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BEFORE THE PATENT TRIAL AND APPEAL BOARD

DJI EUROPE B.V.,

Petitioner

v.

TEXTRON INNOVATIONS INC.,

Patent Owner.

IPR2023-01104

U.S. Patent No. 8,682,505

**PETITION FOR *INTER PARTES* REVIEW
OF U.S. PATENT NO. 8,682,505**

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TABLE OF CONTENTS

I.	INTRODUCTION	1
II.	GROUND FOR STANDING.....	1
III.	IDENTIFICATION OF CHALLENGE	1
	A. Prior Art	1
	B. Grounds For Challenge	2
IV.	THE '505 PATENT.....	2
	A. Technical Background	2
	1. Pilot Control and Aircraft Movement.....	4
	2. Sensors, Actuators and Control Surfaces.....	7
	3. Flight Control Systems	8
	B. Overview of the '505 Patent	11
	C. Level Of Ordinary Skill In The Art	14
	D. Prosecution History.....	14
	1. U.S. Prosecution.....	14
	2. European Prosecution	16
	E. Claim Construction	17
V.	GROUND 1: GOLD RENDERS CLAIMS 1-2, 5-6, 8-9, 11-12, 15-16, AND 18-19 OBVIOUS.....	17
	A. Overview of Gold.....	17
	B. Independent Claim 1	19
	1. Preamble [1P].....	19
	2. “ <i>Lateral Control Architecture</i> ” [1A] and “ <i>Longitudinal Control Architecture</i> ” [1B].....	20
	a. “Longitudinal Control Architecture” [1B]	21
	b. “Lateral Control Architecture” [1A].....	25
	3. “ <i>Control Yaw Movement ...</i> ” [1C].....	29
	4. “ <i>Continuously Moves</i> ” [1D].....	35

TABLE OF CONTENTS (continued)

	Page
C. Independent Claim 11	36
1. Preamble [11P].....	36
2. “ <i>Sensing</i> ” Limitation [11A].....	36
3. “ <i>Determining</i> ” Limitation [11B].	38
4. “ <i>Selectively Controlling</i> ” Limitation [11C].....	42
5. “ <i>Continuously Moves</i> ” [11D].....	44
D. Dependent Claims	44
1. “ <i>Directional Controller</i> ” (Claims 2 and 12).....	44
2. “ <i>Lateral Control Architecture</i> ” (Claims 5 and 15).....	46
a. “Lateral Sideward Groundspeed Control Loop” [5A]/[15A].	46
b. “Lateral Roll Attitude Control Loop” [5B]/[15B].....	50
c. “Lateral Roll Rate Control Loop” [5C]/[15C].....	52
3. “ <i>Lateral Controller</i> ” (Claims 6 and 16)	54
4. “ <i>Longitudinal Control Architecture</i> ” (Claims 8 and 18).....	56
a. “Longitudinal Forward Speed Control Loop” [8A]/[18A]	57
b. “Longitudinal Pitch Angle Control Loop” [8B]/[18B]	61
c. “Longitudinal Pitch Rate Control Loop”	63
5. “ <i>Longitudinal Controller</i> ” (Claims 9 and 19)	65
VI. GROUND 2: COMBINATION OF GOLD AND SKONIECZNY RENDERS CLAIMS 3-4 AND 13-14 OBVIOUS.....	67
A. Combination Overview	67
1. Skonieczny	67
2. Motivation to Combine	69

TABLE OF CONTENTS
(continued)

	Page
B. “ <i>Directional Control Architecture</i> ” (Claims 3 and 13)	73
1. “ <i>Directional Heading Control Loop</i> ” [3A.1]/[13A].....	74
2. “ <i>Directional Turn Coordination Control Loop</i> ” [3A.2]/[13B].....	77
3. “ <i>Directional Yaw Rate Control Loop</i> ”	79
C. “ <i>Directional Control Latch</i> ” (Claims 4 and 14)	81
VII. GROUND 3: COMBINATION OF GOLD AND ADAMS RENDERS CLAIMS 7, 10, 17, AND 20 OBVIOUS.	83
A. Combination Overview	83
1. Adams	83
2. Motivation to Combine	85
B. “ <i>Lateral Control Latch</i> ” (Claims 7 and 17).....	88
C. “ <i>Longitudinal Control Latch</i> ” (Claims 10 and 20).....	89
VIII. DISCRETIONARY DENIAL IS NOT APPROPRIATE	91
IX. MANDATORY NOTICES	92
A. Real Party In Interest.....	92
B. Related Matters	92
C. Notice Of Counsel And Service Information.....	92
X. CONCLUSION.....	93

EXHIBIT LIST

Exhibit	Reference
1001	U.S. Patent 8,682,505 to Christensen et al. (“the ’505 patent”)
1002	File History of U.S. Patent 8,682,505
1003	Declaration of Dr. William Singhose in Support of Petition for <i>Inter Partes</i> Review of U.S. Patent 8,682,505
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	Reserved
1009	Reserved
1010	Reserved
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”

I. Introduction

DJI Europe B.V. (“Petitioner”) petitions for *inter partes* review (“IPR”) of U.S. Patent No. 8,682,505 (“the ’505 patent”; DJI-1001) claims 1-20.

II. Grounds For Standing

Petitioner certifies the ’505 patent is available for IPR and Petitioner is not barred or estopped from requesting IPR.

III. Identification Of Challenge

A. Prior Art

The face of the ’505 patent, filed December 11, 2012, claims priority to Application 13/391,522, filed February 21, 2012 as a National Stage Entry of PCT/US2011/030498, filed on March 30, 2011. (DJI-1001.) Petitioner does not acquiesce that the ’505 patent is entitled to priority to either of these applications. Regardless, 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 §102(b).

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

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

None of the applied references were cited in or discussed during prosecution of the '505 patent, weighing heavily against discretionary denial under 35 U.S.C. §325(d). (*See* DJI-1002.)

B. Grounds For Challenge

1. Claims 1-2, 5-6, 8-9, 11-12, 15-16, and 18-19 are obvious over Gold.
2. Claims 3-4 and 13-14 are obvious over Gold in combination with Skonieczny.
3. Claims 7, 10, 17, and 20 are obvious over Gold in combination with Adams.

IV. The '505 Patent

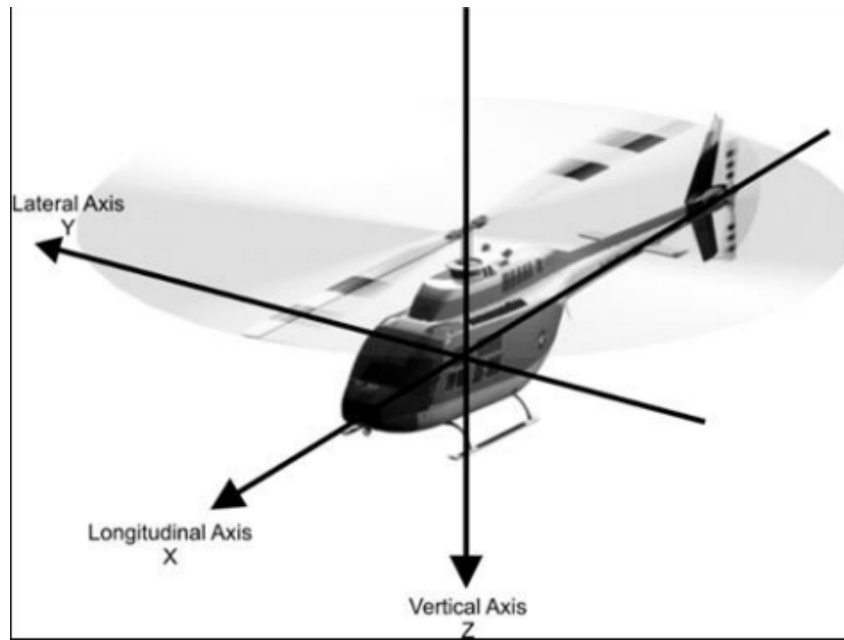
The '505 patent relates “to a flight control system having flight control laws which enable precise aircraft maneuvering relative to the ground.” (DJI-1001, 1:7-10.) The '505 patent focuses its discussion on “rotorcraft, such as helicopters.” (DJI-1001, 1:13-15.) The use of a flight control system in both fixed wing aircraft and rotorcraft was extremely well-known and in use by the earliest possible priority date of the '505 patent (March 30, 2011). (DJI-1003, ¶22.)

A. Technical Background

A helicopter, illustrated below, uses a main rotor that produces thrust, primarily for vertical lift, but also for directional control, and a tail rotor that

controls the heading¹ of the helicopter. (DJI-1003, ¶23.) A useful reference system for an aircraft (e.g., a helicopter) consists of three mutually perpendicular lines (axes) (longitudinal, lateral, and vertical) that intersect at the center of gravity of the aircraft. (DJI-1003, ¶24.) The longitudinal axis passes through the nose end and the tail of the aircraft. 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 The **heading** of an aircraft is the direction in which the nose of the aircraft points during flight. (DJI-1016, 1-6.)

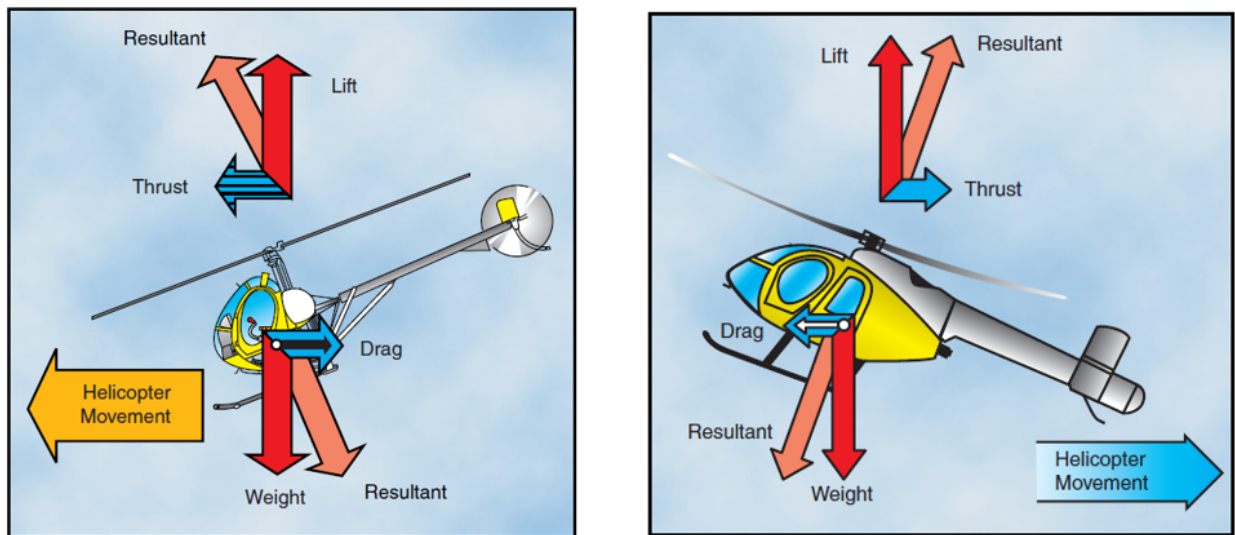


1. Pilot Control and Aircraft Movement

Helicopters often come equipped with one or more controllers used by a pilot to control movement of the aircraft. The cyclic stick controls the main rotor disc angle and thus changes the helicopter's pitch and roll attitude². (DJI-1003, ¶¶25-26.) When the main rotor disc is tilted (attitude or 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 as shown in Figure 3-11 (below left). (DJI-1003, ¶¶26, 44.) If the cyclic stick is moved aft, the disc tilts aft, resulting in

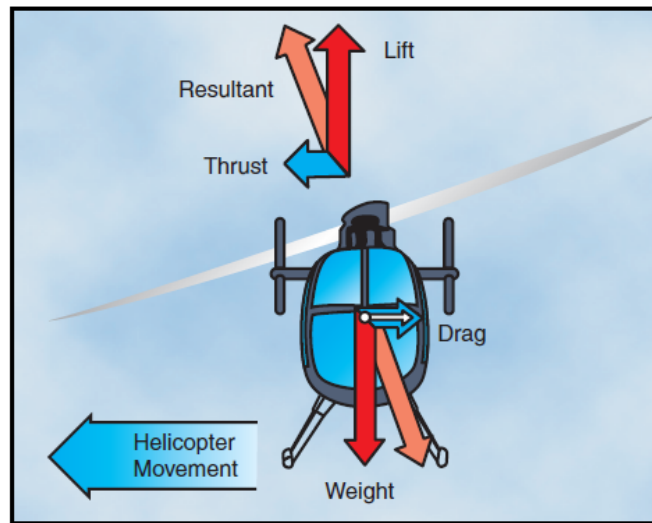
² Attitude is the set of three angles defining the orientation of the aircraft. (DJI-1003, ¶25.)

backward acceleration as shown in Figure 3-18 (below right). (DJI-1003, ¶¶26, 46.) Change in the pitch angle is very strongly correlated with longitudinal motion and pitch control is generally synonymous with longitudinal control. (DJI-1003, ¶26.)



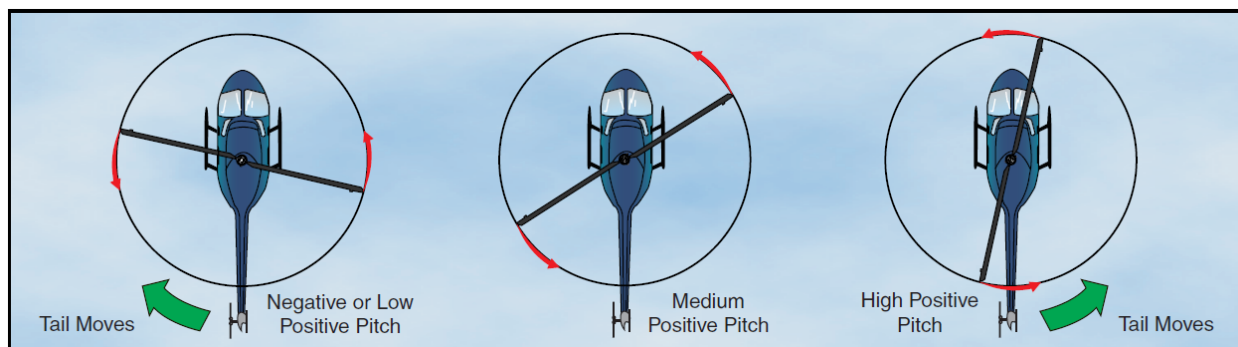
Rotorcraft Flying Handbook, Figure 3-11 (left); Figure 3-18 (right)

If the cyclic stick is moved to the side, the main rotor disc is rolled to the side, resulting in sideward motion, as shown in the Figure below. (DJI-1003, ¶¶27, 45.) Changes in the 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 which control the heading of the helicopter as shown below. (DJI-1015, 4-3.) That is, the pedals cause the helicopter to rotate about the vertical axis (when it is in level flight) to change its yaw angle. (DJI-1003, ¶28.) A high positive pitch angle tends to move the tail to the right; a low positive or negative pitch angle moves the tail to the left; and a medium pitch keeps the tail in line and maintains the yaw angle. (DJI-1015, 4-3.)



Rotorcraft Flying Handbook, Figure 4-6

Some helicopters combine the cyclic stick and pedals into a single three-axis stick (controlling forward and backward, left and right, and rotational movement). (DJI-1003, ¶31.) Others combine the cyclic stick, collective stick, and pedals into a single four-axis stick (movement forward and backwards, left and right, up and down, and rotational). (*Id.*)

2. Sensors, Actuators and Control Surfaces

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.) For example, Inertial Measurement Units (IMUs) are typically a combination of gyroscopes and accelerometers that provide measurements for attitude, attitude rate, relative velocity, and position. (DJI-1003, ¶33.) GPS is used for position measurements, from which velocity and heading can be estimated. (DJI-1003, ¶35.) Altitude is measured using a combination of barometric altimeters, which measure static pressure, and temperature sensors. (DJI-1003, ¶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.) One common control surface is a swash plate which transmits control inputs to the main rotor blades. (DJI-1015, 5-5.) Another common control surface is a "pitch change mechanism on the tail rotor gearbox" which changes the

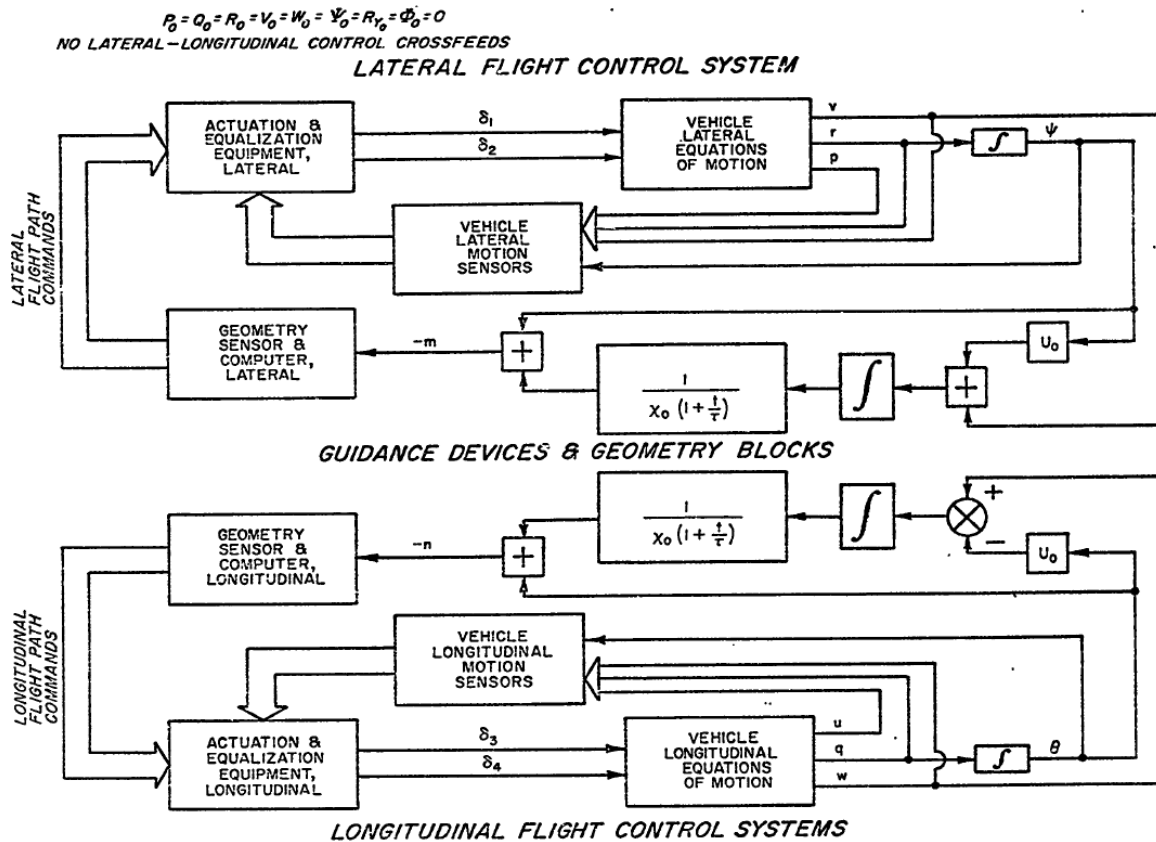
collective pitch of the tail rotor. (DJI-1015, 4-3.) The actuators move the control surfaces based on the received commands. (DJI-1003, ¶¶37-40.) In modern flight control systems (described further below), the pilot commands are monitored by a flight computer which issues commands to the aircraft's actuators to move the control surfaces to move the aircraft in the desired manner. (DJI-1003, ¶48.)

