupled at either end. In response to the failure of the first co-pilot shaft **200** and/or the co-pilot
15 connecting rod **204**, the position transducers **108A**, **108B**, **110**, **210** mechanically coupled to the respective first pilot shaft **100**, second pilot shaft **102**, and second co-pilot shaft **202** will communicate an electrical signal to the flight control unit that indicates the respective shafts are rotating in a corresponding manner, while the position transducers **208A**, **208B** coupled to the first co-pilot shaft **200** will provide an
20 electrical signal that indicates that the first co-pilot shaft **200** has failed (i.e., the first co-pilot shaft **200** is not rotating). In response, the flight control unit may be configured to communicate the electrical signals from the operational position transducer **108A**, **108B**, **110**, **210** to the respective aircraft flight control surfaces to compensate for the detected failure. In another aspect, the flight control unit may
25 determine that the electrical signals communicated by the position transducers **208A**, **208B** associated with the first co-pilot shaft **200** do not correspond with the electrical signals generated by the other position transducers **108A**, **108B**, **110**, **210**, and the flight control unit may be configured to communicate an electrical signal that corresponds to a corrected control command to operate the respective aircraft
30 control surfaces.

In another possible scenario, the second pilot shaft **102** may fail, for example, by shearing into separate pieces. In such an event, the position transducer **110** mechanically coupled to the second pilot shaft **102** may communicate an electrical signal to the flight control unit that differs from the electrical signals provided to the flight control unit by the other position transducers **108A**, **108B**, **208A**, **208B**, **210** mechanically coupled to the respective first pilot shaft **100**, first co-pilot shaft **200**, and second co-pilot shaft **202**. In response to the detected failure, the flight control unit may be configured to communicate an electrical signal to the respective aircraft control surfaces that corresponds to a corrected control command.

Likewise, if the second co-pilot shaft **202** were to fail, the position transducer **210** mechanically coupled to the second co-pilot shaft **202** may communicate an electrical signal to the flight control unit that differs from the electrical signals communicated to the flight control unit by the other position transducers **108A**, **108B**, **110**, **208A**, **208B** mechanically coupled to the respective first pilot shaft **100**, second pilot shaft **102**, and first co-pilot shaft **200**. In response to the detected failure, the flight control unit may be configured to communicate an electrical signal to the respective aircraft control surfaces that corresponds to a corrected control command.

According to another example scenario, the first coupling rod **300** mechanically coupling the second pilot shaft **102** to the second co-pilot shaft **202** may become decoupled. In such a case, the pilot position transducers **108A**, **108B**, **110** associated with the first and second pilot shafts **100**, **102** will communicate electrical signals to the flight control unit that indicate the shafts are rotating in a corresponding manner through the first pilot connecting rod **104**. Likewise, the co-pilot position transducers **208A**, **208B**, **210** will communicate respective electrical signals to the flight control unit that indicate the co-pilot shafts **200**, **202** are rotating in a corresponding manner with respect to one another through the first co-pilot connecting rod **204**. However, the failure of the first coupling rod **300** will cause the pilot position transducers **108A**, **108B**, **110** to communicate electrical signals to the flight control unit that differ from the electrical signals communicated by the co-pilot

position transducers **208A**, **208B**, **210**, and in response to the detected failure, the flight control unit may be configured to communicate an electrical signal to the respective aircraft control surfaces that corresponds to a corrected control command.

5 According to another aspect of the present disclosure, a method of manufacturing a fly-by-wire aircraft control system is also provided. As shown in FIG. **5**, the method **500** may include coupling a first shaft to a second shaft of a pilot flight control system and coupling a first shaft to a second shaft of a co-pilot flight control system (Block **502**). The respective first shafts of the pilot and co-pilot flight control systems being displaced apart from the respective second shafts of the pilot and co-pilot flight control systems.

 Additionally, the method may include coupling a position transducer to each shaft of the pilot and co-pilot flight control system (Block **504**). Each position transducer is configured to generate an electrical signal corresponding to the rotation
15 of the respective shaft to a flight control unit.

 According to some aspects, the method may include connecting the flight control unit in electrical communication with each of the position transducers (Block **506**). The flight control unit is configured to receive the electrical signal from each of the position transducers. Additionally, the flight control unit is configured to detect a
20 failure of the pilot or co-pilot flight control system, in part, by detecting differences in the electrical signals generated by the position transducers. The flight control unit may be further configured to communicate the electrical signal from the operational position transducer(s) to a flight control surface to compensate for the detected failure.

25 In some aspects, the method may further include coupling a pilot flight deck controller and a co-pilot flight deck controller to the corresponding first shafts of the pilot flight control system and the co-pilot flight control system respectively. The pilot and co-pilot flight deck controllers may be configured to rotate the respective first pilot and first co-pilot shafts about the longitudinal axis thereof. In addition, the
30 method may include coupling at least one of the pilot shafts to one of the co-pilot

shafts with at least one linkage such that rotation of the one of the pilot shafts about the longitudinal axis thereof causes rotation of the coupled one of the co-pilot shafts about the longitudinal axis thereof.

5 The method may further include coupling a first end of a first pilot connecting rod to the first pilot shaft and an opposing second end of the first pilot connecting rod to the second pilot shaft. Additionally, the method may include coupling a first end of a first co-pilot connecting rod to the first co-pilot shaft and an opposing second end of the first co-pilot connecting rod to the second co-pilot shaft such that rotation of one of the shafts about the longitudinal axis thereof causes rotation in the others of
10 the first and second pilot and first and second co-pilot shafts.

The method may also include coupling a first end of a first coupling rod to the second pilot shaft and an opposing second end to the second co-pilot shaft such that rotation of one of the second pilot shaft and co-pilot shafts about the respective longitudinal axis thereof causes the first coupling rod to correspondingly rotate the
15 other of the second pilot and co-pilot shaft about the longitudinal axis thereof. Likewise, rotation of the first pilot and co-pilot shafts about the respective longitudinal axis thereof causes corresponding rotation of the respective second pilot and co-pilot shafts about the respective longitudinal axis thereof.

