

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

DJI EUROPE B.V.,
Petitioner

v.

TEXTRON INNOVATIONS INC.,
Patent Owner.

IPR2023-01105
U.S. Patent No. 8,332,082

**PETITION FOR *INTER PARTES* REVIEW
OF U.S. PATENT 8,332,082**

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EXHIBIT LIST

Exhibit	Reference
1001	U.S. Patent 8,332,082 to Christensen et al. (“the ’082 patent”)
1002	File History of U.S. Patent 8,332,082
1003	Declaration of Dr. William Singhose in Support of Petition for <i>Inter Partes</i> Review of U.S. Patent 8,332,082
1004	CV of Dr. William Singhose
1005	U.S. Patent 5,553,812 to Gold, et al. (“Gold”)
1006	U.S. Patent 5,238,203 to Skonieczny, et al. (“Skonieczny”)
1007	U.S. Patent 5,065,962 to Adams, et al. (“Adams”)
1008	U.S. Patent Publication 2008/0097658 to Shue, et al. (“Shue”)
1009	“Design and Pilot Evaluation of the RAH-66 Comanche Selectable Control Modes” by Gold, et al. (“Gold Paper”)]
1010	Declaration of Trenton J. Roche
1011	EP 2673681 B1 to Christensen, et al (“Companion EP Patent”)
1012	Prosecution History of EP 2673681
1013	U.S. Patent Publication 2010/0324758 to Piasecki, et al (“Piasecki”)
1014	U.S. Patent 5,001,646 to Caldwell, et al (“Caldwell”)
1015	U.S. Department of Transportation, Federal Aviation Administration, “Rotorcraft Flying Handbook”, FAA-H-8083-21 (2000)
1016	U.S. Department of Transportation, Federal Aviation Administration, “Helicopter Flying Handbook”, FAA-H-8083-21B (2019) (“Helicopter Flying Handbook”)
1017	Excerpts from “Aircraft Dynamics and Automatic Control” by McRuer, et al (Princeton Legacy Library 1973) (“McRuer”)
1018	“Flight Stability and Automatic Control”, Second Edition, by Nelson (WCB/McGraw-Hill 1998) (“Nelson”)
1019	“Mechanics of Flight” by Phillips (John Wiley & Sons 2004) (“Mechanics of Flight”)

Exhibit	Reference
1020	“Advanced Flight Control Research and Development at Boeing Helicopters” by Landis, et al in “Advances in Aircraft Flight Control” (1996)
1021	“The Characteristics of Model-Following Systems as Synthesized by Optimal Control” by Tyler, IEEE Transactions on Automatic Control, October 1964 (“Tyler”)
1022	“Input-Shaping and Model-Following Control of a Helicopter Carrying a Suspended Load” by Adams, et al, Journal of Guidance, Control, and Dynamics, Vol. 38, No. 1, January 2015 (“Adams”)
1023	Excerpt from “Dynamics of Helicopter Flight” by Saunders (1975)
1024	“Helicopter Aerodynamics-Aircraft Theory of Flight”
1025	File History of U.S. Patent 8,682,505
1026	“Aeronautical Design Standard Performance Specification, Handling Qualities Requirements for Military Rotorcraft”, ADS-33E-PRF (March 21, 2000)
1027	NASA Technical Reports Server Record Details for Gold, <i>available at</i> https://ntrs.nasa.gov/citations/19940008849
1028	Piloting Vertical Flight Aircraft: A Conference on Flying Qualities and Human Factors, Proceedings of a Workshop Held in San Francisco, CA (January 20-22, 1993), <i>available at</i> https://ntrs.nasa.gov/api/citations/19940008821/downloads/19940008821.pdf [Excerpts]

I. Introduction

DJI Europe B.V. (“Petitioner”) petitions for *inter partes* review (“IPR”) of U.S. Patent 8,332,082 (“’082 patent”; DJI-1001) claims 1-20.

II. Grounds For Standing

Petitioner certifies the ’082 patent is available for IPR and Petitioner is not barred or estopped from requesting IPR.

III. Identification Of Challenge

A. Prior Art

The ’082 patent is the National Stage of PCT/US2011/030498, filed on March 30, 2011. (DJI-1001.) Each applied reference issued before March 30, 2011.

1. **U.S. Patent 5,553,812 to Gold, et al.** (“Gold”; DJI-1005), issued September 10, 1996, is prior art under 35 U.S.C. §102(b).
2. **U.S. Patent Publication 2008/0097658 to Shue, et al.** (“Shue”; DJI-1008), published April 24, 2008, is prior art under 35 U.S.C. §102(b).
3. **“Design and Pilot Evaluation of the RAH-66 Comanche Selectable Control Modes” by Gold, et al.** (“Gold-Paper”; DJI-1009) is prior art under 35 U.S.C. §102(b). Gold-Paper was publicly available before March 30, 2011 and was disclosed to members of the interested public. Gold-Paper was at least publicly available on NASA’s Technical Reports Server (“NTRS”) with Document ID 19940008849 since NTRS was brought online in 2003. (*See* DJI-1010, ¶5.) NTRS “is free and publicly accessible, contains record details for all of the published

materials, and is publicly searchable by keyword.” (DJI-1010, ¶3.) The record details on NTRS indicate that Gold-Paper is a conference paper originally published in “Piloting Vertical Flight Aircraft: A Conference on Flying Qualities and Human Factors” on July 1, 1993 and is a public document without distribution limits. (DJI-1027.) The full conference proceedings from that conference state that Gold-Paper was presented as a part of a workshop held in San Francisco, California from January 20-22, 1993, and includes eleven pages of attendees. (DJI-1028.)

4. **U.S. Patent 5,238,203 to Skonieczny, et al** (“Skonieczny”; DJI-1006), issued August 24, 1993, is prior art under 35 U.S.C. §102(b).

5. **U.S. Patent 5,065,962 to Adams, et al** (“Adams”; DJI-1007, issued November 19, 1991, is prior art under 35 U.S.C. §102(b).

B. Grounds For Challenge

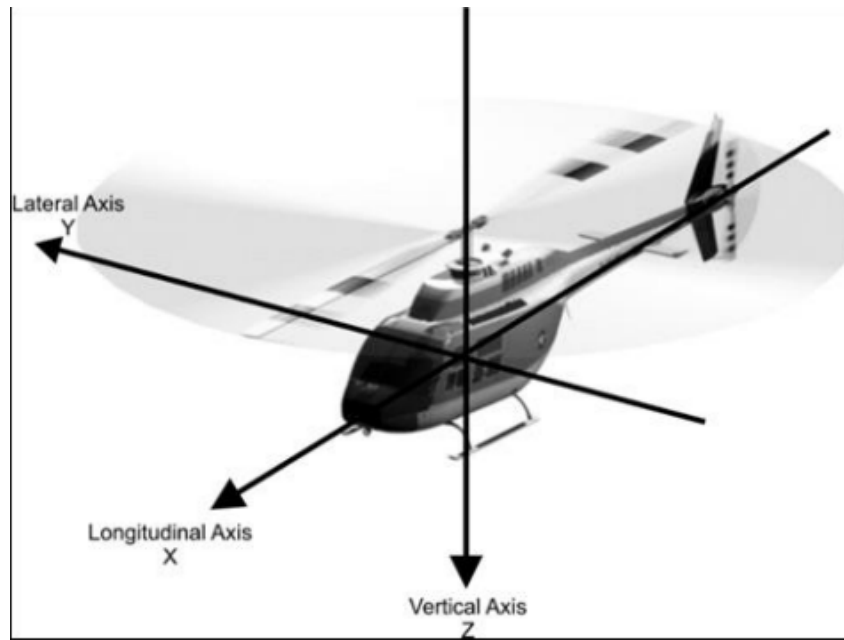
		Claims	References
1	103	1-2, 5-6, 8-9, 11-12, 15-16, 18-19	Gold, Shue, and Gold-Paper
2	103	3-4, 13-14	Gold, Shue, Gold-Paper, and Skonieczny
3	103	7, 10, 17, 20	Gold, Shue, Gold-Paper, and Adams

IV. The '082 Patent

The '082 patent relates “to a flight control system having flight control laws.” (DJI-1001, 1:6-9.) The use of a flight control system in an aircraft was extremely well-known by March 30, 2011. (DJI-1003, ¶22.)

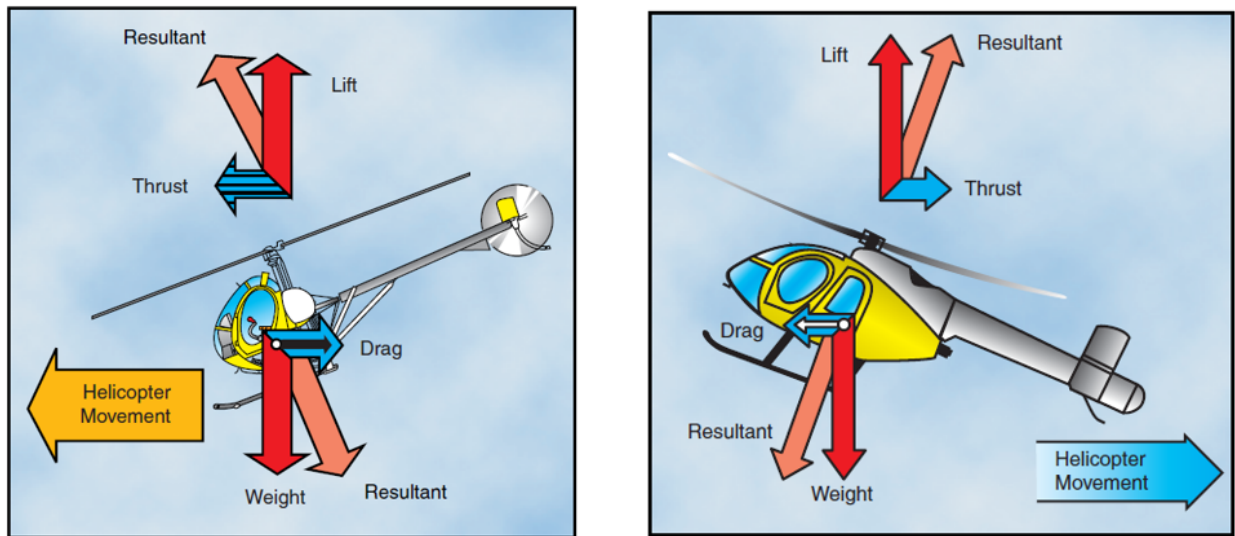
A. Technical Background

A helicopter, illustrated below, uses a main rotor producing thrust, primarily for vertical lift, but also for directional control, and a tail rotor controlling the helicopter's heading. (DJI-1003, ¶23.) A useful reference system consists of three mutually perpendicular lines (axes) (longitudinal, lateral, and vertical) intersecting at the center of gravity. (DJI-1003, ¶24.) The longitudinal axis passes through the nose and tail. Rotation about the longitudinal axis is referred to as **roll** and is used for **lateral** control. (*Id.*) The lateral axis extends from left to right. Rotation about the lateral axis is referred to as **pitch** and is used for **longitudinal** control. (*Id.*) The vertical axis passes vertically through the center of gravity. Rotation about the vertical axis is **yaw** and is used to control the direction that the nose of the aircraft is pointing. (*Id.*)



1. Pilot Control/Aircraft Movement

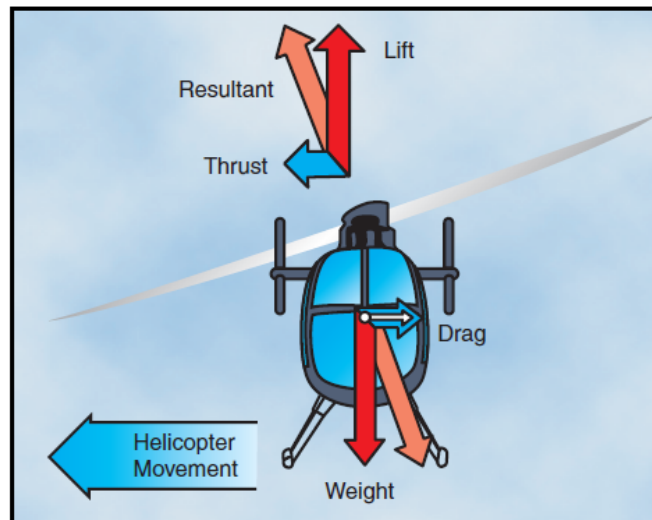
Helicopters often come equipped with one or more controllers used by a pilot to control aircraft movement. The cyclic stick controls the main rotor disc angle. (DJI-1003, ¶¶25-26.) When the main rotor disc is tilted (attitude/angle changes), the horizontal force component moves the helicopter in the direction of the tilt. (*Id.*, citing DJI-1015, 4-2.) If the cyclic stick is moved forward, the rotor disc tilts forward, resulting in forward acceleration (Figure 3-11, below left). (DJI-1003, ¶¶26, 44.) If the cyclic stick is moved aft, the disc tilts aft, resulting in backward acceleration (Figure 3-18, below right). (DJI-1003, ¶¶26, 46.) Change in pitch angle is strongly correlated with longitudinal motion and pitch control is generally synonymous with longitudinal control. (DJI-1003, ¶26.)



Rotorcraft Flying Handbook, Figure 3-11 (left); Figure 3-18 (right)

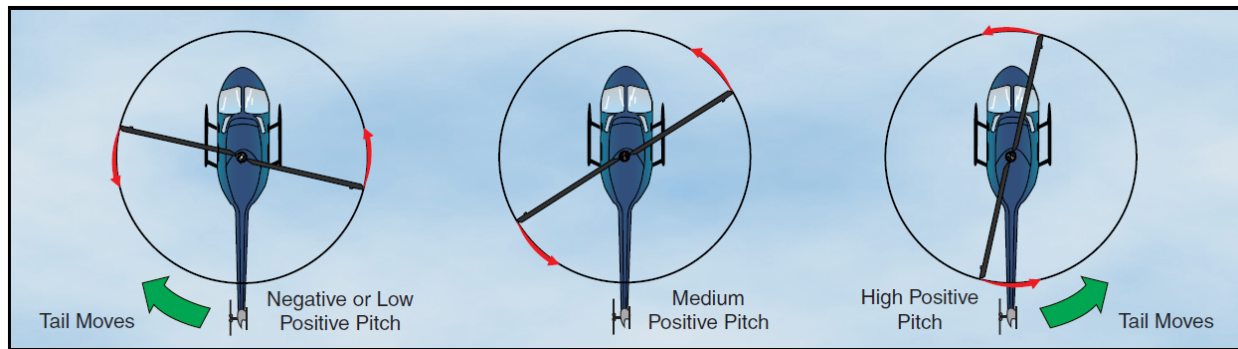
If the cyclic stick is moved to the side, the main rotor disc is rolled to the side, resulting in sideward motion (Figure 3-17 below). (DJI-1003, ¶¶27, 45.)

Changes in roll angle are therefore correlated with lateral motion and roll control is generally synonymous with lateral control. (DJI-1003, ¶27.)



Rotorcraft Flying Handbook, Figure 3-17

Pedals control the pitch of the tail rotor blades. (DJI-1015, 4-3.) That is, the pedals cause the helicopter to rotate about the vertical axis (when in level flight) to change its yaw angle. (DJI-1003, ¶28.)



Rotorcraft Flying Handbook, Figure 4-6

2. Sensors and Actuators

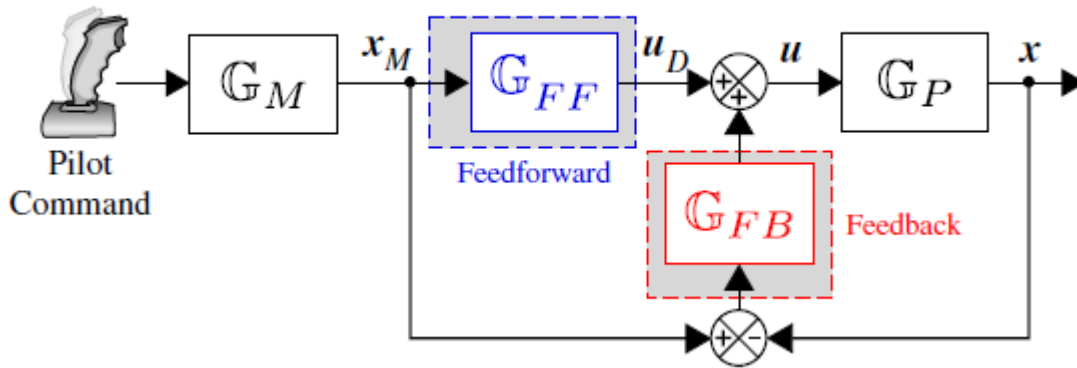
Helicopters are equipped with a range of sensors to provide pilots and flight control systems with measurements and information necessary to safely complete their missions. (DJI-1003, ¶¶32-36.) Pilot commands issued through the pilot's controller are applied to control surfaces associated with the main and tail rotors through actuators or servos. (DJI-1003, ¶37.) Actuators move the control surfaces based on the received commands. (DJI-1003, ¶¶37-40.) In flight control systems (described below), pilot commands are monitored by a flight computer which issues the commands to the actuators to move the aircraft in the desired manner. (DJI-1003, ¶48.)

3. Flight Control Systems

Modern control systems use a control architecture depending on the dynamic model of the system being controlled. (DJI-1003, ¶49.) Helicopter dynamic models are sets of equations describing the motion and aerodynamics of the helicopter, its rotor(s), and other components. (*Id.*) The helicopter equations of motion are derived by summing the force and moment contributions of various structural components of the helicopter. (DJI-1003, ¶¶55-56.) For flight control system design, it was (and remains) common to use linearized equations of motion to describe the vehicle's dynamics near a prescribed operating point in the flight envelope. (DJI-1003, ¶57.) These linearized equations are separated into lateral equations of motion and longitudinal equations of motion. (DJI-1003, ¶57, *citing* DJI-1018, 104, DJI-1019, 720-721.)

Model-following control systems integrate the aircraft model as part of the control system. (DJI-1022, 98.) These control systems were first developed in the early 1960's, nearly **half a century** before the '082 patent. (DJI-1003, ¶¶52-53, *citing* DJI-1021, 494-496.) In an explicit model following control system, the pilot command is used as input to a prescribed model G_M (referred to as the command model). (*See* DJI-1022, 98; DJI-1003, ¶54.) The rest of the control system is designed to force the output of the helicopter plant, G_P , to track the prescribed model output, x_M . (*Id.*) Feedback, G_{FB} , determines the error dynamics of the model

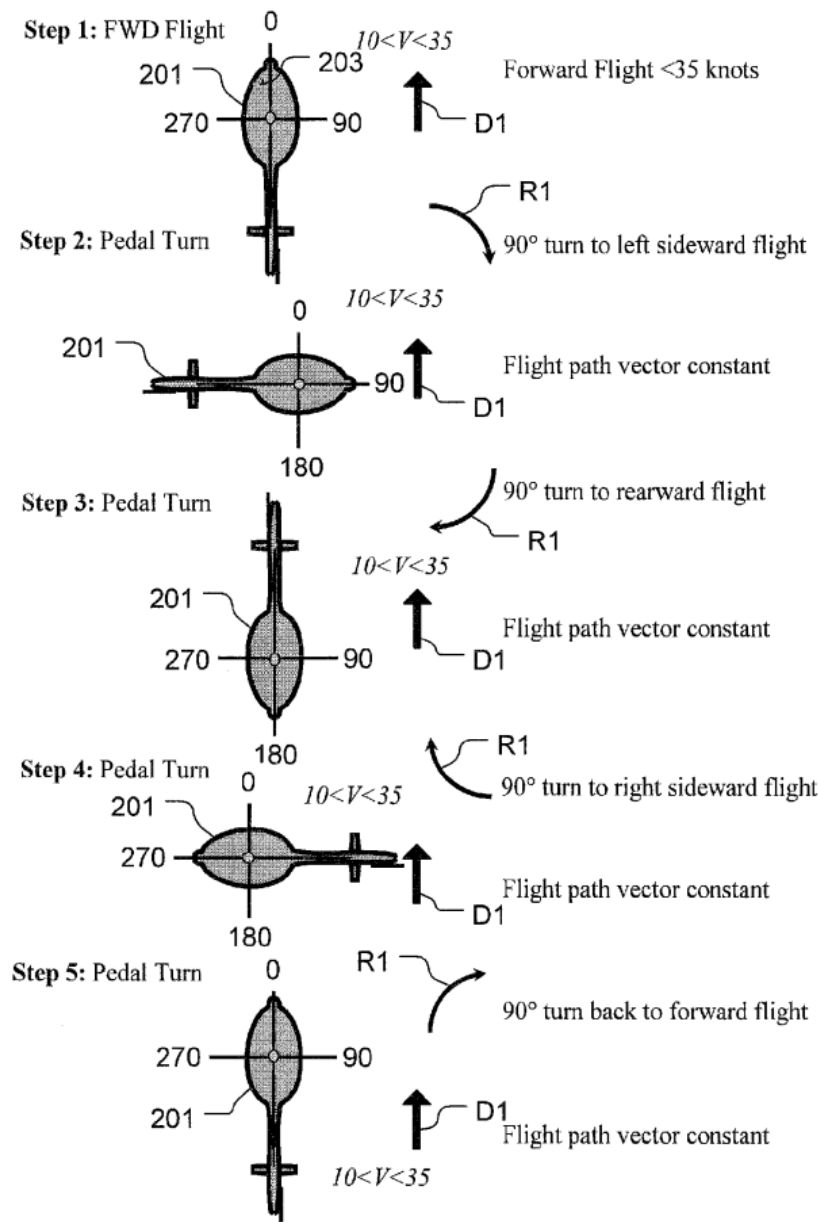
tracking. (DJI-1022, 98.) Feedforward control G_{FF} is selected to cancel undesired helicopter dynamics using model inversion techniques and is often referred to as an inverse model. (DJI-1022, 98; DJI-1003, ¶54.)



Adams/Singhose (DJI-1022), Figure 6

B. '082 Patent Overview

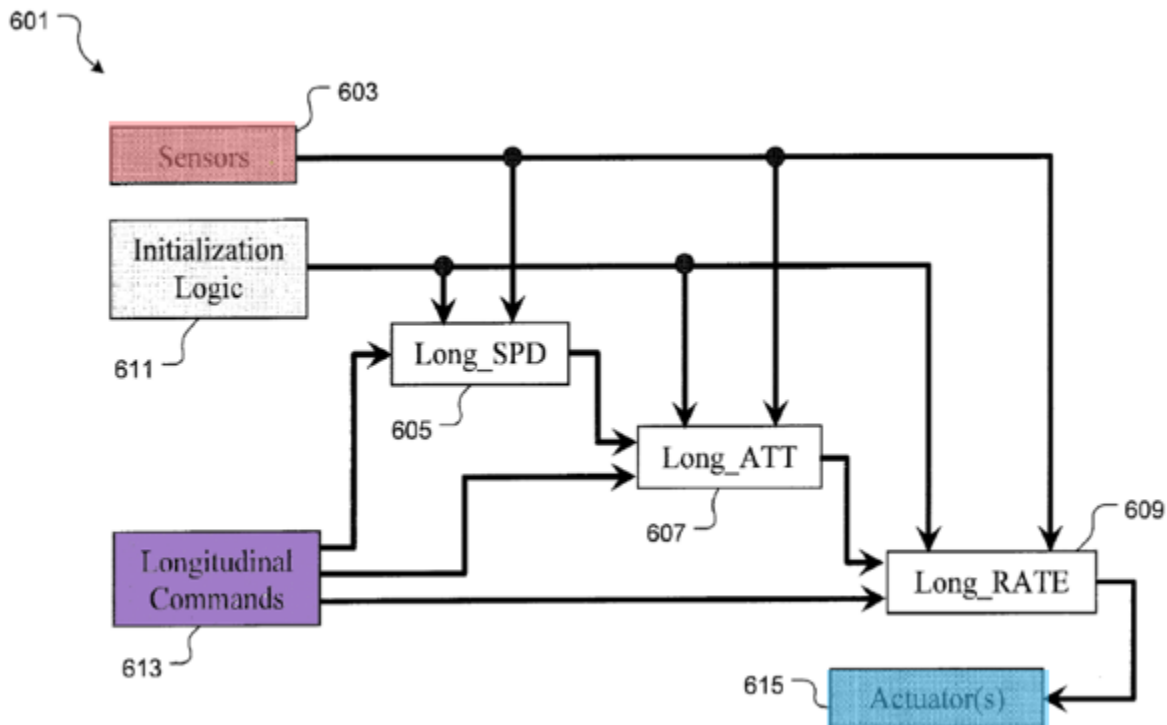
The '082 patent claims an aircraft control system controlling yaw rotation while the aircraft maintains a constant velocity flight path relative to the ground surface. (DJI-1001, Abstract.) As shown in Figure 2 below, directional inputs from the pilot turn the aircraft “in a complete 360 degree yaw movement R1 ... without changing the speed and flight heading.” (DJI-1001, 3:2-5.) The aircraft rotates about its vertical axis in a yaw motion, while simultaneously, the body of the aircraft travels at a constant velocity (straight line) relative to the ground surface. That is, the aircraft maintains its **course** (ground track) D1. (DJI-1003, ¶63.)



'082 Patent, Figure 2

The control system includes longitudinal, lateral, and directional control architectures. (DJI-1001, 4:35-42.) Longitudinal control laws process inputs from the pilot's controller and from the aircraft's sensors "to generate the appropriate aircraft response commands" which "are routed to an actuator 615 for each dynamic axis." (DJI-1001, 5:11-26, Figure 6.) The lateral and directional control

architectures 701 and 801 have the same basic structure. (*See, e.g.*, DJI-1001, 5:41-50 (lateral), 6:11-26 (directional); *See* DJI-1003, ¶¶69-71.)



'082 Patent, Figure 6

C. Level Of Ordinary Skill In The Art

A person of ordinary skill in the art (“POSITA”) would have had at least an equivalent of a Bachelor’s degree from an accredited institution in mechanical engineering, aerospace engineering, electrical engineering, robotics or any other discipline covering principles of the design or operation of flight controls for helicopters, drones, or other rotary aircraft, as well as one year of experience working on the design, development, implementation, or operation of such technologies. Significant experience could substitute for formal education, and

significant additional education could substitute for work experience. (DJI-1003, ¶73.)

D. Prosecution History

The '082 patent was allowed without any substantive rejections. (*See* DJI-1002, 115-117.) However, the corresponding European National Stage application was filed with claims having substantially overlapping limitations with the issued '082 claims: “a model adapted to decouple directional movement of the aircraft into a lateral equation of motion and a longitudinal equation of motion”, “lateral control architecture”, “longitudinal control architecture”, and “initialization command logic.” (DJI-1012, 254.) The EP Examiner found the filed claims lacked novelty over Gold, citing generally “col. 1 - col. 2, line 22; col. 2, line 65 - col. 3, line 60; col. 4, lines 16-30; col. 5, lines 48-57; [and] col. 6, lines 35-67.” (DJI-1012, 143-144.) In response, Applicant amended the independent claims to recite that the control system “utilizes the lateral control architecture and the longitudinal control architecture to maintain a constant vector heading across a ground surface while the aircraft (201) flies with a crab angle greater than zero.” (DJI-1012, 116.) The Examiner however maintained the rejection and after further narrowing amendments, the EP patent was allowed. (DJI-1003, ¶¶84-85.)