3. Flight Control Systems

Modern control systems use a control architecture that depends on the dynamic model of the system being controlled. (DJI-1003, ¶49.) Helicopter dynamic models are sets of equations that describe the motion and aerodynamics of the helicopter, its rotor(s), and other components. (*Id.*) The equations of motion for a helicopter are derived by summing the force and moment contributions of various structural components of the helicopter (e.g., main rotor, tail rotor, and fuselage). (DJI-1003, ¶¶55-56.) For the design of a flight control system, 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.) The following exemplary flight control system, from the 1973 book "Aircraft Dynamics and Automatic Control" by McRuer, includes a lateral control component utilizing the lateral equations of motion and a separate

longitudinal control component utilizing the longitudinal equations of motion.

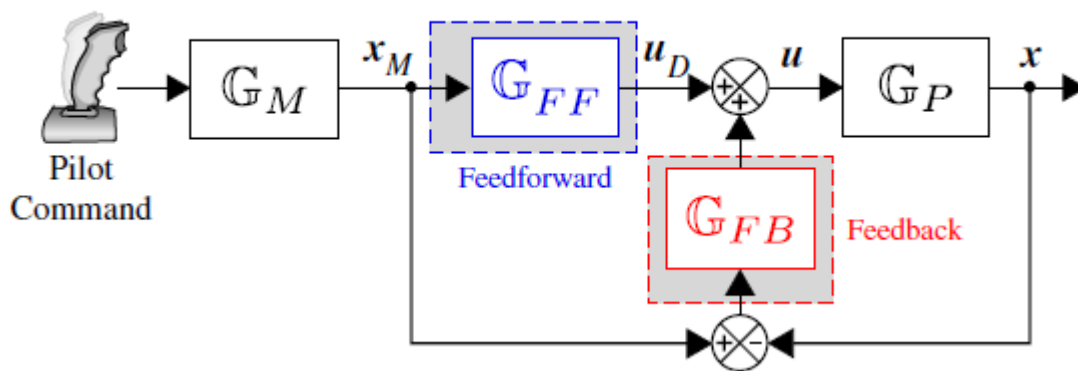
(DJI-1017, 16.)



McRuer (1973), Figure 1-4

Helicopters can have different operational modes, also referred to as response types, for different flight conditions. (DJI-1003, ¶50.) The response type (e.g., Attitude Command/Attitude Hold, Attitude Command/Velocity Hold, Yaw Rate Command/Direction (Heading) Hold, etc.) determines how the helicopter responds to a given pilot input. (*Id.*) The specific response to a given pilot input depends on the design of the flight control laws. (*Id.*)

Many modern control systems, referred to as 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 earliest possible priority date of the '505 patent. (DJI-1003, ¶¶52-53, *citing* DJI-1021, 494-496.) In an explicit model following controller, the pilot command is used as input to a prescribed model G_M (which is sometimes 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.)

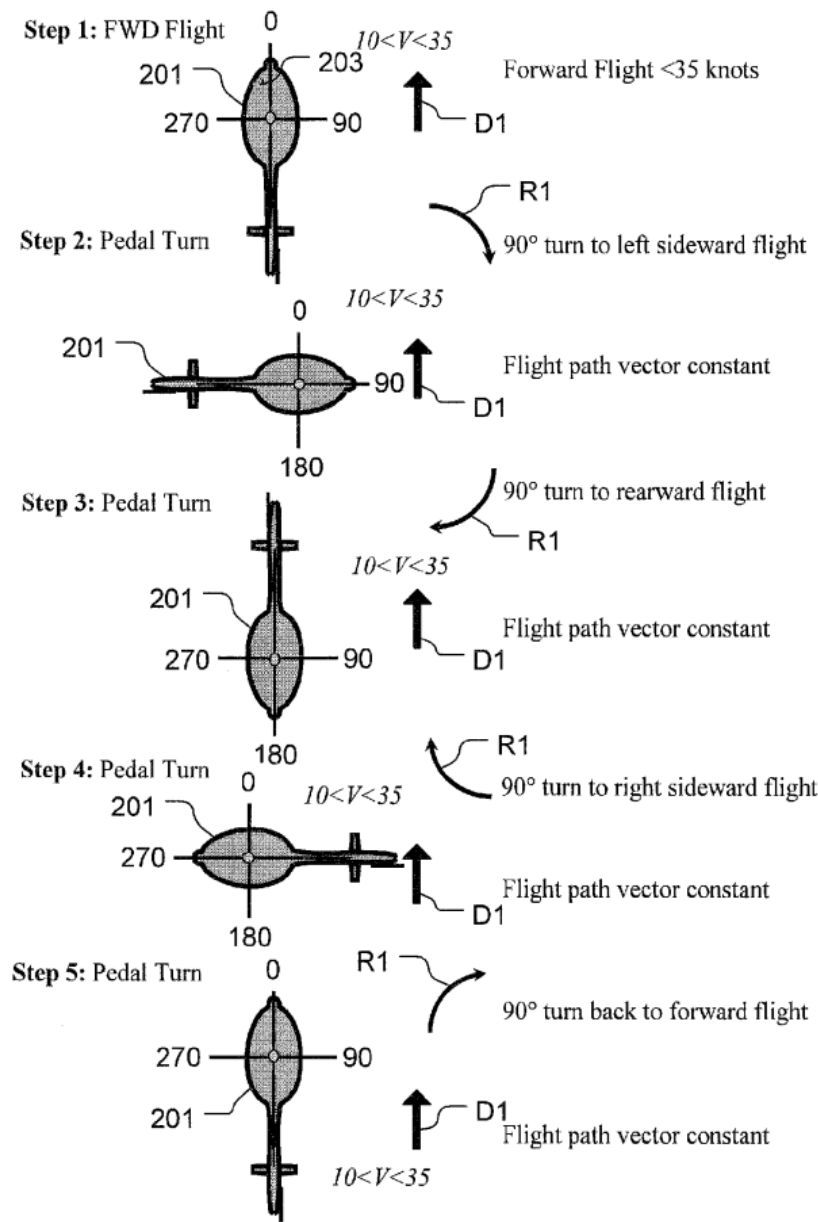


Adams/Singhose (DJI-1022), Figure 6

B. Overview of the '505 Patent

The claims of the '505 patent are directed to an aircraft control system that controls yaw rotation while the aircraft maintains a constant velocity flight path relative to the ground surface. (DJI-1001, Abstract; claims 1, 11.) As shown in Figure 2 below, the helicopter flies with a flight path in the D1 direction.

Directional inputs from the pilot turn the aircraft “in a complete 360 degree yaw movement R1, stopping every 90 degrees, and without changing the speed and flight heading” of the aircraft. (DJI-1001, 3:12-15.) Thus, 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.)

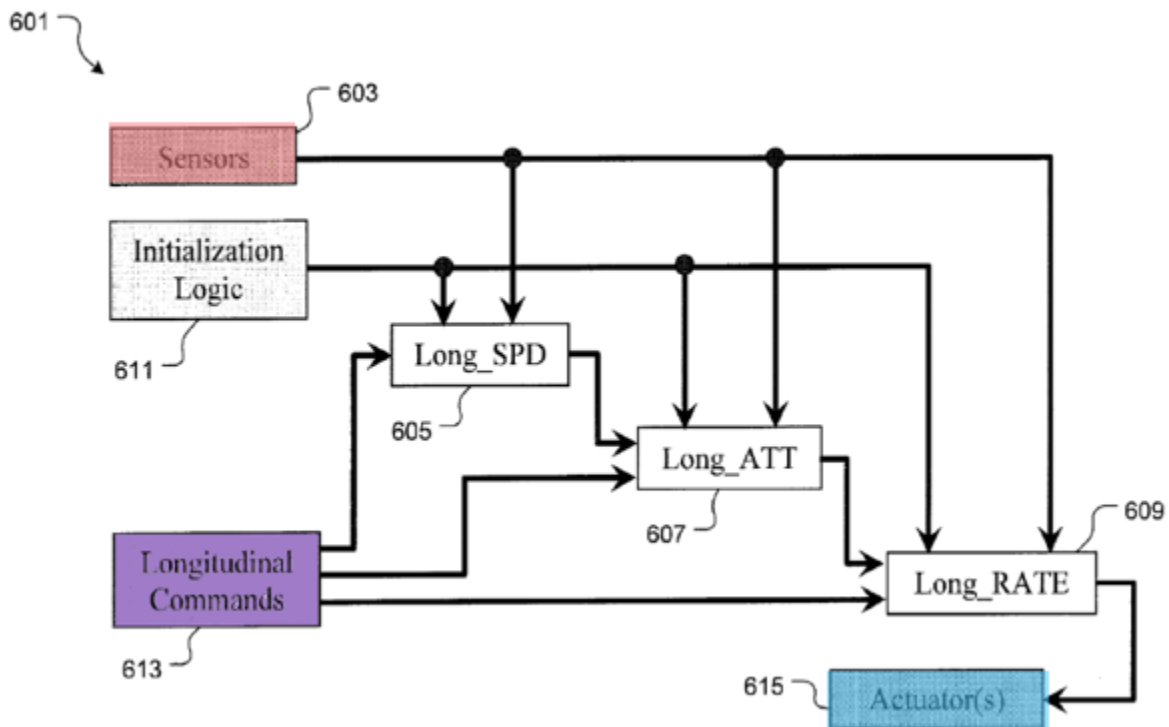


'505 Patent, Figure 2

The control system includes a longitudinal control architecture, a lateral control architecture, and a directional control architecture. (DJI-1001, 4:45-52.)

The longitudinal control architecture 601 is illustrated in Figure 6 below. The inputs to the longitudinal control architecture are (1) a command signal from the pilot's controller (e.g., "the difference between the controller's present position and

the centered, no force position” (the ‘detent’ position)) and (2) data from sensors 603. (DJI-1001, 5:22-25.) The longitudinal control laws process the inputs “to generate the appropriate aircraft response commands” which “are routed to an actuator 615 for each dynamic axis.” (DJI-1001, 5:27-38.) The lateral and directional control architectures 701 and 801 respectively have the same basic structure—sensors 603, pilot command input, control laws, and actuators 615. (See, e.g., DJI-1001, 5:53-67 (lateral control architecture), 6:27-42 (directional control architecture); See DJI-1003, ¶¶69-71.)



'505 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

1. U.S. Prosecution

The originally filed independent claims, reproduced below, were rejected as being anticipated by U.S. Publication 2010/0324758 to Piasecki, et al (“Piasecki”). (DJI-1002, DJI-1002, 38-39.)

[1P] A control system for an aircraft, comprising:

[1A] a lateral control architecture configured to control lateral motion of the aircraft; and

[1B] a longitudinal control architecture configured to control longitudinal motion of the aircraft;

[1C] wherein the control system utilizes the lateral control architecture and the longitudinal control architecture to control yaw

movement of the aircraft while the aircraft maintains a constant vector heading across a ground surface.

[11P] A method, comprising:

[11A] sensing a directional movement of an aircraft;

[11B] determining lateral and longitudinal movements of the aircraft; and

[11C] selectively controlling flat yaw movement of the aircraft while maintaining a constant vector flat turn relative to a ground surface.

In response, Applicant amended these claims to add the limitation “*wherein the aircraft continuously moves in a yaw direction while maintaining the constant vector heading.*” (DJI-1002, 23, 25.) Applicant further argued that “[a]lthough Piasecki **does disclose** a system that **utilizes lateral and longitudinal motions**, the art is silent with respect to using these movements along with maintaining a constant vector heading.” (DJI-1002, 27.) Applicant therefore admitted systems with separate lateral and longitudinal control architectures were known. The Examiner subsequently allowed the claims after this amendment without further comment. (DJI-1002, 16.)

The concept of the aircraft continuously moving in a yaw direction while maintaining a constant ground track was known and disclosed by Gold, as

discussed in §V.B and recognized by the Examiner in the European companion application discussed in the next section.

2. European Prosecution

The European National Stage application of the parent PCT application (now the '082 patent) was filed with a set of claims reciting lateral and longitudinal control architectures as well as the limitation “utiliz[ing] the lateral control architecture and the longitudinal control architecture to control a yaw movement of the aircraft while the aircraft maintains a constant vector heading across a ground surface.” (DJI-1012, 254.) The EP Examiner found the independent claims lacked novelty over U.S. Patent 5,553,812 to Gold (“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 last clause of 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.) PO further amended the European specification to acknowledge Gold as prior art and specifically highlighted that Gold discloses “the flight path referenced velocities are held constant during pilot commanded yaw maneuvers so that the aircraft maintains a fixed inertial referenced flight path regardless of the pointing direction of the aircraft.” (DJI-

1012, 122-123.) After further narrowing amendments, the EP patent was allowed.
(DJI-1003, ¶¶84-85.)

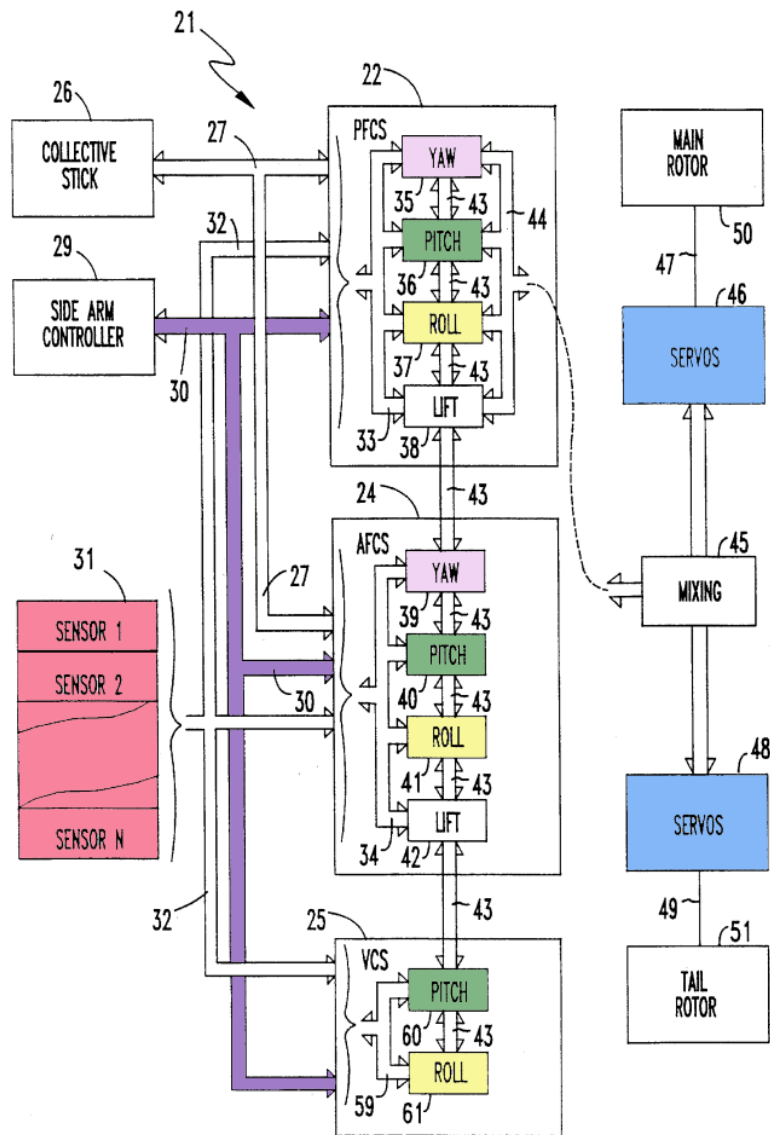
E. Claim Construction

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: Gold Renders Claims 1-2, 5-6, 8-9, 11-12, 15-16, and 18-19 Obvious.

A. Overview of Gold

Gold relates “to a velocity command system having an inertial reference 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, illustrated in annotated Figure 3 below, includes primary flight control system (PFCS) 22, automatic flight control system (AFCS) 24 and velocity command system (VCS) 25. (DJI-1005, 3:4-7.) 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

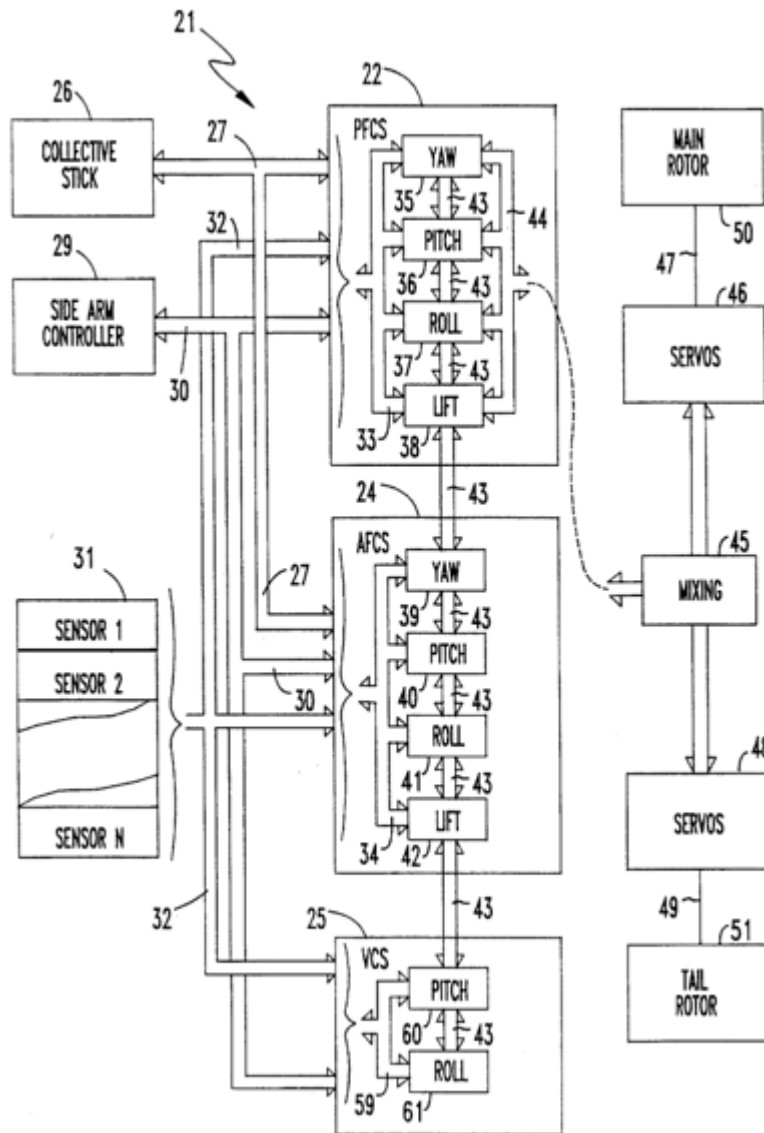
The PFCS and AFCS provide rotor command signals to rotor mixing function 45 which commands displacement of mechanical servos (shaded blue) to control the tip path plane of main rotor 50 and thrust of tail rotor 51. (DJI-1005, 3:25-32.) Sensors (shaded red) provide the PFCS and AFCS with the aircraft's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

35.) The sensors also “provide information related to velocity, altitude, acceleration, etc.” (DJI-1005, 3:35-36.)