The method may further include coupling a pilot and a co-pilot flight deck
20 controller to a respective pilot and co-pilot jackshaft assembly. Each jackshaft assembly may include a jackshaft configured to rotate about a respective longitudinal axis defined thereby. In particular, the pilot and co-pilot jackshafts may be configured to rotate about their respective longitudinal axis in response to a force exerted onto the corresponding pilot and co-pilot flight deck controllers. The pilot
25 and co-pilot flight deck controllers are mechanically coupled to the corresponding jackshaft assembly and may include a pair of pedals.

The method may further include coupling a first end of a second pilot connecting rod to the second pilot shaft and coupling a first end of a second co-pilot connecting rod to the second co-pilot shaft. In some aspects, the method may
30 include coupling an opposing second end of the second pilot connecting rod to the

pilot jackshaft and coupling an opposing second end of the second co-pilot connecting rod to the co-pilot jackshaft. Accordingly, rotation of the pilot jackshaft about the longitudinal axis defined thereby causes an associated rotation of the first pilot shaft about the longitudinal axis thereof through the first pilot connecting rod.

5 Additionally, the rotation of the pilot jackshaft about the longitudinal axis defined thereby causes the second pilot shaft to rotate about its longitudinal axis that corresponds with the rotation of the first pilot shaft via the second pilot connecting rod. Likewise, rotation of the co-pilot jackshaft about the longitudinal axis thereof causes an associated rotation of the first co-pilot shaft about the longitudinal axis
10 thereof through the first co-pilot connecting rod mechanically coupled to the first co-pilot shaft. Additionally, the rotation of the co-pilot jackshaft about the longitudinal axis thereof causes the second co-pilot connecting rod to displace and rotate the second co-pilot shaft that corresponds with the rotation of the first co-pilot shaft.

The method may further include coupling a first end of a second coupling rod
15 to the pilot jackshaft and an opposing second end of the second coupling rod to the co-pilot jackshaft. As one of the pilot and co-pilot jackshafts rotates about its respective longitudinal axis, the second coupling rod causes corresponding rotation of the other of the pilot and co-pilot jackshafts about the longitudinal axis thereof.

In some aspects, the method may further include coupling a first end of a pilot
20 flight data recorder force transducer directly to a pilot flight data recorder linkage having a first end securely attached to a pilot wheel pulley. The method may further include coupling an opposing second end of the pilot flight data recorder force transducer directly to a pilot force transducer linkage, the pilot force transducer linkage being axially displaced along the first pilot shaft from the pilot wheel pulley
25 and being rotatable about the first pilot shaft.

In some aspects, the method may include coupling a first end of a bank angle protection force transducer directly to the pilot force transducer linkage. The method may further include coupling an opposing second end of the bank angle protection force transducer directly to a first pilot dead zone linkage. In some aspects, the
30 method may include attaching a second pilot deadzone linkage to the first pilot shaft.

Additionally, the method may include coupling a first end of a co-pilot flight data recorder force transducer directly to a co-pilot flight data recorder linkage having a first end securely attached to a co-pilot wheel pulley.

5 The method may further include coupling an opposing second end of the co-pilot flight data recorder force transducer directly to a co-pilot force transducer linkage. In some aspects, the method includes attaching a first co-pilot dead zone linkage to the first co-pilot shaft. The method may further include attaching a second co-pilot deadzone linkage to the first co-pilot shaft, coupling a first end of a second coupling rod directly to the pilot force transducer linkage, and coupling an opposing
10 second end of the second coupling rod directly to the co-pilot force transducer linkage.

According to some aspects, the method may further include coupling a first end of a pilot flight data recorder force transducer to the pilot flight deck controller and coupling an opposing second end of the pilot flight data recorder force
15 transducer to the first pilot shaft. The method may include coupling a first end of a co-pilot flight data recorder force transducer to the co-pilot flight deck controller and coupling an opposing second end of the co-pilot flight data recorder force transducer to the first co-pilot shaft.

In some aspects, a method of controlling a fly-by-wire aircraft control system
20 is also provided. As shown in FIG. 6, the method 600 may include receiving an electrical signal from a plurality of position transducers (Block 602). Each position transducer may be coupled to one of a first shaft and a second shaft of a pilot flight control system, and a first shaft and a second shaft of a co-pilot flight control system. The first and second shafts define independent longitudinal axes, and each shaft is
25 rotatable about the respective longitudinal axes. The flight control system may further include a connecting link that enables rotation of one of the shafts to rotate a corresponding one of the connected shafts.

In some aspects, the method may include receiving an electrical signal from a position transducer coupled to the first shafts of the respective pilot and co-pilot flight
30 control systems. The first shafts may be mechanically coupled to respective pilot

and co-pilot flight deck controllers. According to some aspects, the method may include receiving an electrical signal from a position transducer coupled to one of the first and second shafts of the respective pilot and co-pilot control systems. Additionally, at least one linkage may mechanically couple one of the pilot shafts to one of the co-pilot shafts such that rotation of one of the pilot shafts about the longitudinal axis thereof causes corresponding rotation of the coupled one of the co-pilot shafts.

In some aspects, the method may further include receiving an electrical signal from the first pilot position transducer associated with the rotation of the first pilot shaft that differs from an electrical signal received from the second pilot position transducer associated with the rotation of the second pilot shaft in response to a failure of a first pilot connecting rod having one end mechanically coupled to the first pilot shaft and an opposing second end mechanically coupled to the second pilot shaft.

According to some aspects, the method may further include receiving an electrical signal from the first co-pilot position transducer associated with the rotation of the first co-pilot shaft that differs from an electrical signal received from the second co-pilot position transducer associated with the rotation of the second co-pilot shaft in response to a failure of the first co-pilot connecting rod having one end mechanically coupled to the first co-pilot shaft and an opposing second end mechanically coupled to the second co-pilot shaft.

In some aspects, the flight control system may include a pilot and co-pilot jackshaft assembly. Each jackshaft assembly may include a jackshaft that defines a longitudinal axis. The pilot and co-pilot jackshafts may be configured to rotate about the respective longitudinal axis in response to a force exerted onto the flight deck controller. In some aspects, the flight deck controller may each include a pair of pedals that are mechanically coupled to the corresponding jackshaft assembly. Additionally, the flight control system may include a first coupling rod and a second coupling rod. Each coupling rod may mechanically couple one of the pilot shafts to one of the co-pilot shafts. For example, a coupling rod may include a first end

mechanically coupled to the pilot jackshaft and an opposing second end mechanically coupled to the co-pilot jackshaft. Further, the method may include receiving an electrical signal from one of the pilot position transducers, in response to a failure of one of the first and second coupling rods, that is equal to an electrical
5 signal received from one of the co-pilot position transducers.