E. Claim Construction

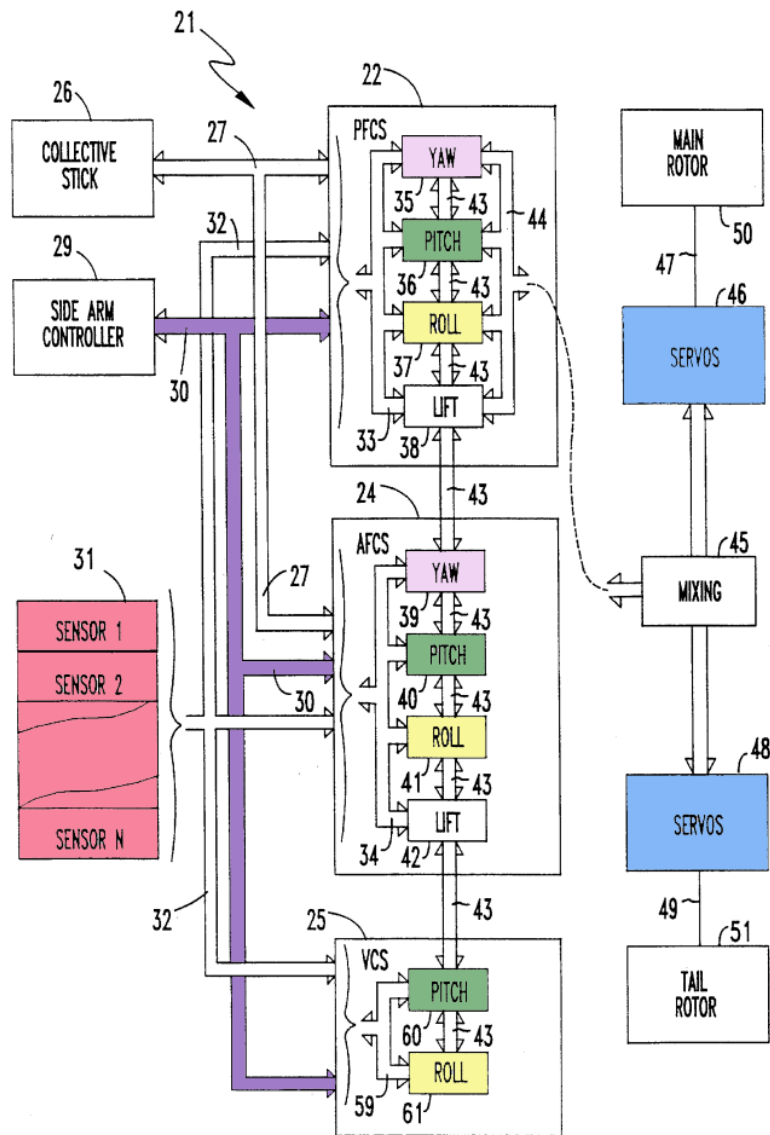
Petitioner does not believe any claims require construction to resolve the patentability disputes in this proceeding. Accordingly, Petitioner applies the plain and ordinary meaning for each term in the challenged claims.

V. GROUND 1: Combination of Gold, Shue and Gold-Paper renders claims 1-2, 5-12, and 15-20 Obvious.

A. Combination Overview

1. Gold

Gold describes a system “which allows a pilot to yaw the aircraft during operation in a velocity stabilization mode without changing the flight path of the aircraft with respect to the inertial reference.” (DJI-1005, 1:9-14.) Gold’s flight control system 21 includes primary flight control system (PFCS) 22, automatic flight control system (AFCS) 24 and velocity command system (VCS) 25. (DJI-1005, 3:4-7, Figure 3 below.) The PFCS and AFCS each contain “control modules for controlling the yaw [shaded pink], pitch [shaded green], roll [shaded yellow] and lift axes of the aircraft.” (DJI-1005, 3:17-20.) The VCS also includes a pitch and roll control module.

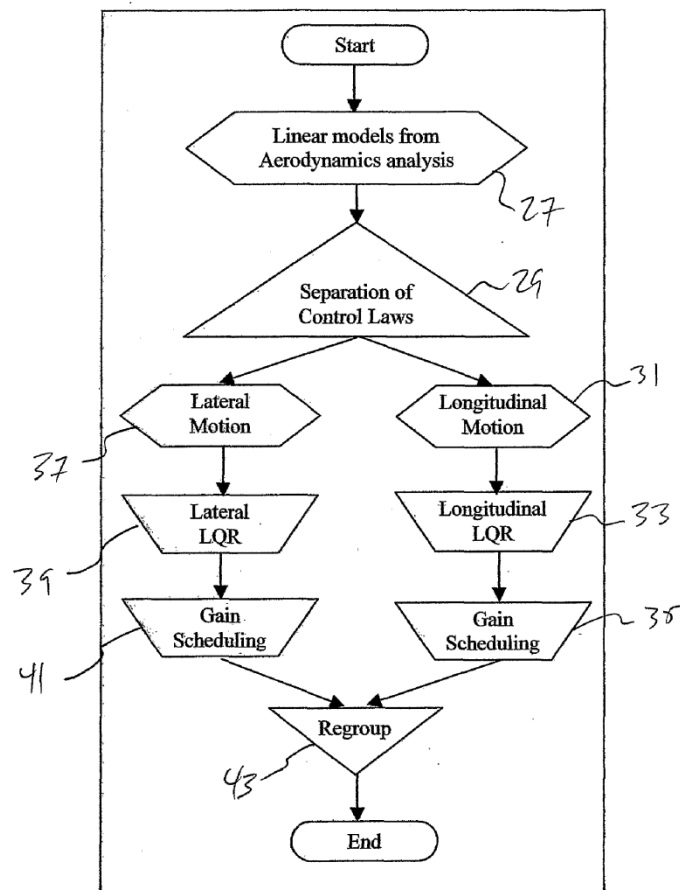


Gold, Annotated Figure 3

The control system provides command signals to rotor mixing function 45 which commands displacement of servos (shaded blue) that control the tip path plane of main rotor 50 and the thrust of tail rotor 51. (DJI-1005, 3:25-32.) Sensors (shaded red) provide the control system with the aircraft's rate and attitude response to the command signals. (DJI-1005, 3:32-36.)

2. Shue

Shue also relates to flight control systems. In Shue, “[a]ircraft control, guidance, and navigation are implemented by a group of linear models, which are computed from aerodynamic analysis.” (DJI-1008, ¶26.) The linear models are separated into longitudinal and lateral control laws, as shown in block 29 of Figure 5 below. (DJI-1008, ¶40.) The longitudinal control laws utilize longitudinal equations of motion and the lateral control laws utilize lateral equations of motion. (See DJI-1008, ¶¶40-43; DJI-1003, ¶45.)



Shue, Figure 5

3. Gold-Paper

Gold-Paper describes control law design for a Comanche helicopter. (DJI-1009, 419.) Like Gold, Gold-Paper’s control system includes a PFCS and an AFCS which “consists of both automatic and manually selected modes which allow the pilot to tailor the control system for the existing flight conditions.” (*Id.*)

In Gold-Paper’s velocity stabilization mode, the “roll axis response-type is AC/VH at low speeds, except when in the Hover Hold mode (VC/PH) or when in a low speed coordinated turn (attitude command/attitude hold (AC/AH)).” (DJI-1009, 421, Figure 2 below.) “The roll response-type automatically changes modes from AC/VH to RC/AH [rate command/attitude hold] between 60 and 80 kts.” (*Id.*) Hover Hold “engages when groundspeed, pitch and roll rates, longitudinal and lateral linear accelerations, and pitch and roll stick commands are small.” (*Id.*)

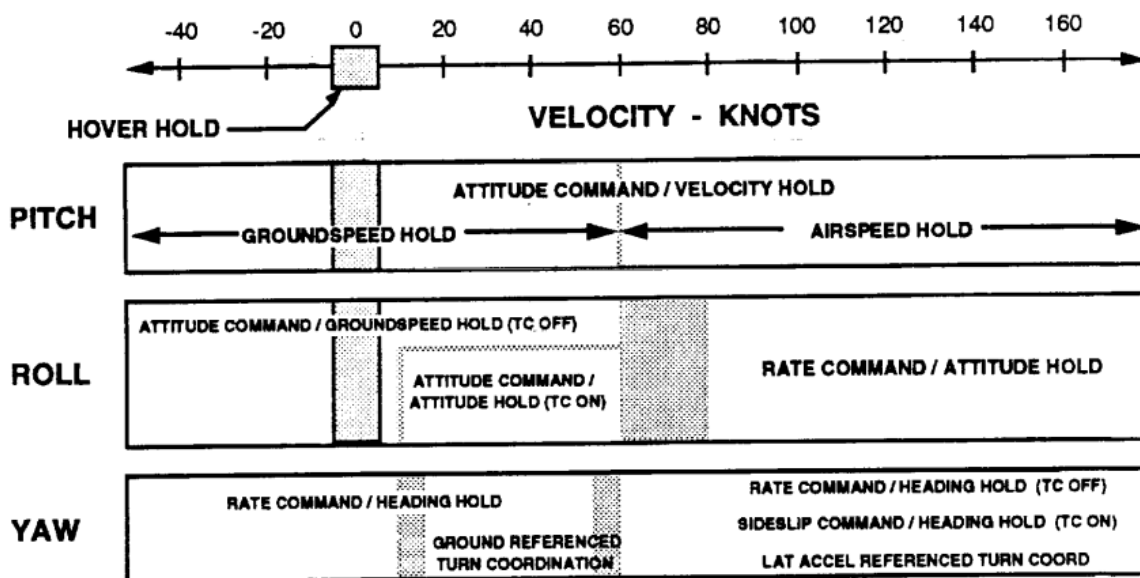


FIGURE 2. VELSTAB CHARACTERISTICS vs VELOCITY

4. Motivation to Combine

a. Gold and Shue

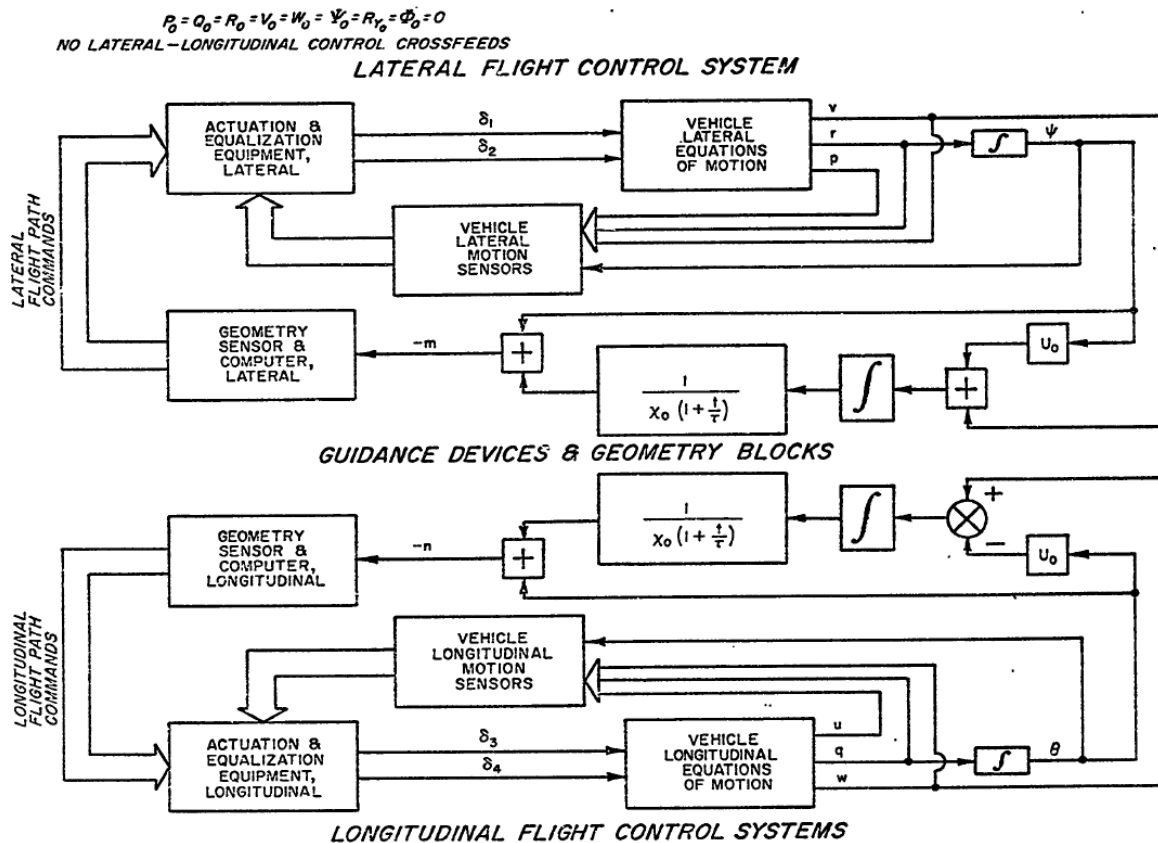
A POSITA would have been motivated to combine Shue's teachings regarding use of a lateral equation of motion in a lateral control architecture and a longitudinal equation of motion in a longitudinal control architecture in Gold's flight control system having separate roll (lateral) and pitch (longitudinal) control modules. (DJI-1003, ¶¶99-104.) Gold's control system uses a “**model following algorithm in each control axis**” (yaw, pitch, roll, and vertical). (DJI-1005, 3:25-26; 3:17-18.) However, Gold does not specify the underlying equations used by its decoupled architecture to control lateral and longitudinal movement. Therefore, a POSITA would have been motivated to search for references describing these equations in a control system having separate lateral and longitudinal controls and would have been led to Shue. (DJI-1003, ¶100.) Shue and Gold are in the same field of endeavor as the '082 patent—aircraft control systems—and are therefore analogous art. (*Id.*)

A POSITA would have further been motivated to combine Shue's equations with Gold's control system to permit the development of an operational flight control system. (DJI-1003, ¶101.) Model-following control systems were known for over 50 years before the '082 patent. (*See*, DJI-1021, 486, 498.) It was equally, if not more well-known, that automatic control of aircraft and aircraft models utilize the equations of motion for an aircraft. (*See*, DJI-1017, 203-414; DJI-1018,

96-130; *see also*, §IV.A.3.) It was also well-known that, in practice, the equations of motion are divided into lateral and longitudinal equations of motion when implementing a flight control system. (*See* §IV.A.3; DJI-1018, 104-108; DJI-1003, ¶104.) Philips, for example, stresses in “Mechanics of Flight” that for small deviations from equilibrium “no coupling exists between the longitudinal motion and the lateral motion”, allowing each set of equations to be solved independently. (DJI-1019, 720-721.) A POSITA would have therefore recognized that Gold’s lateral and longitudinal flight controls utilized lateral and longitudinal equations of motion and would have been motivated to combine Shue’s disclosures of such equations of motion to achieve Gold’s automatic flight control. (DJI-1003, ¶101.)

The combination of Gold’s model-following control system having separate lateral and longitudinal control and Shue’s teaching of a decoupled model in which lateral equations of motion are used by a lateral control architecture and longitudinal equations of motion are used by a longitudinal control architecture is simply the combination of prior art elements. (DJI-1003, ¶102.) The method of combining Shue’s teachings with Gold’s flight control system would have been extremely well-known because as discussed above and further in §IV.A.3, use of lateral and longitudinal equations of motion in a control system was known for decades prior to the ’082 patent. (*Id.*)

A POSITA would have had a reasonable expectation of success in the combination and the results of the combination would have been predictable because the decoupling of an aircraft model into a lateral equation of motion to control lateral movement and a longitudinal equation of motion was well-known for almost 50 years before the '082 patent, as highlighted by this figure from McRuer (1973). (DJI-1003, ¶¶103-104.)



McRuer (1973), Figure 1-4

b. Gold, Shue, and Gold-Paper

A POSITA would have been motivated to combine the teachings of Gold-Paper regarding logic for activating portions of the lateral and longitudinal

architectures to perform modes of operation with the combined control system of Gold and Shue. (DJI-1003, ¶¶105-108.) Gold describes a velocity stabilization mode and mentions other operating modes, such as automatic turn coordination mode. (*See, e.g.*, DJI-1005, 3:54-6:57; 6:46-48.) Gold, however, fails to provide details regarding the logic used to engage/disengage these modes. A POSITA would have therefore been motivated to search for references describing logic to integrate different operating modes into a flight control system and would have been led to Gold-Paper. (DJI-1003, ¶105.) Gold-Paper, Shue, and Gold are in the same field of endeavor as the '082 patent—aircraft control systems—and are therefore analogous art. (*Id.*)

A POSITA would have further been motivated to combine Gold-Paper's teachings with Gold and Shue to enhance automatic mode switching in the control system to reduce pilot workload and permit smooth transition between control modes. (DJI-1003, ¶106.) A POSITA would have understood that it was desirable to limit the need for a pilot to manually engage/disengage modes. (*Id.*) Indeed, one object of Gold is to reduce a pilot's workload. (DJI-1005, 2:20-22, 1:22-25.) Gold-Paper also stresses this goal. (*See, e.g.*, DJI-1009, 419 ("These modes provide increasing levels of vehicle augmentation combined with improved control precision to produce superior flight performance and low pilot workload"), 428 ("Position Hold and Altitude Hold modes, when engaged, alleviated the pilot of

virtually all workload in the pitch/roll and collective axes respectively”), 429 (noting that “low speed turn coordination was a major plus in reducing workload for this task”).)

The combination of the flight control system of Gold and Shue with Gold-Paper’s mode initialization logic teachings is simply the combination of prior art elements. (DJI-1003, ¶107.) It was well-known that automatic flight control systems were implemented in software and therefore a POSITA would have understood how to use known methods to achieve the combination. (*Id.*) Gold-Paper repeatedly references use of “logic” in its mode switching. (*See, e.g.*, DJI-1009, 424 (discussing the “ALTHLD logic smoothly transitions the aircraft to level flight and then holds altitude” and the “logic of switching”).) A POSITA would have understood how to integrate the software logic of Gold-Paper into the flight control system of Gold and Shue because software-based control systems were well-known prior to the ’082 patent. (DJI-1003, ¶107, *citing* DJI-1006, 4:58-5:26 (describing a software-based flight control system).)

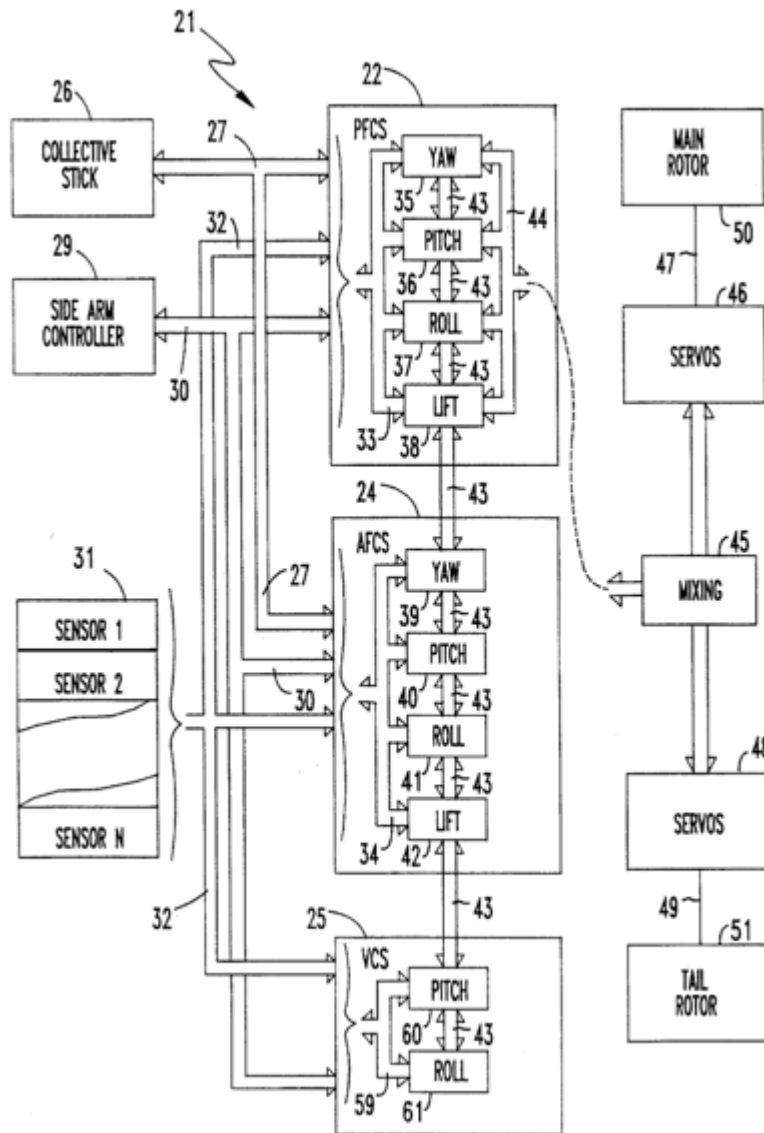
A POSITA would have had a reasonable expectation of success and the results would have been predictable because both Gold and Gold-Paper describe a model following control system having a PFCS and AFCS with “control modules for controlling the yaw, pitch, roll and lift axes of the aircraft.” (DJI-1005, 3:17-20; DJI-1009, 419; DJI-1003, ¶108.) Gold-Paper provides a block diagram of the

exemplary longitudinal control which is analogous to Gold's Figure 4. Gold-Paper also supports a similar architecture for lateral control. (*See*, DJI-1009, 420 (referencing the lateral axis of the PFCS).)

B. Independent Claim 1

1. Preamble [1P]

Gold describes its system “with respect to a model following flight control system for a **rotary winged aircraft**.” (DJI-1005, 2:65-67, Figure 3 below.) Accordingly, Gold discloses an “*aircraft*” [1P]. (DJI-1003, ¶110; *see also*, DJI-1005, claim 1 (“An **aircraft** flight control system”).)



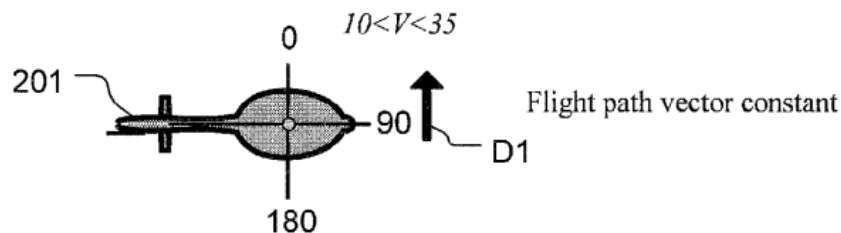
Gold, Figure 3

2. “Sensor” [1A] and “Actuator” [1B].

Claim 1 recites a “sensor being adapted to sense a directional movement of the aircraft” [1A] and an “actuator being utilized to control the directional movement of the aircraft” [1B]. Aside from these recitations, the ’082 patent uses the term “directional movement” once in the discussion of Figure 2 (excerpt

below): “[s]tep 2 shows aircraft 201 traveling in forward flight while the fuselage faces 90 degrees relative to the **directional movement**.” (DJI-1001, 3:31-33.) In this citation, the ’082 patent equates “directional movement” to the direction in which the aircraft’s center of mass is moving. The ’082 patent further associates its directional control architecture to heading control, turn coordination, and yaw control. (See, e.g., DJI-1001, claims 3 and 13.) Accordingly, “*directional movement*” encompasses movement in any direction. (DJI-1003, ¶111.)

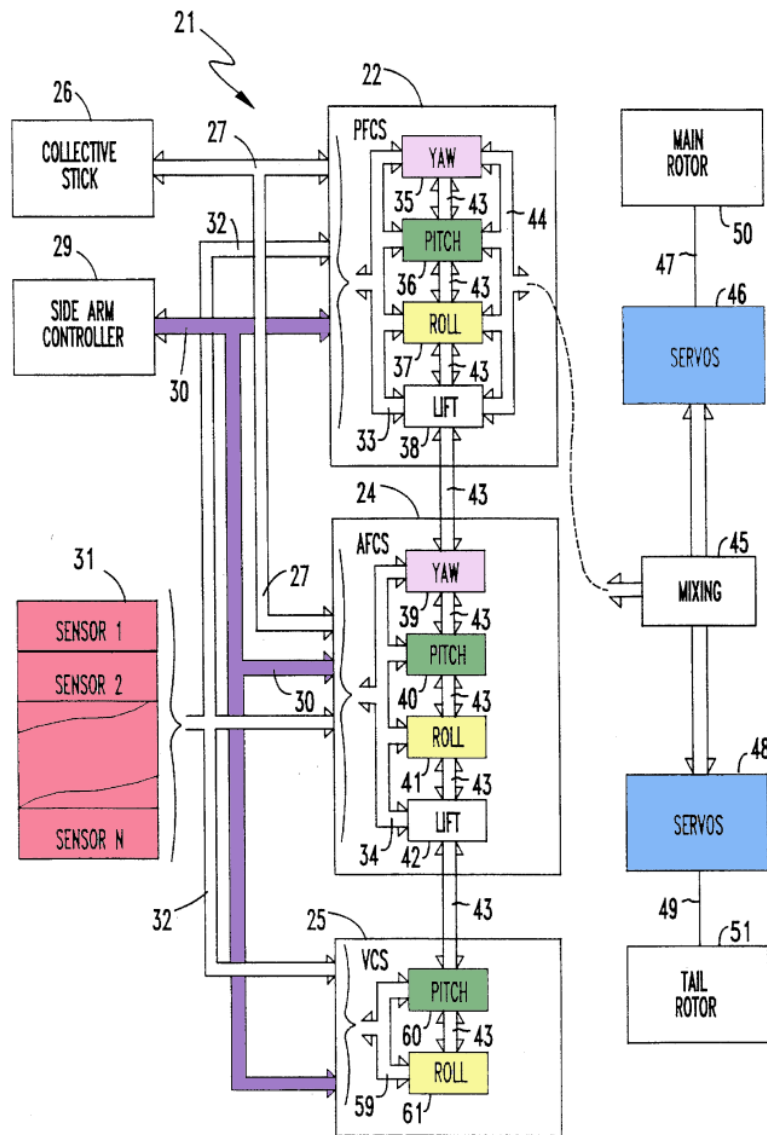
Step 2: Pedal Turn



’082 Patent, Excerpt from Figure 2

a. “Sensor”

Gold discloses “a sensor carried by the aircraft.” (DJI-1003, ¶112.) The PFCS, AFCS, and VCS of Gold’s flight control system receive “sensed parameter signals from **sensors 31** [shaded red in the annotated version of Gold Figure 3 below].” (DJI-1005, 3:10-13, 3:39-41.)



Gold, Annotated Figure 3

The sensed parameter signals provide “the aircraft’s angular rate and attitude response to the main rotor and tail rotor command signals” and provide “information related to velocity, altitude, acceleration, etc.” (DJI-1005, 3:32-36.) For example, the longitudinal groundspeed and lateral groundspeed are provided to the VCS from the sensors. (DJI-1005, 5:23-26; *see also*, DJI-1005, Figure 5.) By sensing angular rate, velocity (including speed), altitude, and acceleration, Gold

discloses the “*sensor being adapted to sense a directional movement of an aircraft*” [1A]. (DJI-1003, ¶¶113-114; *See also*, §IV.A.2; DJI-1003, ¶¶32-36; DJI-1006, 4:48-53 (incorporated by reference by Gold (DJI-1005, 4:38-43)).)

b. “Actuator”

Gold’s PFCS and AFCS provide command signals “to a rotor mixing functions 45 which commands displacement of mechanical servos 46 and linkages to control the tip path plan of a main rotor 50” and “tail rotor servos 48 which control the thrust of a tail rotor 51.” (DJI-1005, 3:25-32.) Actuators are devices that convert electrical signals into pressure, temperature, or mechanical movements. (*See* DJI-1003, ¶¶37-40.) Each control surface of the aircraft has an associated actuator. (*Id.*) As discussed in §IV.A.1, main rotor is tilted in the direction of the desired motion (e.g., lateral or longitudinal) and the tail rotor controls yaw movement. Accordingly, Gold’s servos/linkages include “*actuators*” that are “*utilized to control the directional movement of the aircraft*” [1B]. (DJI-1003, ¶115.)

3. “Control System” [1C]

Flight control system 21 is a “*control system.*” (DJI-1003, ¶116.) The PFCS, AFCS, and VCS each receives “sensed parameter signals from sensors 31.” (DJI-1005, 3:10-13, 3:39-41.) The PFCS and AFCS, in turn, provide command signals “to a rotor mixing function 45 which commands displacement” of the mechanical servos/linkages of the main and tail rotors (“*actuator[s]*”). (DJI-1005, 3:25-29.)