B. Independent Claim 1

1. Preamble [1P]

Gold’s flight control system 21 “includes a primary **flight** control system (PFCS) 22, an automatic **flight** control system (AFCS) 24 and a velocity command system (VCS) 25.” (DJI-1005, 3:4-7, annotated Figure 3 below.) Gold describes its system “with respect to a model following flight control system for a **rotary winged aircraft**.” (DJI-1005, 2:65-67.) Accordingly, Gold discloses a “*control system for an aircraft*” [1P]. (DJI-1003, ¶94; *see also*, DJI-1005, claim 1 (reciting “An aircraft flight control system”).)



Gold, Figure 3

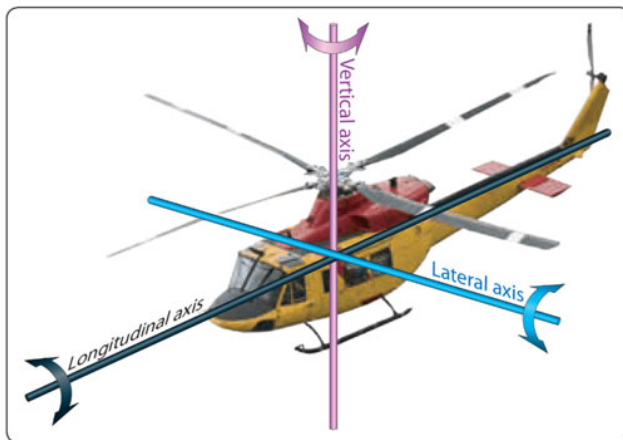
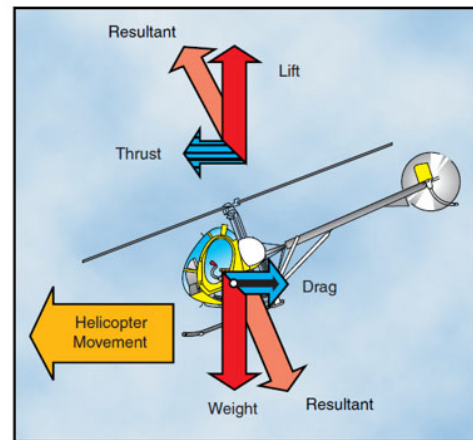
2. “*Lateral Control Architecture*” [1A] and “*Longitudinal Control Architecture*” [1B]

Gold describes the functional interconnection of the PFCS, AFCS, and VCS with respect to the pitch axis control modules 36, 40, 60. (DJI-1005, 3:54-56.)

Accordingly, for ease of discussion, Petitioner addresses the “*longitudinal control architecture*” [1B] limitation first.

a. “Longitudinal Control Architecture” [1B]

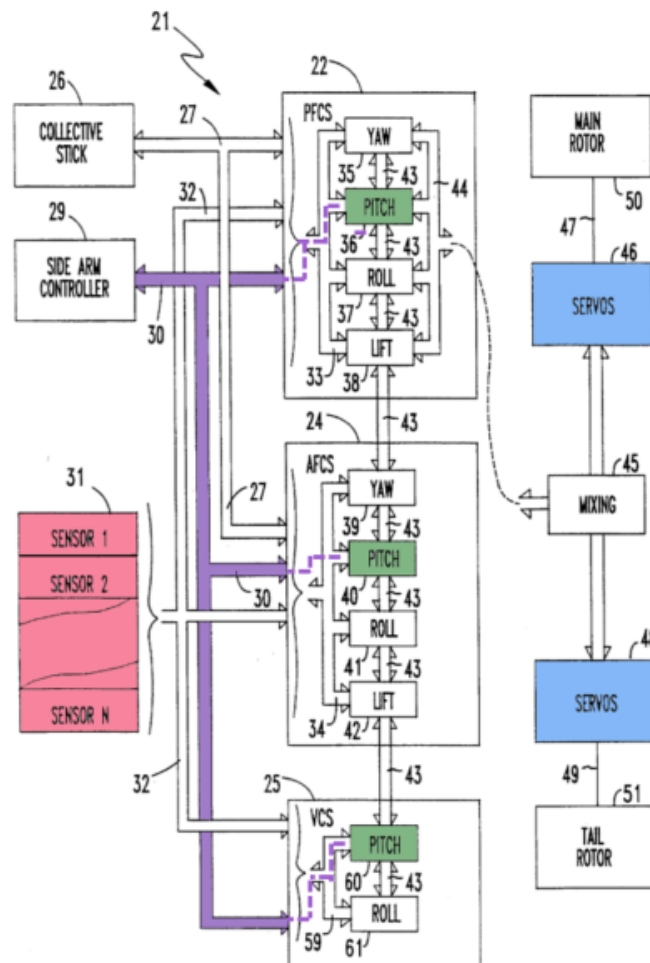
Gold’s “control system” includes “a longitudinal control architecture configured to control longitudinal motion of the aircraft” [1B]. (DJI-1003, ¶¶95-100.) As discussed in §IV.A.1 and illustrated below (left), a coordinate system for an aircraft consists of three perpendicular axes—longitudinal, lateral, and vertical. Rotation about the lateral axis is referred to as pitch. (DJI-1003, ¶¶96, 24.) Changes in pitch angle (attitude) induce movement in the longitudinal direction, as shown below right. (See §IV.A.1; DJI-1003, ¶¶96, 44, 46.) Accordingly, controlling pitch controls the “longitudinal motion of the aircraft.” (DJI-1003, ¶¶96, 99; DJI-1015, 3-11; *see also*, DJI-1001, 5:7-12 (correlating pitch and longitudinal control).)



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

The PFCS, AFCS, and VCS of Gold’s flight control system 21 each contains a control module 36, 40, 60 (shaded green in annotated Figure 3 below) for

controlling pitch (longitudinal motion) of the aircraft. (DJI-1005, 3:17-18, 3:45-46.) The pitch control modules receive command signals (shaded purple) from sidearm controller 29 on line 30 and sensed parameter signals from sensors 31 on lines 32. (DJI-1005, 3:10-13, 3:40-42.) The longitudinal control architecture 36, 40 (shaded green) of the PFCS and AFCS provide rotor command signals to mixing function 45 “which commands 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.)

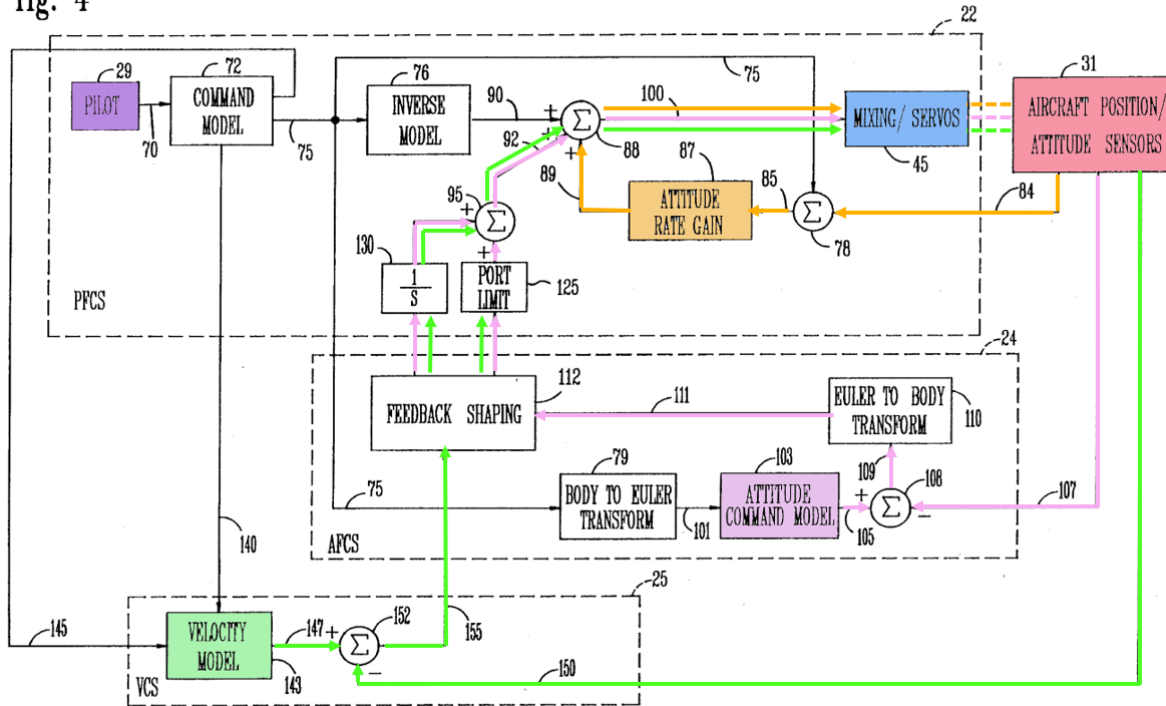
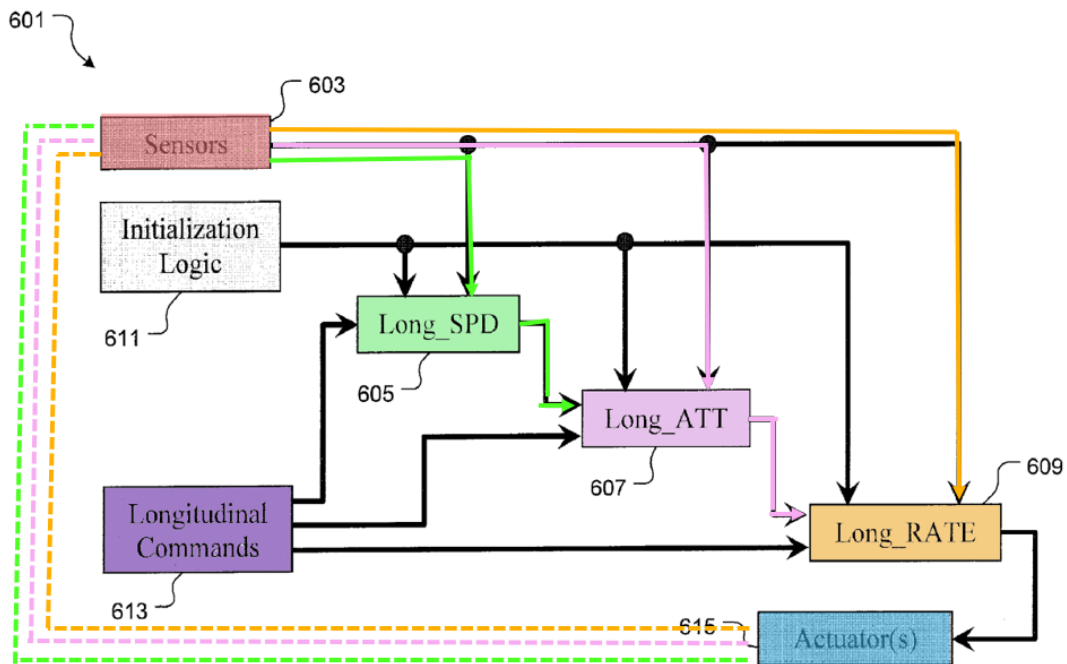


Gold, Annotated Figure 3

Pitch control module 36 of the PFCS, pitch module 40 of the AFCS, and pitch control module 60 of the VCS are collectively part of the “*longitudinal control architecture*” [1B] of flight control system 21. (DJI-1003, ¶¶97-98.) By controlling the pitch of aircraft (tip path plane of the main rotor), the “*longitudinal control architecture*” of Gold is “*configured to control longitudinal motion of the aircraft*” [1B]. (DJI-1003, ¶99.)

Moreover, Gold’s longitudinal control architecture is analogous to the longitudinal control architecture of the ’505 patent, as illustrated in Gold’s annotated Figure 4 (top figure below) and the ’505 patent’s Figure 6 (bottom figure below). (DJI-1003, ¶100.) As shown in these Figures, Gold discloses a longitudinal speed loop (indicated by bright green lines in Figure 4) like the ’505 patent, an attitude (pitch angle) loop (indicated by pink lines in Figure 4) like the ’505 patent, and a pitch rate loop (indicated by orange lines in Figure 4) like the ’505 patent. (*Id.*) Each of these loops is described further in §V.D.4, discussing dependent claims 8 and 18.

fig. 4

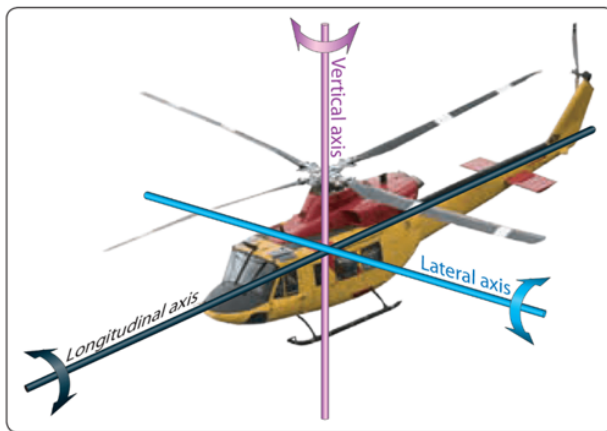
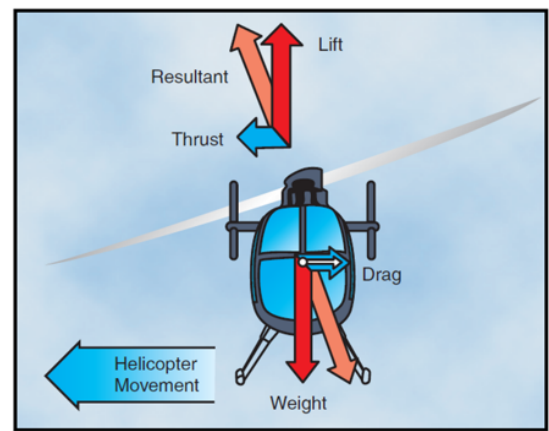


Gold, Annotated Figure 4 (top), '505 Patent, Annotated Figure 6 (bottom)

b. “Lateral Control Architecture” [1A]

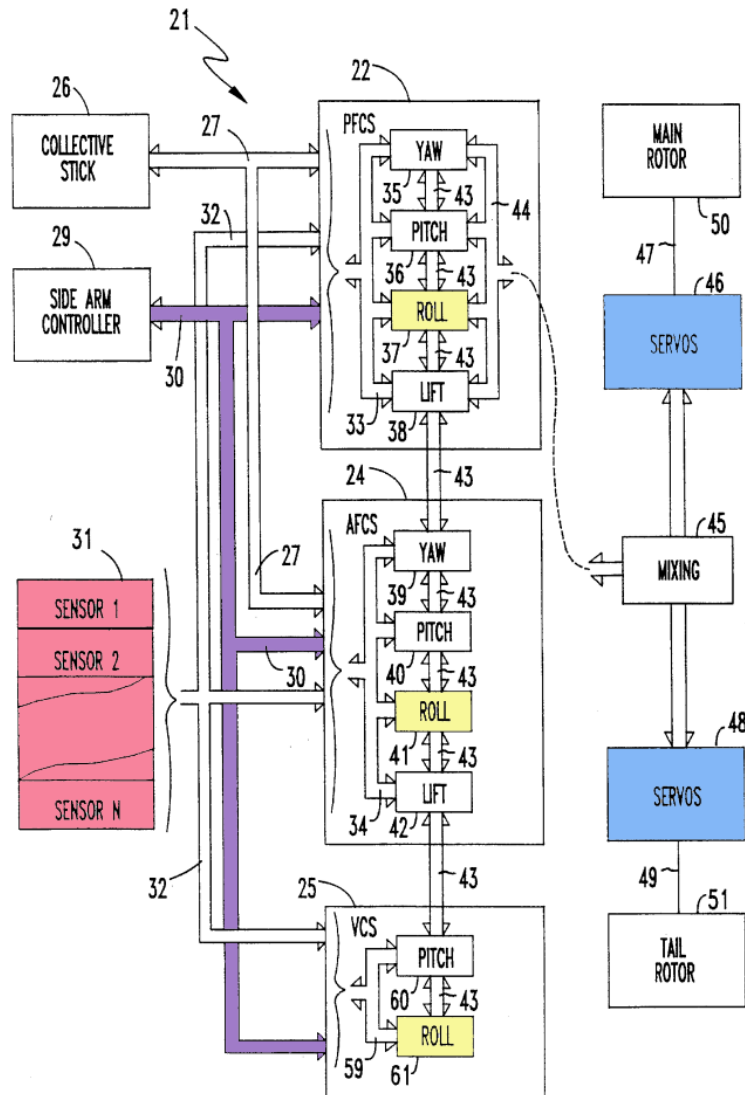
Gold discloses a “control system” having “a lateral control architecture configured to control lateral motion of the aircraft” [1A]. (DJI-1003, ¶¶101-107.)

Rotation about the longitudinal axis of the aircraft 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, ¶¶101, 105, 24, 45; §IV.A.1.) Accordingly, controlling roll controls the “lateral motion of the aircraft.” (DJI-1003, ¶¶101, 105; *see also*, DJI-1001, 5:53-62 (correlating roll and lateral control).)



The PFCS, AFCS, and VCS of Gold’s flight control system 21 each contains a control module 37, 41, 61 (shaded yellow in annotated Figure 3 below) for controlling roll (lateral motion) of the aircraft. (DJI-1005, 3:17-18, 3:45-46.) The roll control modules receive command signals (shaded purple) from sidearm controller 29 on line 30 and sensed parameter signals from sensors 31 on lines 32. (DJI-1005, 3:10-13, 3:40-42.) The lateral control architecture 37, 41 of the PFCS

and AFCS provide rotor command signals to mixing function 45 “which commands 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.)