According to some aspects, the method may further include receiving an electrical signal from a pilot flight data recorder force transducer and an electrical signal from a co-pilot flight data recorder force transducer. Each flight data recorder force transducer may have a first end mechanically coupled to the respective pilot
10 and co-pilot flight deck controllers and an opposing second end mechanically coupled to the respective first pilot and co-pilot shafts. Additionally, in response to a failure of the corresponding one of the pilot and co-pilot flight data recorder force transducers, the corresponding one of the pilot and co-pilot flight deck controllers may be configured to lose fidelity in flight control.

According to some aspects, the method may further include detecting a failure of the pilot or co-pilot flight control systems by detecting differences in the electrical signals received from each of the position transducers (Block **604**). In some aspects, a flight control unit may be configured to detect a failure of the pilot and/or co-pilot flight control systems. The pilot and co-pilot flight control systems may
20 include a plurality of position transducers, and the electrical signals transmitted by the plurality of position transducers may be compared to one another to determine the operational state (e.g., healthy, degraded, faulty, etc.) of the position transducers.

In some aspects, the method may further include communicating the electrical signal from the position transducers to a flight control surface actuation system to
25 compensate for the detected failure (Block **606**). For example, the flight control unit may be configured to communicate the electrical signal from the operational position transducers to a flight control surface actuation system to compensate for the detected failure.

Many modifications and other implementations of the disclosure set forth
30 herein will come to mind to one skilled in the art to which the disclosure pertains

having the benefit of the teachings presented in the foregoing description and the associated drawings. Therefore, it is to be understood that the disclosure is not to be limited to the specific implementations disclosed and that modifications and other implementations are intended to be included within the scope of the appended
5 claims. Moreover, although the foregoing description and the associated drawings describe example implementations in the context of certain example combinations of elements and/or functions, it should be appreciated that different combinations of elements and/or functions may be provided by alternative implementations without departing from the scope of the appended claims. In this regard, for example,
10 different combinations of elements and/or functions than those explicitly described above are also contemplated as may be set forth in some of the appended claims. Although specific terms are employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation.

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EMBODIMENTS IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. An aircraft control system comprising:

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pilot and co-pilot flight control systems, each including a first shaft mechanically coupled to and displaced apart from a second shaft, the shafts defining and being rotatable about independent longitudinal axes, wherein a connecting link enables rotation of one of the first shafts to rotate a corresponding one of the second shafts;

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a position transducer mechanically coupled to each shaft and configured to communicate an electrical signal corresponding to the rotation of the respective shaft; and

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a flight control unit in communication with the position transducers and configured to (a) receive the electrical signal from each of the position transducers, (b) detect a failure of the pilot or co-pilot flight control system by detecting differences in the electrical signals from the position transducers, and (c) communicate the electrical signal from the position transducer to a flight control surface actuation system to compensate for the detected failure.

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2. The aircraft control system of Claim 1 further comprising:

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a pilot flight deck controller mechanically coupled to the first pilot shaft, the pilot flight deck controller being configured to rotate the first pilot shaft about the longitudinal axis thereof; and

a co-pilot flight deck controller mechanically coupled to the first co-pilot shaft, the co-pilot flight deck controller being configured to rotate the first co-pilot shaft about the longitudinal axis thereof.

- 5 **3.** The aircraft control system of Claim **2** further comprising at least one linkage mechanically coupling one of the pilot shafts to one of the co-pilot shafts such that rotation of the one of the pilot shafts about the longitudinal axis thereof causes corresponding rotation of the coupled one of the co-pilot shafts.

- 10 **4.** The system of Claim **3**, wherein the connecting link enabling rotation of one of the first shafts to rotate a corresponding one of the second shafts further comprises a first pilot connecting rod and a first co-pilot connecting rod, each connecting rod having a first end mechanically coupled to the respective first pilot and co-pilot shaft and an opposing second end mechanically coupled to

15 the respective second pilot and co-pilot shaft, wherein the first pilot transducer, in response to a failure of the first pilot connecting rod, is configured to provide an electrical signal associated with the rotation of the first pilot shaft to the flight control unit that differs from the electrical signal provided by the second pilot transducer associated with the rotation of the

20 second pilot shaft, and wherein the first co-pilot transducer, in response to a failure of the first co-pilot connecting rod, is configured to provide an electrical signal associated with the rotation of the first co-pilot shaft to the flight control unit that differs from the electrical signal provided by the second co-pilot transducer associated with the rotation of the second co-pilot shaft.

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- 30 **5.** The system of Claim **4**, wherein the at least one linkage mechanically coupling one of the pilot shafts to one of the co-pilot shafts further comprises a first coupling rod having a first end mechanically coupled to the second pilot shaft and an opposing second end mechanically coupled to the second co-pilot shaft such that rotation of one of the second pilot and co-pilot shaft about

the respective longitudinal axis thereof causes the first coupling rod to correspondingly rotate the other of the second pilot and co-pilot shaft about the longitudinal axis thereof, wherein the first and second pilot position transducers, in response to a failure of the first coupling rod, are configured to provide electrical signals associated with the rotation of the corresponding first and second pilot shafts to the flight control unit that differ from the electrical signals provided by the first and second co-pilot position transducers associated with the rotation of the corresponding first and second co-pilot shafts to the flight control unit.