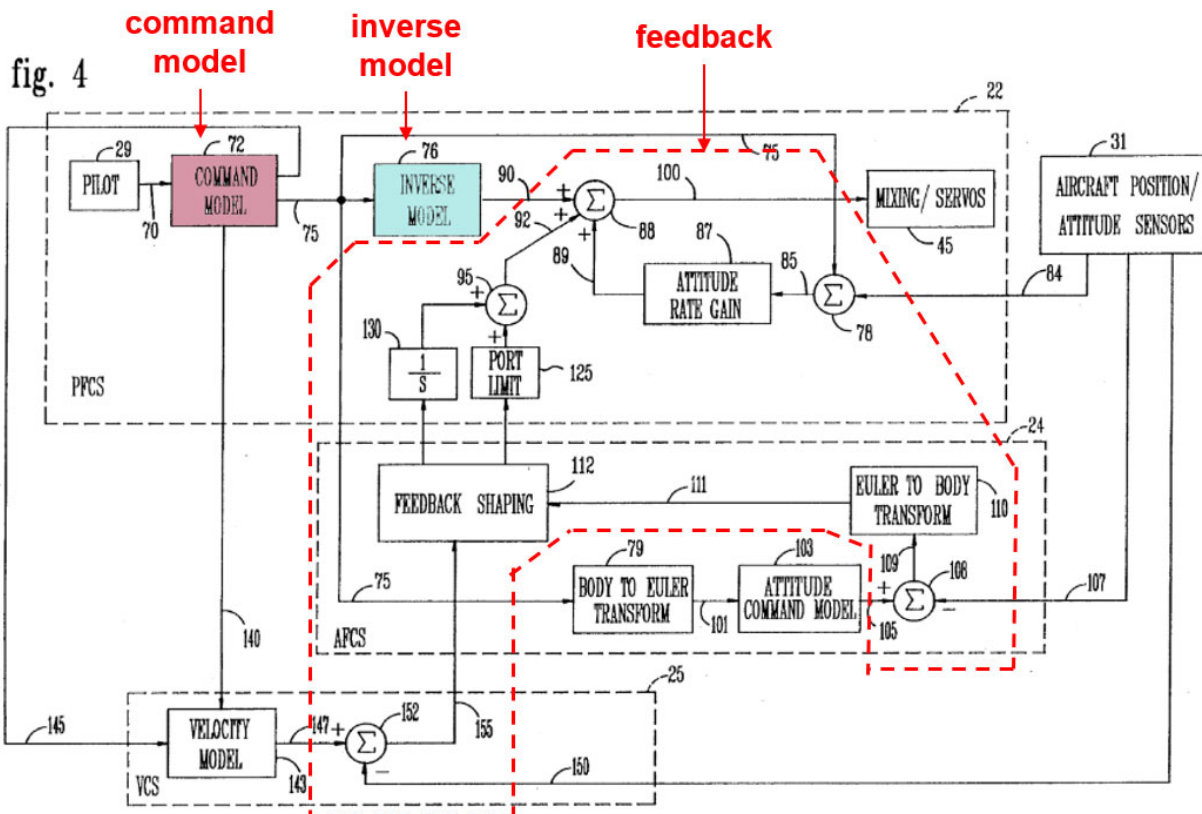
Thus, Gold discloses “*a control system in data communication with the aircraft sensor and operably associated with the actuator*” [1C]. (DJI-1003, ¶116.)

4. “Model”, “Lateral Control Architecture”, and “Longitudinal Control Architecture” Limitations [1C.1]-[1C.3]

Limitations [1C.1]-[1C.3] interweave the concepts of a “*model*”, “*equations of motions*”, “*lateral control architecture*”, and “*longitudinal control architecture*.” Petitioner addresses each concept separately. Because Gold describes the interconnection of the PFCS, AFCS, and VCS with respect to the pitch axis control modules 36, 40, 60 (DJI-1005, 3:54-56), Petitioner addresses the “*longitudinal control architecture*” before the “*lateral control architecture*.”

a. “Model”

Gold’s control system uses a “**model following algorithm** in each control axis” (yaw, pitch, roll, and vertical). (DJI-1005, 3:25-26; 3:17-18.) Figure 4 (below), illustrating the interconnection of VCS 25, PFCS 22, and AFCS 24 with respect to the pitch axis (longitudinal) control modules 36, 40, 60, has been annotated to depict the command model, inverse model, and feedback portions of a model-following control system (See DJI-1005, 3:54-56; DJI-1003, ¶118-119, citing DJI-1021, DJI-1022.)



Gold, Annotated Figure 4

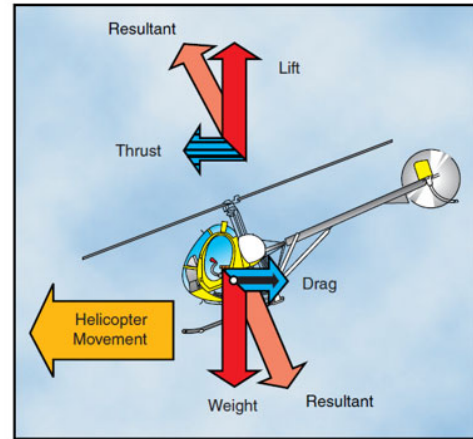
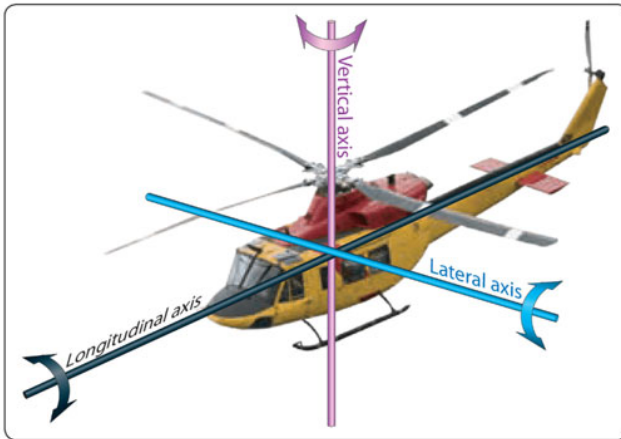
Command model 72 (shaded red) receives commands from the pilot's controller and shapes these commands "to yield a desired rate and/or attitude response." (DJI-1005, 4:6-7.) Inverse model 76 (shaded blue) "provides a control command signal on a line 90 which represents the approximate rotor command necessary to achieve the desired pitch axis rate of change of the aircraft for each pilot commanded maneuver." (DJI-1005, 4:10-15.) The desired control command signal(s) are provided to the feedback portion of the control module, as illustrated above. (DJI-1003, ¶120.)

Because Gold’s control system uses a “**model following algorithm** in each control axis”, the pitch, roll, yaw and lift control modules each includes a command model and an inverse model. (*See* DJI-1005, 3:25-26; 3:17-18.) The command and inverse models for the pitch axis, the roll axis, the yaw axis, and the lift axis are, therefore, collectively a “*model*” for the aircraft. (DJI-1003, ¶121.) Thus, Gold discloses a “*control system*” having a “*model*.” (*Id.*)

The remaining portions of “*model*” limitation [1C.1] associated with the “*lateral equation of motion*” and “*longitudinal equation of motion*” are addressed in §V.B.4.d (“*equations of motion*”).

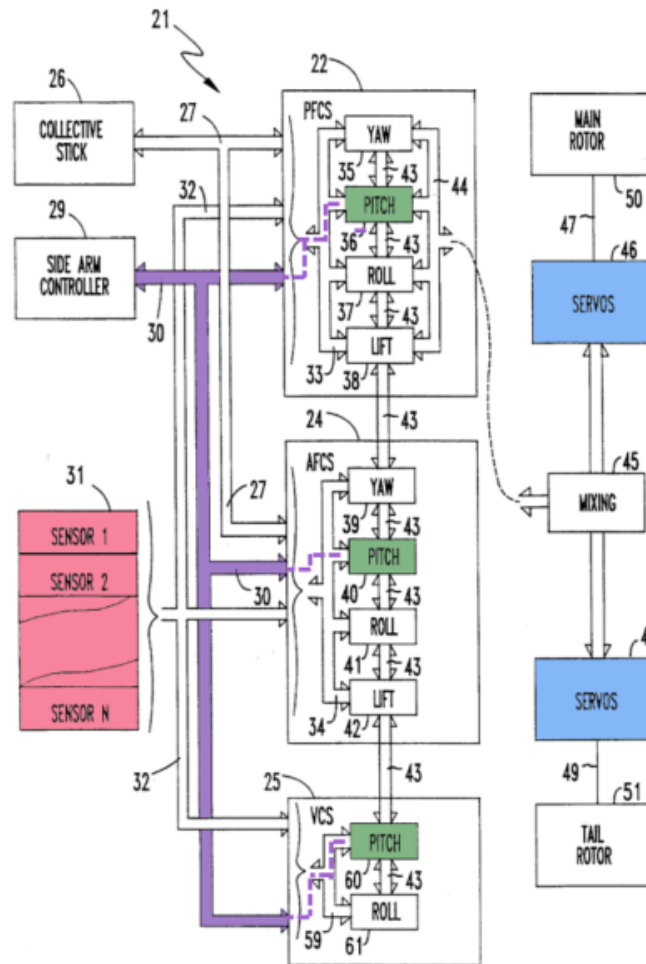
b. “Longitudinal Control Architecture” [1C.3].

Gold’s “*control system*” includes “*a longitudinal control architecture configured to control longitudinal motion of the aircraft*” [1C.3]. (DJI-1003, ¶¶123-131.) As discussed in §IV.A.1 and illustrated below (left), an aircraft coordinate system consists of three axes—longitudinal, lateral, and vertical. Rotation about the lateral axis is referred to as pitch. (DJI-1003, ¶¶124, 24.) Changes in pitch angle (attitude) induce movement in the longitudinal direction, as shown below right. (*See* §IV.A.1; DJI-1003, ¶¶124, 44, 46.) Accordingly, controlling pitch controls the “*longitudinal motion of the aircraft*.” (DJI-1003, ¶¶124-125, 130; DJI-1015, 3-11; *see also*, DJI-1001, 5:7-12 (correlating pitch and longitudinal control).)



DJI-1024, Figure 10 (left); DJI-1015, Figure 3-11 (right)

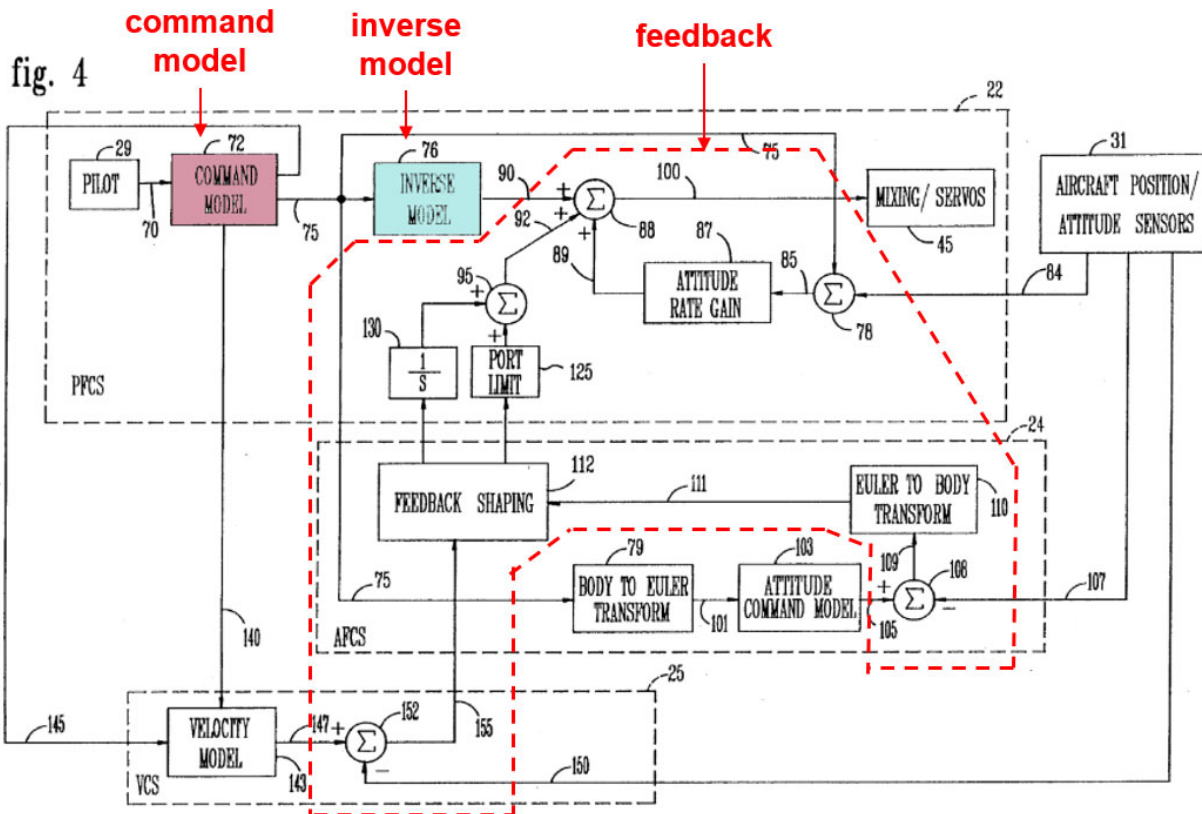
The PFCS, AFCS, and VCS each contains a control module 36, 40, 60 (shaded green in annotated Figure 3 below) for controlling aircraft pitch (longitudinal motion). (DJI-1005, 3:17-18, 3:45-46.) The pitch control modules receive command signals (shaded purple) from sidearm controller 29 and sensed parameter signals from sensors 31. (DJI-1005, 3:10-13, 3:40-42.) PFCS and AFCS longitudinal control architectures 36, 40 (shaded green) provide command signals that “command[] displacement of mechanical servos 46 and linkages 47 to control the tip path plane of a main rotor 50” as shown on right side of annotated Figure 3 below. (DJI-1005, 2:25-29.) Pitch control modules 36, 40, and 60 are therefore collectively part of the “*longitudinal control architecture*” [1C.3] of flight control system 21. (DJI-1003, ¶¶123-127.)



Gold, Annotated Figure 3

As illustrated in annotated Figure 4 (below), pitch control includes command model 72, inverse model 76, and a feedback portion. (See DJI-1005, 3:25-26; 3:17-18.) Because Gold’s inverse model generates “a control command signal on a line 90 which represents the approximate rotor command necessary to achieve the desired” response for the control axis (DJI-1005, 4:10-15) and the command model provides shaped commands (DJI-1005, 4:6-7), Gold discloses “a longitudinal control architecture in data communication with the model” [1C.3]. (DJI-1003,

¶¶127-128.) The portion of limitation [1C.3] directed to “*utiliz[ation of] the longitudinal equation of motion*” is addressed in in §V.B.4.d.

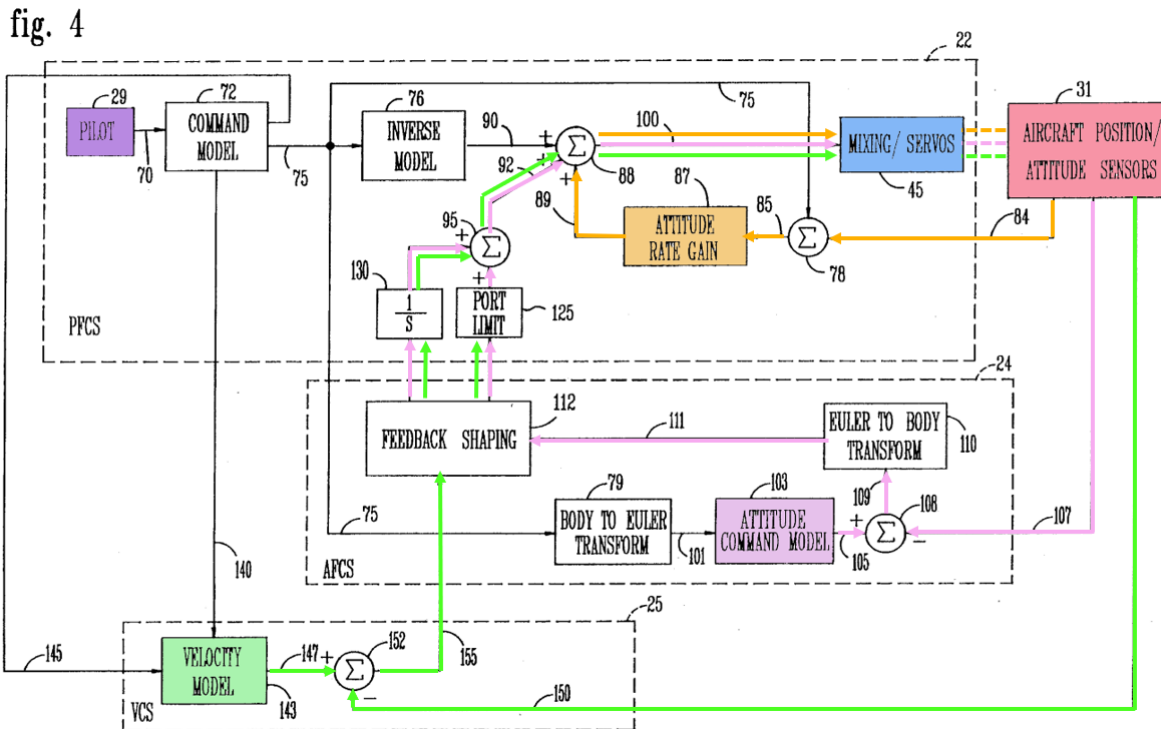


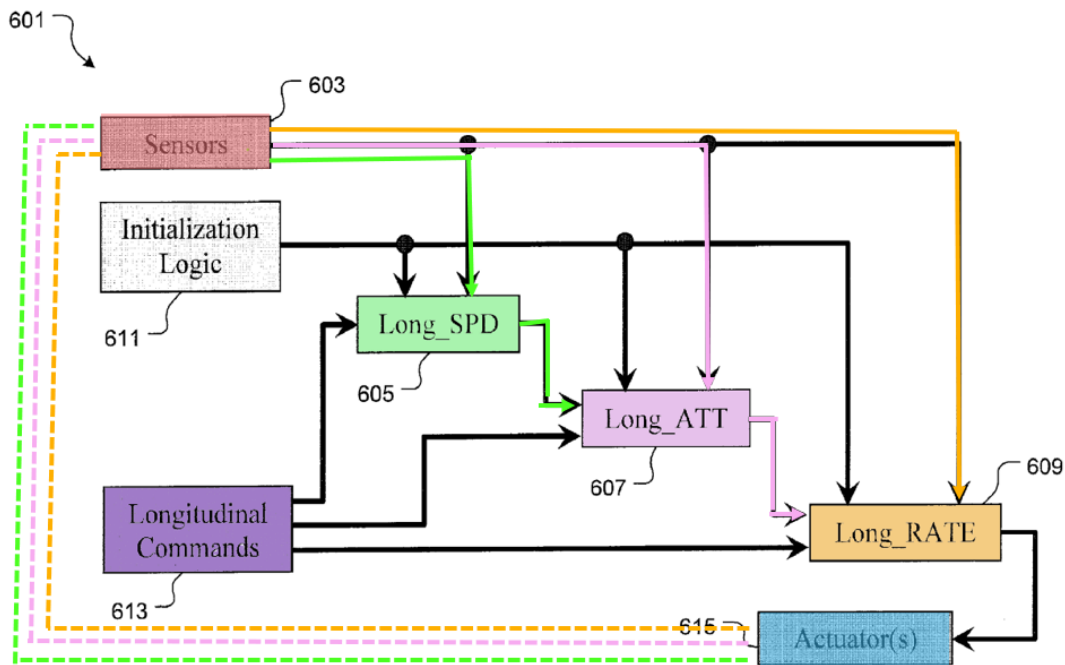
Gold, Annotated Figure 4

Should PO contend the longitudinal command model is separate from the control architecture, a POSITA would have understood the feedback portion of Gold’s pitch axis control is also a “*longitudinal control architecture*” because it is responsible for generating the rotor commands to drive the servos/linkages (“*actuator/s*”) of the aircraft. (DJI-1003, ¶127.)

Moreover, Gold’s longitudinal control architecture is analogous to the ’082 patent’s longitudinal control architecture, as illustrated in Gold’s annotated Figure

4 (top figure below) and '082 patent's Figure 6 (bottom figure below). (DJI-1003, ¶131.) As shown in these Figures, like the '082 patent, Gold discloses a longitudinal speed loop (indicated by bright green lines), an attitude (pitch angle) loop (indicated by pink lines), and a pitch rate loop (indicated by orange lines) like the '082 patent. (*Id.*) Each of these loops is described further in §V.D.4, discussing dependent claims 8 and 18.

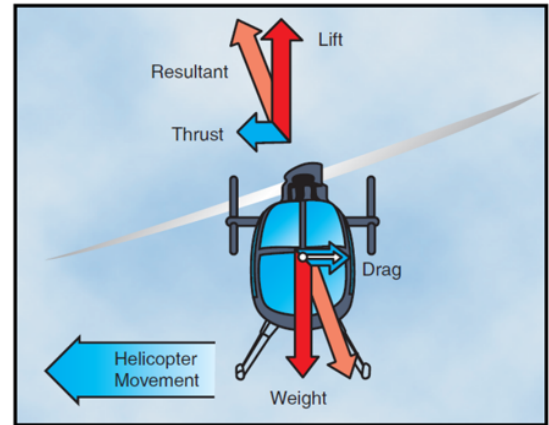
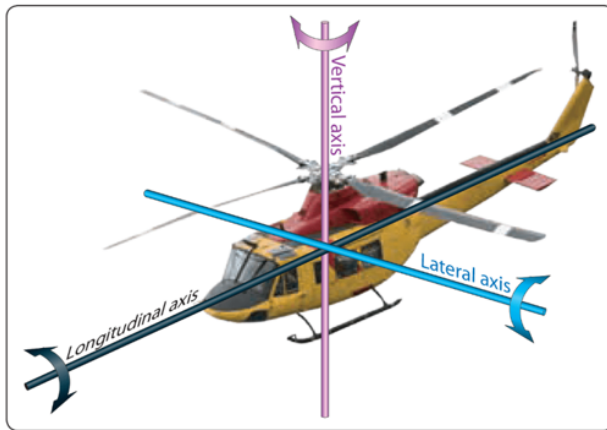




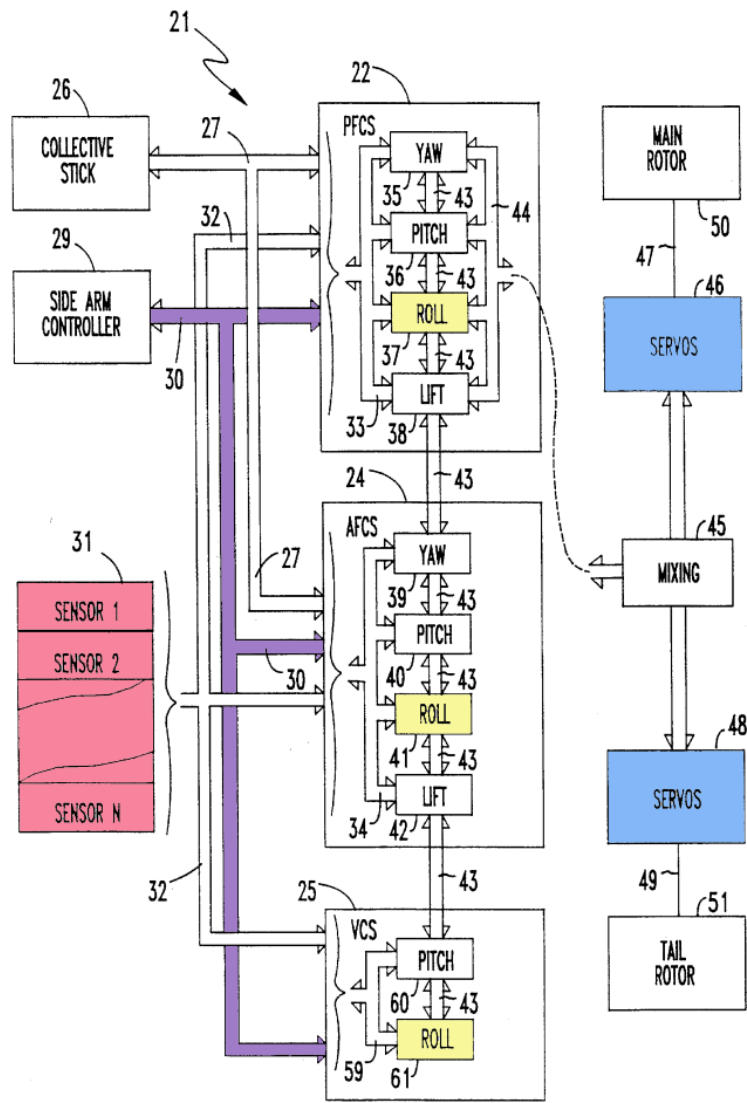
Gold, Annotated Figure 4 (top), '082 Patent, Annotated Figure 6 (bottom)

c. “Lateral Control Architecture” [1C.2]

Gold’s “control system” includes “a lateral control architecture configured to control lateral motion of the aircraft” [1C.2]. (DJI-1003, ¶¶132-140.) Rotation about the longitudinal axis is referred to a roll. Specifically, when the main rotor is “rolled” (or tilted) sideways, a portion of its thrust is in the lateral direction, thereby inducing lateral motion. (DJI-1003, ¶¶132, 24, 45; §IV.A.1.) Accordingly, controlling roll controls the “lateral motion of the aircraft.” (DJI-1003, ¶¶132, 139; *see also*, DJI-1001, 5:53-62 (correlating roll and lateral control).)



Gold's PFCS, AFCS, and VCS each also contains a control module 37, 41, 61 (shaded yellow in annotated Figure 3 below) for controlling roll. (DJI-1005, 3:17-18, 3:45-46.) The roll control modules receive command signals (shaded purple) from sidearm controller 29 and sensed parameter signals from sensors 31. (DJI-1005, 3:10-13, 3:40-42.) PFCS and AFCS lateral control architectures 37, 41 provide rotor command signals that “command[] displacement of mechanical servos 46 and linkages 47 to control the tip path plane of a main rotor 50” as shown on right side of annotated Figure 3 below. (DJI-1005, 2:25-29.) Roll control modules 37, 41, and 61 are therefore collectively part of the “*lateral control architecture*” [1C.2] of flight control system 21. (DJI-1003, ¶¶133-136.)