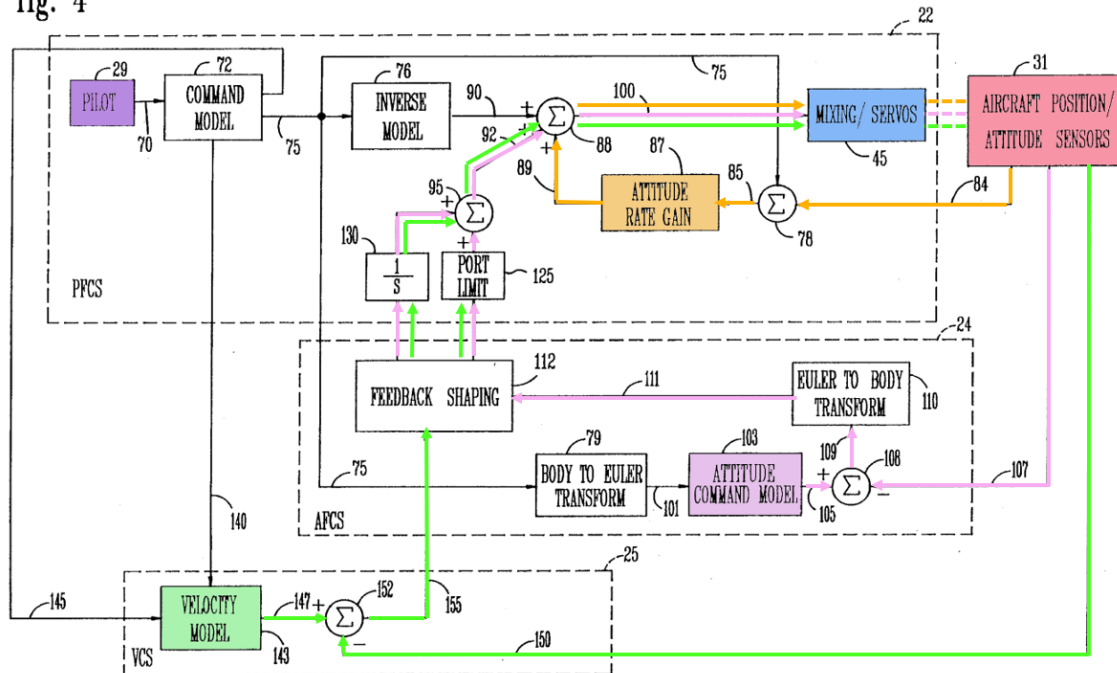
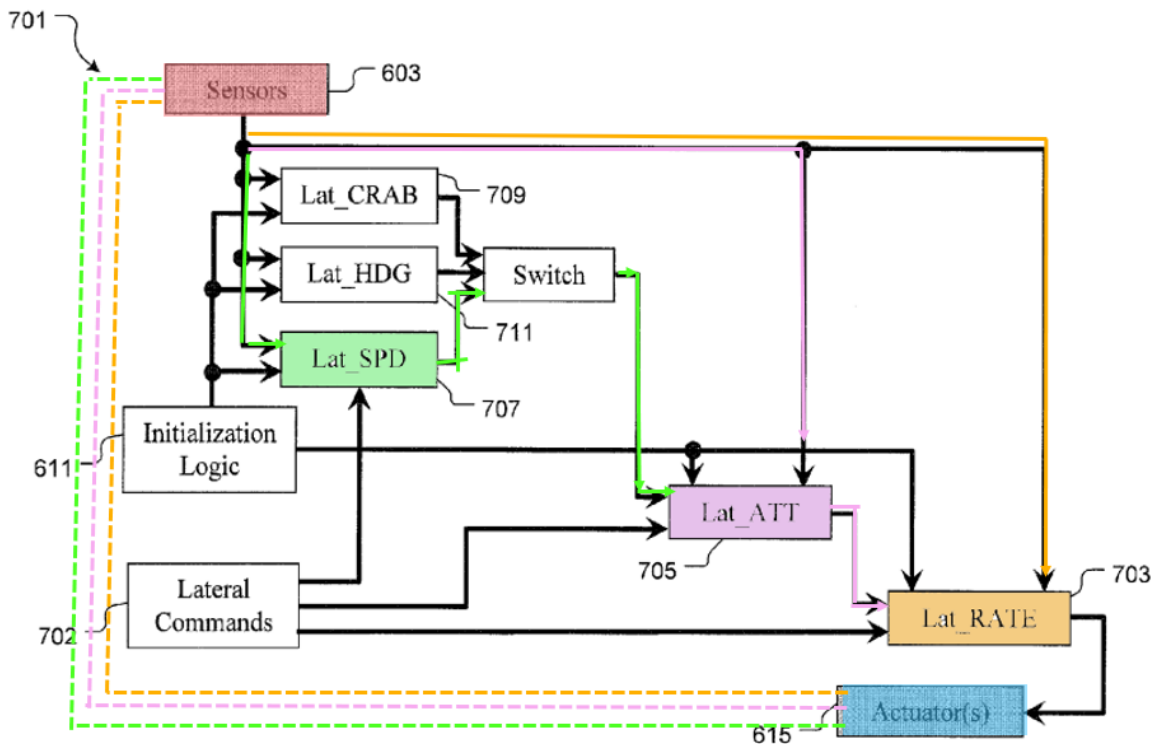
Gold, Annotated Figure 3

Roll control module 37 of the PFCS, roll control module 41 of the AFCS, and roll control module 61 of the VCS are collectively part of the “*lateral control*

architecture” [1A] of flight control system 21. (DJI-1003, ¶¶102-104.) By controlling the roll of the aircraft (rolling the main rotor sideways), the “*lateral control architecture*” of Gold is “*configured to control lateral motion of the aircraft*” [1A]. (DJI-1003, ¶¶101, 105.)

Moreover, Gold’s lateral control architecture is analogous to the lateral control architecture of the ’505 patent, as illustrated in Gold’s annotated Figure 4 (top figure below) and the ’505 patent’s annotated Figure 7 (bottom figure below). (See DJI-1005, 3:54-61 (“the functional interconnection of FIG. 4 is equally applicable to flight control roll attitude reference and VCS roll axis velocity error signals”); DJI-1003, ¶¶106-107.) As shown in these Figures, Gold discloses a lateral speed loop (indicated by bright green lines in Figure 4) like the ’505 patent, an attitude (roll angle) loop (indicated by pink lines in Figure 4) like the ’505 patent, and a roll rate loop (indicated by orange lines in Figure 4) like the ’505 patent. (DJI-1003, ¶107.) Each of these loops is described further in §V.D.2, discussing dependent claims 5 and 15.

fig. 4



Gold, Annotated Figure 4 (top), '505 Patent, Annotated Figure 7 (bottom)

3. “Control Yaw Movement ...” [1C].

Claim 1 further recites “*the control system utilizes the lateral control architecture and the longitudinal control architecture to control yaw movement of the aircraft while the aircraft maintains a constant vector heading across a ground surface.*” Aside from the abstract and claims, the ’505 patent does not use the terminology “constant vector **heading** across a ground surface.” The ’505 patent instead refers to a “constant vector” throughout the detailed description. (See, e.g., DJI-1001, 2:47-50 (“enable a pilot to use the directional controller to command flat yawing turns at low groundspeeds, while maintaining a **constant vector across the ground**”); 7:59-61 (“This design enables the pilot to command and hold any crab angle around the 360 degree circle, while the aircraft continues to move across the ground on a **constant vector**”).) Consistent with the specification, the “*constant vector heading across a ground surface*” is the straight-line track or course of the aircraft 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 or course) at a constant speed. (DJI-1003, ¶¶108-109.)

Additionally, the ’505 patent provides no support for utilizing the lateral and longitudinal control architecture to control yaw movement of the aircraft.

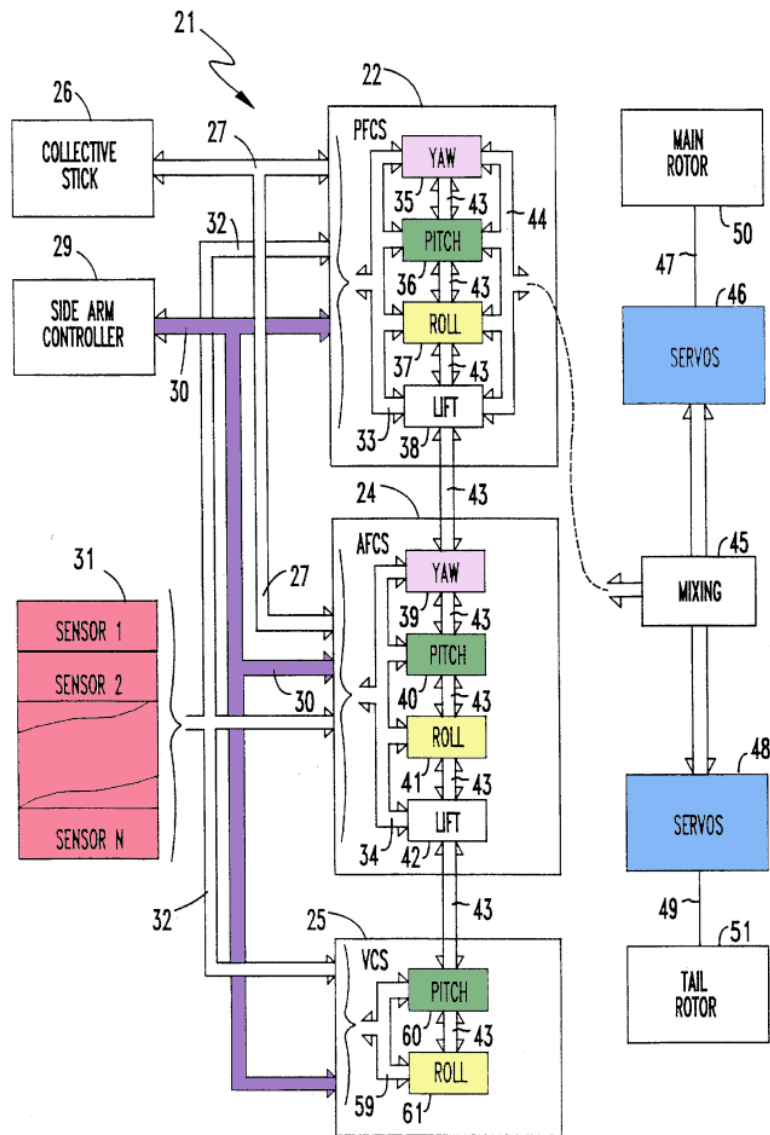
However, the ’505 patent discusses using these control architectures to maintain a

constant vector track. (*See, e.g.*, DJI-1001, 7:2-3 (“the control laws will maintain a constant ground vector by using the Long_SPD 605 and Lat_SPD 707 loops”).)

Accordingly, limitation [1C] encompasses the interworking between the yaw (directional) control architecture and the lateral and longitudinal control architectures to accomplish the functions of (1) performing a yaw maneuver and (2) maintaining a constant straight-line track at a specific speed during the yaw maneuver. (DJI-1003, ¶110.)

Gold discloses “*utiliz[ing] the lateral control architecture and the longitudinal control architecture to control yaw movement of the aircraft while the aircraft maintains*” a constant straight-line path (ground track) at a specific speed (“*a constant vector heading across a ground surface*”). (DJI-1003, ¶¶108-117.)

Gold’s PFCS and AFCS each contain a control module 35, 39 (shaded pink in annotated Figure 3 below) for controlling yaw. (DJI-1005, 3:17-18.)



Gold, Annotated Figure 3

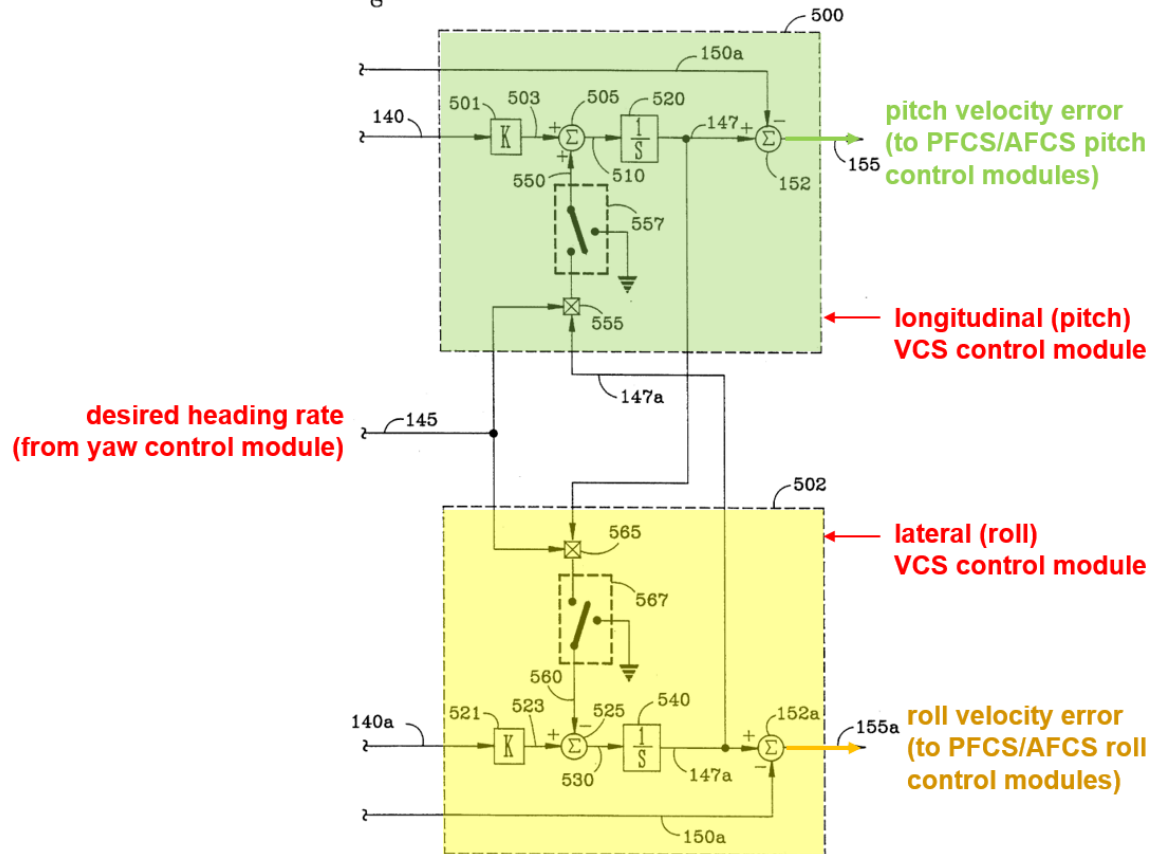
In Gold, the command model for the yaw axis “provides a desired yaw axis rate response, i.e., desired heading rate, on a line 145” to the lateral control module (shaded yellow in annotated Figure 5 below) and longitudinal control module (shaded green below) of the VCS. (DJI-1005, 5:9-13.) The velocity model of the VCS “uses the heading rate signal on the line 145 and the desired attitude response for the pitch axis and the yaw axis to develop centrifugal acceleration terms.” (DJI-

1005, 5:15-20.) These centrifugal acceleration terms, caused by the pilot yawing the vehicle, “must be included in the pitch axis and roll axis velocity models” to hold the flight path (inertial) referenced velocities constant. (DJI-1005, 6:35-38.)

After integration to produce velocity terms, pitch and roll velocity error terms are determined and provided on lines 155 and 155a, respectively, to the pitch (longitudinal) and roll (lateral) control modules of the AFCS and PFCS which “drive the velocity error to zero.” (See DJI-1005, Figure 4; 6:15-17.) By driving the velocity errors to zero, the longitudinal and lateral control architectures maintain constant speed and direction of the aircraft. (DJI-1003, ¶112.)

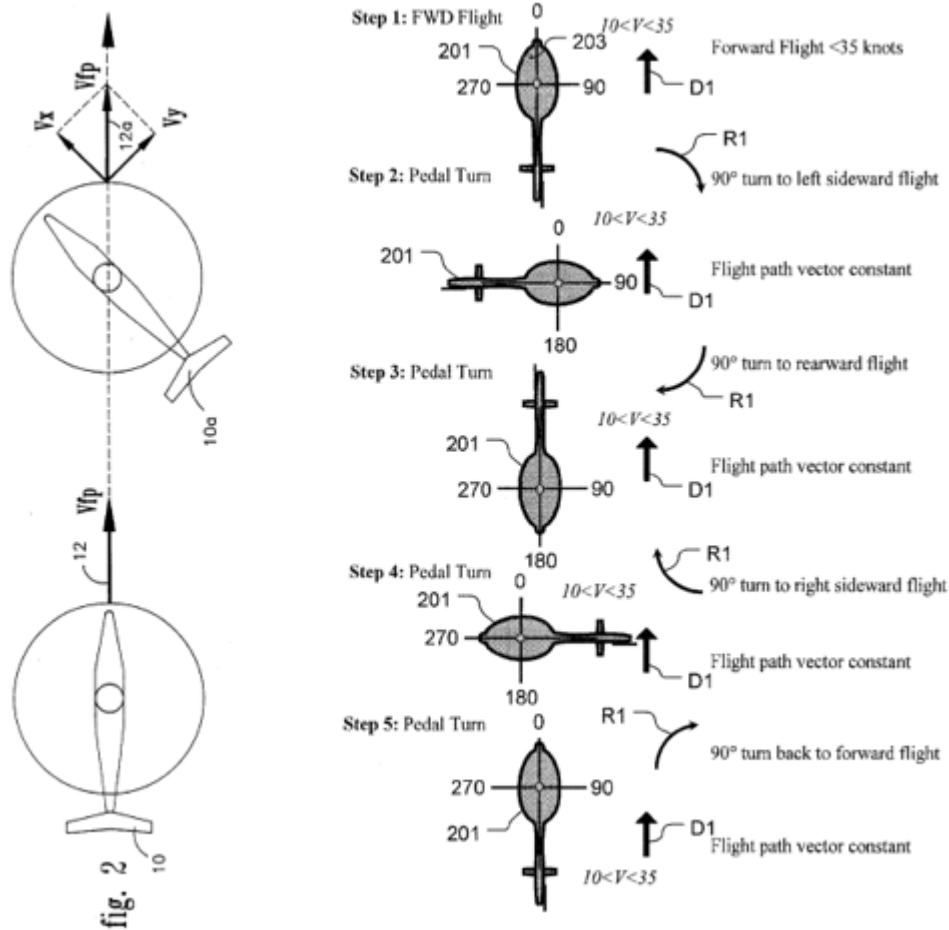
Accordingly, Gold teaches that when the yaw control architecture is controlling yaw of the aircraft and the aircraft is in velocity stabilization mode, both the longitudinal and lateral control architectures are used to maintain the constant flight path (track) at the specific speed. (DJI-1003, ¶¶111-112.)

fig. 5



Gold, Annotated Figure 5

In Gold, an aircraft operating in velocity stabilization mode has “a fixed velocity along a selected flight path as indicated by velocity vector 12.” (DJI-1005, 2:58-60.) In response to a yaw command while in velocity stabilization mode, “the aircraft 10a yaws while maintaining a constant flight path reference velocity 12a.” (DJI-1005, 2:60-64.) Gold’s system therefore operates in the same manner as the ’505 patent as illustrated by Gold’s Figure 2 (below left, rotated 90°) and the ’505 patent’s Figure 2 (right). (DJI-1003, ¶113.)



Gold, Figure 2 (left); '505 Patent, Figure 2

PO acknowledged Gold discloses this limitation in the amendment made to the specification of the European companion patent summarizing the Gold reference:

An example velocity command system is described in US 5553812, in which an aircraft flight path referenced velocities are determined with respect to an inertial frame of reference, the flight path referenced velocities are held constant during pilot commanded yaw maneuvers so that **the aircraft maintains a fixed inertial referenced flight path**

regardless of the pointing direction of the aircraft. Velocity control with respect to an inertial frame of reference is accomplished by controlling the aircraft flight path based on aircraft body referenced **commanded lateral and longitudinal acceleration** and based on aircraft body referenced **lateral and longitudinal centrifugal acceleration.**

(DJI-1012, 122-123; EP patent, DJI-1011, ¶4.)

Thus, Gold discloses “*the control system utilizes the lateral control architecture and the longitudinal control architecture to control yaw movement of the aircraft while the aircraft maintains a constant vector heading across a ground surface*” [1C]. (DJI-1003, ¶¶108-117.)

4. “Continuously Moves” [1D].

Claim 1 further recites the “*aircraft continuously moves in a yaw direction while maintaining the constant vector heading*”³ [1D]. Limitation [1D] does not provide any limits (duration or yaw angle) for the term “*continuously moves*” and therefore encompasses an aircraft continuously moving in a yaw direction until a commanded (desired) yaw angle is achieved by the aircraft while the aircraft maintains its constant ground track. (See §V.B.3 (discussion of term “*constant vector heading*”).) Gold discloses continuously moving in a yaw direction to a

³ Petitioner reserves the right to challenge claim 1 under 35 U.S.C. §112 in another forum.

desired yaw angle while the aircraft maintains a constant track. As discussed in §V.B.3, in response to a pilot's yaw command during operation 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, Figure 2.)