6. The system of Claim 5 further comprising:

a pilot and co-pilot jackshaft assembly, each jackshaft assembly including a jackshaft configured to rotate about a respective longitudinal axis defined thereby in response to a force exerted onto the flight deck controller mechanically coupled to the corresponding jackshaft assembly, wherein each flight deck controller includes a pair of pedals;

wherein the connecting link enabling rotation of one of the first shafts to rotate a corresponding one of the second shafts further comprises a second pilot and a second co-pilot connecting rod, each connecting rod having a first end mechanically coupled to the respective second pilot and co-pilot shaft and an opposing second end mechanically coupled to the respective pilot and co-pilot jackshaft such that rotation of the pilot jackshaft about the longitudinal axis thereof causes an associated rotation of the first pilot shaft about the longitudinal axis thereof and a rotation of the second pilot shaft that corresponds with the rotation of the first pilot shaft, and such that rotation of the co-pilot jackshaft about the longitudinal axis thereof causes an associated rotation of the first

co-pilot shaft about the longitudinal axis thereof and a rotation of the second co-pilot shaft that corresponds with the rotation of the first co-pilot shaft,

5 wherein the first end of the first coupling rod is mechanically coupled to the pilot jackshaft and the opposing second end is mechanically coupled to the co-pilot jackshaft such that rotation of one of the pilot and co-pilot jackshafts about the longitudinal axis thereof causes a corresponding rotation of the other one of the pilot and co-pilot
10 jackshaft about the longitudinal axis thereof,

wherein the at least one linkage mechanically coupling one of the pilot shafts to one of the co-pilot shafts further comprises a second coupling rod having a first end mechanically coupled to the pilot jackshaft and
15 an opposing second end mechanically coupled to the co-pilot jackshaft, and

wherein, in response to a failure of one of the first and second coupling rods, the pilot and co-pilot jackshafts are rotated about the longitudinal
20 axes thereof by the other of the first and second coupling rods, and the pilot and co-pilot position transducers are configured to provide the flight control unit with equal electrical signals.

7. The system of any one of Claims **2-3** further comprising:

25 a pilot flight data recorder force transducer and a co-pilot flight data recorder force transducer, each flight data recorder force transducer having a first end mechanically coupled to the respective pilot and co-pilot flight deck controllers and an opposing second end mechanically
30 coupled to the respective first pilot and co-pilot shafts, and wherein, in

response to a failure of the corresponding one of the pilot and co-pilot flight data recorder force transducers, the corresponding one of the pilot and co-pilot flight deck controllers is configured to lose fidelity in flight control.

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8. The system of Claim 7, wherein the pilot and co-pilot flight deck controller further includes a pilot and co-pilot column flight deck controller, the pilot and co-pilot column flight deck controller being configured to become unresponsive to user input, in response to a failure of one of the corresponding pilot and co-pilot flight data recorder force transducers.

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9. A method of controlling a fly-by-wire aircraft control system comprising:

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receiving an electrical signal from a plurality of position transducers, each position transducer coupled to one of a first shaft and a second shaft of a pilot flight control system and a first shaft and a second shaft of a co-pilot flight control system, the first and second shafts defining and being rotatable about independent longitudinal axes, wherein a connecting link enables rotation of one of the shafts to rotate a corresponding one of the connected shafts;

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detecting a failure of the pilot or co-pilot flight control systems by detecting differences in the electrical signals received from each of the position transducers; and

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communicating the electrical signal from the position transducer to a flight control surface actuation system to compensate for the detected failure.

- 5 **10.** The method of Claim **9**, wherein receiving an electrical signal from a position transducer includes receiving an electrical signal from a position transducer coupled to the first shafts of the pilot and co-pilot flight control systems, the first shafts being mechanically coupled to respective pilot and co-pilot flight deck controllers.
- 10 **11.** The method of any one of Claims **9-10**, wherein receiving an electrical signal from a position transducer includes receiving an electrical signal from a position transducer coupled to one of the first and second shafts of the pilot and co-pilot control systems, wherein at least one linkage mechanically couples one of the pilot shafts to one of the co-pilot shafts such that rotation of one of the pilot shafts about the longitudinal axis thereof causes corresponding rotation of the coupled one of the co-pilot shafts.
- 15 **12.** The method of Claim **11**, wherein a first end of a first pilot connecting rod is mechanically coupled to the first pilot shaft and an opposing second end of the first pilot connecting rod is mechanically coupled to the second pilot shaft, wherein a first end of a first co-pilot connecting rod is mechanically coupled to the first co-pilot shaft and an opposing second end of the first co-pilot connecting rod is mechanically coupled to the second co-pilot shaft, and wherein receiving an electrical signal from a position transducer includes, in response to a failure of the first pilot connecting rod, receiving an electrical signal from the first pilot position transducer associated with the rotation of the first pilot shaft that differs from an electrical signal from the second pilot position transducer associated with the rotation of the second pilot shaft.
- 20
- 25
- 30 **13.** The method of Claim **12**, wherein receiving an electrical signal from a position transducer includes, in response to a failure of the first co-pilot connecting rod, receiving an electrical signal from the first co-pilot position transducer associated with the rotation of the first co-pilot shaft that differs from an

electrical signal from the second co-pilot position transducer associated with the rotation of the second co-pilot shaft.

- 5 **14.** The method of any one of Claims **12-13**, wherein the flight control system further includes a pilot and co-pilot jackshaft assembly, each jackshaft assembly including a jackshaft configured to rotate about a respective longitudinal axis defined thereby in response to a force exerted onto the flight deck controller mechanically coupled to the corresponding jackshaft assembly, wherein each flight deck controller includes a pair of pedals, 10 wherein the at least one linkage mechanically coupling one of the pilot shafts to one of the co-pilot shafts further includes a second coupling rod, and wherein receiving an electrical signal from a position transducer further includes receiving an electrical signal from one of the pilot position transducers, in response to a failure of one of the first and second coupling rods, that is equal to an electrical signal received from one of the co-pilot position transducers. 15
- 20 **15.** The method of any one of Claims **11-12** further comprising receiving an electrical signal from a pilot flight data recorder force transducer and a co-pilot flight data recorder force transducer, wherein each flight data recorder force transducer has a first end mechanically coupled to the respective pilot and co-pilot flight deck controllers and an opposing second end mechanically coupled to the respective first pilot and co-pilot shafts, and wherein in response to a failure of the corresponding one of the pilot and co-pilot flight data recorder force transducers, the corresponding one of the pilot and co-pilot flight deck controllers is configured to lose fidelity in flight control. 25
- 16.** An aircraft control system comprising:

pilot and co-pilot flight control systems, each including a first shaft mechanically coupled to and displaced apart from a second shaft, the shafts defining and being rotatable about independent longitudinal axes, wherein a pilot and a co-pilot connecting link respectively enables rotation of one of the first shafts to rotate a corresponding one of the second shafts of the pilot and co-pilot flight control systems;

a pilot and a co-pilot flight deck controller mechanically coupled to the respective first pilot and co-pilot shafts;

a position transducer mechanically coupled to each shaft and configured to communicate an electrical signal corresponding to the rotation of the respective shaft;

a pilot and a co-pilot wheel pulley mechanically coupled to the respective pilot and co-pilot flight deck controllers, the pilot and co-pilot wheel pulleys configured to, in response to a failure of one of the connecting links, rotate the respective first shafts; and

a flight control unit in communication with the position transducers and configured to (a) receive the electrical signal from each of the position transducers, (b) detect a failure of the pilot or co-pilot flight control system by detecting differences in the electrical signals from the position transducers, and (c) communicate the electrical signal from the position transducer to a flight control surface actuation system to compensate for the detected failure.