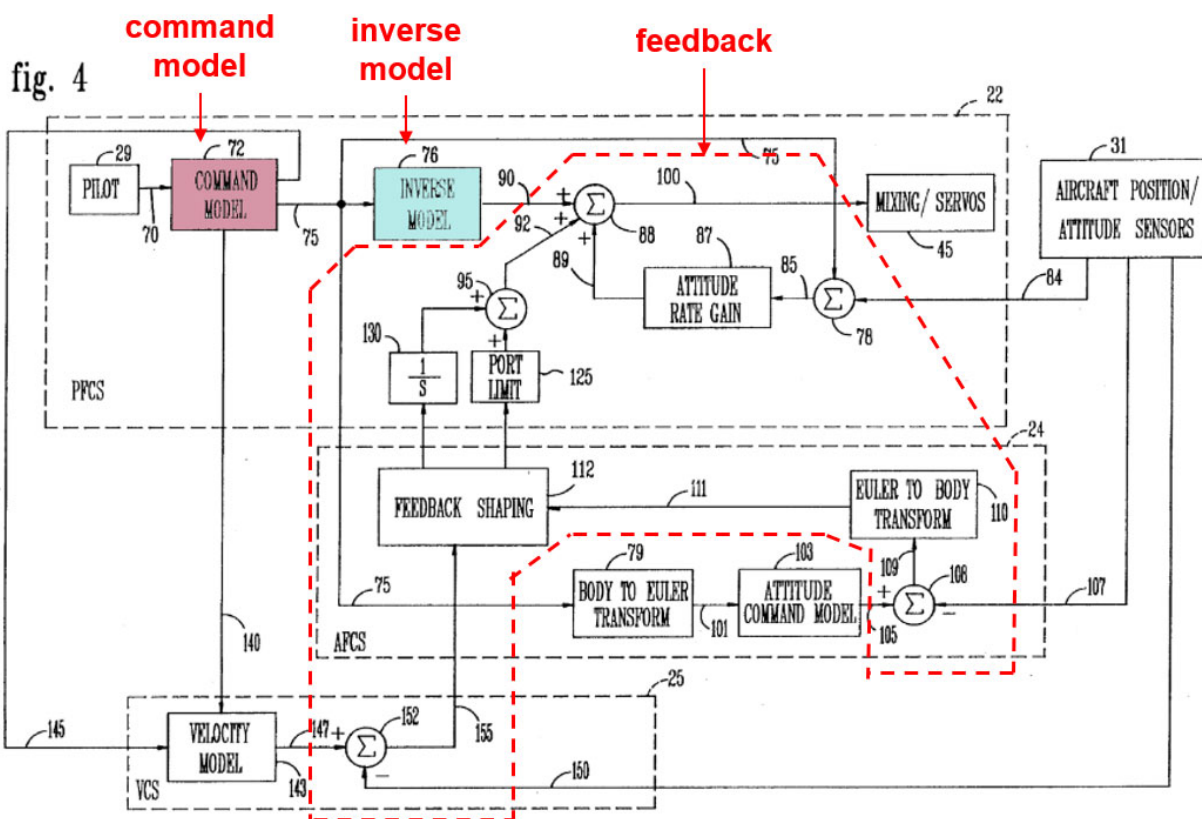


Gold, Annotated Figure 3

As illustrated in annotated Figure 4¹ below, roll control includes command model 72, inverse model 76, and a feedback portion. (See DJI-1005, 3:25-26; 3:17-

¹ Gold describes Figure 4 with respect to pitch axis modules but, as explained by Gold, “the functional interconnection of FIG. 4 is equally applicable

18.) Because Gold's command model provides shaped commands to the roll control modules, Gold discloses "a lateral control architecture in data communication with the model" [1C.2]. (DJI-1003, ¶¶136-137.) The portion of limitation [1C.2] directed to "utiliz[ation of] the lateral equation of motion" is addressed in §V.B.4.d.



Gold, Annotated Figure 4

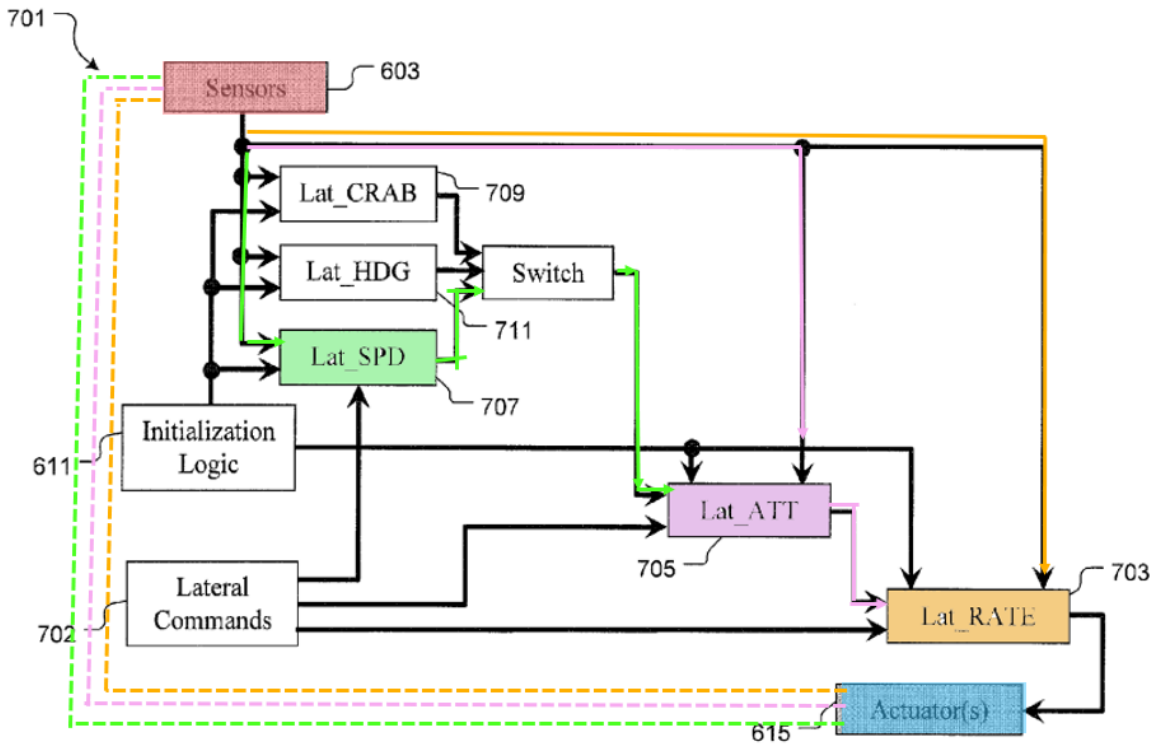
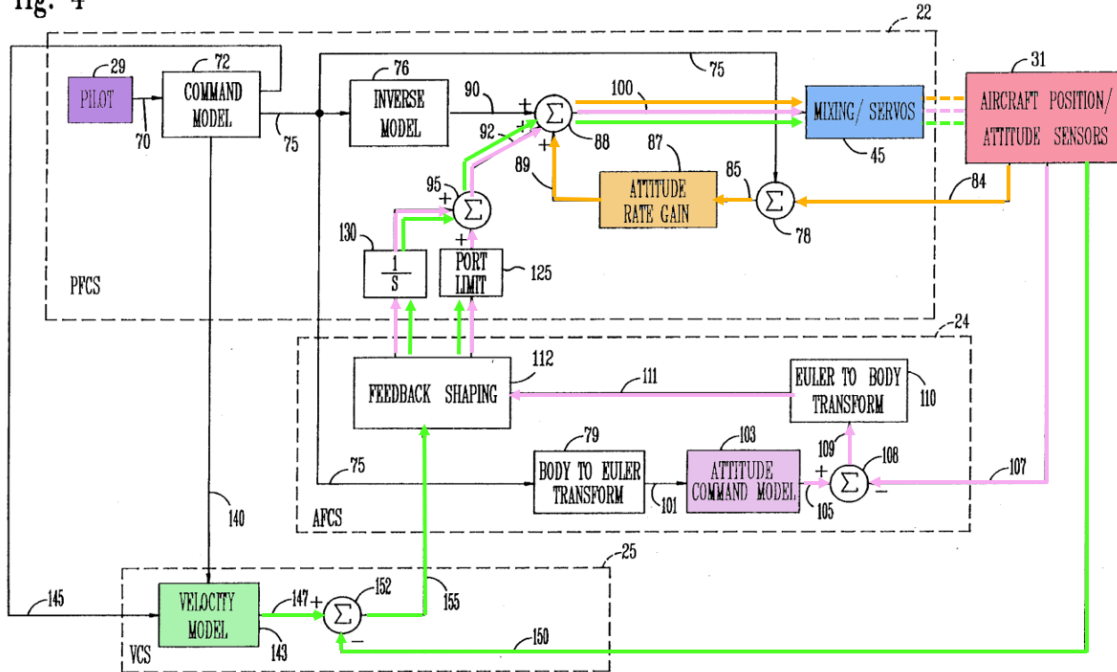
to flight control roll attitude reference and VCS roll axis velocity error signals.”

(DJI-1005, 3:54-61.)

Should PO contend the lateral command model is separate from the control architecture, a POSITA would have understood the feedback portion of Gold's pitch axis control is also a "*lateral control architecture*" because it is responsible for generating the rotor commands to drive the servos/linkages ("*actuator[s]*") of the aircraft. (DJI-1003, ¶136.)

Gold's lateral control architecture is analogous to the '082 patent's lateral control architecture, as illustrated in Gold's annotated Figure 4 (top figure below) and '082 patent's annotated Figure 7 (bottom figure below). (*See* DJI-1005, 3:54-61; DJI-1003, ¶140.) As shown in these Figures, like the '082 patent, Gold discloses a lateral speed loop (indicated by bright green lines), an attitude (roll angle) loop (indicated by pink lines), and a roll rate loop (indicated by orange lines). (DJI-1003, ¶140.) Each of these loops is described further in §V.D.2, discussing dependent claims 5 and 15.

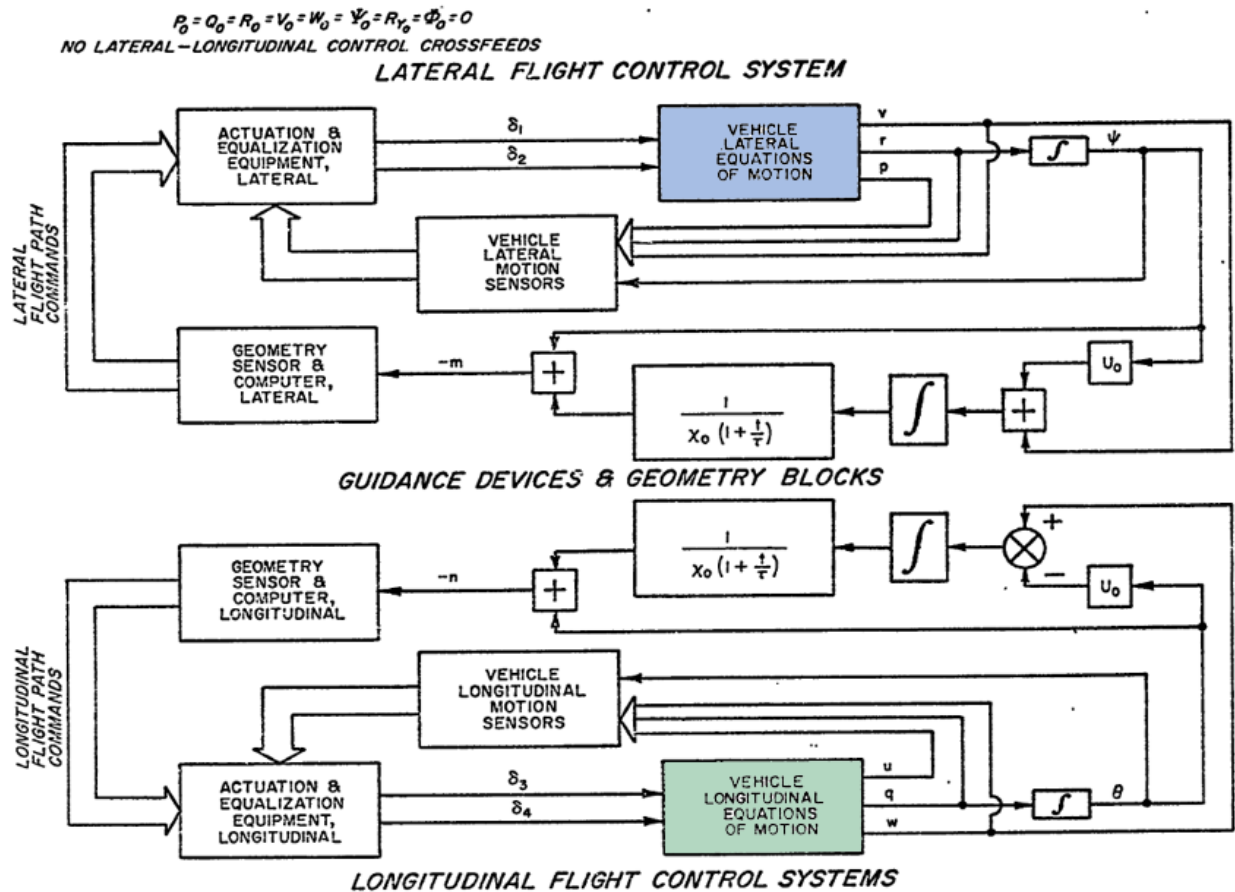
fig. 4



Gold, Annotated Figure 4 (top), '082 Patent, Annotated Figure 7 (bottom)

d. “Equations of Motion”

The combination of Gold, Shue, and Gold-Paper discloses the “*model*” is “*adapted to decouple the directional movement of the aircraft into a lateral equation of motion and a longitudinal equation of motion*” [1C.1]. (DJI-1003, ¶¶141-148.) The ’082 patent provides only a limited discussion of the concept of a “model” and “decoupling,” mentioning the linear aircraft model is decoupled into lateral and longitudinal equations of motion because of the size of aircraft model matrices. (See DJI-1001, 4:51-63; DJI-1003, ¶141.) However, as discussed in §IV.A.3, decoupling a linear aircraft model into lateral and longitudinal equations of motions used by lateral and longitudinal control architectures was well-known long before the ’082 patent. (See DJI-1017, 14, 15, Figure 1-4 below.)

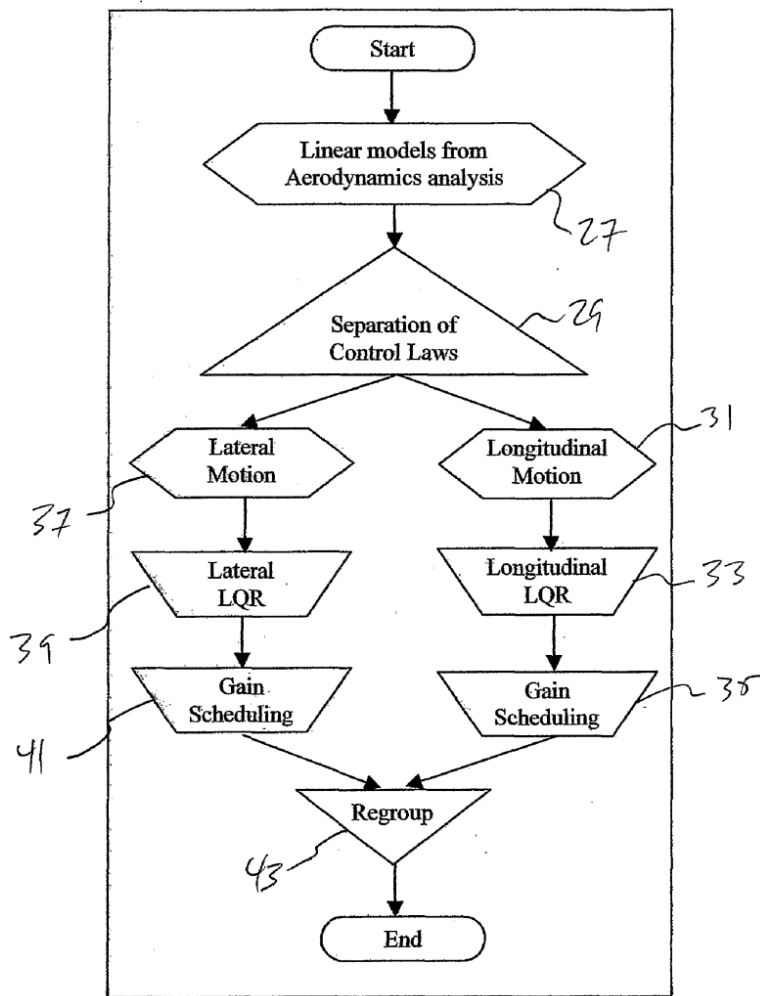


McRuer (1973), Figure 1-4

Like the flight control system of McRuer above, Gold separates its control system into lateral and longitudinal architectures. (See §§V.B.4.b-c.) Thus, based on common knowledge in the art, as reflected by McRuer’s Figure 1-4 above and references describing the separation of linearized equations of motion into linear and longitudinal components (see DJI-1003, ¶¶55-57), a POSITA would have understood that Gold’s “model” is “adapted to decouple [separate] the directional movement of the aircraft into a lateral equation of motion and a longitudinal equation of motion.” (DJI-1003, ¶143.) A POSITA would have also understood

that Gold's "*lateral control architecture*" is "*adapted to utilize the lateral equation of motion to control the lateral motion of the aircraft*" [1C.2] and that its "*longitudinal control architecture*" is "*adapted to utilize the longitudinal equation of motion to control the longitudinal motion of the aircraft*" [1C.3]. (DJI-1003, ¶¶142-144.)

Regardless, Shue explicitly discloses using decoupled lateral and longitudinal equations of motion in lateral and longitudinal control architectures. (DJI-1003, ¶144.) In Shue, the linear aircraft model is decoupled into "lateral and longitudinal equations of motion" as shown in Figure 5 below (blocks 29, 31, and 27). (DJI-1008, ¶¶41-43.) The lateral control architecture (lateral LQR) uses the lateral equations of motion to minimize a lateral cost function and the longitudinal control architecture (longitudinal LQR) uses the longitudinal equations of motion to minimize a longitudinal cost function to drive condition errors to zero. (DJI-1008, ¶43.)



Shue, Figure 5

Because the combination uses Shue's explicit teachings regarding decoupled lateral and longitudinal equations of motion in Gold's flight control system having separate lateral and longitudinal control architectures, the combination of Gold, Shue, and Gold-Paper also discloses limitations [1C.1], [1C.2], and [1C.3]. (DJI-1003, ¶¶144-148.)

5. “Initialization Command Logic” [1C.4], [1D]

The combination of Gold, Shue, and Gold-Paper discloses “*initialization command logic*” [1C.4]. (DJI-1003, ¶¶149-152.) Gold-Paper describes multiple examples of “*command logic*” that initialize modes of operation. For example, Gold-Paper teaches that “[a]utomatic turn coordination is enabled above 60 kts.” (DJI-1009, 421.) That is, the logic receives data from the sensors and when speed of the aircraft is above 60 kts, the logic selectively activates the necessary portions of the lateral, longitudinal, and directional control architectures to perform turn coordination. (DJI-1003, ¶150.)

Gold-Paper also discloses the automatic activation of various other modes by the “*initialization command logic*.” For example, Gold-Paper explains that when the helicopter is in velocity stabilization mode, the “roll response-type **automatically changes modes** from AC/VH [attitude command/attitude hold] to RC/AH [rate command/attitude hold] between 60 and 80 kts.” (DJI-1009, 421; *See* DJI-1009, Figure 2.) Additionally, Hover Hold is **automatically** “engage[d] when ground speed, pitch and roll rates, longitudinal and lateral linear acceleration, and pitch and roll stick commands are small.” (DJI-1009, 421.) And while in velocity stabilization mode, “the yaw axis control laws provide **automatic** low speed turn coordination (LSTC) which is enabled above 15 kts groundspeed.” (DJI-1009, 423.) As a final example, Altitude Hold mode “engages **automatically**” when in

velocity stabilization mode and Hover Hold mode is entered. (*Id.*) To activate these modes automatically and selectively, the “*initialization command logic*” receives sensor input (e.g., speed) and provides command input to the lateral and longitudinal control architectures to enable or disable portions of those architectures to achieve the desired mode operation—i.e., the “*initialization command logic*” is “*in data communication with the lateral control architecture and in data communication with the longitudinal control architecture*” [1C.4]. (DJI-1003, ¶151.)

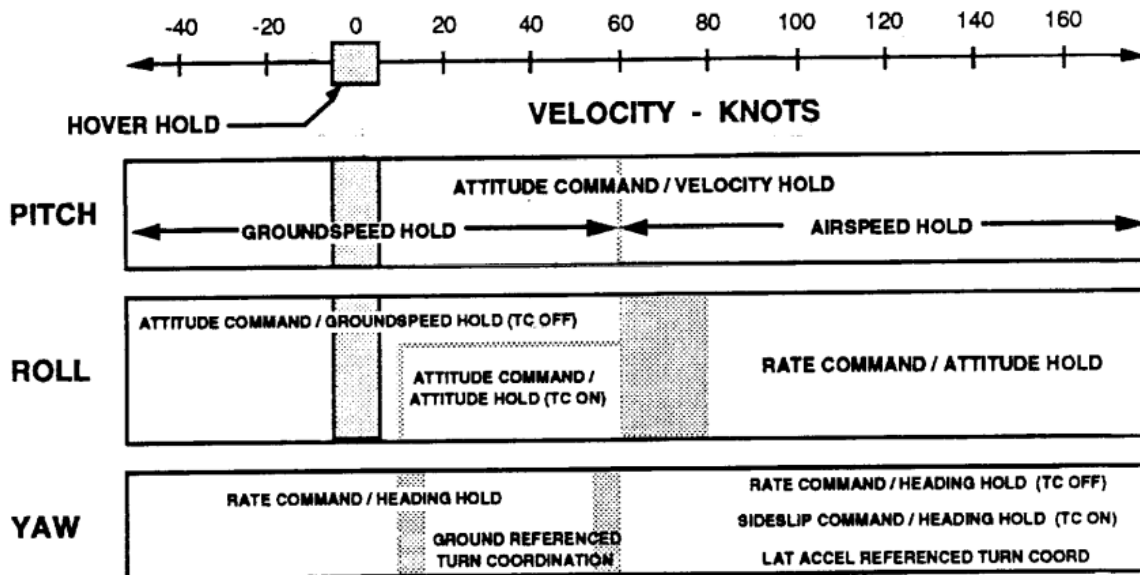


FIGURE 2. VELSTAB CHARACTERISTICS vs VELOCITY

Thus, the combination of Gold, Shue and Gold-Paper discloses “*the initialization command logic selectively activates the lateral control architecture for controlling the lateral motion of the aircraft and selectively activates the*

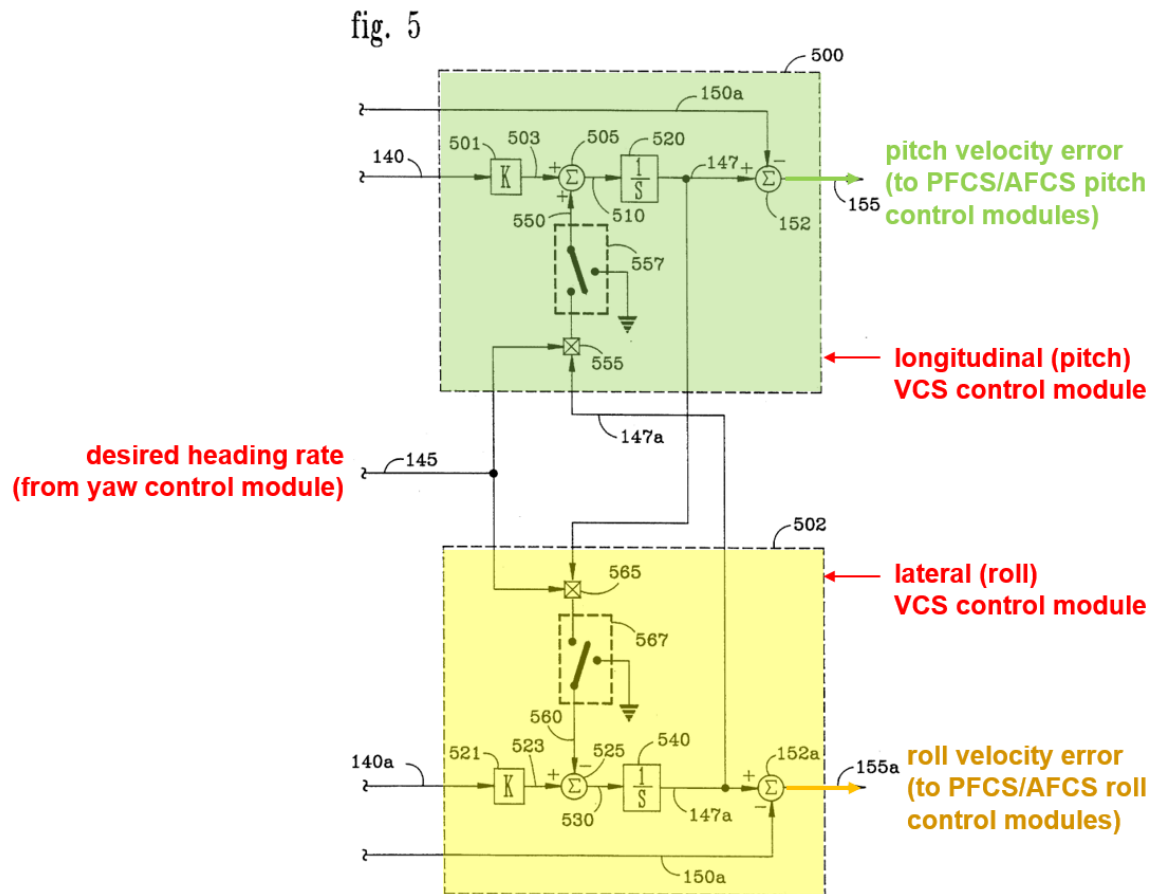
longitudinal control architecture for controlling the longitudinal motion of the aircraft” [1D]. (DJI-1003, ¶¶149-152.)

6. “Control Speed Variations ... While the Aircraft Maintains a Constant Vector Heading Across a Ground Surface” [1E]

Limitation [1E] recites “*the control system utilizes the lateral control architecture and the longitudinal control architecture to control speed variations of the aircraft while the aircraft maintains a constant vector heading across a ground surface.*” Aside from the abstract and claims, the ’082 patent does not use the terminology “*constant vector heading across a ground surface.*” The ’082 patent instead refers to a “constant vector.” (See, e.g., DJI-1001, 2:47-50 (“use the directional controller to command flat yawing turns at low groundspeeds, while maintaining a **constant vector across the ground**”); 7:59-61.) The “*heading across a ground surface*” is therefore the aircraft’s straight-line track or course and an “*aircraft maintain[ing] a constant vector heading across a ground surface*” means the aircraft flies over the ground in a particular straight-line direction (i.e., the ground track/course) at a constant speed. (DJI-1003, ¶¶153-154.)

Gold discloses “*utiliz[ing] the lateral control architecture and the longitudinal control architecture to control speed variations of the aircraft while the aircraft maintains*” a constant flight path (ground track) at a specific speed (“*a constant vector heading across a ground surface*”). (DJI-1003, ¶¶153-157.) Gold’s yaw axis command model “provides a desired yaw axis rate response, i.e., desired

heading rate” to the VCS velocity model 143. (DJI-1005, 5:11-13.) The VCS “uses the heading rate signal” and “the desired attitude response for the pitch axis and the yaw axis to develop centrifugal acceleration terms.” (DJI-1005, 5:15-20, Figure 5 below.) The longitudinal centrifugal acceleration term is provided to the summing junction 505 and the lateral centrifugal acceleration term is provided to summing junction 525. (DJI-1005, 5:38-40, 5:48-51; Figure 5.) The resulting acceleration terms are provided to integrators 520, 540 which produce desired pitch and roll velocity signals, respectively. (See DJI-1005, 6:7-10.) A summing junction compares the commanded velocity with the actual velocity (groundspeed) to produce pitch and roll velocity error signals. (See DJI-1005, 6:10-15.)



Gold, Annotated Figure 5

The resulting error signals are provided to the AFCS and PFCS pitch (longitudinal) and roll (lateral) control modules which “drive the velocity error to zero” in the lateral and longitudinal axes. (See DJI-1005, Figure 4; 6:15-17.) By driving the velocity errors to zero, the longitudinal and lateral control architectures control speed variations of the aircraft and maintain the aircraft on a “*constant vector heading across a ground surface*” (straight-line flight path at a constant speed). (DJI-1003, ¶¶155-156.)