Gold, therefore, discloses that the "*aircraft continuously moves in a yaw direction while maintaining the constant vector heading*" (straight-line path at a constant speed) [1D]. (DJI-1003, ¶¶118-119.)

C. Independent Claim 11

1. Preamble [11P]

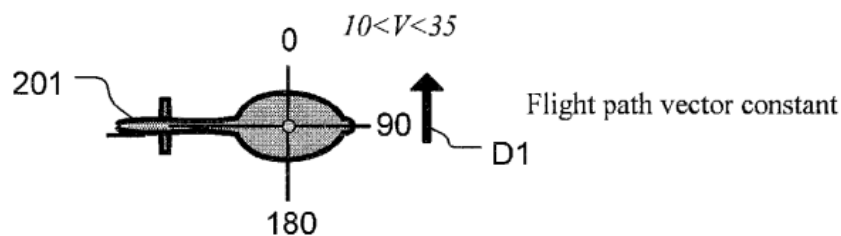
Gold discloses a method performed by its "model following flight control system for a rotary winged aircraft." (DJI-1005, 2:65-67.) Thus, Gold discloses a "*method*." (DJI-1003, ¶121.)

2. "*Sensing*" Limitation [11A].

Claim 11 recites "*sensing a directional movement of an aircraft*" [11A]. Aside from the recitation in claim 11, the '505 patent uses the term "*directional movement*" only twice. First, in the discussion of Figure 2 (excerpt below), the '505 patent states "[s]tep 2 shows aircraft 201 traveling in forward flight while the fuselage faces 90 degrees relative to the **directional movement**." (DJI-1001, 3:41-43.) In this citation, the '505 patent equates "directional movement" to the direction in which the aircraft's center of mass is moving. (DJI-1003, ¶122.)

Second, in the abstract, the '505 patent describes a model that “decouples the **directional movement** of the aircraft into a **lateral** equation of motion and a **longitudinal** equation of motion.” (DJI-1001, Abstract.) The abstract then specifies that “lateral control architecture utilizes the **lateral equation of motion to control the aircraft in the lateral direction**, while the longitudinal control architecture utilizes the **longitudinal equation of motion to control the aircraft in the longitudinal direction.**” (DJI-1001, Abstract.) The second use of the term “directional movement” therefore encompasses lateral and longitudinal movement. (DJI-1003, ¶122.) The '505 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 including lateral, longitudinal, vertical, or yaw. (DJI-1003, ¶122.)

Step 2: Pedal Turn



'505 Patent, Excerpt from Figure 2

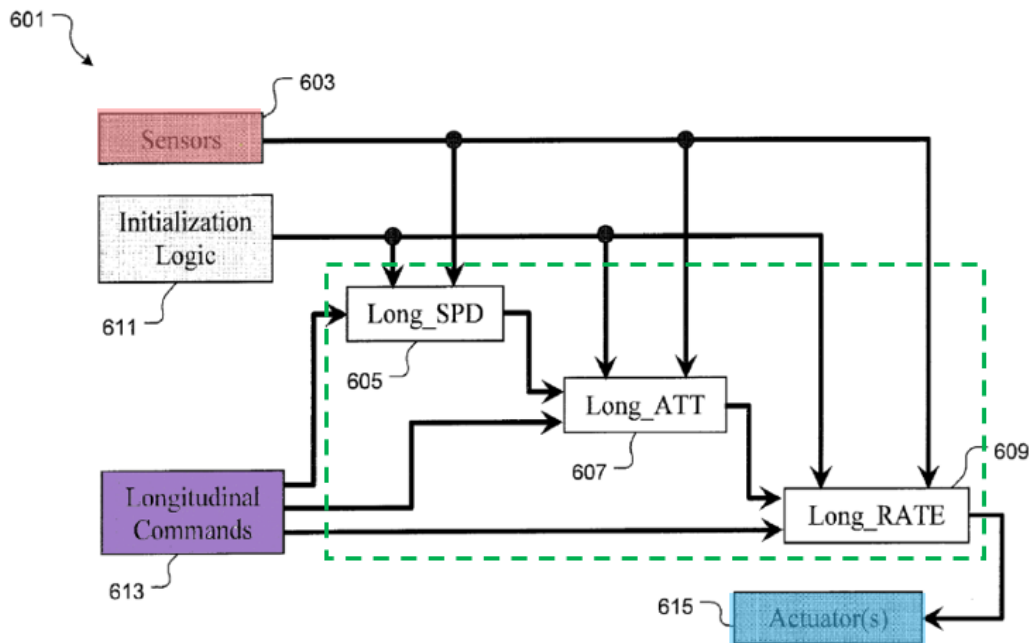
Gold discloses “*sensing a directional movement of an aircraft*” [11A]. (DJI-1003, ¶¶122-124.) The PFCS, AFCS, and VCS of flight control system 21 receive

“sensed parameter signals from sensors 31 [shaded red in annotated Figure 3 below] on lines 32.” (DJI-1005, 3:10-13. 3:39-41.) These sensed parameter signals provide “the PFCS and AFCS with the aircraft’s angular rate and attitude response to the main rotor and tail rotor command signals.” (DJI-1005, 3:32-35.) The sensors further provide “information related to velocity, altitude, acceleration, etc.” (DJI-1005, 3:35-36.) For example, the longitudinal groundspeed and the lateral groundspeed are both provided to the VCS from the sensors. (DJI-1005, 5:23-26; *see also*, Gold, Figure 4.) By sensing angular rate, velocity (including speed), altitude, and acceleration, Gold discloses “*sensing a directional movement [yaw, lateral, longitudinal, vertical movement] of an aircraft*” [11A]. (DJI-1003, ¶¶122-124; *see also*, DJI-1003, ¶¶32-36; DJI-1006, 4:48-53 (incorporated by reference by Gold (DJI-1005, 4:38-43).)

3. “*Determining*” Limitation [11B].

Claim 11 further recites “*determining lateral and longitudinal movements of the aircraft*” [11B]. The ’505 patent does not explicitly disclose or discuss the determination of lateral and longitudinal movements of the aircraft. However, a POSITA would have understood that “*determining lateral and longitudinal movements*” encompasses determining, in the control system, the necessary lateral and longitudinal movements to drive the aircraft to a commanded position. (DJI-1003, ¶125.)

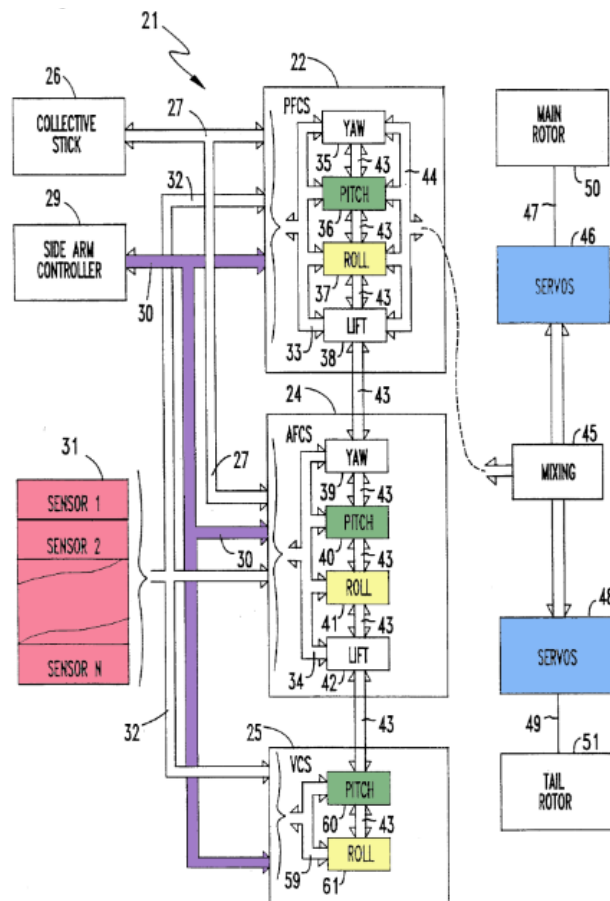
As shown below in an annotated version of Figure 6 of the '505 patent, the flight control system obtains data from one or more sensors (shaded red), compares commands (shaded purple) with the observed sensor data, and determines the signal(s) necessary to drive the lateral and longitudinal movements of the aircraft to the commanded (desired) state of the aircraft. A POSITA would however have understood that the control system of the '505 patent (like any flight control system) uses its control logic (laws) to determine the lateral and longitudinal movements of the aircraft needed to transition from its present state to the desired (commanded) state. (*See* §IV.A.3; DJI-1003, ¶126.) As shown below, in the '505 patent, inputs to the control laws of each control architecture are (1) a command signal from the pilot's controller (e.g., "the difference between the controller's present position and the centered, no force position" (the 'detent' position)) and (2) data fed back from sensors 603 to the control architecture. (DJI-1001, 5:22-25; *see, e.g.,* annotated Figure 6 below.) The control laws process the inputs "to generate the appropriate aircraft response commands." (DJI-1001, 5:27-29.) The control system's outputs (commands) "are routed to an actuator 615 for each dynamic axis." (DJI-1001, 5:33-38.) The actuator commands move the control surfaces of the aircraft (e.g., the lateral and longitudinal angle of the main rotor swashplate) which in turn induces movement (e.g., lateral and/or longitudinal) of the aircraft. (*see, e.g.,* DJI-1001, 5:33-38; DJI-1003, ¶126.)



'505 Patent, Annotated Figure 6

Gold operates in the same manner as described in the '505 patent to determine aircraft motion. (DJI-1003, ¶127.) Gold's flight control system, shown below in an annotated version of Figure 3, obtains data from one or more sensors (shaded red), compares the command (shaded purple) with the sensed (actual) data, and determines the command(s) to send to the actuators to achieve the lateral and longitudinal movements needed to transition the aircraft from its present state to its desired state. (DJI-1003, ¶127.) For example, Gold's PFCS, AFCS, and VCS "each receive the force output command signals of a four-axis sidearm controller 29 on lines 30 and sensed parameter signals from sensors 31 on lines 32." (DJI-1005, 3:10-13, 3:40-42.) Gold's PFCS and AFCS "use a model following algorithm in each control axis to provide rotor command signals on output lines 44 to a rotor

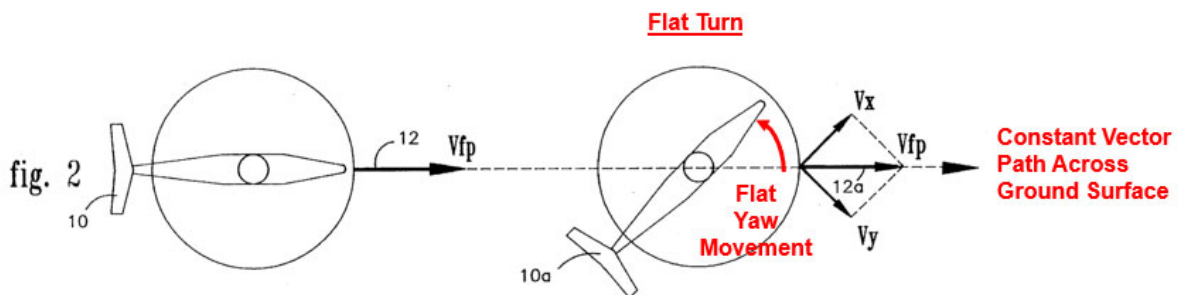
mixing function 45 which commands displacement of mechanical servos 46 and linkages 47 to control the tip path plane of a main rotor.” (DJI-1005, 3:25-29.) The displacement of the main rotor achieves the necessary lateral and/or longitudinal movement of the aircraft. (DJI-1003, ¶127.) Gold therefore teaches “*determining lateral and longitudinal movements of the aircraft*” [11B] in the same manner as the ’505 patent. (DJI-1003, ¶127.)



Gold, Annotated Figure 3

4. “*Selectively Controlling*” Limitation [11C].

Gold discloses “*selectively controlling flat yaw movement of the aircraft while maintaining a constant vector flat turn relative to a ground surface*” [11C]. (DJI-1003, ¶¶128-131.) As discussed in §V.B.3, Gold discloses “*control[ing] yaw movement of the aircraft while the aircraft maintains a constant vector heading across a ground surface*” [1C]. The yaw movement controlled by Gold and illustrated in annotated Figure 2 is a “*flat yaw movement*” (bank angle is zero) which results in a “*flat turn*” because during the movement the aircraft rotates about its vertical axis (turning the nose of the aircraft) 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, ¶128.)



Gold, Annotated Figure 2

The specification of the '505 patent does not describe the recited “*selectively controlling flat yaw movement of the aircraft while maintaining a constant vector flat turn relative to a ground surface.*” At most, the '505 patent discloses that a pedal input by the pilot initiates and controls yaw movement. (See, e.g., DJI-1001,

4:7-15.) Regarding maintenance of the constant vector path, the '505 patent discloses that “the control laws will automatically adjust pitch and roll attitude to keep the aircraft moving in the same direction at a constant speed whenever the pilot inputs a directional command at low speed.” (DJI-1001, 2:52-55.)

Gold discloses this limitation in the same manner as the '505 patent. (DJI-1003, ¶¶130-131.) In response to a yaw command by a pilot during operation in Gold's velocity stabilization mode, the aircraft “yaws while maintaining a constant flight path reference velocity 12a with respect to an inertial frame of reference.” (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, as discussed in §§V.B.2-3. Thus, like the '505 patent, the pilot selectively initiates a yaw maneuver using the controller and in response to these selections, Gold's flight control system automatically “*control[s] flat yaw movement of the aircraft while maintaining a constant vector flat turn relative to a ground surface.*” (DJI-1003, ¶¶129-130.)

Accordingly, Gold discloses “*selectively controlling flat yaw movement of the aircraft while maintaining a constant vector flat turn relative to a ground surface*” [11C]. (DJI-1003, ¶¶128-131.)

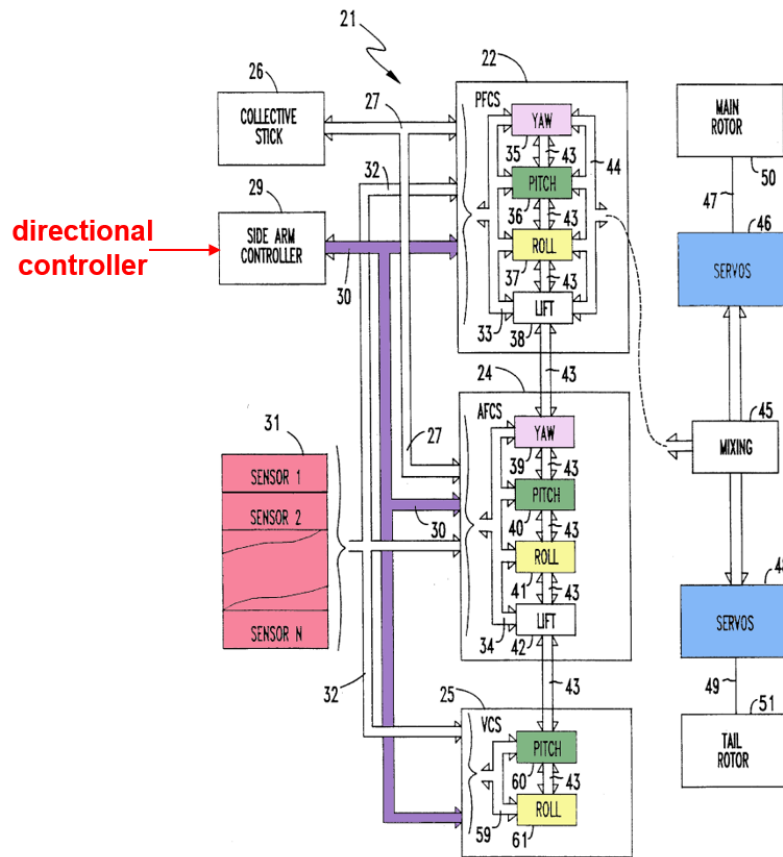
5. “Continuously Moves” [11D].

Limitation [11D] is identical to limitation [1D]. For the same reasons discussed in §V.B.4, Gold discloses “*wherein the aircraft continuously moves in a yaw direction while maintaining the constant vector heading*” [11D]. (DJI-1003, ¶¶132, 118-119.)

D. Dependent Claims

1. “Directional Controller” (Claims 2 and 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 from sidearm controller 29 are provided to flight control system 21, as illustrated in Figure 3 below. (DJI-1005, 3:10-12.) Because Gold’s sidearm controller controls yaw movements, the sidearm controller is a “*directional controller*.” (DJI-1003, ¶135; *see also*, DJI-1001, 4:32-40 (acknowledging a single device controlling multiple axes is a directional controller).) Gold therefore discloses “*the control system is operably associated with a directional controller manually manipulated by a pilot*” [2]. (DJI-1003, ¶¶134-137.)



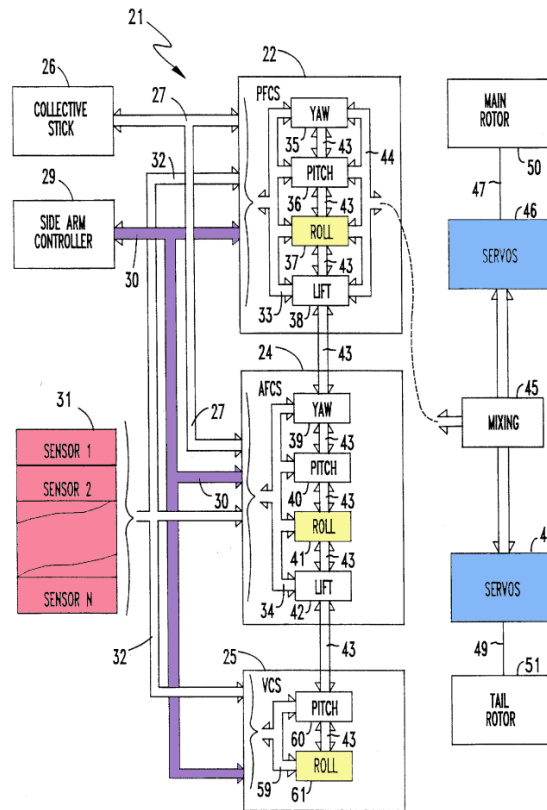
Gold, Annotated Figure 3

In response to a yaw command made by the pilot during operation in velocity stabilization mode, the aircraft “yaws while maintaining a constant flight path reference velocity 12a with respect to an inertial frame of reference.” (DJI-1005, 2:60-64.) Gold’s Figure 2 shows “the response of a vehicle to a pilot yaw command during operation in a velocity stabilization mode.” (DJI-1005, 2:34-36.) The result of this yaw command is a “*flat yaw movement*.” (See §V.C.4 (describing “flat yaw movement”); DJI-1003, ¶128.) Thus, Gold further discloses “*commanding the flat yaw movement with a directional controller manipulated by*

a pilot controlling the aircraft” [12]. (DJI-1003, ¶¶138-140, *see also*, DJI-1003, ¶¶128-130.)