- 17.** The system of Claim 16, wherein the pilot and co-pilot flight deck controllers each include a pilot and a co-pilot wheel controller, the pilot and co-pilot wheel pulleys being mechanically coupled to respective wheel controllers such that

rotation of the pilot wheel pulley about the longitudinal axis of the first pilot shaft correspondingly rotates the pilot wheel controller and rotation of the co-pilot wheel pulley about the longitudinal axis of the first co-pilot shaft correspondingly rotations the co-pilot wheel controller.

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- 18.** The system of Claim **17**, wherein the pilot and co-pilot wheel pulleys each define an arcuate slot proximate a respective outer peripheral portion, the pilot and co-pilot wheel pulleys being rotatable about the respective first pilot and co-pilot shafts.

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- 19.** The system of Claim **18** further comprising a first and second pilot deadzone linkage and a first and second co-pilot deadzone linkage, each deadzone linkage being non-rotatable attached to and extending radially from the respective first pilot and co-pilot shafts, each deadzone linkage having an engaging element extending therefrom along a direction parallel to the longitudinal axis of the respective pilot and co-pilot shafts, the second pilot and co-pilot engaging elements extending through the respective arcuate slots defined by the pilot and co-pilot wheel pulleys.

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- 20.** The system of Claim **19**, wherein rotation of the respective first pilot and co-pilot shafts about the longitudinal axis thereof causes the respective engaging elements to orbit about the respective first shafts.