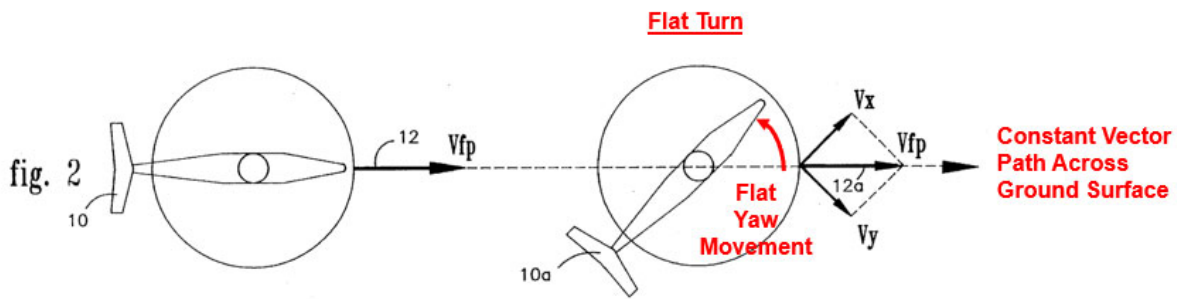
Thus, the combination of Gold, Shue, and Gold-Paper discloses limitation [1E]. (DJI-1003, ¶¶153-157.)

C. Independent Claim 11

1. Preamble [11P]

The combination of Gold, Shue, and Gold-Paper discloses a “*method to control flat yawing turns of an aircraft while maintaining a constant vector heading across a ground surface*” [11P]. (DJI-1003, ¶¶159-161.) Gold’s PFCS and AFCS each contain a yaw control module. (DJI-1005, 3:17-18.) In response to a pilot’s yaw command while in velocity stabilization mode, “the aircraft 10a yaws while maintaining a constant flight path reference velocity 12a with respect to an inertial frame of reference.” (DJI-1005, 2:60-64; *see also*, DJI-1005, 1:51-55.) Gold’s flight control system automatically adjusts pitch and roll attitude to keep the aircraft moving in the same direction at a constant speed. (*See, e.g.*, DJI-1005, 5:9-6:57.)

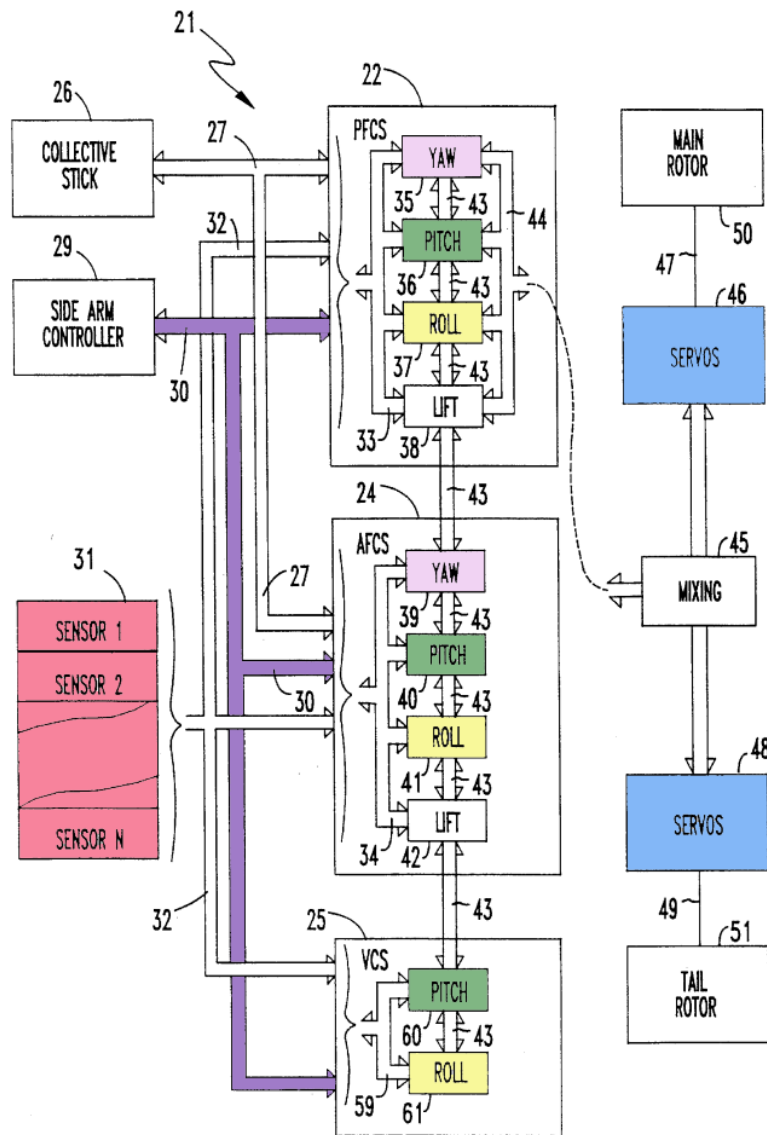
The yaw movement controlled by Gold’s yaw control modules, illustrated in annotated Figure 2, is a “*flat yawing turn*” (bank angle is zero) because the aircraft rotates about its vertical axis (turning the aircraft’s nose) without pitching or rolling to any significant degree that would induce lateral or longitudinal motion and drive the aircraft off its constant velocity path. (DJI-1003, ¶160.)



Gold, Annotated Figure 2

2. “Sensing” Limitation [11A].

Gold discloses “sensing the speed variation of the aircraft with a sensor carried by the aircraft, the speed variation having a longitudinal direction of motion; and a lateral direction of motion” [11A]. (DJI-1003, ¶¶162-164.) The PFCS, AFCS, and VCS receive “sensed parameter signals from sensors 31 [shaded red]” including aircraft’s rate and attitude response and “information related to velocity, altitude, acceleration, etc.” (DJI-1005, 3:10-13, 3:32-41, Figure 3 below.) For example, longitudinal and lateral groundspeed are both provided to the VCS from the sensors. (DJI-1005, 5:23-26; *see also*, Figure 4.) Longitudinal groundspeed signal provides sensed variation of “a longitudinal direction of motion” and lateral groundspeed signal provides sensed variation of “a lateral direction of motion.” Additionally, sensors measuring acceleration “sense[] speed variation of the aircraft” because acceleration is a measurement of how speed varies. (DJI-1003, ¶¶162-163; DJI-1006, 4:48-53; DJI-1005, 4:38-43 (incorporating Skonieczny by reference).)



Gold, Annotated Figure 3

3. Limitations [11B]-[11F]

Limitations [11B]-[11F] recite substantially similar subject matter as limitations [1C] and [1D]. For the reasons set forth in the sections listed in the table below, the combination of Gold, Shue, and Gold-Paper discloses limitations [11B]-[11F]. (See DJI-1003, ¶¶165-171.)

Claim 11

[11B] providing a control system ...	§V.B.3
[11B.1] model	§V.B.4.a
[11B.2] lateral control architecture	§§V.B.4.c-d
[11B.3] longitudinal control architecture	§§V.B.4.b, d
[11B.4] initialization command logic ...	§V.B.5
[11C] decoupling ...	§§V.B.4.a, d
[11D] controlling lateral direction of motion ...	§§V.B.4.c-d
[11E] controlling longitudinal direction of motion ...	§§V.B.4.b, d
[11F] selectively activating	§V.B.5

4. “*Selective Control of the Yawing Turns*” [11G].

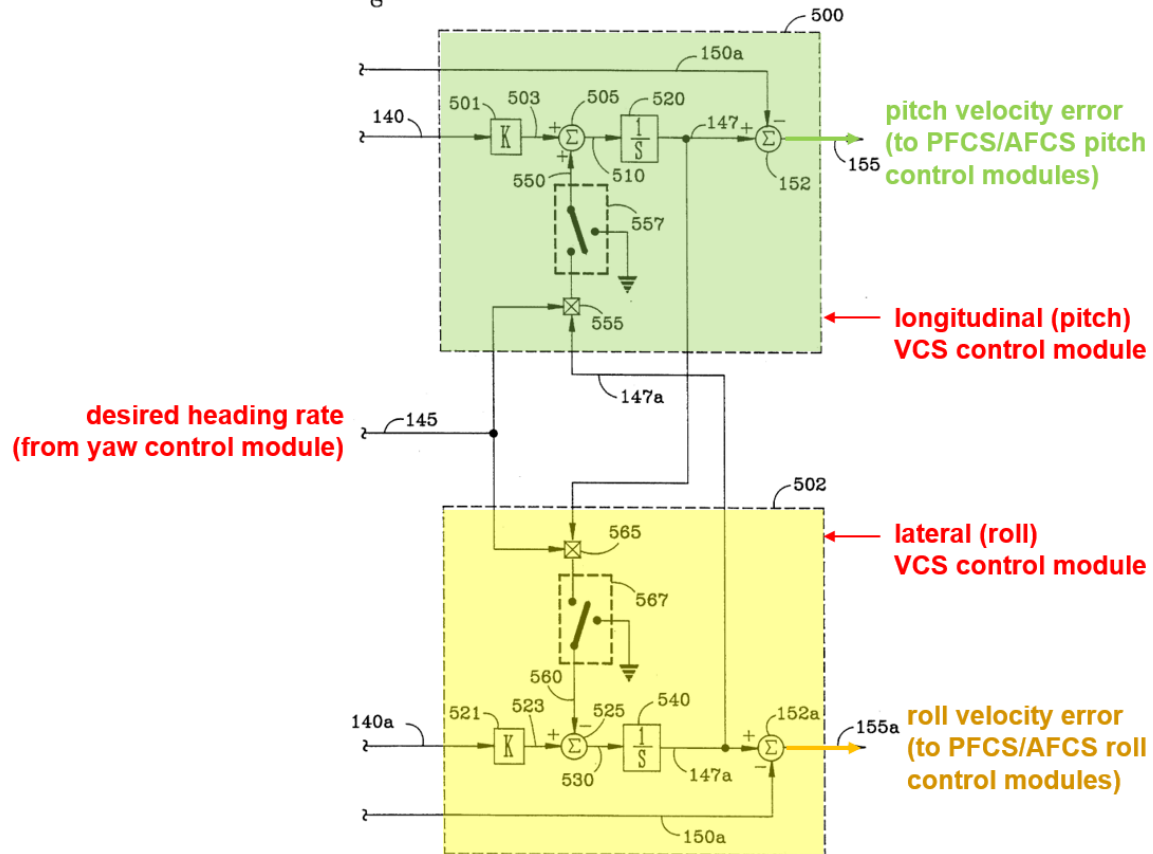
The combination of Gold, Shue, and Gold-Paper discloses the “*control system receives sensed speed variation data from the sensor and operably controls the actuators, thus providing selective control of the yawing turns of the aircraft while maintaining a constant vector across a ground surface*” [1G]. (DJI-1003, ¶¶172-176.) The ’082 patent does not describe “*selective* control of yawing turns.” At most, the ’082 patent discloses that a pilot initiates yaw movement and the control system “automatically adjust pitch and roll attitude to keep the aircraft moving in the same direction at a constant speed.” (DJI-1001, 3:64-4:5, 2:42-45.)

Gold operates in the same manner. In Gold, “[i]n response to a yaw command by a pilot during operation in a velocity stabilization mode, the aircraft 10a yaws while maintaining a constant flight path reference velocity 12a.” (DJI-1005, 2:61-64.) When in velocity stabilization mode, Gold’s flight control system

automatically adjusts pitch and roll attitude to keep the aircraft moving in the same direction at a constant speed. (§§V.B.6, V.C.1.) Thus, like the '082 patent, the pilot selectively initiates a yaw maneuver and in response, Gold's flight control system automatically provides "*control of the yawing turns of the aircraft while maintaining a constant vector across a ground surface.*" (DJI-1003, ¶¶172-173.)

As shown in annotated Figure 5 below, as part of adjusting the pitch and roll attitude, the longitudinal and lateral groundspeeds ("*sensed speed variation data*") are received from sensors 31. (See, DJI-1005, 6:30-31.) The sensed values are compared with the desired pitch and roll axis command signals to provide pitch and roll axis velocity error signals to AFCS/PFCS. (See DJI-1005, 6:32-33.)

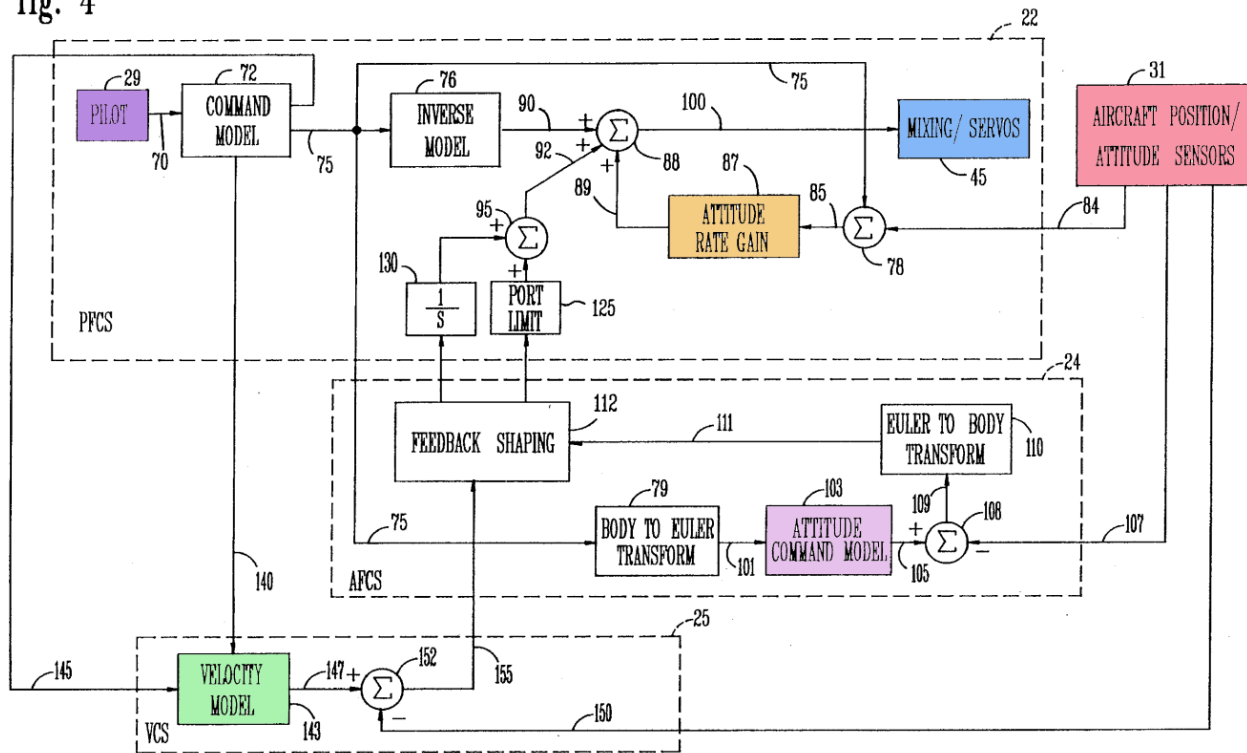
fig. 5



Gold, Annotated Figure 5

Command modifying signal 92 is generated using the velocity error signals (after shaping) to adjust the command signal from inverse model 76. (DJI-1003, ¶175.) The resulting signal is provided to mixing function 45 which commands displacement of mechanical servos/linkages (actuators). (DJI-1005, 4:9-11; DJI-1003, ¶175.)

fig. 4



Gold, Annotated Figure 4

The combination of Gold, Shue, and Gold-Paper discloses limitation [11G].

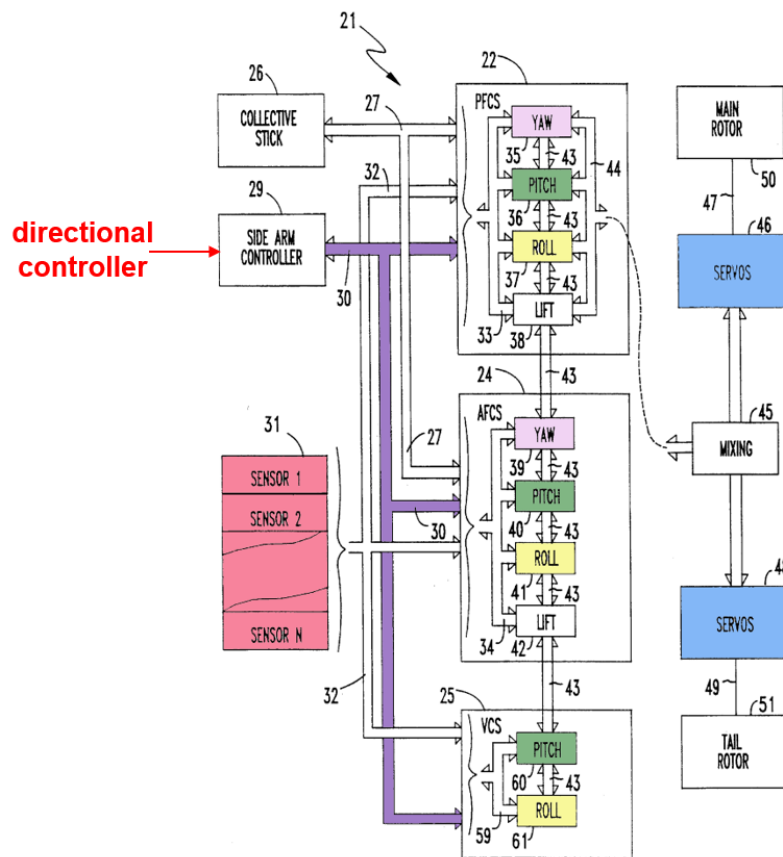
(DJI-1003, ¶¶172-176.)

D. Dependent Claims

1. “Directional Controller” (Claims 2/12)

In Gold, “the **pilot’s lateral twisting** (left or right) of the sidearm controller” generates yaw command signals. (DJI-1005, 3:64-4:4.) The generated yaw command signals are provided to flight control system 21. (DJI-1005, 3:10-12, Figure 3 below.) Because Gold’s sidearm controller controls yaw movements, the sidearm controller is a “*directional controller*” that is “*manipulated by a pilot controlling the aircraft.*” (DJI-1003, ¶179; see also, DJI-1001, 4:32-40

(acknowledging a single device controlling multiple axes is a directional controller).) The combination of Gold, Shue, and Gold-Paper discloses “a directional controller, the directional controller being manipulated by a pilot controlling the aircraft, the directional controller being in data communication with the control system” [2]. (DJI-1003, ¶¶178-180.)



Gold, Annotated Figure 3

Gold discloses a “directional control architecture” [12]. (DJI-1003, ¶¶181-183.) Gold’s PFCS and AFCS each contains a control module (35, 39) for controlling yaw (shaded pink). (DJI-1005, 3:17-18.) Because the yaw control modules control yaw movement in response to pilot commands provided via the

sidearm controller, PFCS yaw control module 35 and AFCS yaw control module 39 are collectively part of “*a directional control architecture*” of the flight control system which is “*operably associated*” with the “*directional controller*” (sidearm controller) and is “*in data communication with the control system.*” (DJI-1003, ¶181.)

In response to a pilot’s yaw command while in velocity stabilization mode, the aircraft “yaws while maintaining a constant flight path reference velocity 12a.” (DJI-1005, 2:60-64.) The result of this yaw command is a “*flat yaw movement.*” (See §V.C.1; DJI-1003, ¶128.) Thus, the combination of Gold, Shue, and Gold-Paper discloses “*commanding the flat yawing turns with the directional controller manipulated by a pilot controlling the aircraft, the directional controller being operably associated with a directional control architecture, the directional control architecture being in data communication with the control system*” [12]. (DJI-1003, ¶¶181-183.)

2. “*Lateral Control Architecture*” (Claims 5/15)

Gold’s “*lateral control architecture*” includes “*lateral sideward groundspeed control loop*” [5A]/[15A], “*lateral roll attitude control loop*” [5B]/[15B] and “*lateral roll rate control loop*” [5C]/[15C]. (DJI-1003, ¶¶185-197.)

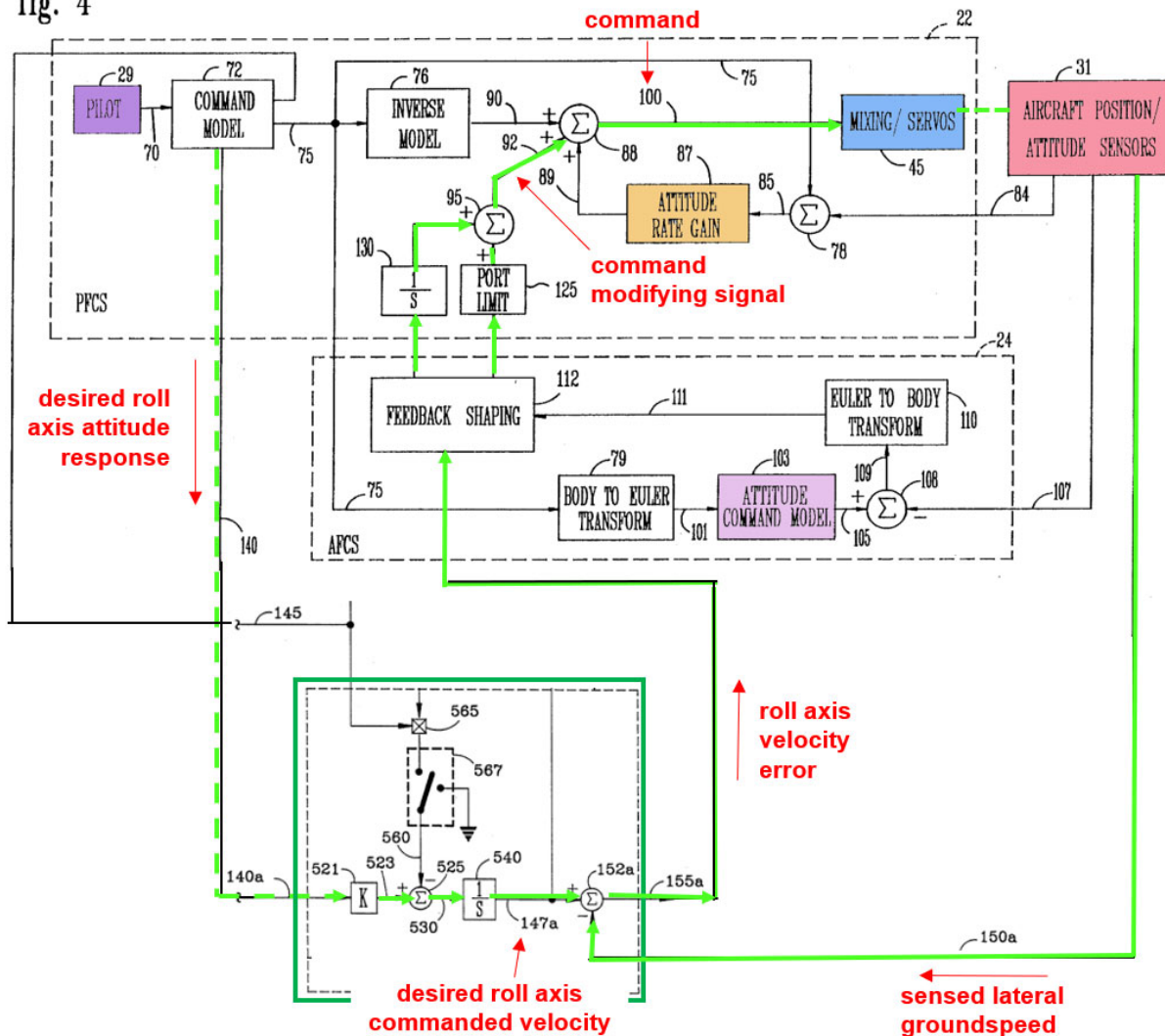
a. “*Lateral Sideward Groundspeed Control Loop*” [5A]/[15A].

When Gold’s system operates in velocity stabilization mode, VCS roll (lateral) control module 61 generates VCS roll velocity error signals using actual

lateral groundspeed data provided by the sensors. These roll velocity error signals “drive the error signals to zero.” (DJI-1005, 3:50-52.) This control loop, illustrated in Singhose Figure A² below, is highlighted by green lines.

² Singhose Figure A combines and annotates Gold’s Figure 4 with excerpts from Gold’s Figure 5 providing details of the VCS roll axis component. (DJI-1003, ¶188; DJI-1005, 3:54-61 (Figure 4 “is equally applicable” to roll axis control modules).)

fig. 4



Singhose Figure A

Specifically, command model 72 provides the desired roll axis attitude response, required to maintain velocity in velocity stabilization mode, to VCS roll control module 502 (indicated by the green box above). (See DJI-1005, 5:59-64; DJI-1003, ¶189.) The desired roll attitude is multiplied by a gravitational constant and integrated (after combination with a centrifugal acceleration term) to generate a desired roll axis commanded velocity signal. (See DJI-1005, 6:27-30, 6:48-50;

DJI-1003, ¶189.) The lateral **groundspeed** signal from sensors 31 is compared with the desired roll axis commanded velocity signal to generate a “roll axis velocity error signal.” (See DJI-1005, 6:32-33; DJI-1003, ¶189.)

The roll axis velocity error signal is provided to AFCS roll control module 41 and subsequently to PFCS roll control module 37 after shaping. (See DJI-1005, 5:37-42; DJI-1003, ¶¶189-190.) PFCS roll control module 37, in turn, generates a command modifying signal using the shaped velocity error signal. (See DJI-1005, 4:27-28; DJI-1003, ¶190.) The control command from inverse model 76, representing the approximate rotor command necessary to achieve the desired response, is modified in PFCS summing junction 88 by the command modifying signal. (See DJI-1005, 4:9-11; DJI-1003, ¶190.) The resulting command is provided to mixing function 45 which commands displacement of mechanical servos/linkages. (See DJI-1005, 3:25-29; DJI-1003, ¶190.) Sensors 31 feed the aircraft’s actual response to these commands back to the lateral control modules and the processing loop continues. (See DJI-1005, 3:32-35; DJI-1003, ¶190.) The above loop therefore controls the lateral (sideward) component of the velocity. (DJI-1003, ¶190.)

Gold’s “*lateral control architecture*” includes a “*lateral sideward groundspeed control loop*” [5A]/[15A]. (DJI-1003, ¶¶187-190.)

The roll axis velocity error determined in the VCS roll control module is “*lateral motion data.*” (DJI-1003, ¶191.) As discussed above, the roll axis velocity error is provided to the AFCS and subsequently to the PFCS through the lateral sideward groundspeed control loop (indicated by green lines in Singhose Figure A above). Thus, Gold discloses “*communicating lateral motion data through a lateral sideward groundspeed control loop*” [15A]. (*Id.*)

b. “*Lateral Roll Attitude Control Loop*” [5B]/[15B]

Gold discloses “*a lateral roll attitude control loop*” [5B]/[15B], highlighted by pink lines in Figure 4 below. (*See* DJI-1005, 3:60-61; DJI-1003, ¶¶192-193.) When a pilot applies a left or right force to the sidearm controller, the resulting roll axis command signals are provided to command model 72 which shapes the commands “to yield a desired rate and/or attitude response.” (DJI-1005, 4:1-7.) The resulting desired rate response is provided to AFCS roll (lateral) control module. After transformation, the desired roll rate response is integrated to obtain the desired roll attitude. (*See, e.g.,* DJI-1005, 4:50-54; DJI-1003, ¶192.) The actual roll attitude signal from the sensors is then compared with the desired roll attitude signal to generate a roll attitude feedback error signal. (*See*, DJI-1005, 4:54-63; DJI-1003, ¶192.)

aircraft's actual response to these commands back to the roll control modules and the processing loop continues. (See DJI-1005, 3:32-35; DJI-1003, ¶193.)