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

Gold’s “lateral control architecture”, having 3 roll control modules (shaded yellow in annotated Figure 3 below), includes “a lateral sideward groundspeed control loop” [5A]/[15A], “a lateral roll attitude control loop” [5B]/[15B] and “a lateral roll rate control loop” [5C]/[15C]. (DJI-1003, ¶¶141-153.)



Gold, Annotated Figure 3

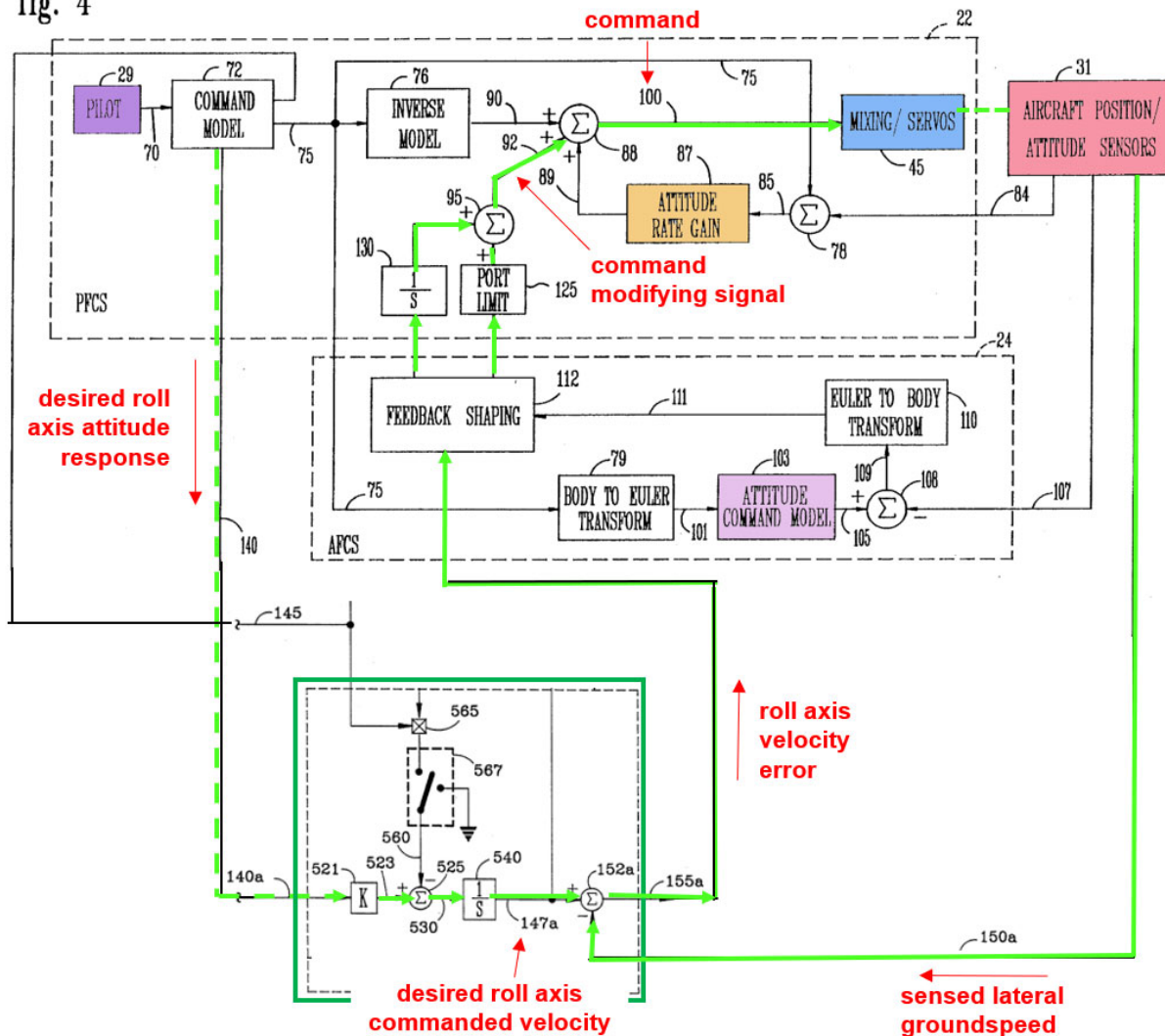
a. “Lateral Sideward Groundspeed Control Loop” [5A]/[15A].

Gold discloses a “lateral sideward groundspeed control loop” [5A]/[15A]. (DJI-1003, ¶¶143-146.) When Gold’s system operates in velocity stabilization

mode, the roll (lateral) control module 61 of the VCS generates VCS roll velocity error signals using actual lateral groundspeed data fed back to the roll (lateral) control modules from the sensors. These roll velocity error signals are provided through the AFCS roll control module and PFCS roll control module “to drive the error signals to zero.” (DJI-1005, 3:50-52.) This control loop, illustrated in Singhose Figure A⁴ below, is highlighted by green lines.

⁴ Singhose Figure A combines and annotates Gold’s Figure 4 illustrating interconnection of VCS 25, PFCS 22 and AFCS 24 with excerpts from Gold’s Figure 5 providing details of the roll (lateral) axis component of the VCS. (DJI-1003, ¶188; DJI-1005, 3:54-61 (Figure 4 “is equally applicable” to roll (lateral) axis control modules).)

fig. 4



Singhose Figure A

Specifically, command module 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, ¶145.) The desired roll (lateral) 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, ¶145.) 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, ¶145.)

The roll axis velocity error signal is provided to AFCS roll control module 41 on line 155a and subsequently to PFCS roll control module 37 after shaping. (See DJI-1005, 5:37-42; DJI-1003, ¶¶145-146.) 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, ¶146.) The control command from inverse model 76, representing the approximate rotor command necessary to achieve the desired response, is modified in summing junction 88 of the PFCS by the command modifying signal. (See DJI-1005, 4:9-11; DJI-1003, ¶146.) 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, ¶146.) 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, ¶146.) The above loop therefore controls the lateral (sideward) component of the velocity. (DJI-1003, ¶146.)

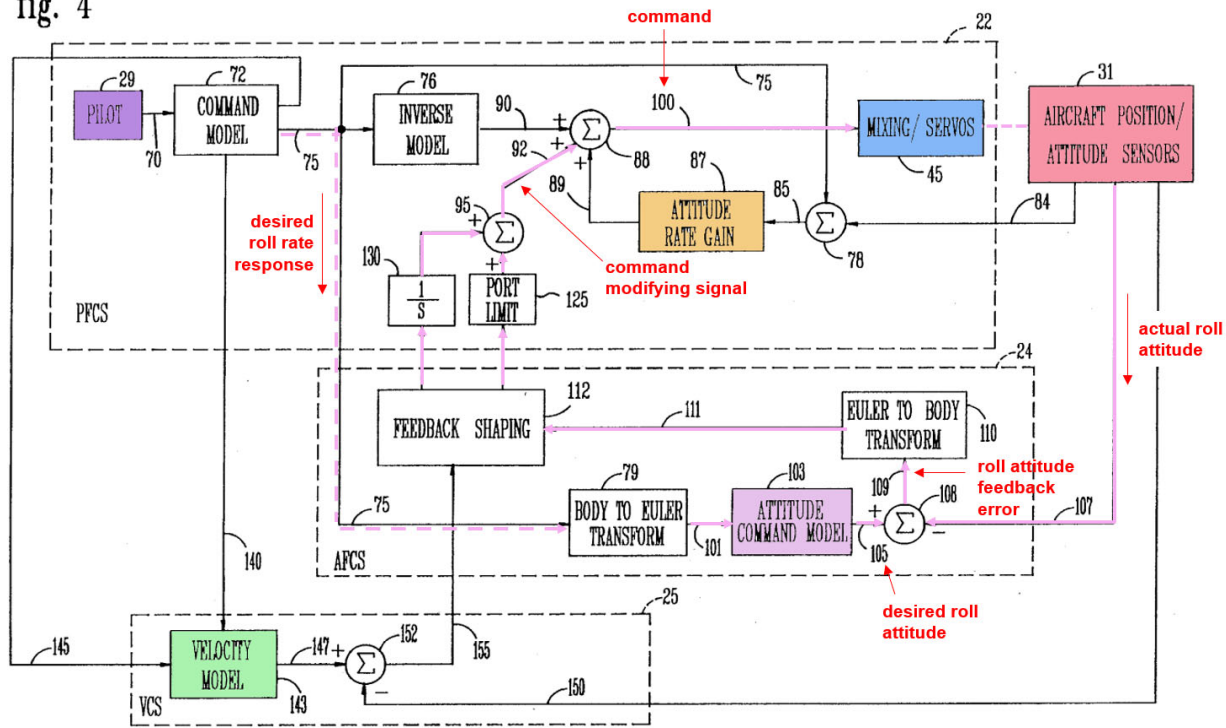
Gold’s “*lateral control architecture*” therefore includes a “*lateral sideward groundspeed control loop*” [5A]/[15A]. (DJI-1003, ¶¶143-146.)

The roll (lateral) axis velocity error determined in the VCS roll control module is “*lateral motion data.*” (DJI-1003, ¶147.) As discussed above, the roll (lateral) axis velocity error is provided to the AFCS on line 155a and is subsequently provided to the PFCS through the lateral sideward groundspeed control loop (indicated by bright green lines in Singhose Figure A above). Thus, Gold discloses “*communicating lateral motion data through a lateral sideward groundspeed control loop*” [15A]. (DJI-1003, ¶147.)

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 (Figure 4 “equally applicable” to roll control); DJI-1003, ¶¶148-149.) When a pilot applies a left or right force to the sidearm controller, the resulting roll (lateral) 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 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, ¶148.) 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, ¶148.)

fig. 4



Gold, Annotated Figure 4

After transformation and feedback shaping, the roll attitude feedback error signal is provided to the PFCS roll (lateral) control module. (See, e.g., DJI-1005, 5:1-6; DJI-1003, ¶149.) The PFCS roll control module, in turn, generates a command modifying signal using the shaped roll attitude feedback error signal. (See DJI-1005, 4:27-28; DJI-1003, ¶149.) The control command from inverse model 76, representing the approximate rotor command necessary to achieve the desired response, is modified in summing junction 88 of the PFCS by the command modifying signal. (See DJI-1005, 4:9-11; DJI-1003, ¶149.) 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, ¶149.) Sensors

31 feed the aircraft's actual response to these rotor commands back to the roll (lateral) control modules and the processing loop continues. (See DJI-1005, 3:32-35; DJI-1003, ¶149.)

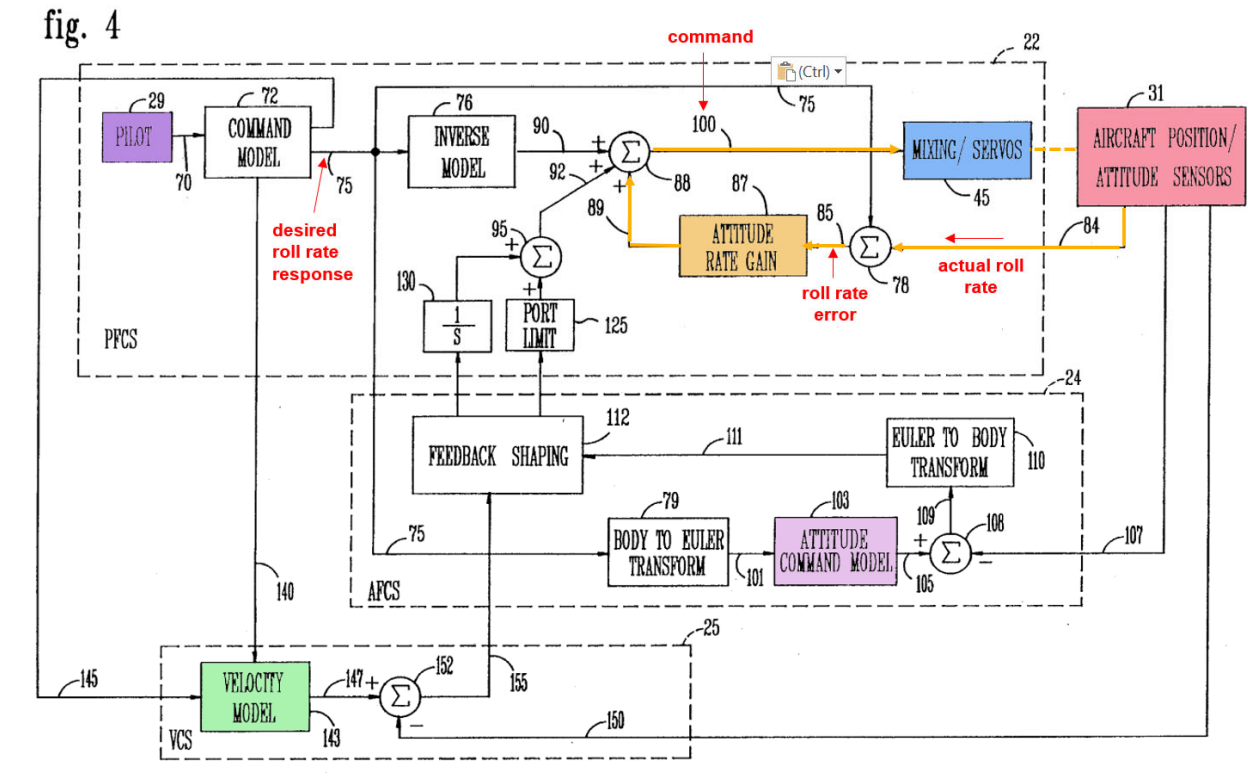
Gold's "*lateral control architecture*" includes a "*lateral roll attitude control loop*" [5B]/[15B]. (DJI-1003, ¶¶148-149.)

The roll (lateral) attitude feedback error is also "*lateral motion data.*" (DJI-1003, ¶150.) The roll (lateral) attitude feedback error is communicated from the AFCS roll (lateral) control module to the PFCS roll (lateral) control module through the roll attitude control loop (indicated by pink lines in annotated Figure 4 above). 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 (Figure 4 "equally applicable" to roll control); DJI-1003, ¶¶151-152.) 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

U.S. Patent 8,682,505
IPR2023-01104



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, ¶152.) The control 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, ¶152.) 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, ¶152.) 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, ¶152.)

Gold’s “*lateral control architecture*” includes a “*lateral roll rate control loop*” [5C]/[15C]. (DJI-1003, ¶¶151-152.)

The roll (lateral) rate error is “*lateral motion data*.” (DJI-1003, ¶153.) The roll (lateral) rate error is provided through the rate control loop (indicated by orange lines in annotated Figure 4 above) 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]. (DJI-1003, ¶153.)

3. “*Lateral Controller*” (Claims 6 and 16)

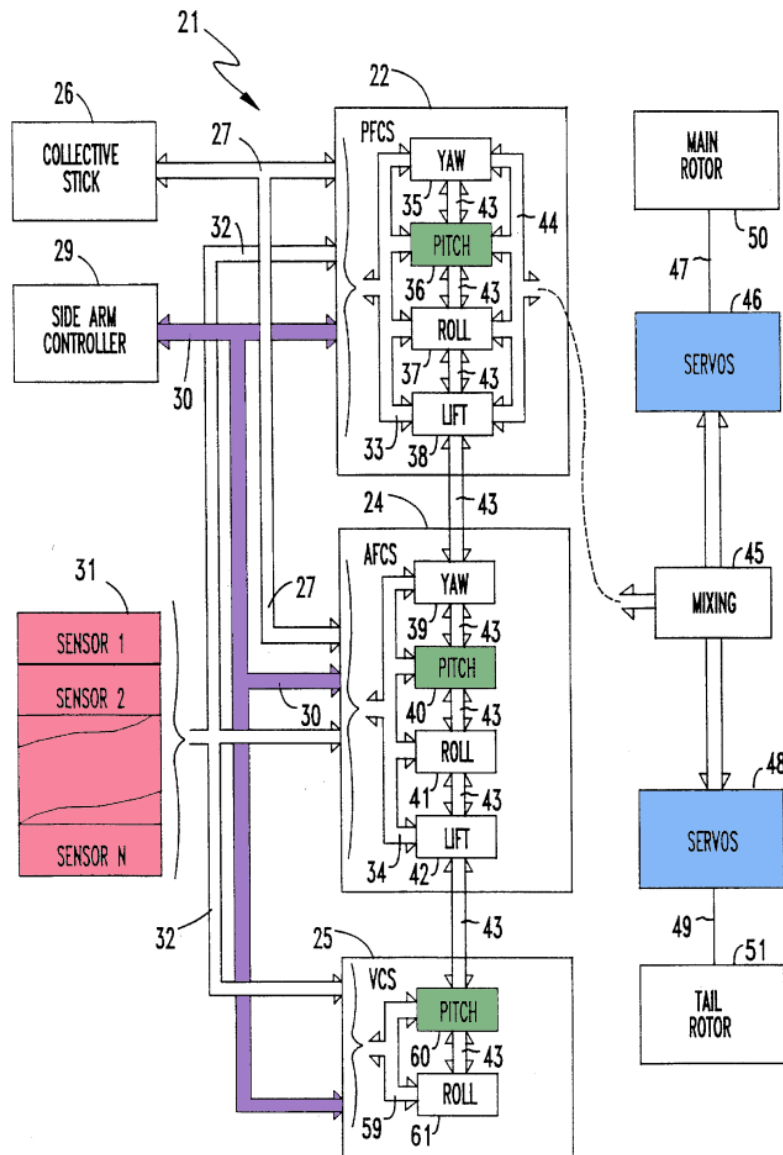
In Gold, “the pilot applying a left or right force to the sidearm controller” generates **roll (lateral) command** signals. (DJI-1005, 3:64-4:4.) The generated roll (lateral) axis command signals from sidearm controller 29 are provided to flight control system 21, as illustrated in Figure 3. (DJI-1005, 3:10-12.) Because it controls roll axis (lateral) 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, ¶155; see also, DJI-1001, 4:32-40 (acknowledging a single device controlling multiple axes is a lateral controller).)

The PFCS and AFCS of the flight control system each contain control modules for controlling the roll (lateral) axis of the aircraft. (DJI-1005, 3:17-18.) The command module 72 associated with the roll (lateral) 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.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, ¶156.)

In response to a roll (lateral) command from the pilot, the roll (lateral) control module generates and “provide[s] rotor command signals” to “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.) Tilting the tip path plane of the main rotor sideways induces lateral movement. (DJI-1003, ¶¶157, 45; §IV.A.1.) Thus, Gold discloses “*controlling lateral movement with a lateral controller manipulated by a pilot controlling the aircraft*” [16]. (DJI-1003, ¶157.)

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

Gold’s “*longitudinal control architecture*”, having 3 pitch control modules (shaded green in annotated Figure 3 below), includes “*a longitudinal forward speed control loop*” [8A]/[18A], “*a longitudinal pitch angle control loop*” [8B]/[18B] and “*a longitudinal pitch rate control loop*” [8C]/[18C]. (DJI-1003, ¶¶159-171.)



Gold, Annotated Figure 3

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

Gold discloses a “longitudinal forward speed control loop” [8A]/[18A]. (DJI-1003, ¶¶161-165.) When Gold’s system operates in velocity stabilization mode, the VCS pitch (longitudinal) control module 60 generates pitch velocity error signals using actual longitudinal groundspeed data fed back to the pitch

(longitudinal) control modules from the sensors. These pitch velocity error signals are provided through the AFCS pitch control module and PFCS pitch control module “to drive the error signals to zero.” (DJI-1005, 3:50-52.) This control loop, illustrated in Singhose Figure B⁵ below, is highlighted by green lines.