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1/6

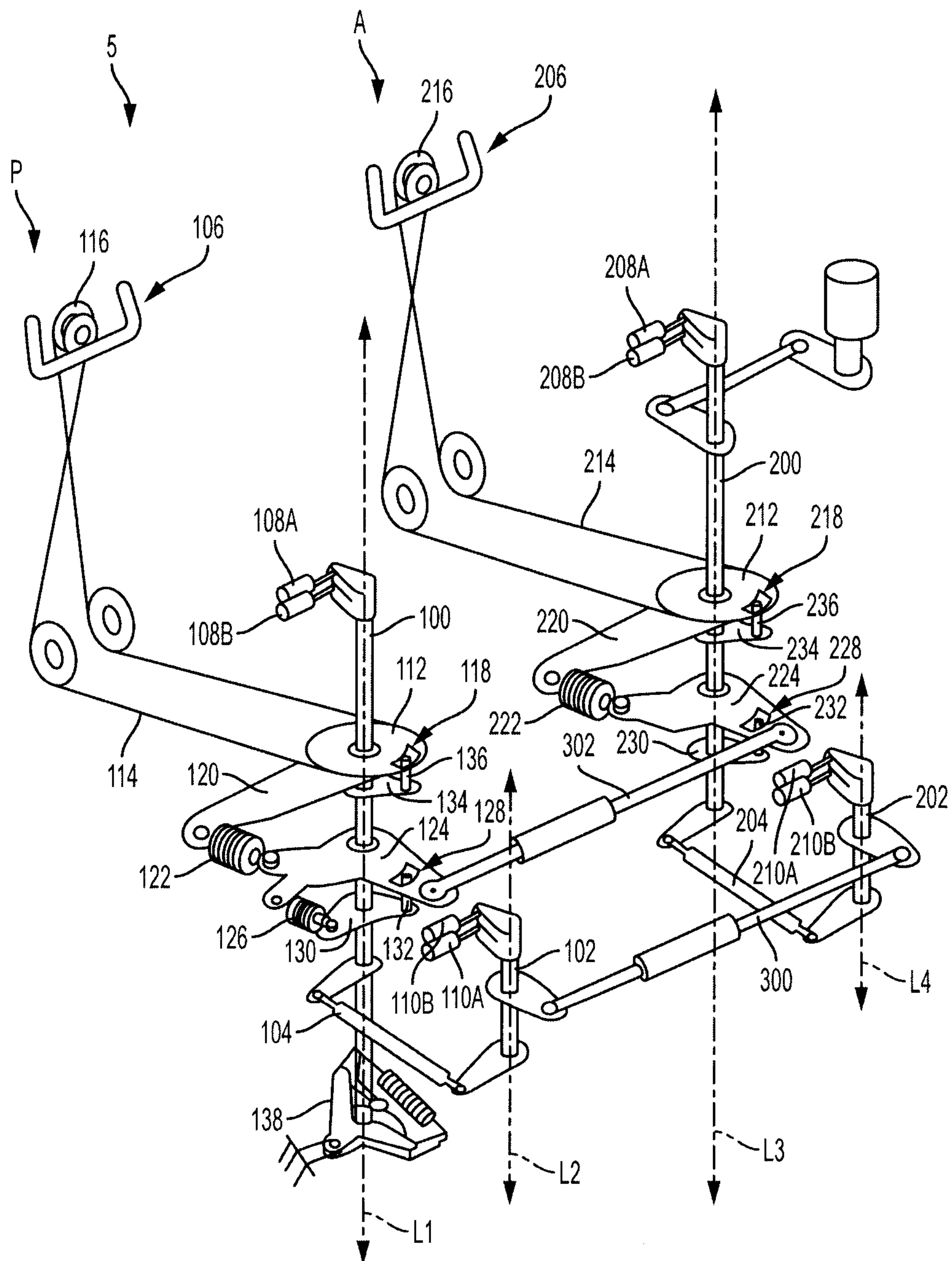
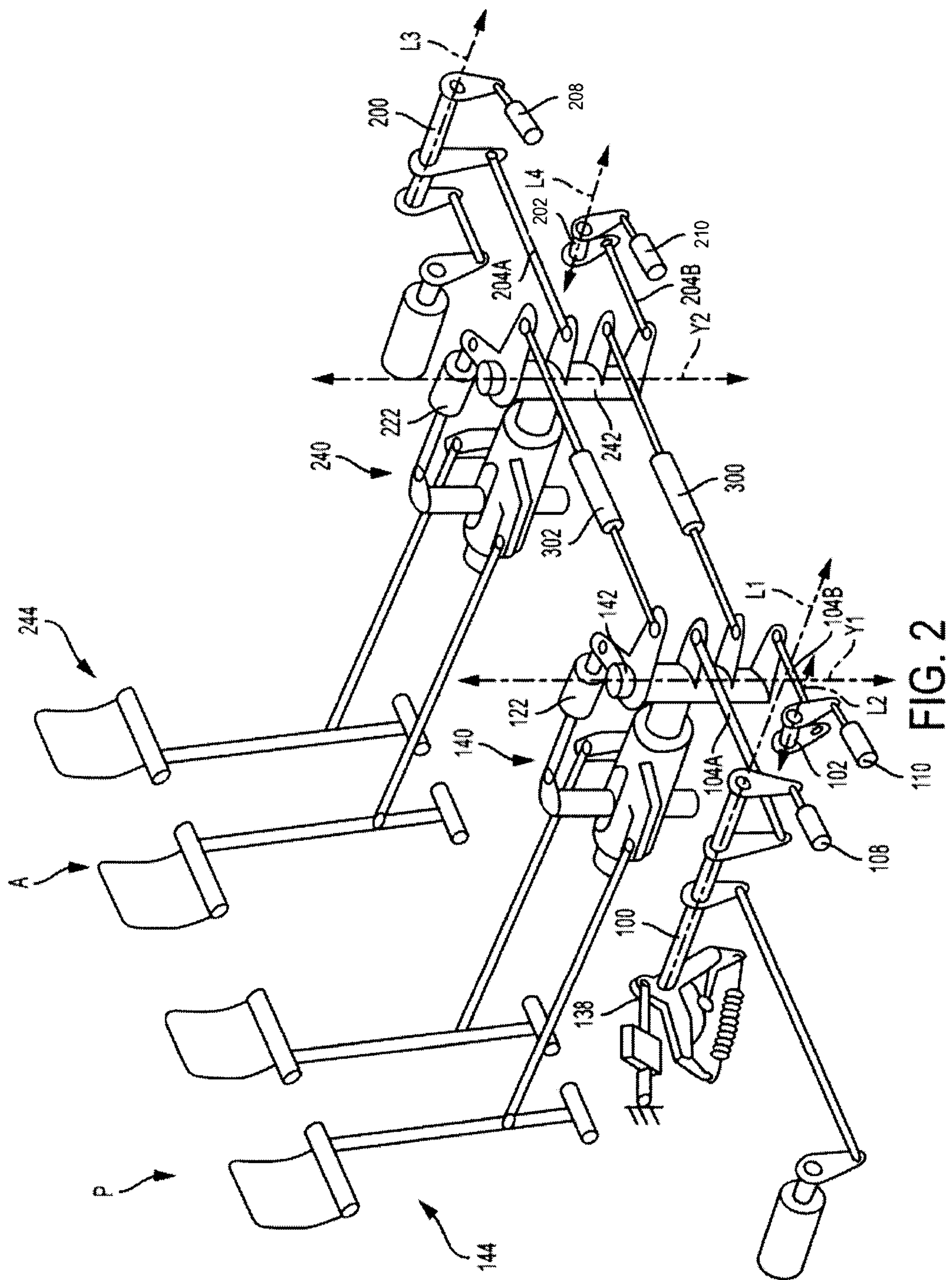
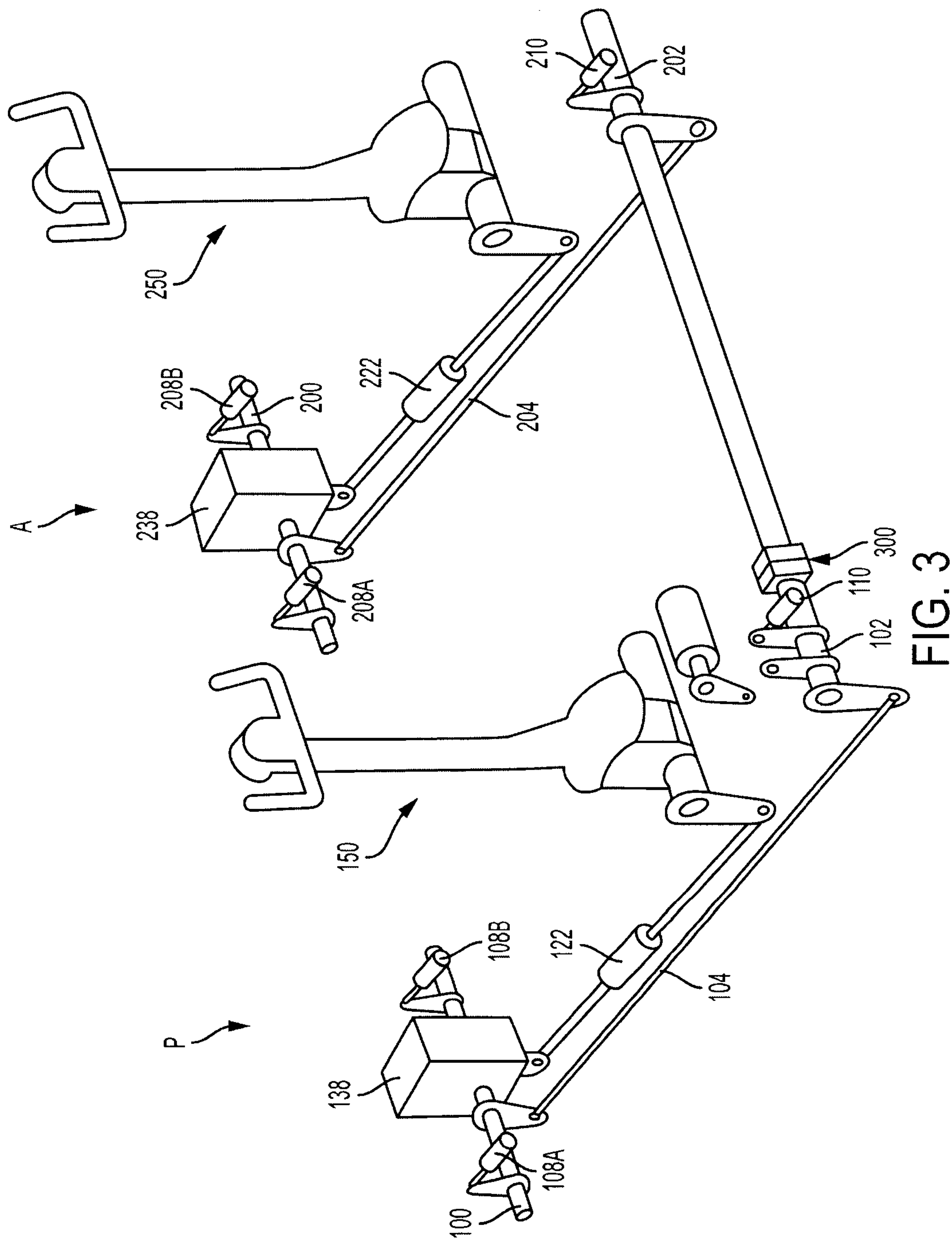