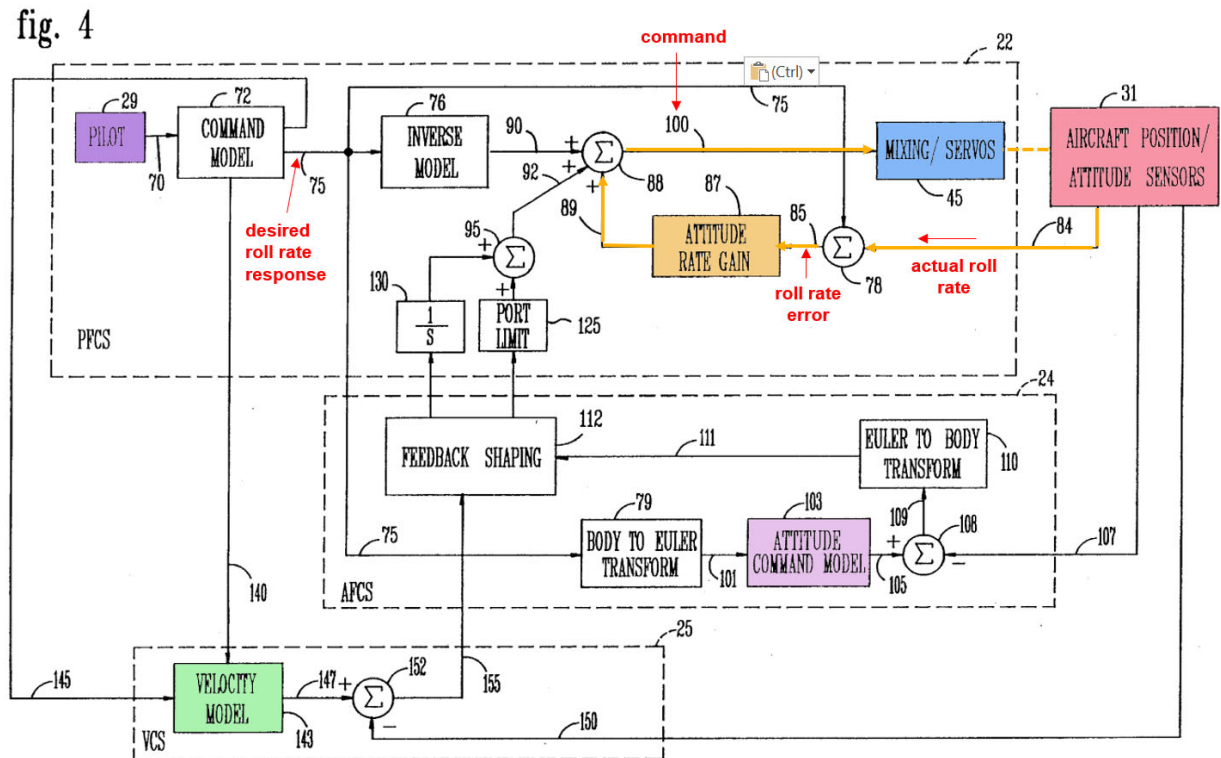
Gold's "*lateral control architecture*" includes a "*lateral roll attitude control loop*" [5B]/[15B]. (DJI-1003, ¶¶192-193.)

The roll attitude feedback error is also "*lateral motion data*." (DJI-1003, ¶194.) The roll attitude feedback error is communicated from the AFCS roll control module to the PFCS roll control module through the roll attitude control loop (indicated by pink lines). Thus, Gold discloses "*communicating lateral motion data through a lateral roll attitude control loop*" [15B]. (*Id.*)

c. "*Lateral Roll Rate Control Loop*" [5C]/[15C]

Gold discloses "*a lateral roll rate control loop*" [5C]/[15C], highlighted by orange lines in annotated Figure 4 below. (See DJI-1005, 3:60-61; DJI-1003, ¶¶195-196.) In Gold, the roll command signals from the sidearm controller are provided to command model 72 which shapes the commands "to yield a desired rate" response. (DJI-1005, 4:6-7.) The desired rate response is provided to inverse model 76 of the PFCS roll control module which "provides a command signal" representing the approximate rotor command necessary to achieve the desired roll axis rate of change. (See, e.g., DJI-1005, 4:10-13.)

fig. 4



Gold, Annotated Figure 4

The desired rate response is also compared to the actual roll rate provided by sensors 31 to generate a roll rate error signal. (See, e.g., DJI-1005, 4:17-22; DJI-1003, ¶196.) The command from inverse model 76 is modified by the roll rate error signal (after gain applied). (See, e.g., DJI-1005, 4:21-27; DJI-1003, ¶196.) The resulting command is provided to mixing function 45 which commands displacement of mechanical servos/linkages. (See DJI-1005, 3:25-29; DJI-1003, ¶196.) Sensors 31 feed the aircraft's actual response to these rotor commands back to the lateral control modules and the processing loop continues. (See DJI-1005, 3:32-35; DJI-1003, ¶196.)

Gold's "*lateral control architecture*" includes a "*lateral roll rate control loop*" [5C]/[15C]. (DJI-1003, ¶¶195-196.)

The roll rate error is "*lateral motion data*." (DJI-1003, ¶197.) The roll rate error is provided through the rate control loop (indicated by orange lines) to gain function 87 on a line 85 whose output is provided to summing junction 88, as discussed above. (See, e.g., DJI-1005, 4:21-22.) Thus, Gold discloses "*communicating lateral motion data through a lateral roll rate control loop*" [15C]. (*Id.*)

3. "*Lateral Controller*" (Claims 6/16)

In Gold, "the pilot applying a left or right force to the sidearm controller" generates roll (lateral) command signals. (DJI-1005, 3:64-4:4.) The generated roll command signals from sidearm controller 29 are provided to flight control system 21, as illustrated in Figure 3. (DJI-1005, 3:10-12.) Because it controls roll axis movement, Gold's sidearm controller 29 is a "*lateral controller carried by the aircraft, the lateral controller being manipulated by a pilot controlling the aircraft*" [6A]. (DJI-1003, ¶199; see also, DJI-1001, 4:32-40 (acknowledging single device controlling multiple axes is a lateral controller).)

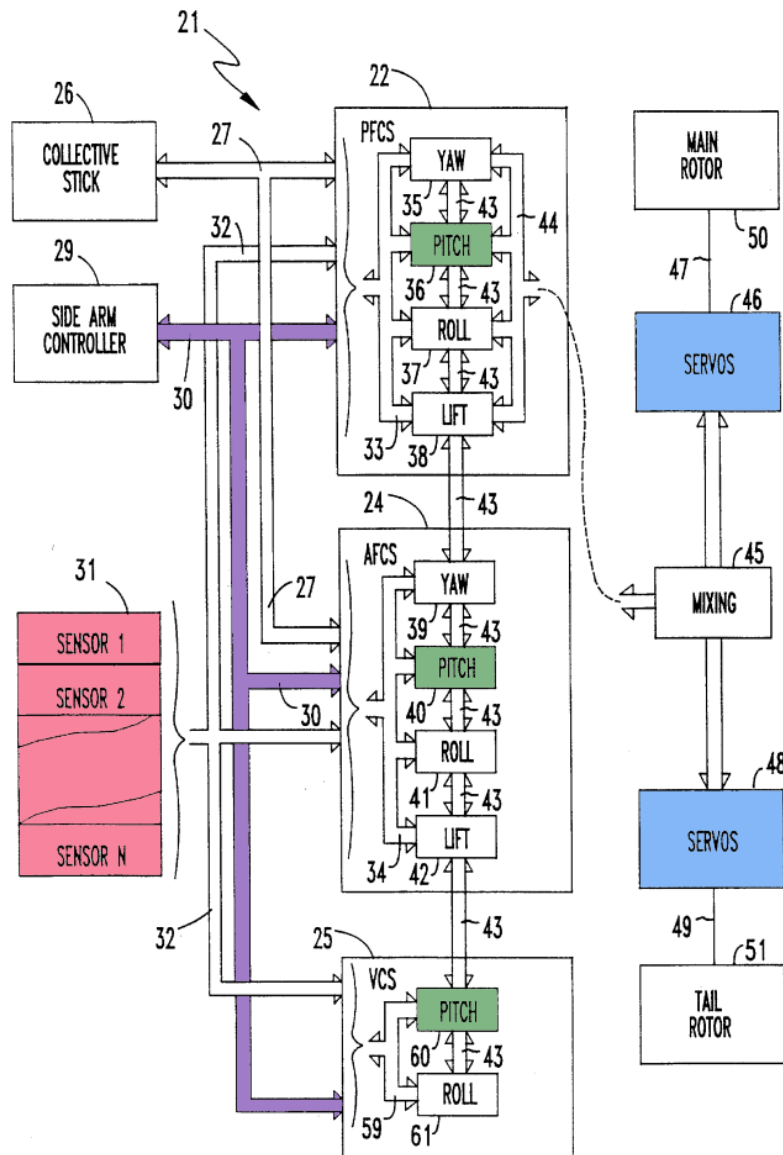
The PFCS and AFCS each contain roll control modules. (DJI-1005, 3:17-18.) The command model associated with the roll control module shapes commands from the controller "to yield a desired rate and/or attitude response."

(DJI-1005, 4:6-7.) As discussed in §V.D.2, a shaped roll command is provided by command model 72 to each of the “*the lateral sideward groundspeed control loop, the lateral roll attitude control loop, and the lateral roll rate control loop.*” (DJI-1003, ¶156.) Thus, Gold discloses “*the lateral controller creating a lateral command in data communication with the lateral sideward groundspeed control loop, the lateral roll attitude control loop, and the lateral roll rate control loop*” [6B]. (DJI-1003, ¶200.)

In response to a pilot roll command, the roll control module generates and “provide[s] rotor command signals” to “rotor mixing function 45 which commands displacement” of the servos/linkages “to control the tip path plane of a main rotor 50.” (DJI-1005, 3:25-29.) Tilting the main rotor sideways induces lateral movement. (DJI-1003, ¶¶201, 45; §IV.A.1.) Thus, Gold discloses “*controlling lateral movement with a lateral controller manipulated by a pilot controlling the aircraft*” [16]. (DJI-1003, ¶201.)

4. “Longitudinal Control Architecture” (Claims 8/18)

Gold’s “*longitudinal control architecture*” includes *longitudinal forward speed control loop*” [8A]/[18A], “*longitudinal pitch angle control loop*” [8B]/[18B] and “*longitudinal pitch rate control loop*” [8C]/[18C]. (DJI-1003, ¶¶202-214.)

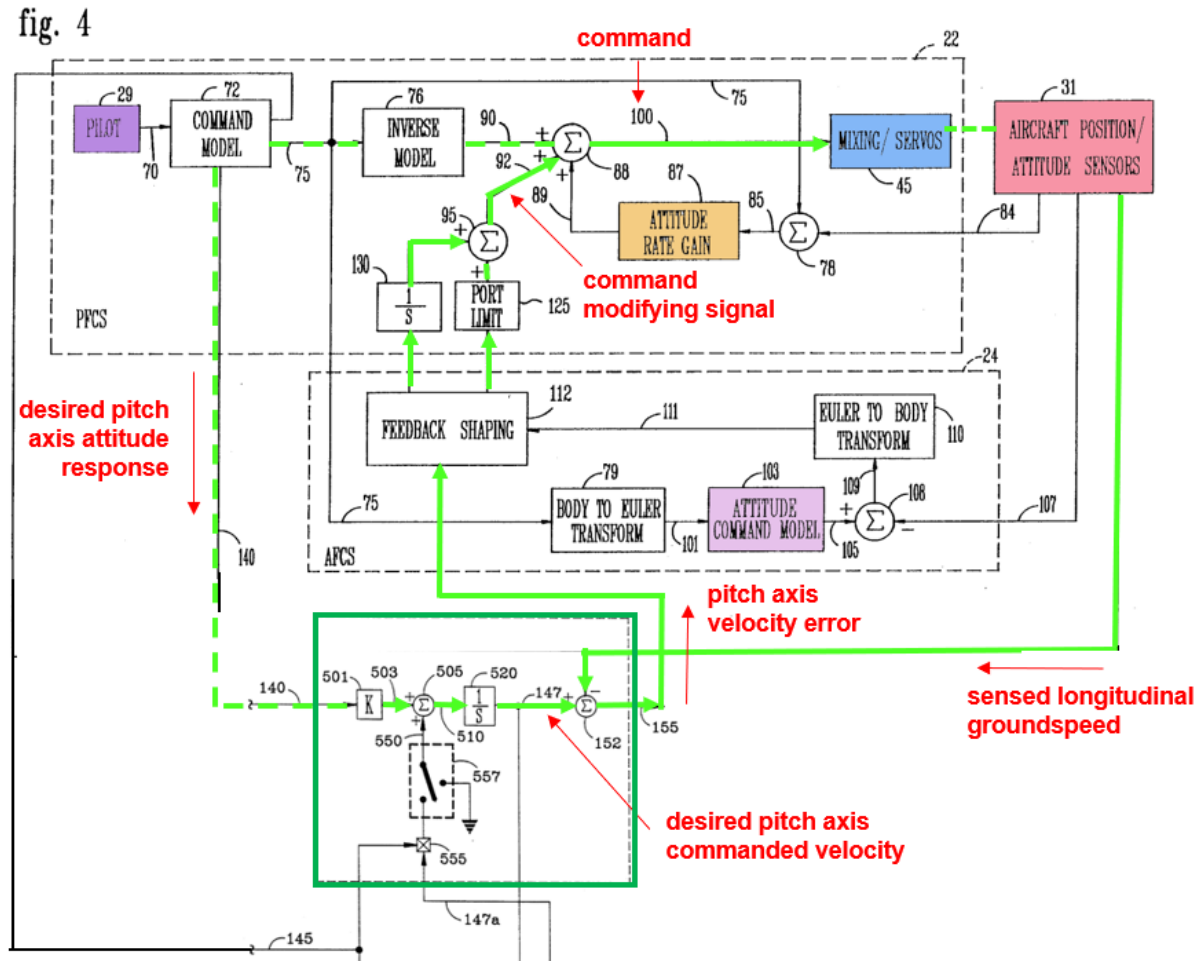


Gold, Annotated Figure 3

a. “Longitudinal Forward Speed Control Loop” [8A]/[18A]

When Gold’s system operates in velocity stabilization mode, VCS pitch control module 60 generates pitch velocity error signals using actual longitudinal groundspeed data provided to the pitch control modules from the sensors. These pitch velocity error signals “drive the error signals to zero.” (DJI-1005, 3:50-52.)

This control loop, illustrated in Singhose Figure B³ below, is highlighted by green lines.



Singhose, Figure B

³ Singhose Figure B combines and annotates Gold's Figure 4 with excerpts from Gold's Figure 5 which provides details of the pitch axis component of the VCS. (DJI-1003, ¶205.)

Specifically, command model 72 provides the desired pitch axis attitude response, required to maintain velocity in velocity stabilization mode, to VCS pitch control module 500 (indicated by the green box above). (DJI-1005, 5:59-64; DJI-1003, ¶206.) The desired pitch axis attitude is multiplied by a gravitational constant and integrated (after combination with a centrifugal acceleration term) to generate a desired pitch axis commanded velocity signal. (DJI-1005, 6:27-30, 6:48-50; DJI-1003, ¶206.) The longitudinal **groundspeed** signal from sensors 31 is compared with the desired pitch axis commanded velocity signal to generate a “pitch axis velocity error signal.” (DJI-1005, 6:13-18; DJI-1003, ¶206.)

After shaping, the pitch axis velocity error signal is provided to PFCS pitch control. (DJI-1005, 5:37-42; DJI-1003, ¶207.) PFCS pitch control module, in turn, generates a command modifying signal using the shaped velocity error signal. (DJI-1005, 4:27-28; DJI-1003, ¶207.) The control command from inverse model 76, representing the approximate rotor command necessary to achieve the desired response, is modified in PFCS summing junction 88 by the command modifying signal. (DJI-1005, 4:9-11; DJI-1003, ¶207.) The resulting command is provided to mixing function 45 which commands displacement of mechanical servos and linkages. (See DJI-1005, 3:25-29; DJI-1003, ¶207.) Sensors 31 feed the aircraft’s actual response to these rotor commands back to the lateral control modules and the processing loop continues. (See DJI-1005, 3:32-35; DJI-1003, ¶207.) This loop

therefore controls the longitudinal (forward) component of the velocity. (DJI-1003, ¶207; *see also*, §IV.A.1.)

Gold’s “*longitudinal control architecture*” includes a “*longitudinal forward speed control loop*” [8A]/[18A]. (DJI-1003, ¶¶204-207.)

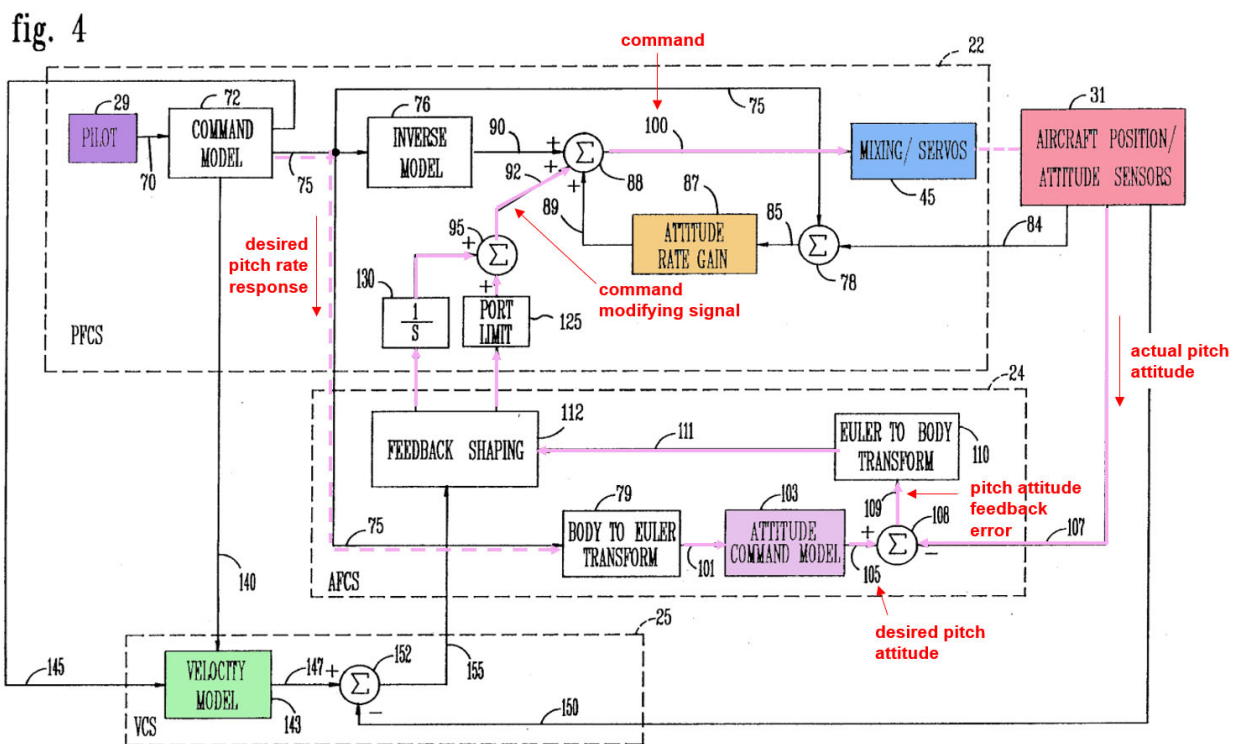
The pitch axis velocity error determined in the VCS pitch control module is “*longitudinal motion data.*” (DJI-1003, ¶208.) As discussed above, the pitch axis velocity error is provided to the AFCS on line 155 and subsequently to the PFCS (after shaping) through the longitudinal forward speed control loop (indicated by bright green lines in Singhose Figure B above). Thus, Gold discloses “*communicating longitudinal motion data through a longitudinal forward speed control loop*” [18A]. (*Id.*)

b. “*Longitudinal Pitch Angle Control Loop*” [8B]/[18B]

Gold discloses “*a longitudinal pitch angle⁴ control loop*” [8B]/[18B], highlighted by pink in annotated Figure 4 below. (DJI-1003, ¶¶209-210.) When a pilot pushes or pulls (front or back) on the sidearm controller, the resulting pitch (longitudinal) axis command signals are provided to command model 72 which shapes the commands “to yield a desired rate and/or attitude response.” (DJI-1005, 4:1-7.) The resulting desired rate response is provided to the AFCS pitch control

⁴ Pitch angle is the pitch attitude. (*See, e.g.*, DJI-1001, 5:9-10.)

module. After transformation, the desired pitch rate response is integrated to obtain the desired roll attitude. (DJI-1005, 4:50-54; DJI-1003, ¶209.) The actual pitch attitude signal from the sensors is then compared with the desired pitch attitude signal to generate a pitch attitude feedback error signal. (DJI-1005, 4:54-63; DJI-1003, ¶209.)



Gold, Annotated Figure 4

After transformation and feedback shaping, the pitch attitude feedback error signal is provided to the PFCS pitch control module. (See, e.g., DJI-1005, 5:1-6; DJI-1003, ¶210.) PFCS pitch control module, in turn, generates a command modifying signal using the pitch attitude feedback error signal. (See DJI-1005, 4:27-28; DJI-1003, ¶210.) The control command from inverse model 76,

representing the approximate rotor command necessary to achieve the desired response, is modified in PFCS summing junction 88 by the command modifying signal. (See DJI-1005, 4:9-11; DJI-1003, ¶210.) The resulting command is provided to mixing function 45 which commands displacement of mechanical servos and linkages. (See DJI-1005, 3:25-29; DJI-1003, ¶210.) Sensors 31 feed the aircraft's actual response to these rotor commands back to the lateral control modules and the processing loop continues. (DJI-1005, 3:32-35; DJI-1003, ¶210.)

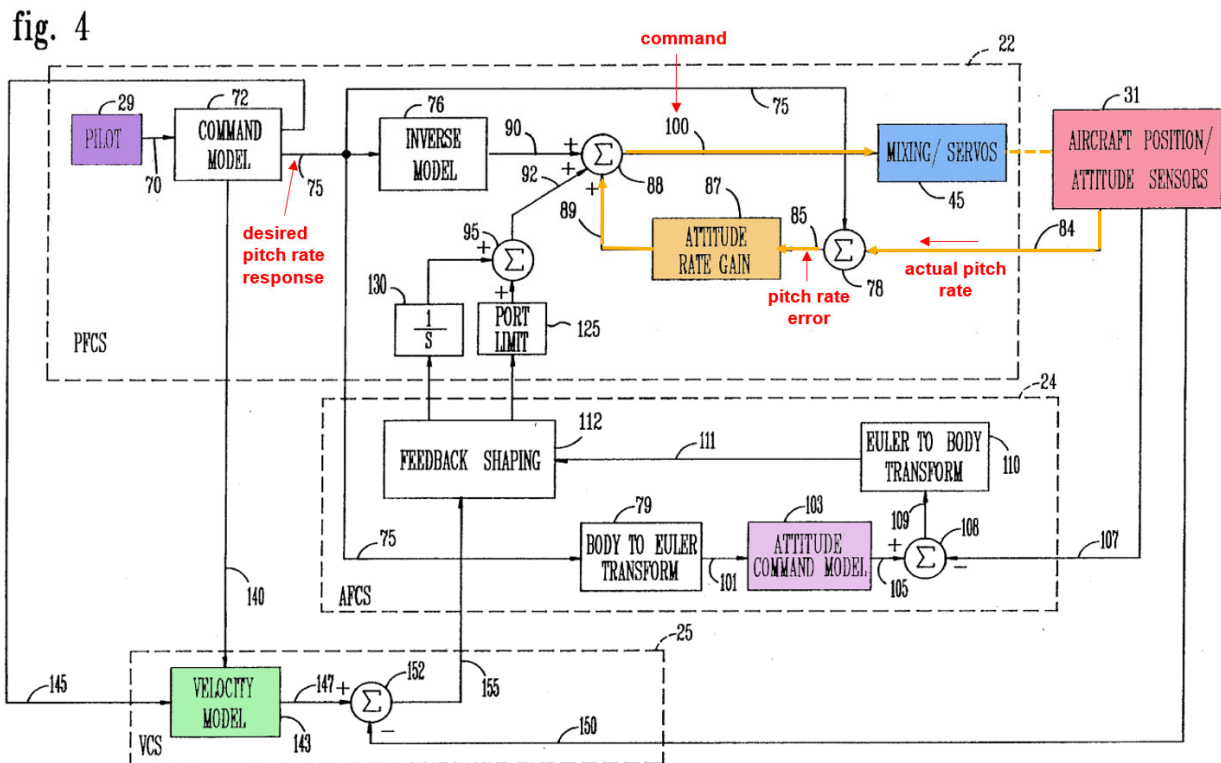
Gold's "*longitudinal control architecture*" therefore includes a "*longitudinal pitch angle control loop*" [8B]/[18B]. (DJI-1003, ¶¶209-210.)

The pitch (longitudinal) attitude feedback error is also "*longitudinal motion data*." (DJI-1003, ¶211.) The pitch attitude feedback error is communicated from AFCS pitch control module to the PFCS pitch control module through the pitch angle control loop (indicated by pink lines). Thus, Gold discloses "*communicating longitudinal motion data through a longitudinal pitch angle control loop*" [18B]. (Id.)

c. "Longitudinal Pitch Rate Control Loop"

Gold discloses "*a longitudinal pitch rate control loop*" [8C]/[18C], highlighted by orange lines in annotated Figure 4 below. (DJI-1003, ¶¶212-213.) In Gold, the pitch command signals from the sidearm controller are provided to command model 72 which shapes the commands "to yield a desired rate" response.

(DJI-1005, 4:6-7.) The desired rate response is provided to inverse model 76 which “provides a command signal” representing “the approximate rotor command necessary to achieve the desired pitch axis rate of change of the aircraft for each pilot commanded maneuver.” (DJI-1005, 4:10-13.)



Gold, Annotated Figure 4

The desired rate response is also compared to the actual pitch rate provided by sensors 31 to generate a pitch rate error signal. (DJI-1005, 4:17-22; DJI-1003, ¶213.) The control command from inverse model 76 is modified by the pitch rate error signal (after gain applied). (DJI-1005, 4:21-27; DJI-1003, ¶213.) The resulting command is provided to mixing function 45 which commands displacement of mechanical servos and linkages. (DJI-1005, 3:25-29; DJI-1003,

¶213.) Sensors 31 feed the aircraft's actual response to these rotor commands back to the lateral control modules and the processing loop continues. (See DJI-1005, 3:32-35; DJI-1003, ¶213.)

Gold's "*longitudinal control architecture*" therefore includes a "*longitudinal pitch rate control loop*" [8C]/[18C]. (DJI-1003, ¶¶212-213.)

The pitch (longitudinal) rate error is also "*longitudinal motion data*." (DJI-1003, ¶214.) The pitch rate error is provided through the pitch rate control loop (indicated by orange lines in annotated Figure 4 above) to gain function 87 on line 85 whose output is provided to summing junction 88, as discussed above. (DJI-1005, 4:21-22.) Thus, Gold discloses "*communicating longitudinal motion data through a longitudinal pitch rate control loop*" [18C]. (DJI-1003, ¶214.)

5. "Longitudinal Controller" (Claims 9/19)

In Gold, "the pilot's pushing and pulling (front or back) of the sidearm controller" generates **pitch (longitudinal) axis command** signals. (DJI-1005, 3:64-4:4.) The generated pitch axis command signals from sidearm controller 29 are provided to flight control system 21. (DJI-1005, 3:10-12.) Because it controls pitch axis (longitudinal) movement, Gold's sidearm controller 29 is a "*longitudinal controller carried by the aircraft, the lateral controller being manipulated by a pilot controlling the aircraft*" [9A]. (DJI-1003, ¶216; *see also*, DJI-1001, 4:32-40

(acknowledging a single device controlling multiple axes is a longitudinal controller).)

The PFCS and AFCS each contain pitch axis control modules. (DJI-1005, 3:17-18.) The command model associated with the pitch control module shapes the commands from the controller “to yield a desired rate and/or attitude response.” (DJI-1005, 4:6-7.) As discussed in §V.D.4, a shaped pitch command is provided to each of *the longitudinal forward speed control loop, the longitudinal pitch angle control loop, and the longitudinal pitch rate control loop.*” (DJI-1003, ¶217.) Thus, Gold also discloses “*the longitudinal controller creating a longitudinal command in data communication with the longitudinal forward speed control loop, the longitudinal pitch angle control loop, and the longitudinal pitch rate control loop*” [9B]. (DJI-1003, ¶217.)