⁵ 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, ¶162.)

The diagram illustrates a flight control system architecture, divided into three main functional blocks: PFCS (Pilot/Flight Control System), AFCS (Automatic Flight Control System), and a detailed actuator model.

- PFCS (Pilot/Flight Control System):**
 - Input: **PILOT** (29) provides a **command** (70) to the **COMMAND MODEL** (72).
 - Output: The **COMMAND MODEL** (72) outputs a **command** (75) to the **INVERSE MODEL** (76).
- AFCS (Automatic Flight Control System):**
 - INVERSE MODEL** (76) outputs a **command** (90) to a summing junction (88).
 - ATTITUDE RATE GAIN** (85) receives a **command modifying signal** (89) and outputs a signal (87) to the same summing junction (88).
 - The summing junction (88) outputs a **command** (100) to the **MIXING/ SERVO** (45).
 - MIXING/ SERVO** (45) outputs a **command** (84) to the **AIRCRAFT POSITION/ ATTITUDE SENSORS** (31).
 - AIRCRAFT POSITION/ ATTITUDE SENSORS** (31) outputs a **sensed longitudinal groundspeed** (107) to the **FEEDBACK SHAPING** (112) block.
 - FEEDBACK SHAPING** (112) outputs a **desired pitch axis attitude response** (140) to the **PORT LIMIT** (125) and the **ATTITUDE COMMAND MODEL** (103).
 - PORT LIMIT** (125) outputs a **desired pitch axis attitude response** (130) to the **INVERSE MODEL** (76).
 - ATTITUDE COMMAND MODEL** (103) outputs a **desired pitch axis attitude response** (109) to a summing junction (108).
 - ATTITUDE RATE GAIN** (85) also receives a **desired pitch axis attitude response** (109) from the summing junction (108) and outputs a **desired pitch axis attitude response** (87) to the summing junction (88).
 - ATTITUDE RATE GAIN** (85) also receives a **desired pitch axis attitude response** (109) from the summing junction (108) and outputs a **desired pitch axis attitude response** (87) to the summing junction (88).
 - ATTITUDE RATE GAIN** (85) also receives a **desired pitch axis attitude response** (109) from the summing junction (108) and outputs a **desired pitch axis attitude response** (87) to the summing junction (88).
- Actuator Model (Detailed View):**
 - Input: **desired pitch axis attitude response** (140) is fed into a gain block (501) and a summing junction (503).
 - Summing junction (503) also receives a **desired pitch axis attitude response** (147) from the **PORT LIMIT** (125) and outputs a **desired pitch axis attitude response** (505) to a summing junction (520).
 - Summing junction (520) also receives a **desired pitch axis attitude response** (147) from the **PORT LIMIT** (125) and outputs a **desired pitch axis attitude response** (520) to a summing junction (510).
 - Summing junction (510) also receives a **desired pitch axis attitude response** (147) from the **PORT LIMIT** (125) and outputs a **desired pitch axis attitude response** (510) to a summing junction (550).
 - Summing junction (550) also receives a **desired pitch axis attitude response** (147) from the **PORT LIMIT** (125) and outputs a **desired pitch axis attitude response** (550) to a summing junction (557).
 - Summing junction (557) also receives a **desired pitch axis attitude response** (147) from the **PORT LIMIT** (125) and outputs a **desired pitch axis attitude response** (557) to a summing junction (555).
 - Summing junction (555) also receives a **desired pitch axis attitude response** (147) from the **PORT LIMIT** (125) and outputs a **desired pitch axis attitude response** (555) to a summing junction (550).

Singhose, Figure B

Specifically, command module 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, ¶163.) 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, ¶163.) 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, ¶163.)

After shaping, the pitch axis velocity error signal is provided to PFCS pitch (longitudinal) control. (DJI-1005, 5:37-42; DJI-1003, ¶164.) PFCS pitch control module, in turn, generates a command modifying signal using the shaped velocity error signal. (DJI-1005, 4:27-28; DJI-1003, ¶164.) The control command from inverse model 76, representing the approximate rotor command necessary to achieve the desired response, is modified in summing junction 88 of the PFCS by the command modifying signal. (DJI-1005, 4:9-11; DJI-1003, ¶164.) 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, ¶164.) 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, ¶164.) This loop controls the longitudinal (forward) component of the velocity. (DJI-1003, ¶164.)

Gold’s “*longitudinal control architecture*” therefore includes a “*longitudinal forward speed control loop*” [8A]/[18A]. (DJI-1003, ¶¶161-164.)

The pitch (longitudinal) axis velocity error determined in the VCS pitch control module is “*longitudinal motion data*.” (DJI-1003, ¶165.) As discussed above, the pitch (longitudinal) axis velocity error is provided to the AFCS on line

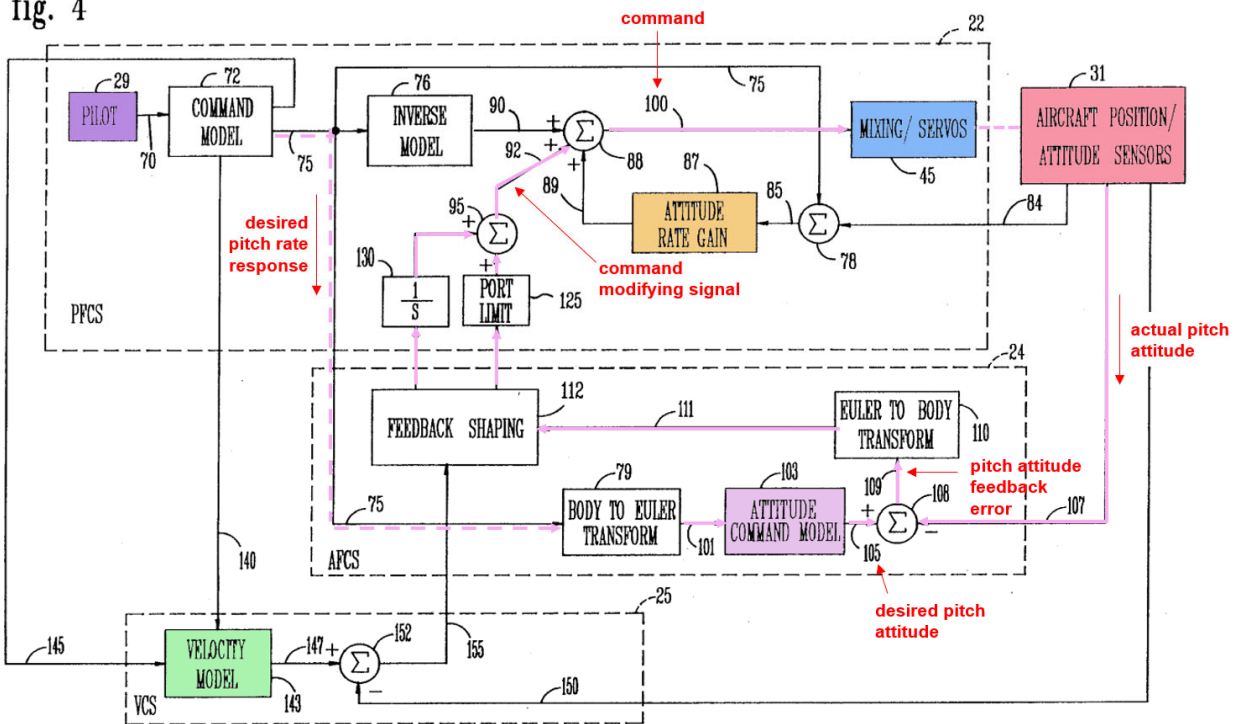
155 and is subsequently provided to the PFCS (after shaping) through the longitudinal forward speed control loop (indicated by bright green lines in Singhose Figure B above). Thus, Gold discloses “*communicating longitudinal motion data through a longitudinal forward speed control loop*” [18A]. (DJI-1003, ¶165.)

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

Gold discloses “*a longitudinal pitch angle⁶ control loop*” [8B]/[18B], highlighted by pink in annotated Figure 4 below. (DJI-1003, ¶¶166-168.) 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 (longitudinal) control module. After transformation, the desired pitch rate response is integrated to obtain the desired roll attitude. (DJI-1005, 4:50-54; DJI-1003, ¶166.) 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, ¶166.)

⁶ Pitch angle is the pitch attitude. (See, e.g., DJI-1001, 5:9-10 (“a longitudinal control law for pitch angle, represented as block 607 ‘Long_ATT’”))

fig. 4



Gold, Annotated Figure 4

After transformation and feedback shaping, the pitch attitude feedback error signal is provided to the PFCS pitch (longitudinal) control module. (See, e.g., DJI-1005, 5:1-6; DJI-1003, ¶167.) PFCS pitch (longitudinal) control module, in turn, generates a command modifying signal using the pitch attitude feedback error signal. (See DJI-1005, 4:27-28; DJI-1003, ¶167.) The control command from inverse model 76, representing the approximate rotor command necessary to achieve the desired response, is modified in summing junction 88 of the PFCS by the command modifying signal. (See DJI-1005, 4:9-11; DJI-1003, ¶167.) 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, ¶167.) 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, ¶167.)

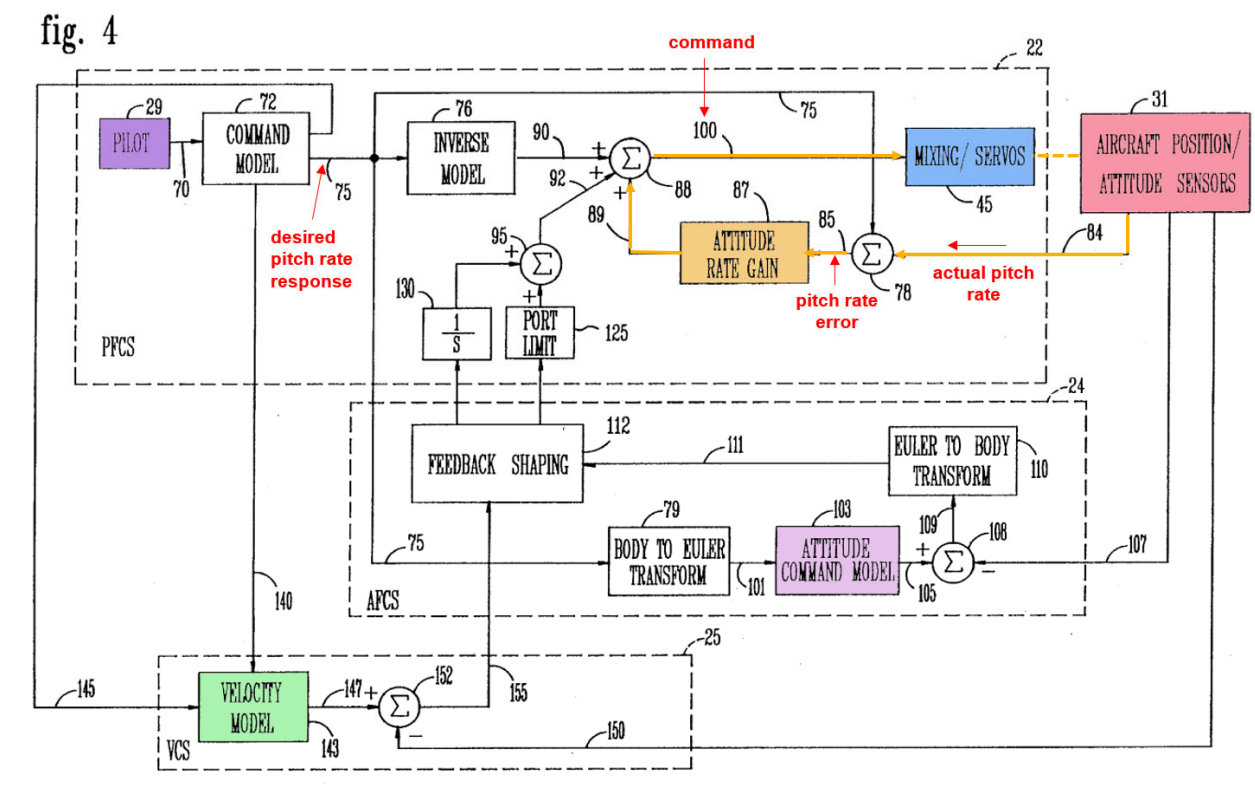
Gold's "*longitudinal control architecture*" therefore includes a "*longitudinal pitch angle control loop*" [8B]/[18B]. (DJI-1003, ¶¶166-167.)

The pitch (longitudinal) attitude feedback error is also "*longitudinal motion data*." (DJI-1003, ¶168.) The pitch (longitudinal) attitude feedback error is communicated from AFCS pitch (longitudinal) control module to PFCS pitch (longitudinal) control module through the pitch angle control loop (indicated by pink lines in annotated Figure 4 above). 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, ¶¶169-170.) 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, ¶170.) 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, ¶170.) The resulting command is provided to mixing function 45 which commands displacement of mechanical servos and linkages. (DJI-1005, 3:25-29; DJI-1003, ¶170.) 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, ¶170.)

Gold's "*longitudinal control architecture*" therefore includes a "*longitudinal pitch rate control loop*" [8C]/[18C]. (DJI-1003, ¶¶169-170.)

The pitch (longitudinal) rate error is also "*longitudinal motion data.*" (DJI-1003, ¶171.) The pitch (longitudinal) 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, ¶171.)

5. "*Longitudinal Controller*" (Claims 9 and 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, ¶173; *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 module 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, ¶174.) 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, ¶174.)

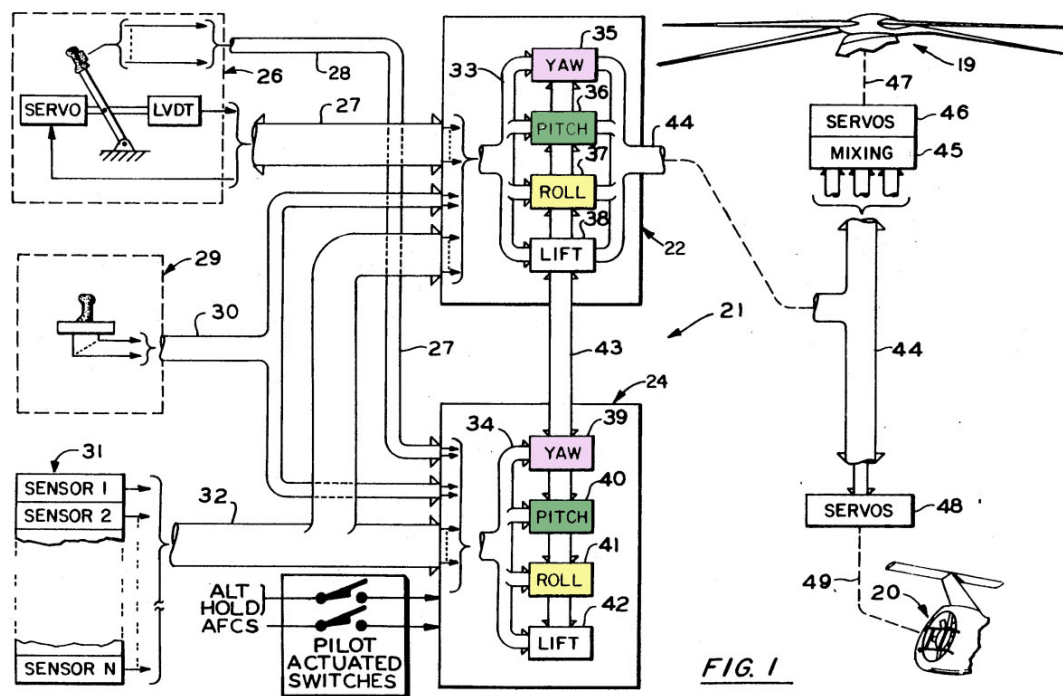
In response to a longitudinal command from the pilot, the pitch (longitudinal) control module generates and “provide[s] rotor command signals” to “a rotor mixing function 45 which commands displacement of mechanical servos 46 and linkages 47 to control the tip path plane of a main rotor 50.” (DJI-1005, 3:25-29; *see also*, §175.) Tilting the tip path plane of the main rotor forward or aft induces longitudinal movement. (DJI-1003, ¶175; *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, ¶175.)

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

A. Combination Overview

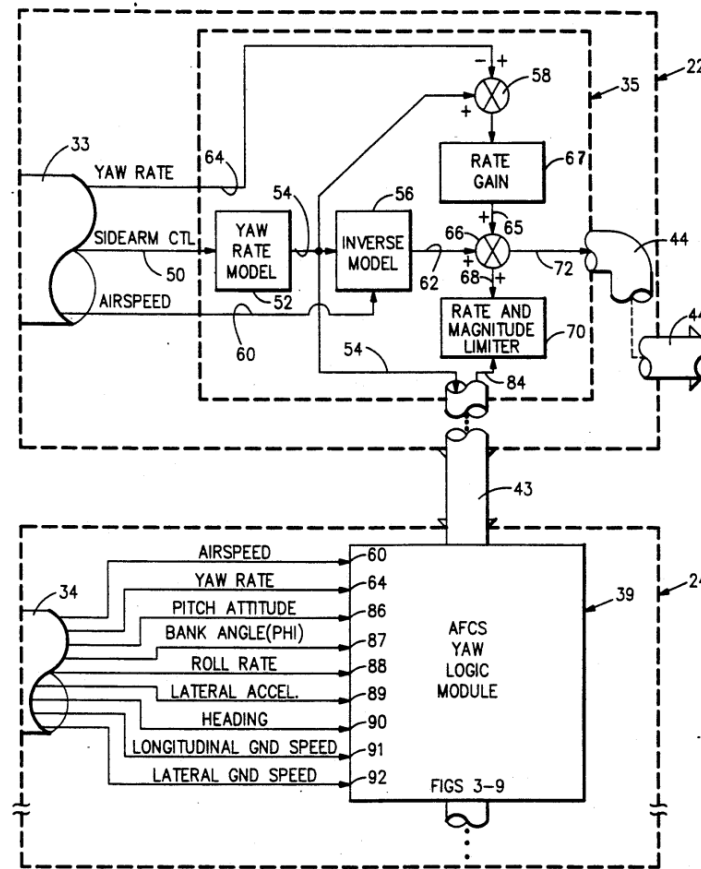
1. Skonieczny

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.)