FIG. 1

2/6





4/6

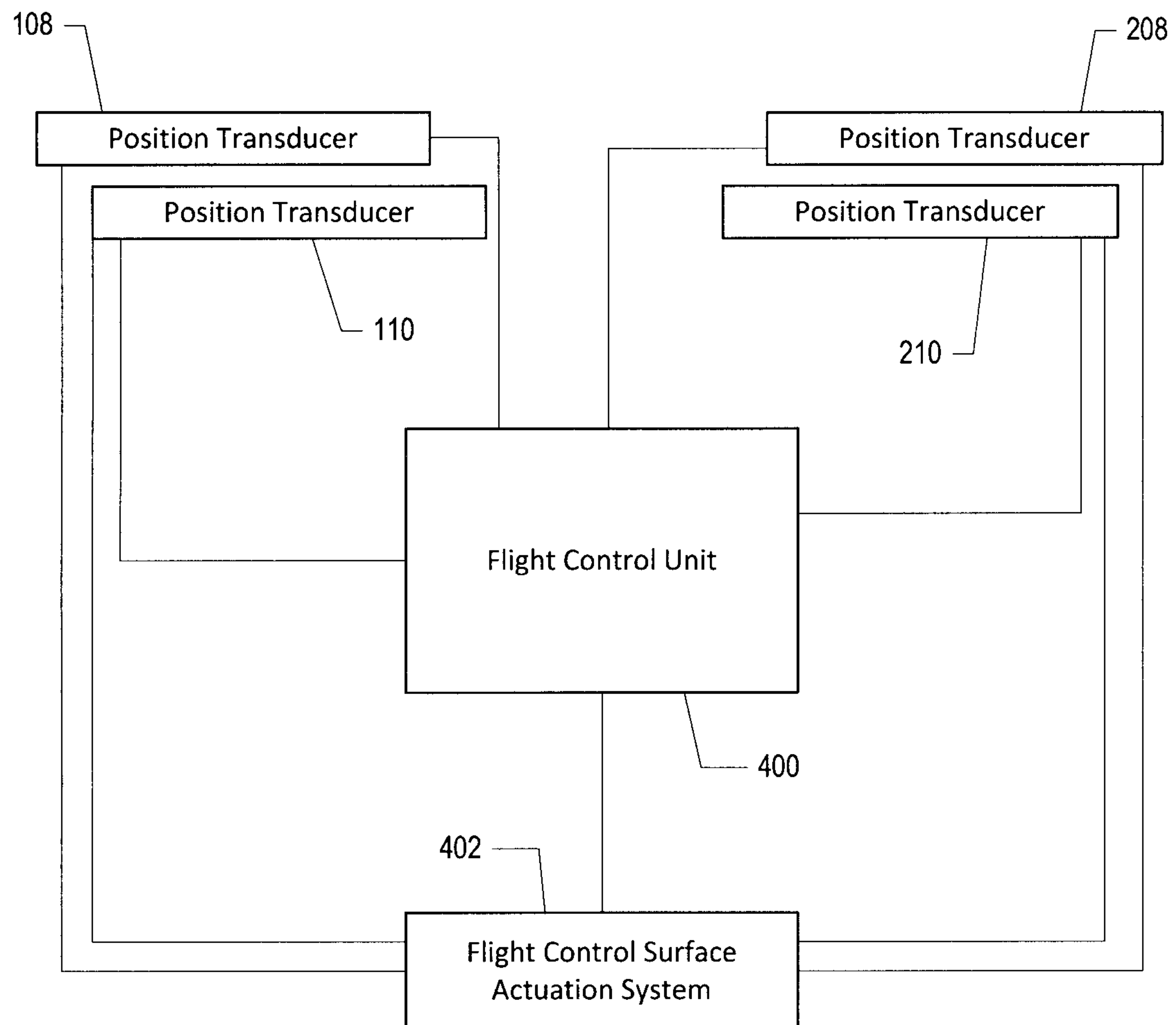
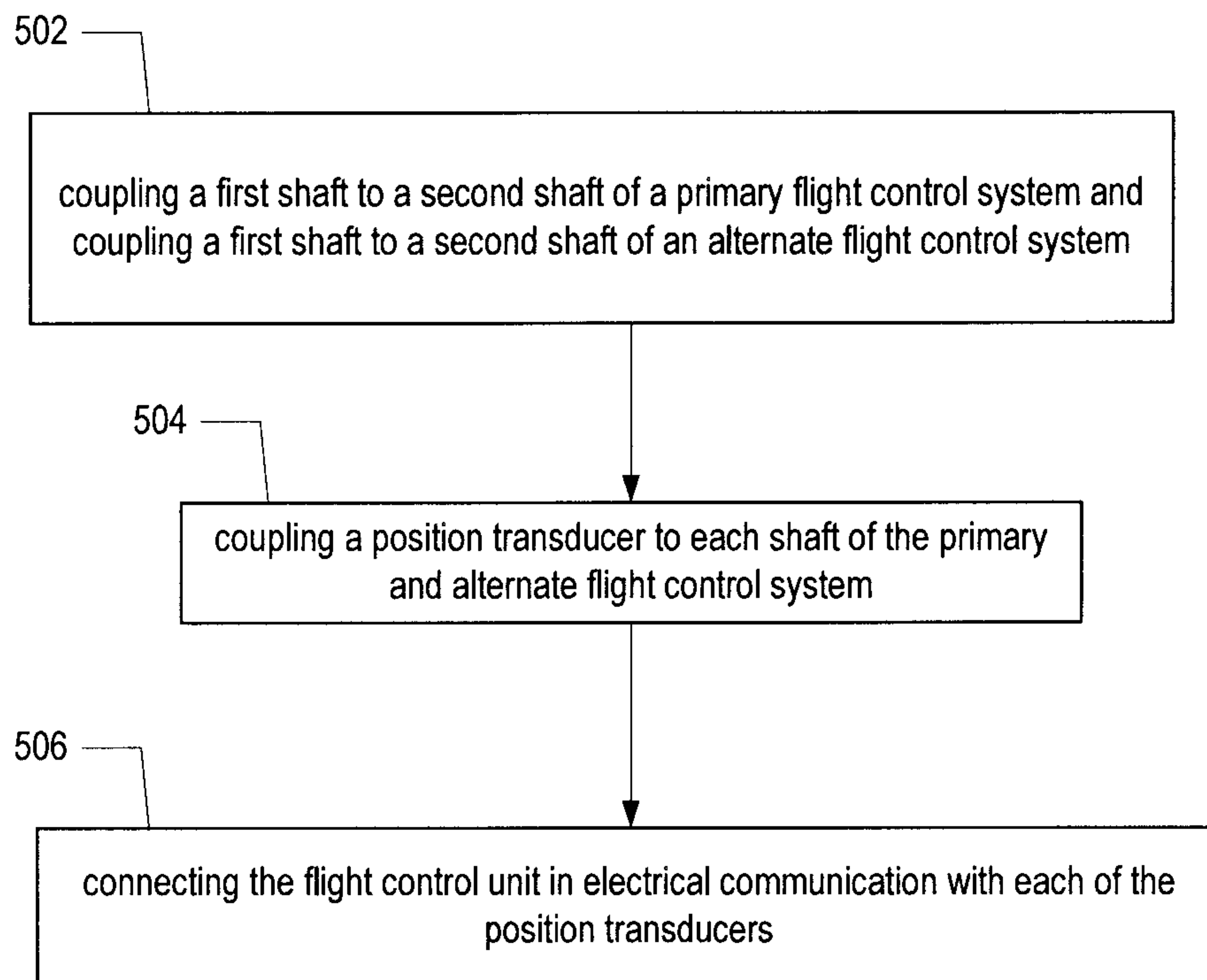