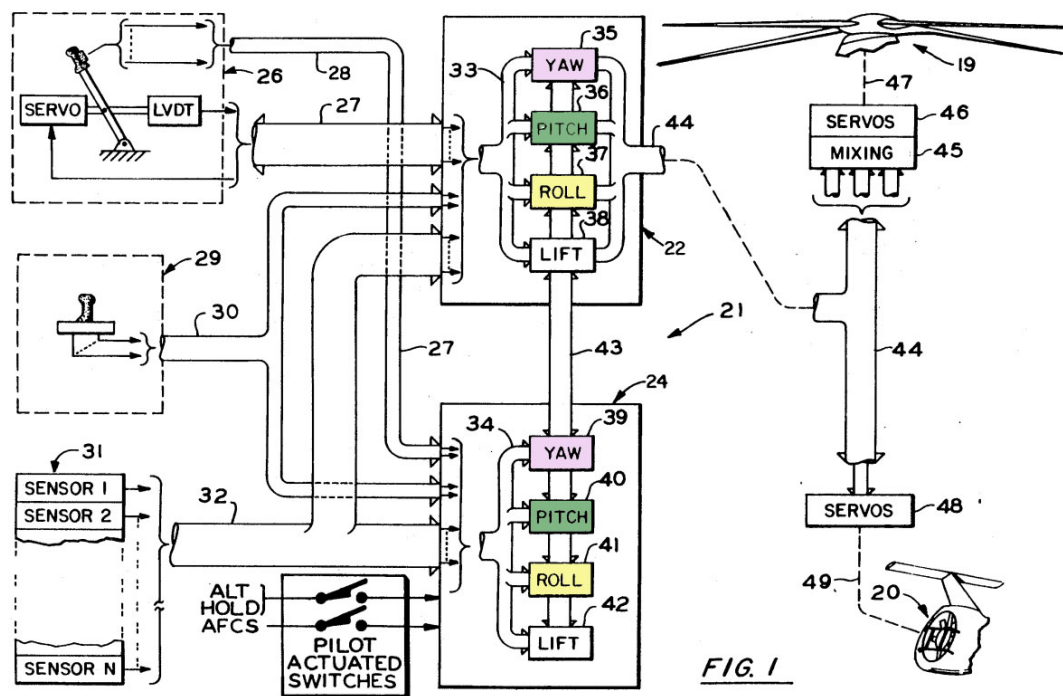
In response to a longitudinal command from the pilot, the PFCS pitch control module generates and “provide[s] rotor command signals” to “a rotor mixing function 45 which commands displacement of mechanical servos 46 and linkages 47 to control the tip path plane of a main rotor 50.” (DJI-1005, 3:25-29; *see also*, DJI-1003, §218.) Tilting the main rotor forward or aft induces longitudinal movement. (DJI-1003, ¶218; *see also*, §IV.A.1.) Thus, Gold discloses “*controlling longitudinal movement with a longitudinal controller manipulated by a pilot controlling the aircraft*” [19]. (DJI-1003, ¶218.)

VI. GROUND 2: Combination of Gold, Shue, Gold-Paper, and Skonieczny renders claims 3-4 and 13-14 obvious.

A. Combination Overview

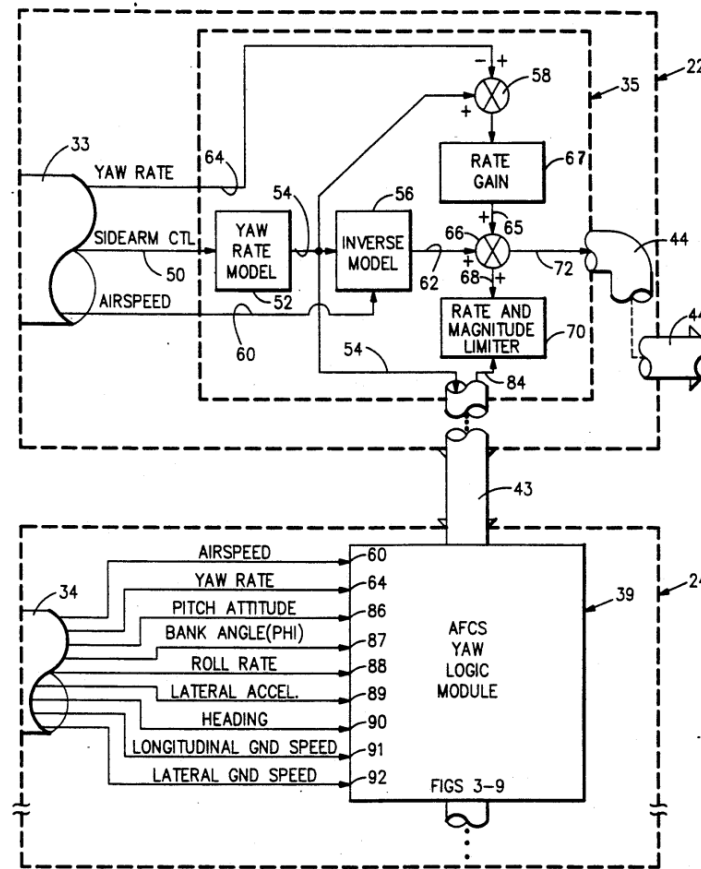
1. Skonieczny

Skonieczny relates to “flight control systems which provide automatic turn coordination control.” (DJI-1006, 1:10-13.) Like Gold, Skonieczny’s flight control system includes a PFCS and an AFCS each containing “logic for controlling the yaw [shaded pink], pitch [shaded green], roll [shaded yellow] and lift axes of the aircraft.” (DJI-1006, 3:12-14, annotated Figure 1 below.)



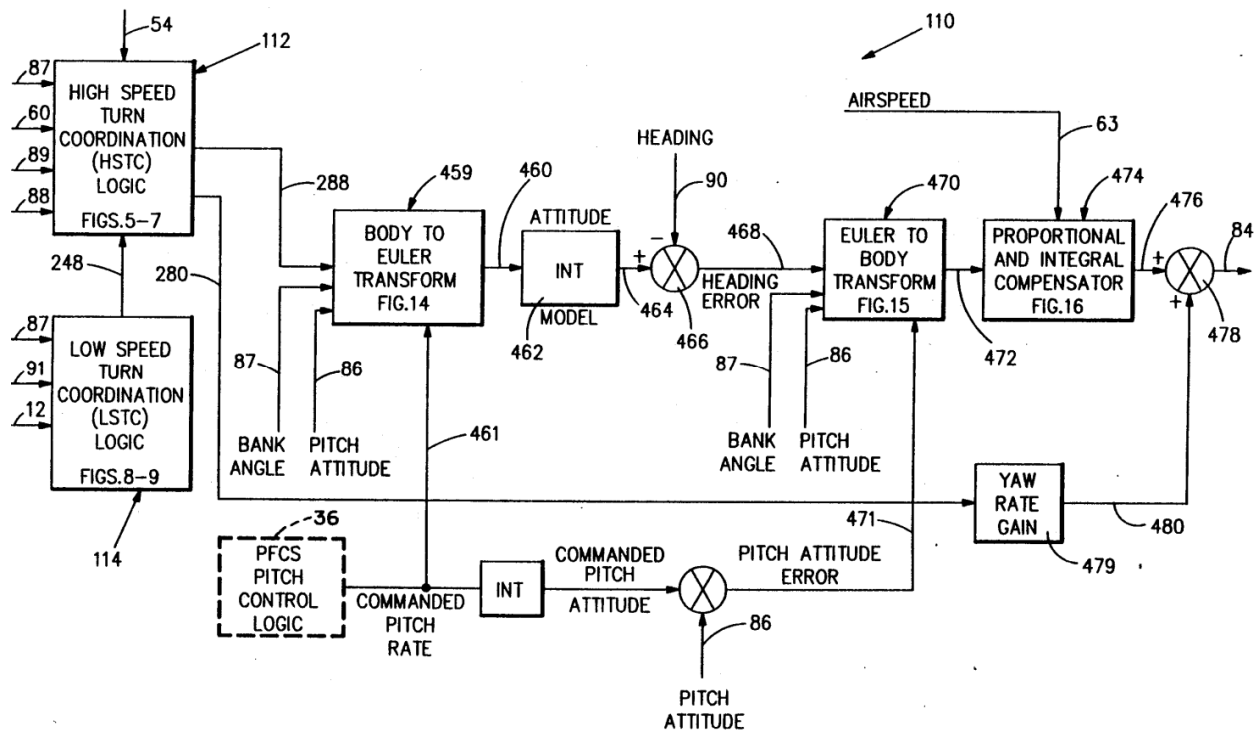
Skonieczny, Annotated Figure 1

Skonieczny describes the functional interconnection of PFCS 22 and AFCS yaw logic modules 35 and 39, illustrated in Figure 2 below.



Skonieczny, Figure 2

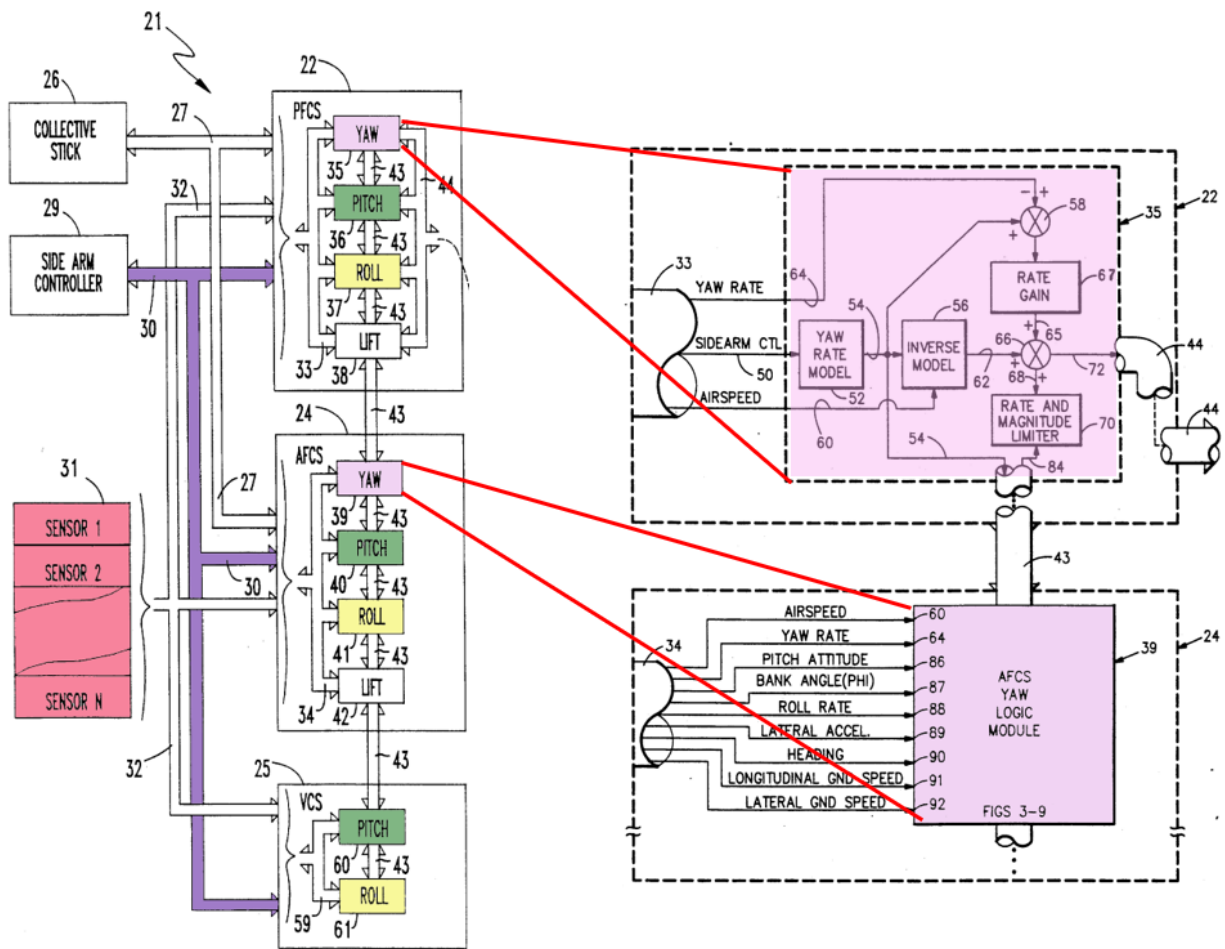
Skonieczny's AFCS yaw logic 110 is illustrated in further detail in Figure 4 (reproduced below). The yaw logic includes high speed turn coordination (HTSC) logic which "condition[s] pilot commanded yaw inputs via the sidearm controller at speeds above 60 knots" and low speed turn coordination (LSTC) logic which "is operational only between 0 and 80 knots; providing full authority from 25 to 60 knots, and limited authority between 0 and 25 knots, and 60 to 80 knots." (DJI-1006, 5:24-26, 9:55-58.)



Skonieczny, Figure 4

2. Motivation to Combine

A POSITA would have been motivated to Skonieczny's yaw module teachings with the flight control system of Gold, Shue, and Gold-Paper, as illustrated in the below figure. (DJI-1003, ¶¶224-228.)



Excerpt from Gold, Annotated Figure 3; Skonieczny, Annotated Figure 2

First, Gold explicitly incorporates Skonieczny by reference and for this reason alone, a POSITA would have been motivated to combine Gold with Skonieczny. (DJI-1006, 4:38-43 (“A more detailed description of the model following algorithms of the AFCS, and AFCS architecture, is given in commonly owned U.S. Pat. No. 5,238,203 ... the disclosure of which is incorporated herein by reference”); 4:63-67; DJI-1003, ¶225.)

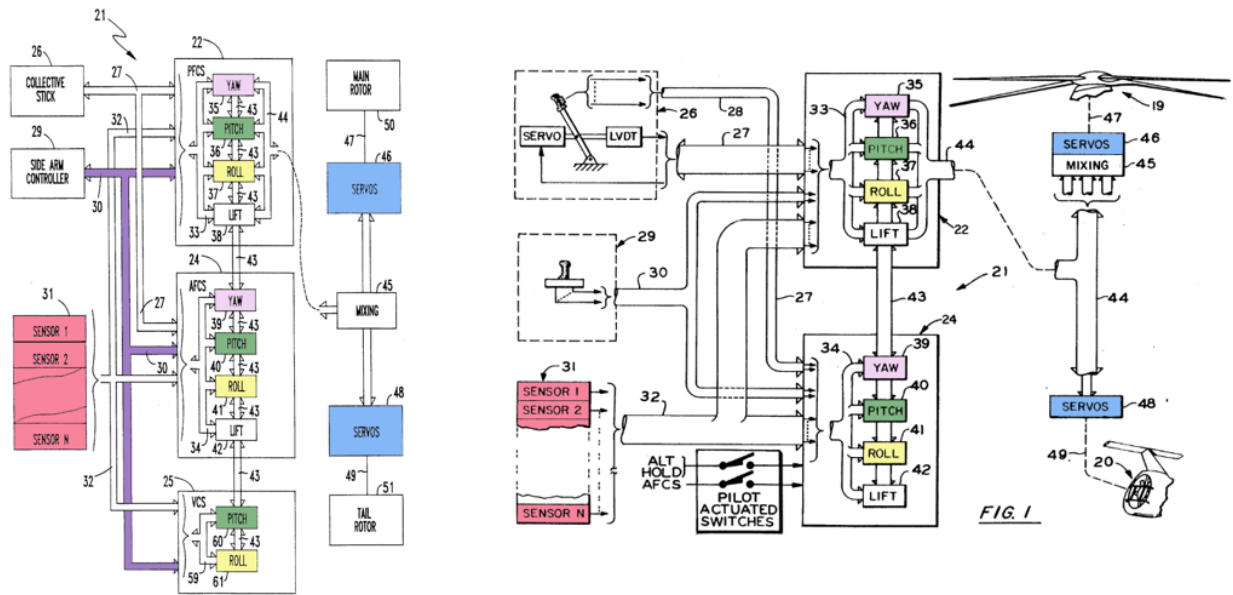
Second, Gold expressly suggests the combination, stating that switches 557 and 567 of Figure 5 “open[] in response to the aircraft operating in the

automatic turn coordination mode.” (DJI-1005, 6:46-48.) Gold however does not provide discussion of the automatic turn coordination logic. Based on this suggestion, a POSITA would have been motivated to combine Gold with Skonieczny which describes automatic turn coordination and uses the same basic flight control system architecture as discussed below. (*See* DJI-1006, 1:10-13; 5:19-21; Title (“High speed turn coordination for rotary wing aircraft”); DJI-1003, ¶226.) Skonieczny and Gold are in the same field of endeavor as the ’082 patent—control systems for aircraft—and are therefore analogous art. (DJI-1003, ¶226.)

Third, Gold relates to “a velocity command system” allowing “a pilot to **yaw** the aircraft.” (DJI-1005, 1:9-14.) Gold focuses its discussion on pitch and roll control modules, providing limited discussion of its yaw control modules. A POSITA would have therefore been motivated to search for references related to yaw control and would have been led to Skonieczny which focuses on yaw control. (DJI-1003, ¶227.) As discussed above, Gold explicitly directs a reader to Skonieczny.

Fourth, the combination is merely the simple substitution of one known element (Gold’s yaw modules 35 and 39) for another (Skonieczny’s yaw modules 35 and 39). (DJI-1003, ¶228.) A POSITA would have had a reasonable expectation of success in the combination and the results would have been predictable because

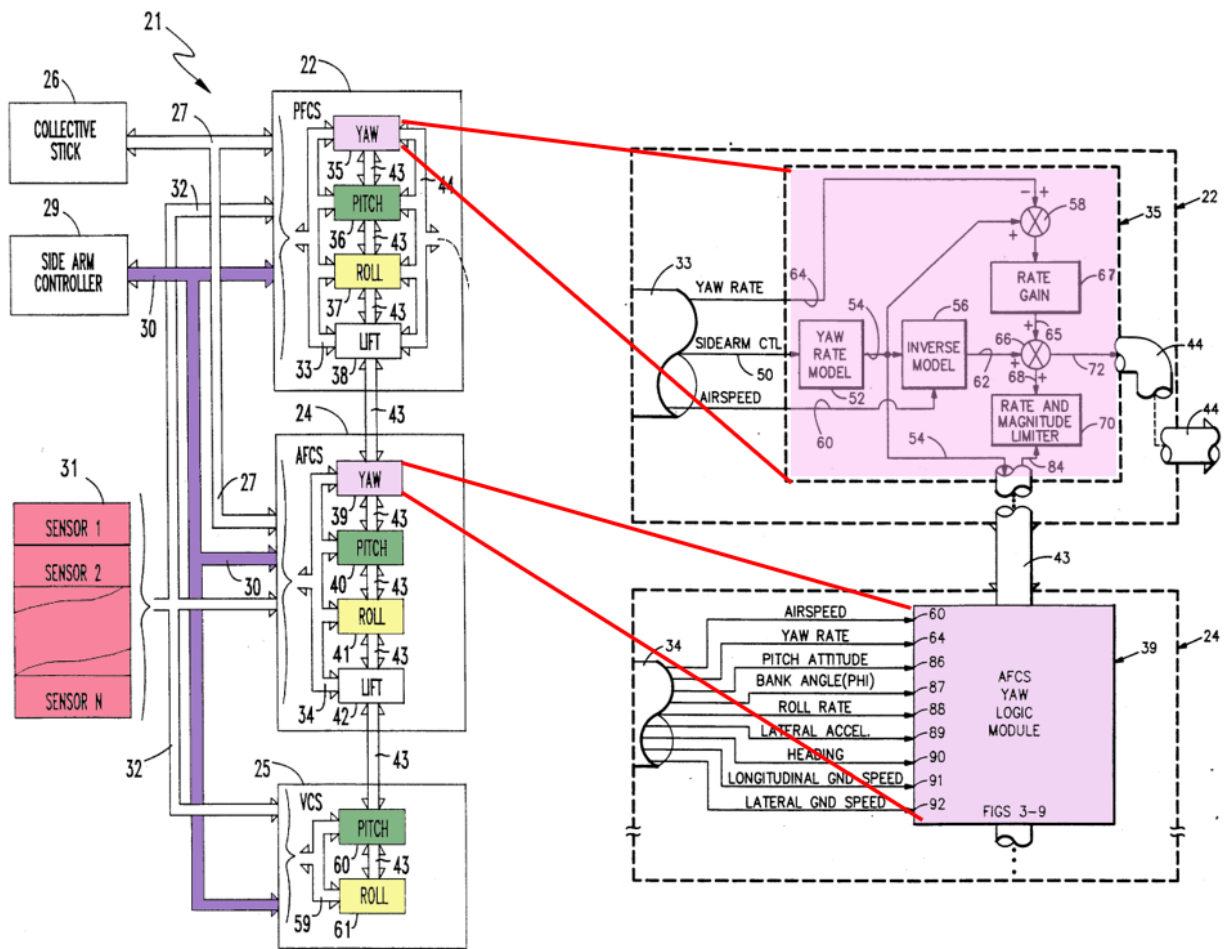
Gold and Skonieczny both use the same basic architecture for the PFCS and AFCS, as illustrated below in the side-by-side comparison of Figure 3 from Gold and Figure 1 from Skonieczny. (*Id.*)



Gold, Annotated Figure 3 (left); Skonieczny, Annotated Figure 1 (right)

B. “Directional Control Architecture” (Claims 3/13)

As discussed in §V.D.1, Gold’s yaw control modules 35, 39 are collectively part of the “*directional control architecture.*” In the combination, the PFCS and AFCS yaw modules described in Skonieczny are combined with Gold’s flight control system as illustrated below. (*See §VI.A.2.*)



Excerpt from Gold, Annotated Figure 3; Skonieczny, Annotated Figure 2

This “*directional control architecture*” includes “*directional heading control loop*” [3A]/[13A], “*directional turn coordination control loop*” [3B]/[13B], and “*directional yaw rate control loop* [3C]/[13C].” (DJI-1003, ¶¶231-243.)

1. “*Directional Heading Control Loop*” [3A]/[13A]

The *directional heading control loop*” is illustrated in Singhose Figure C below which replaces the AFCS yaw module 39 from Skonieczny Figure 2 with the AFCS logic 110 of Skonieczny Figure 4 and adds the servos and sensors from Skonieczny Figure 1. (DJI-1003, ¶232.)



Singhose Figure C

Both PFCS yaw module 35 and AFCS yaw module 39 are active when a yaw maneuver is initiated, regardless of whether HSTC or LSTC is engaged. (DJI-1003, ¶233; *see, e.g.*, DJI-1006, Figure 5 (illustrating the TCENGHS signal that activates switches in HSTC logic).) HSTC logic 112 receives a commanded yaw rate from the PFCS and data from sensors 31. (*See, e.g.*, DJI-1006, 5:29-31; 4:44-58.) The yaw rate command signal output on line 288 from the HSTC is transformed and integrated to provide a desired aircraft heading on line 464. (DJI-

1006, 12:36-42; DJI-1003, ¶¶234-235.) The actual aircraft heading from sensors 31 is compared with the desired aircraft heading to generate a heading error signal. (DJI-1006, 12:42-45; DJI-1003, ¶235.)

After further processing of the heading error signal, a yaw command modifying signal is generated and provided to the PFCS yaw module. (See DJI-1006, 4:22-24; DJI-1003, ¶236.) The desired yaw rate command is modified by the command modifying signal in summing junction 66 of the PFCS yaw module. (DJI-1006, 4:10-13; DJI-1003, ¶236.) The resulting command signal, provided on line 72, is presented to the tail rotor servos (48, Figure 1). (DJI-1006, 4:18-21.) Sensors, in turn, measure the response to these commands and provide sensed heading data to the AFCS logic and the processing loop continues. (DJI-1006, 4:46-53; DJI-1003, ¶236.)

The aircraft heading error, described above, “is the second of two **feedback loops** around the tail rotor command signal.” (DJI-1006, 4:24-26.) Controlling the yaw rate is a way of controlling the directional heading. (DJI-1003, ¶236.) Accordingly, the “*directional control architecture*” of the combination of Gold, Shue, Gold-Paper and Skonieczny therefore includes “*a directional heading control loop*” [3A]/[13A]. (DJI-1003, ¶¶232-236.)

The heading error is one form of “*data*” communicated through and/or used by the “*directional heading control loop*.” (DJI-1003, ¶237.) The yaw modules,

including AFCS logic 110, are active when a yaw maneuver is initiated by a pilot (including during a flat turn or during a banked turn). (*Id.*) The combination of Gold, Shue, Gold-Paper, and Skonieczny therefore discloses “*communicating data* [e.g., heading error] *through a directional heading control loop*” [13A]. (*Id.*)

2. “*Directional Turn Coordination Control Loop*” [3B]/[13B]

The combination of Gold, Shue, and Gold-Paper, and Skonieczny discloses “*a directional turn coordination control loop*” [3B]/[13B], as shown in Singhose Figure D below which replaces the AFCS of Skonieczny Figure 2 with AFCS of Skonieczny Figure 4. (DJI-1003, ¶¶238-239.) The AFCS yaw logic includes HSTC logic 112 and LSTC logic 114. (*See, e.g.*, DJI-1006, 5:29-31; 4:44-58.) Both PFCS yaw module 35 and AFCS yaw module 39 are active when a yaw maneuver is initiated, regardless of whether HSTC or LSTC is engaged. (DJI-1003, ¶¶238, 233; *see, e.g.*, Figure 5 (illustrating the TCENGHS signal that activates switches in HSTC logic).) HSTC logic 112 receives the commanded yaw rate signal and data from the sensors. (*See, e.g.*, DJI-1006, 5:29-31; 4:44-58; *see also*, DJI-1006, 5:29-8:60 (describing operation of HTSC logic).) The LSTC block also receives data from sensors 31. (DJI-1006, 8:63-65, 4:44-53; *see also*, DJI-1006, 8:63-10:17 (describing operation of LSTC logic 114).) HSTC logic outputs two yaw rate command signals on lines 280 and 288.



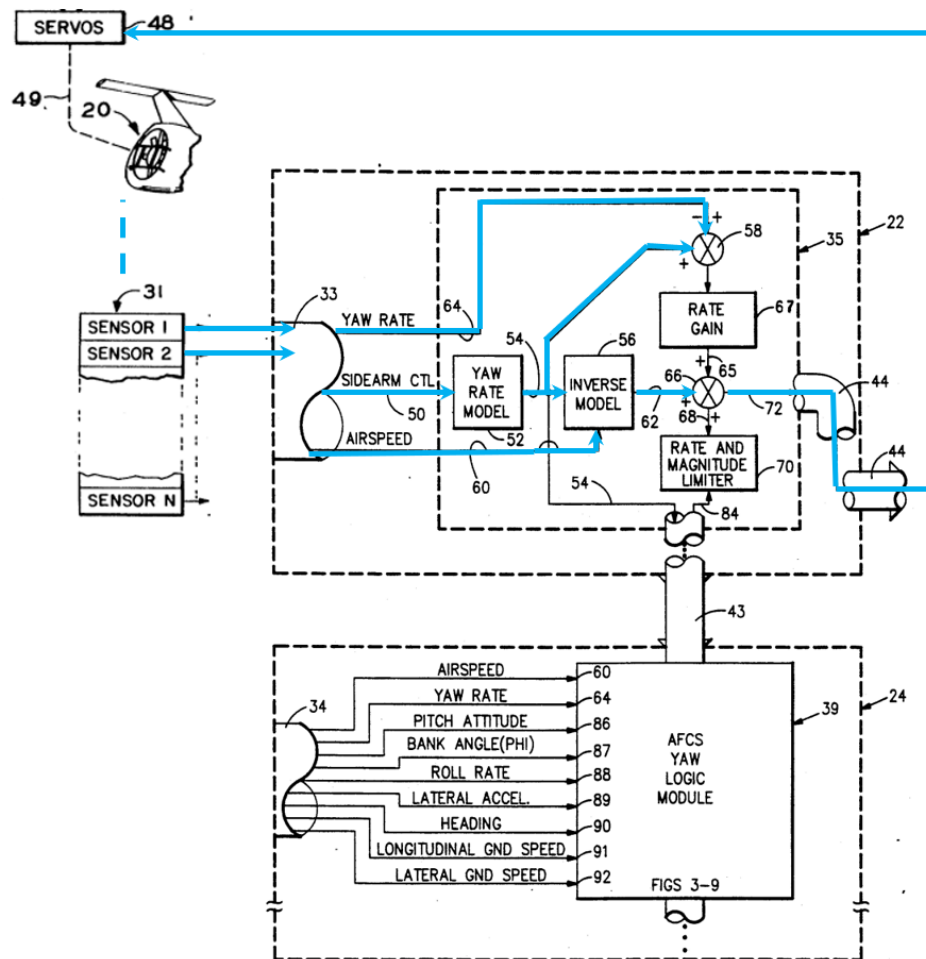
Singhose, Figure D

After transformation, the yaw rate command signal on line 288 is integrated by attitude model 462 to provide a desired aircraft heading. (DJI-1006, 12:36-42; DJI-1003, ¶239.) The actual aircraft heading from sensors 31 is compared with the desired aircraft heading to generate a heading error signal. (DJI-1006, 12:42-45; DJI-1003, ¶239.) After further processing, a yaw command modifying signal is provided to the PFCS yaw module. The “*directional control architecture*” of the combination of Gold, Shue, Gold-Paper, and Skonieczny therefore includes “*a directional turn coordination loop*” [3B]/[13B]. (DJI-1003, ¶¶238-239.)

As shown in Singhose Figure D above, various forms of data are communicated through the turn coordination logic (HSTC and LSTC) including sensor data, yaw rate commands, and error data. (DJI-1003, ¶240.) This data is communicated through AFCS logic 110 as discussed above when a yaw maneuver is initiated by a pilot (including during a flat turn or during a banked turn). (*Id.*) Thus, the combination of Gold, Shue, Gold-Paper, and Skonieczny discloses “communicating data through a directional turn coordination control loop” [13B]. (*Id.*)

3. “Directional Yaw Rate Control Loop”

The combination of Gold, Shue, Gold-Paper, and Skonieczny discloses “a directional yaw rate control loop” [3C]/[13C], highlighted by blue lines in annotated Skonieczny Figure 2 below which incorporates the servos and sensors from Figure 1. (DJI-1003, ¶¶241-242.) Yaw rate model circuitry 52, inverse model 54, and summing junction 58 in PFCS yaw logic module 25 each “receives a yaw axis command signal” from sidearm controller 29 when a yaw maneuver is initiated by the pilot. (DJI-1006, 3:35-43; DJI-1003, ¶241.) Yaw rate model circuitry provides a commanded yaw rate signal “indicative of the desired rate of change for the aircraft attitude about the yaw axis.” (DJI-1006, 3:41-47.) Summing junction 58 sums the commanded yaw rate signal with the aircraft’s actual yaw rate to provide a yaw rate error signal. (DJI-1006, 4:3-7; DJI-1003, ¶241.)



Skonieczny, Annotated Figure 2 (sensors and servos added)

Summing junction 66 receives the rate error signal (gain adjusted), the desired yaw rate signal from inverse model 56, and a yaw modifying signal (from the AFCS). (DJI-1006, 4:10-14.) The resulting command signal is presented to the tail rotor servos (48, Figure 1). (DJI-1006, 4:18-21.) Sensors, in turn, measure the response to these commands and provide sensed heading data to the AFCS logic and the processing loop continues. (DJI-1006, 4:46-53.) The “*directional control architecture*” of the combination of Gold, Shue, Gold-Paper, and Skonieczny

therefore includes “*a directional yaw rate control loop*” [3C]/[13C]. (DJI-1003, ¶¶241-242.)

The yaw rate error signal is one form of “*data*” communicated through and used in the “*directional yaw rate control loop*.” (DJI-1003, ¶243.) As shown in annotated Skonieczny Figure 2 above, the yaw rate error, as well as other data, is communicated through the yaw rate control loop (indicated by light blue lines). (*Id.*) Yaw module 35 is active when a yaw maneuver is initiated by a pilot (including during a flat turn or during a banked turn). (DJI-1003, ¶¶243, 233.) The combination of Gold, Shue, Gold-Paper and Skonieczny therefore discloses “*communicating data through a directional yaw rate control loop*” [13C]. (DJI-1003, ¶243.)

C. “*Directional Control Latch*” (Claims 4/14)

The combination of Gold, Shue, Gold-Paper and Skonieczny discloses “*a directional control latch*” [4A]/[14A]. (DJI-1003, ¶¶245-248.) Gold-Paper discloses control laws for the RAH-66 Comanche helicopter that “have been tailored to satisfy the requirements of ADS-33C”, an earlier version of ADS-33E discussed in DJI-1026. Response types typically include either the word “command” (e.g., translational rate command), the word “hold” (e.g., position hold), or both (e.g., yaw rate command/direction hold). (*See* DJI-1026, 6-10.) The term that immediately precedes the word “command” in a response type generally

describes what the pilot is commanding when the pilot moves the controller out of the detent position, and the term that immediately precedes the word “hold” in a response type generally describes what the aircraft should try to maintain when the corresponding pilot’s controller is in the detent position. (See DJI-1026, 8-9; DJI-1003, ¶246.) Thus, Gold-Paper generally describes activating/de-activating response types based on movement of the controller in and out of detent. (See, e.g., DJI-1009, Figure 2; DJI-1003, ¶246.) Gold-Paper however does not disclose the subject matter of claims 4 and 14.

Gold discloses a “*directional control latch.*” (DJI-1003, ¶247.) Gold provides a system “which allows the pilot, during operation in a velocity stabilization mode, to yaw the aircraft from side to side without changing the inertial flight path of the aircraft.” (DJI-1005, 1:51-55.) Thus, Gold’s flight control system includes logic which activates a constant vector flat turn when the pilot moves the directional controller out of detent. The pilot commands generated by moving the control stick out of detent are processed by the command model associated with the yaw control modules which shapes the pilot commands “to yield a desired rate and/or attitude response.” (DJI-1005, 4:6-7, 5:9-13.) The yaw control modules of the “*directional control architecture*” control movement in the yaw direction and receive shaped commands from a command model. In the absence of a yaw command being generated by the pilot via the control stick, no

shaped command is generated by the command model 72 and the flat turn motion is not activated. (DJI-1003, ¶¶246-248.) Therefore, the command model associated with the yaw control modules (“*directional control architecture*”) acts as a “*directional control latch*” that activates a constant vector flat turn as the pilot moves the directional controller out of a detent position. (*Id.*)

The velocity stabilization mode logic of the combination of Gold, Shue, and Gold-Paper enables a constant vector flat turn motion. However, its functionality is activated only when the pilot moves the directional controller out of detent and the command model 72 sends a signal to the VCS. Accordingly, the command model includes “*a directional control latch in data communication with the directional control architecture*” [4A]/[14A]. (DJI-1003, ¶¶245-248.) The combination of Gold, Shue, Gold-Paper, and Skonieczny further discloses “*as the directional controller is moved out of a detent position, the directional control latch activates a constant flat turn motion*” [4B] and “*activating the constant vector flat turn with a directional control latch as the directional controller is moved out of a detent position*” [14]. (*Id.*)

VII. GROUND 3: Combination of Gold, Shue, Gold-Paper, and Adams renders claims 7, 10, 17, and 20 obvious.

Gold, Shue, and Gold-Paper renders independent claims 1 and 11 obvious. However, the combination does not disclose “*lateral control latch*” or a “*longitudinal control latch.*” Adams discloses these limitations.

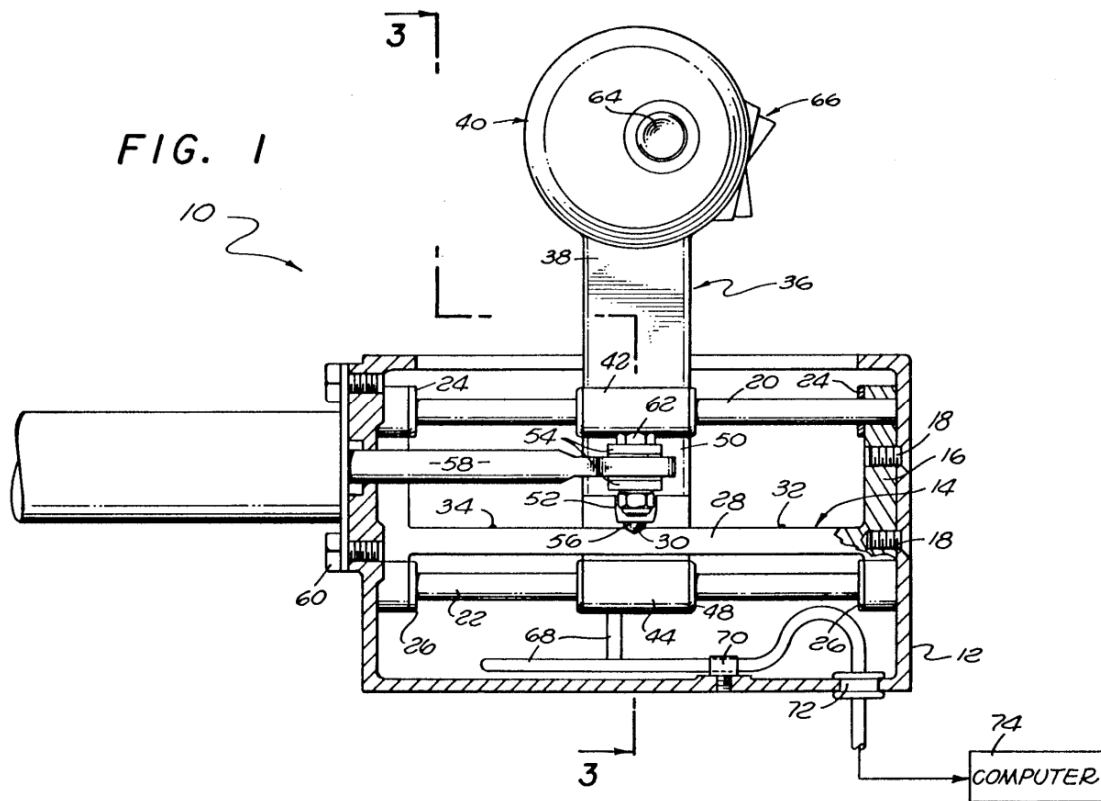
A. Combination Overview

1. Adams

Adams describes a “controller used to command acceleration and deceleration rates and for maintaining a selected velocity.” (DJI-1007, 1:6-9.)

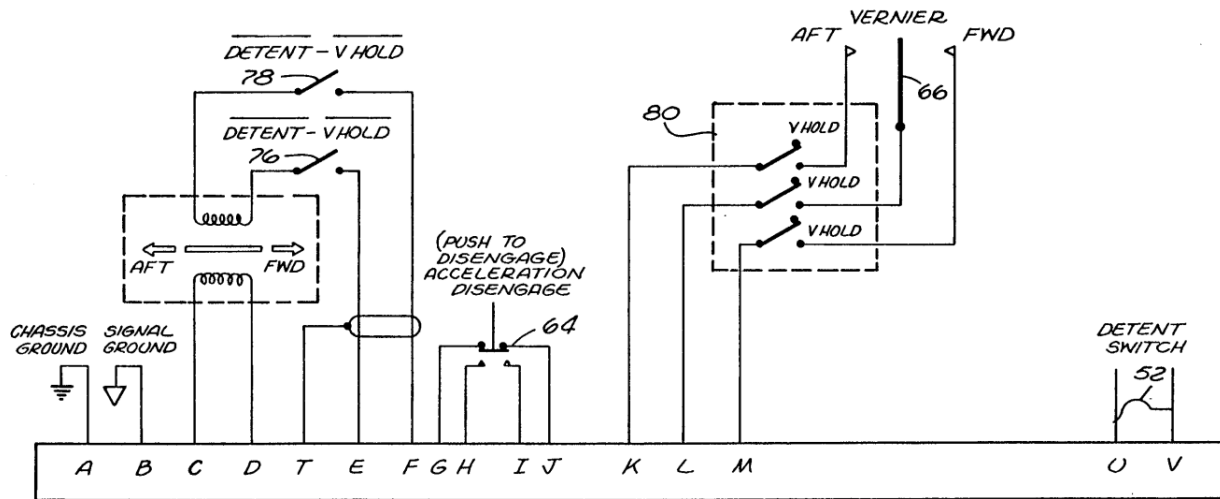
Adams’ controller, illustrated in Figure 1, has a movable handle 36 with shaft 38 including protrusion 50 that “supports a detent switch 52.” (DJI-1007, 3:36-38.)

Handle grip 40 “includes a velocity hold switch 64.” (DJI-1007, 3:45-46.) Wiring connects the switches to computer 74. (DJI-1007, 3:49-56.)



Adams, Figure 1

At the start of operation, Adams' handle 36 is in the neutral detent position with "rollerball 56 rest[ing] in detent groove 30." (DJI-1007, 4:6-8.) Handle 36 is subsequently "moved to a position forward of the detent 30 along handle guides 20, 22." (DJI-1007, 4:9-11.) This action depresses the detent switch, as shown in Figure 4 below, which "sends a signal to the computer" and "disengages velocity hold." (DJI-1007, 3:60-63.) The amount of movement "determines the rate of acceleration." (DJI-1007, 3:63-64.) When the pilot obtains the desired airspeed, "velocity hold switch 64 is depressed," causing computer 74 "to select the current airspeed as the speed for velocity hold." (DJI-1007, 4:16-19.) Velocity hold "is maintained until the movable handle 36 is again removed from the central detent groove and moved either forward or aft." (DJI, 4:30-33.)



Adams, Figure 4

2. Motivation to Combine

A POSITA would have been motivated to combine Adams' teachings regarding use of a switch to engage an operating mode and use of a detent switch to disengage the operating mode with Gold's sidearm controller and the flight control system of Gold, Shue, and Gold-Paper. (DJI-1003, ¶253.) Adams, Gold, Shue and Gold-Paper are in the same field of endeavor as the '082 patent—controlling aircraft movement—and are therefore analogous art.

Specifically, a POSITA would have been motivated to integrate the capability to determine when Gold's sidearm controller moves from the detent position and based on that determination instruct the flight control system to disengage velocity stabilization mode and deactivate the lateral and longitudinal speed holds in place during velocity stabilization mode that are used to maintain the reference velocity. (*Id.*)

Adams' controller is described with reference to an aircraft capable of only forward movement. Therefore, Adams only discloses a longitudinal detent switch. (*Id.*) Because Gold's helicopter is capable of forward-backward (longitudinal) and side-side (lateral) movement initiated by the sidearm controller, a POSITA would have been motivated to incorporate a mechanism for determining when the sidearm controller moves out of the detent position in the lateral and longitudinal direction

and to disengage velocity stabilization mode and deactivate the associated lateral and longitudinal speed holds. (*Id.*)

A POSITA would have been motivated to make the above combination because Gold discloses “in response to the manual activation of the velocity stabilization mode by the pilot during which “the aircraft 10a yaws while maintaining a constant flight path reference velocity 12a.” (DJI-1005, Abstract, 2:60-64.) However, aside from this disclosure and others like it, Gold does not provide details regarding how velocity stabilization mode is engaged or disengaged.

Gold-Paper describes response types within its velocity stabilization mode. As discussed in §VI.C, the term that immediately precedes the word “command” in a response type generally describes what the pilot is commanding when the pilot moves the corresponding controller out of the detent position, and the term that immediately precedes the word “hold” in a response type generally describes what the aircraft should try to maintain when the pilot’s controller is in the detent position. (DJI-1003, ¶255.) For example, in Gold-Paper, when the helicopter is traveling at a groundspeed above a five-knot threshold, the pitch-axis response type is attitude command/velocity hold, meaning returning the longitudinal controller to the detent position automatically engages velocity hold and moving the longitudinal controller out of the detent position allows the pilot to directly

control pitch attitude with the longitudinal controller. (*See, e.g.*, DJI-1009, 421, Figure 2.) Gold-Paper discloses a similar response type for the roll-axis. (*Id.*) Gold-Paper however does not explicitly disclose the subject matter of claims 7, 10, 17, and 20.

A POSITA would have therefore been motivated to search for references describing techniques for engaging/disengaging an operating mode involving a speed/velocity hold and would have been led to Adams. (DJI-1003, ¶256.) Moreover, a POSITA would have been motivated to combine Gold, Shue, Gold-Paper, and Adams because (1) the combination is merely the use of a known technique (Adams' technique to determine when a controller moves out of detent and signal the computer to disengage velocity hold) to improve similar devices (Gold's sidearm controller and flight control system) in the same way (providing the ability to engage/disengage velocity hold); (2) the combination applies a known technique (Adams' technique to determine when a controller moves out of detent and signal the computer to disengage velocity hold) to a known device (Gold's sidearm controller and flight control system) ready for improvement (providing the ability for the pilot to engage or disengage velocity hold); and (3) the combination also combines prior art elements (Adams' technique to determine when a controller moves out of detent and signal the computer to disengage velocity hold with

Gold's sidearm control and flight control system with a velocity stabilization mode having lateral and longitudinal speed holds) according to known methods. (*Id.*)

A POSITA would have had reasonable expectation of success and the results would have been predictable because Gold and Adams both relate to pilot controllers. (DJI-1003, ¶257.) Gold's sidearm controller provides "force output command signals" to the PFCS and AFCS of the flight control system. (DJI-1005, 3:10-11.) The combination therefore adds a signal (1) indicating the directional force (lateral or longitudinal) and (2) commanding the flight control system to disengage velocity stabilization mode (and deactivate lateral and longitudinal speed holds in use during that mode). (DJI-1003, ¶257.) Moreover, Gold's sidearm controller was well-known in the art before the '082 patent. (*Id.*) Therefore, a POSITA would have understood and been able to apply Adams' teachings to the architecture of Gold, Shue, and Gold-Paper. (*Id.*)

B. "*Lateral Control Latch*" (Claims 7/17)

The combination of Gold, Shue, Gold-Paper and Adams discloses "*a lateral control latch*" that "*resets a lateral speed hold.*" (DJI-1003, ¶259.) In the combined system, when the "*lateral controller is moved out of a detent position*" by moving the sidearm controller right or left, the detent detection capability activates, sending a signal to the flight computer indicating the direction of controller movement and rate of acceleration and commanding the system to disengage

velocity stabilization mode. (*Id.*) This process resets the lateral speed hold in place during velocity stabilization mode to maintain the reference velocity. (*Id.*) Thus, the combination of Gold, Shue, Gold-Paper, and Adams discloses “*a lateral control latch in data communication with the control system*” [7A], “*as the lateral controller is moved out of a detent position, the lateral control latch resents a lateral speed hold*” [7B], and “*resetting a lateral speed hold with a lateral control latch as the lateral controller is moved out of a detent position*” [17]. (*Id.*)

Should PO contend that the sidearm controller is not part of the “*control system*” and therefore the combination fails to disclose a “*control system*” comprising “*a lateral control latch*,” the claims do not support such an argument. Claim 6 recites the “*control system*” comprises “*a lateral controller*” that is “*manipulated by the pilot.*” Because the “*lateral controller*” is part of the “*control system*,” its components, including the “*latch*” are also part of the “*control system.*” Regardless, a POSITA would have understood how to integrate a similar software “latching” function as performed by the detent switch of Adams in the flight control system of Gold, Shue, and Gold-Paper. (DJI-1003, ¶260.)

C. “*Longitudinal Control Latch*” (Claims 10/20)

The combination of Gold, Shue, Gold-Paper and Adams discloses “*a longitudinal control latch*” that “*resets a longitudinal speed hold.*” (DJI-1003, ¶262.) In the combined system, when the “*longitudinal controller is moved out of a*

detent position” by moving the sidearm controller forward or backward, the detent detection capability activates, sending a signal to the flight computer indicating the direction of controller movement and rate of acceleration and commanding the system to disengage velocity stabilization mode. (*Id.*) This process resets the longitudinal speed hold in place during velocity stabilization mode to maintain the reference velocity. (*Id.*) Thus, the combination of Gold and Adams discloses “*a longitudinal control latch in data communication with the control system*” [10A], “*as the longitudinal controller is moved out of a detent position, the longitudinal control latch resents a longitudinal speed hold*” [10B], and “*resetting a longitudinal speed hold with a longitudinal control latch as the longitudinal controller is moved out of a detent position*” [20]. (*Id.*)

Should PO contend that the sidearm controller is not part of the “*control system*” and therefore the combination fails to disclose a “*control system*” comprising “*a longitudinal control latch*,” the claims do not support such an argument. Claim 9 recites the “*control system*” comprises “*a longitudinal controller*” that is “*manipulated by the pilot*.” Because the “*longitudinal controller*” is part of the “*control system*”, its components, including the “*latch*” are also part of the “*control system*.” Regardless, a POSITA would have understood how to integrate a similar software “latching” function as performed by the detent switch of Adams in the flight control system. (DJI-1003, ¶263.)

VIII. Discretionary Denial Is Not Appropriate

A. 35 U.S.C. §325(d)

Discretionary denial under 35 U.S.C. § 325(d) is not appropriate. The grounds and arguments presented in the Petition were not previously considered by the Office. Gold, Gold-Paper, Skonieczny, and Adams were not cited or discussed during prosecution. The foreign counterpart to Shue (WO 2007/018572) was cited but not discussed or applied by the Examiner in a rejection. Therefore, it is not possible to conclude the Examiner substantively considered Shue during prosecution. For these reasons, the first part of the *Advanced Bionics* framework is not satisfied. *Advanced Bionics, LLC v. Med-El Elektromedizinische Geräte GmbH*, IPR2019-01469, Paper 6 (PTAB Feb. 13, 2020) (precedential).

Moreover, the Examiner did not have the benefit of the testimony of Petitioner's Expert, Dr. Singhose, and the supporting extrinsic evidence, submitted herein. Thus, there is no overlap between arguments made during examination and the manner in which Petitioner relies on the prior art because there were no arguments made on the record related to Shue and no arguments made on the record related to the combination of Gold, Shue, Gold-Paper, and/or Adams. Therefore, even if the second part of the *Advanced Bionics* framework is considered, the evidence and facts presented in the Petition warrant consideration by the Office. *Advanced Bionics*, 9-11.

B. 35 U.S.C. §314(a)

The Board should reach the merits in this proceeding because the Petition presents a compelling unpatentability challenge. (*See* Interim Procedure for Discretionary Denials, 4-5.) A flight control system having lateral and longitudinal control architectures and a model that decouples the aircraft equations of motion into lateral and longitudinal equations of motion was known for decades prior to the '082 patent. (*See, e.g., V.B.*) Moreover, during prosecution of a corresponding EP application having substantially overlapping claims, the Examiner found the claims lacked novelty over Gold. (DJI-1012, 143-144.)

Should PO raise discretionary denial under *Fintiv* in its preliminary response, Petitioner reserves the right to offer a stipulation at that time to mitigate or foreclose *Fintiv* discretionary denial.

IX. Mandatory Notices

A. Real Party In Interest

The real parties-in interest are DJI Europe B.V. (Petitioner), SZ DJI Technology Co., Ltd., DJI Technology, Inc., iFlight Technology Company Limited, SZ DJI Baiwang Technology Co. Ltd., and DJI Research LLC.

B. Related Matters

To the best of Petitioner's knowledge, the '082 patent has been involved in the following district court litigations:

Textron Innovations Inc. v. SZ DJI Technology Co., Ltd.,

2-22-cv-00351 (EDTX)

C. Notice Of Counsel And Service Information

Pursuant to 37 C.F.R. §§ 42.8(b)(3), 42.8(b)(4) and 42.10(a), Petitioner appoints **Lori A. Gordon** (Reg. No. 50,633) at the address of Perkins Coie LLP, 700 Thirteenth Street, N.W., Suite 800, Washington, DC 2005-3960, phone number 202-654-6200, as its lead counsel; and **Zane Bi** (Reg. No. 79,130), at the above address, as its backup counsel.

Petitioner consents to electronic service by email at the email addresses: gordon-ptab@perkinscoie.com and bi-ptab@perkinscoie.com.

X. Conclusion

Inter partes review of the challenged claims is respectfully requested.

Respectfully submitted,

/Lori A. Gordon/

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Attorney for Petitioner

PERKINS COIE LLP
700 Thirteenth Street, NW, Suite 800
Washington, DC 2005

Date: July 28, 2023

CERTIFICATE OF WORD COUNT UNDER 37 CFR §42.24(d)

Pursuant to 37 C.F.R. §42.24(a), Petitioner hereby certifies that portions of the above-captioned Petition for *Inter Partes* Review of U.S. Patent No. 8,332,082, in accordance with and reliance on the word count provided by the word-processing system used to prepare this Petition, that the number of words in this paper is 13,983. Pursuant to 37 C.F.R. §42.24(a), this word count is in compliance and excludes the table of contents, table of authorities, mandatory notices under §42.8, certificate of service, certificate of word count, appendix of exhibits, and any claim listing. This word count was prepared using Microsoft Word.

Respectfully submitted,

/Lori A. Gordon/

Lori A. Gordon
Attorney for Petitioner

Date: July 28, 2023

CERTIFICATE OF SERVICE

The undersigned certifies that true copies of the Petition for *Inter Partes* Review of U.S. Patent No. 8,332,082 and supporting materials were served via overnight delivery on the Patent Owner at the correspondence address of record as listed on PAIR:

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/Lori A. Gordon/

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Attorney for Petitioner

Date: July 28, 2023

Appendix A: Listing of Independent Claims

[1P] An aircraft, comprising:

[1A] a sensor carried by the aircraft, the sensor being adapted to sense a directional movement of the aircraft;

[1B] an actuator carried by the aircraft, the actuator being utilized to control the directional movement of the aircraft; and

[1C] a control system in data communication with the aircraft sensor and operably associated with the actuator, the control system having:

[1C.1] a model adapted to decouple the directional movement of the aircraft into a lateral equation of motion and a longitudinal equation of motion;

[1C.2] a lateral control architecture in data communication with the model, the lateral control architecture being adapted to utilize the lateral equation of motion to control the lateral motion of the aircraft;

[1C.3] a longitudinal control architecture in data communication with the model, the longitudinal control architecture adapted to utilize the longitudinal equation of motion to control the longitudinal motion of the aircraft; and

[1C.4] an initialization command logic in data communication with the lateral control architecture and in data communication with the longitudinal control architecture;

[1D] wherein the initialization command logic selectively activates the lateral control architecture for controlling the lateral motion of the aircraft and selectively activates the longitudinal control architecture for controlling the longitudinal motion of the aircraft; and

[1E] wherein the control system utilizes the lateral control architecture and the longitudinal control architecture to control speed variations of the aircraft while the aircraft maintains a constant vector heading across a ground surface.

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[11P] A method to control flat yawing turns of an aircraft while maintaining a constant vector heading across a ground surface, the method comprising:

[11A] sensing the speed variation of the aircraft with a sensor carried by the aircraft, the speed variation having:

a longitudinal direction of motion; and

a lateral direction of motion;

[11B] providing a control system in data communication with the aircraft sensor and operably associated with the actuators, the control system having:

[11B.1] a model;

[11B.2] a lateral control architecture;

[11B.3] a longitudinal control architecture;

[11B.4] an initialization command logic in data communication with the lateral control architecture and in data communication with the longitudinal control architecture;

[11C] decoupling the directional movement of the aircraft into the lateral equation of motion and the longitudinal equation of motion with the model;

[11D] controlling the lateral direction of motion with a lateral control architecture, the lateral control architecture utilizing the lateral equation of motion;

[11E] controlling the longitudinal direction of motion with a longitudinal control architecture, the longitudinal control architecture utilizing the longitudinal equation of motion; and

[11F] selectively activating the lateral control architecture and the longitudinal control architecture with the initialization command logic;

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[11G] wherein the control system receives sensed speed variation data from the sensor and operably controls the actuators, thus providing selective control of the yawing turns of the aircraft while maintaining a constant vector across a ground surface,