FIG. 4

5/6500**FIG. 5**

6/6

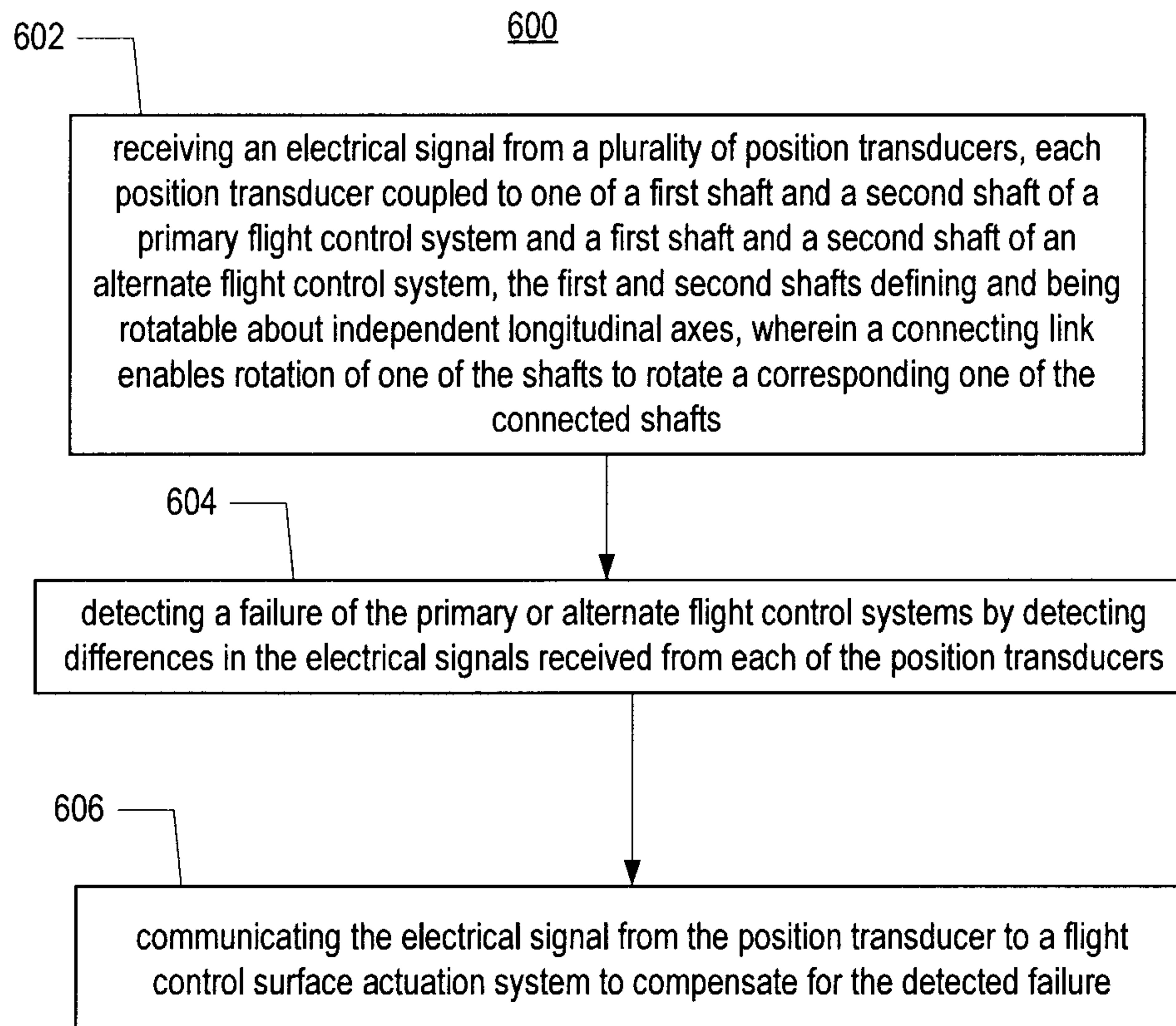


FIG. 6