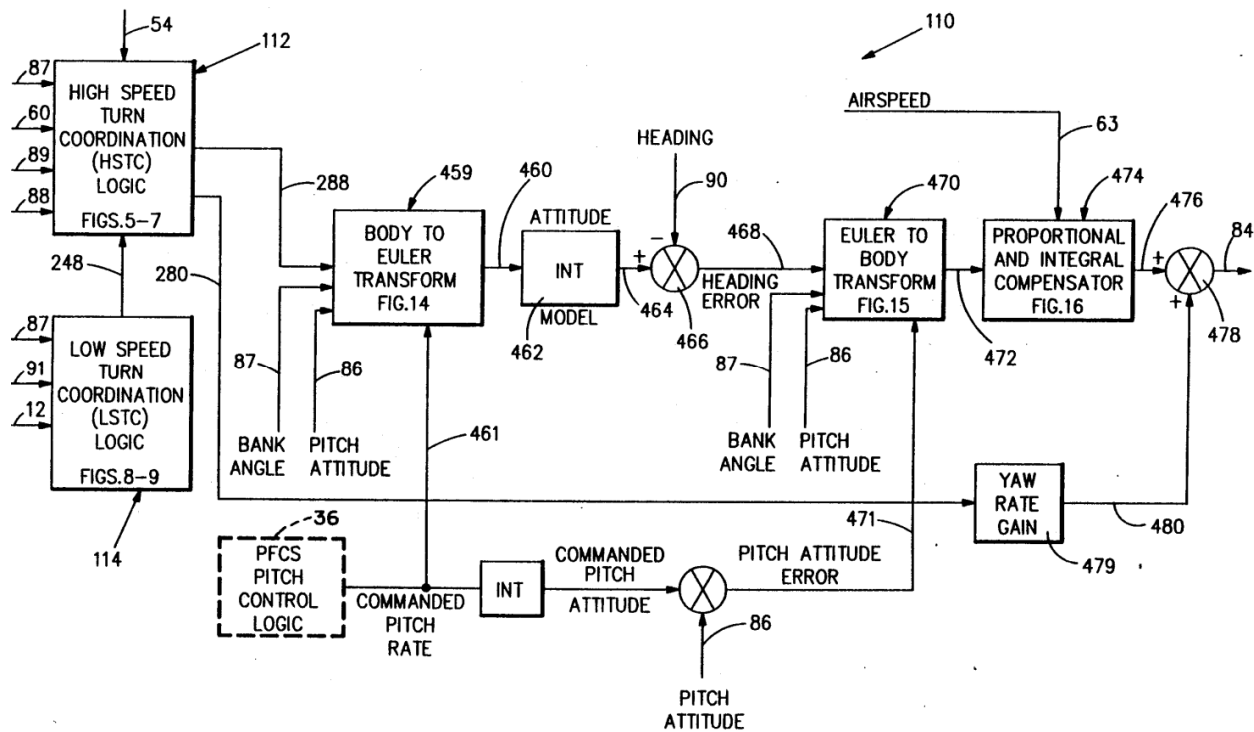
Skonieczny, Annotated Figure 1

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



Skonieczny, Figure 2

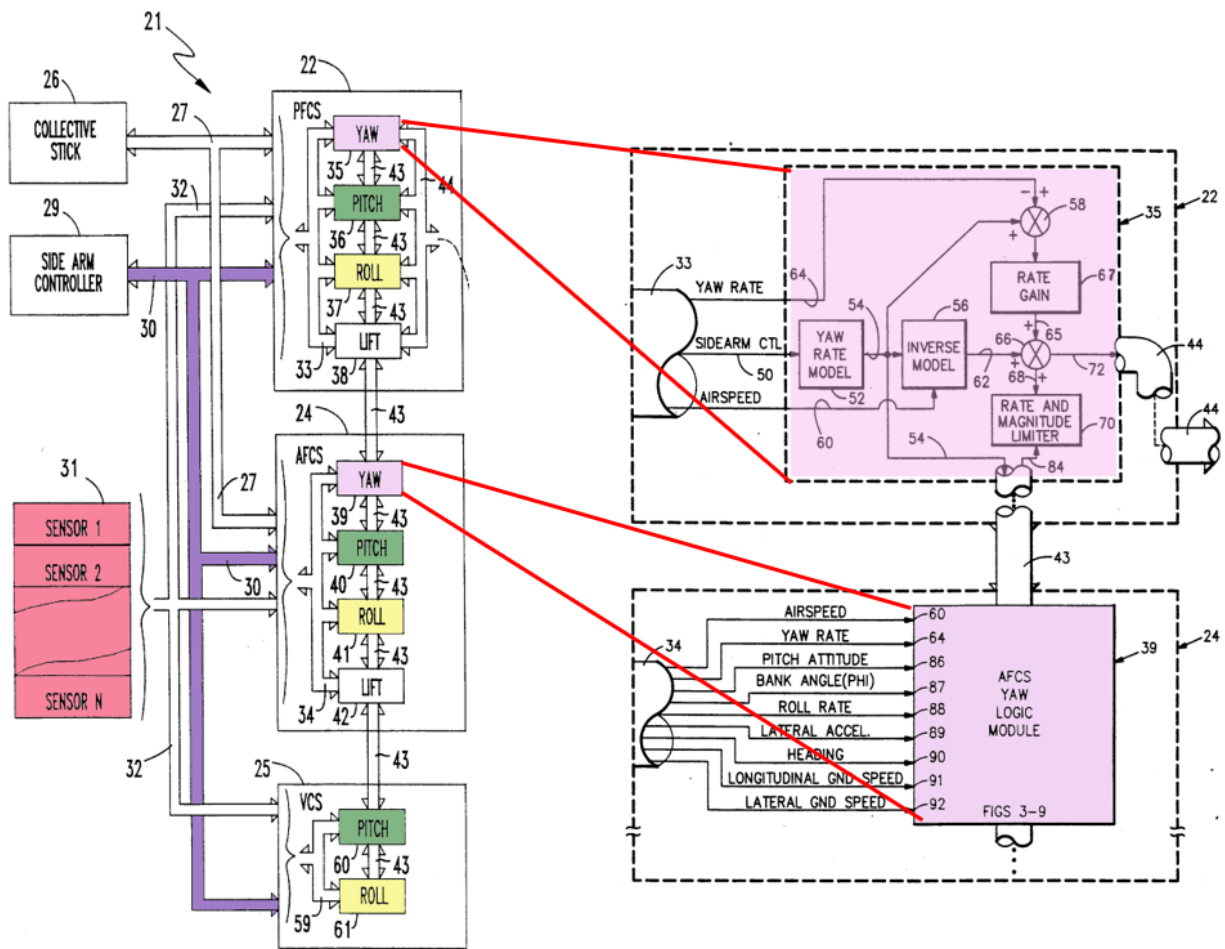
Skonieczny's AFCS yaw logic 110 (labeled 39 in Figure 2 above) is illustrated in further detail in Figure 4 (reproduced below). The control logic is executed on a microprocessor of the AFCS. (*See, e.g.,* DJI-1006, 5:16-18; Figure 3.) The yaw logic includes high speed turn coordination (HTSC) logic 112 and low speed turn coordination (LTSC) logic 114. HSTC logic 112 “condition[s] pilot commanded yaw inputs via the sidearm controller at speeds above 60 knots.” (DJI-1006, 5:24-26.) In contrast, LSTC logic “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, 9:55-58.)



Skonieczny, Figure 4

2. Motivation to Combine

A POSITA would have been motivated to Skonieczny's yaw module teachings with Gold's flight control system, as illustrated in the below figure. (DJI-1003, ¶¶182-186.)



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 (“The operation of both Transform functions 79, 110 are described in greater detail in the aforementioned commonly owned U.S.

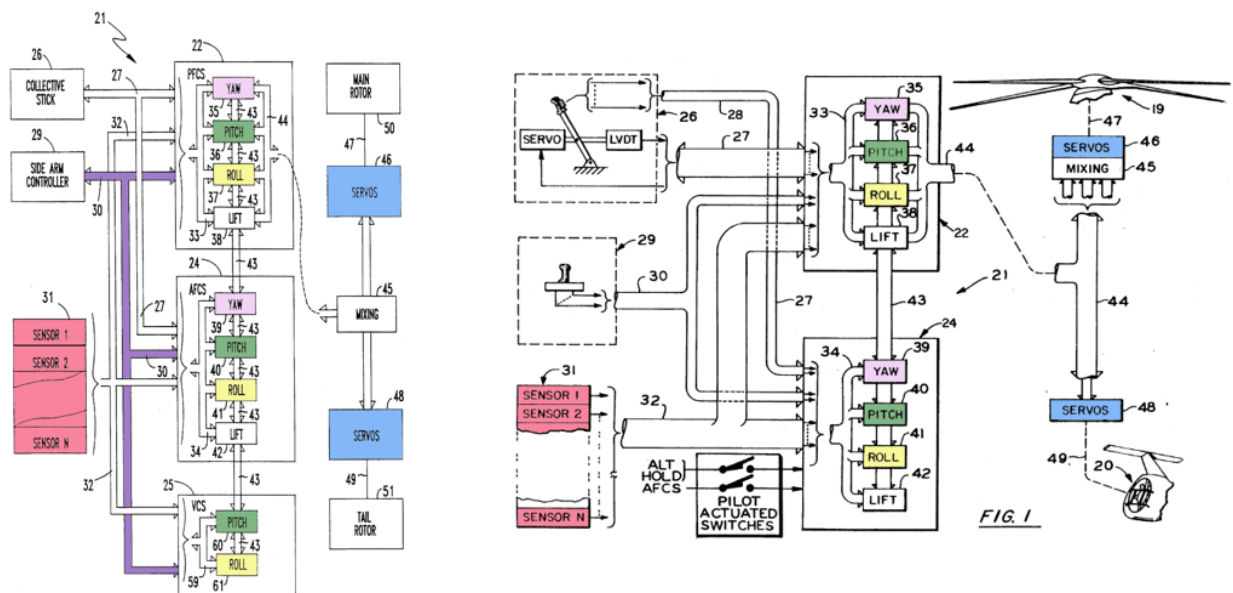
Pat. No. 5,238,203, the disclosure of which is incorporated herein by reference”); DJI-1003, ¶183.)

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 any disclosure of automatic turn coordination logic. Based on this suggestion, a POSITA would have been motivated to combine Gold with Skonieczny which discloses 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, ¶184.) Skonieczny and Gold are in the same field of endeavor as the ’505 patent—control systems for aircraft—and are therefore analogous art. (DJI-1003, ¶184.)

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, ¶185.) As discussed above, Gold explicitly directs a reader to

Skonieczny for further details and Skonieczny's inventor list includes the same inventors as Gold (Gold, Fogler, and Dryfoos).

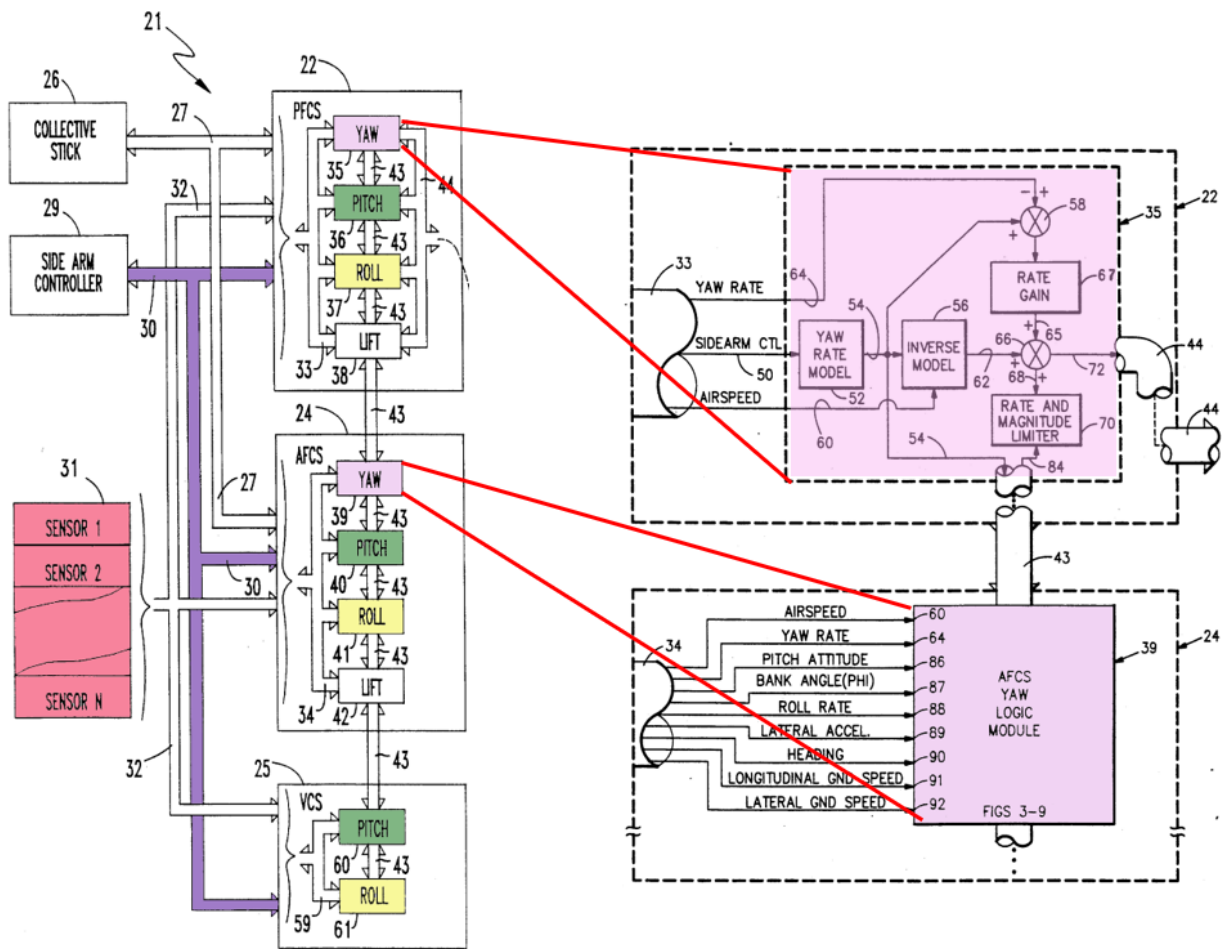
Fourth, the combination is merely the simple substitution of one known element (Gold's yaw modules 35 and 39) for another (Skonieczny's yaw modules 35 and 39). (DJI-1003, ¶186.) A POSITA would have had a reasonable expectation of success and the results of the combination would have been predictable because Gold and Skonieczny both use the same basic architecture for the PFCS and AFCS. (*Id.*) Gold describes a model following control system having a PFCS and AFCS each with “control modules for controlling the yaw, pitch, roll and lift axes of the aircraft.” (DJI-1005, 3:17-20.) Skonieczny discloses an identical model following architecture for the PFCS and AFCS and even uses the same reference numbers for components, 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 and 13)

The combination of Gold and Skonieczny discloses “*a directional control architecture*” [3A]. (DJI-1003, ¶188.) The PFCS and AFCS of Gold’s flight control system 21 each contain a control module 35, 39 (shaded pink in annotated Figure 3 below left) for controlling yaw. (DJI-1003, 3:17-18.) In the combination of Gold and Skonieczny, illustrated below, the PFCS and AFCS yaw modules described in Skonieczny are combined with Gold’s flight control system. (See §VI.A.2.) The yaw control module of PFCS and the yaw control module of the AFCS are collectively part of the “*directional control architecture*” [3A] of the combined flight control system because they control movement of the aircraft in the yaw direction. (DJI-1003, ¶188.)



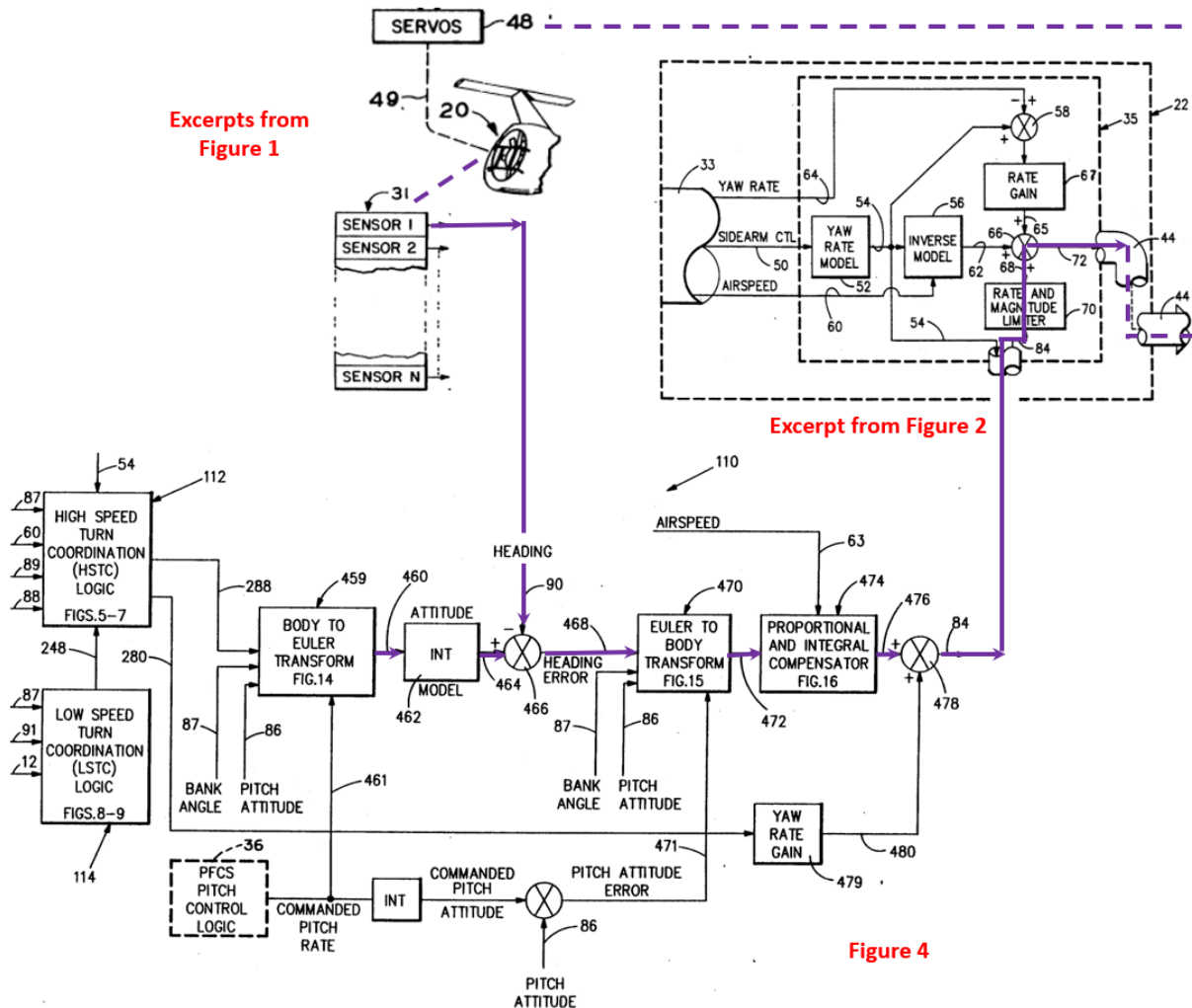
Excerpt from Gold, Annotated Figure 3; Skonieczny, Annotated Figure 2

The “*directional control architecture*” of the combination of Gold and Skonieczny includes “*a directional heading control loop*” [3A.1]/[13A], “*a directional turn coordination control loop*” [3A.2]/[13B], and “*a directional yaw rate control loop* [3A.3]/[13C].” (DJI-1003, ¶¶190-201.)

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

The combination of Gold and Skonieczny discloses “*a directional heading control loop*” [3A.1]/[13A]. (DJI-1003, ¶¶190-195.) This 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, ¶190.)



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, ¶191; *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 HTSC is transformed and integrated to provide a desired aircraft heading on line 464. (DJI-1006, 12:36-42; DJI-1003, ¶¶192-193.) 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, ¶193.)

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, ¶194.) 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, ¶194.) 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, ¶194.)

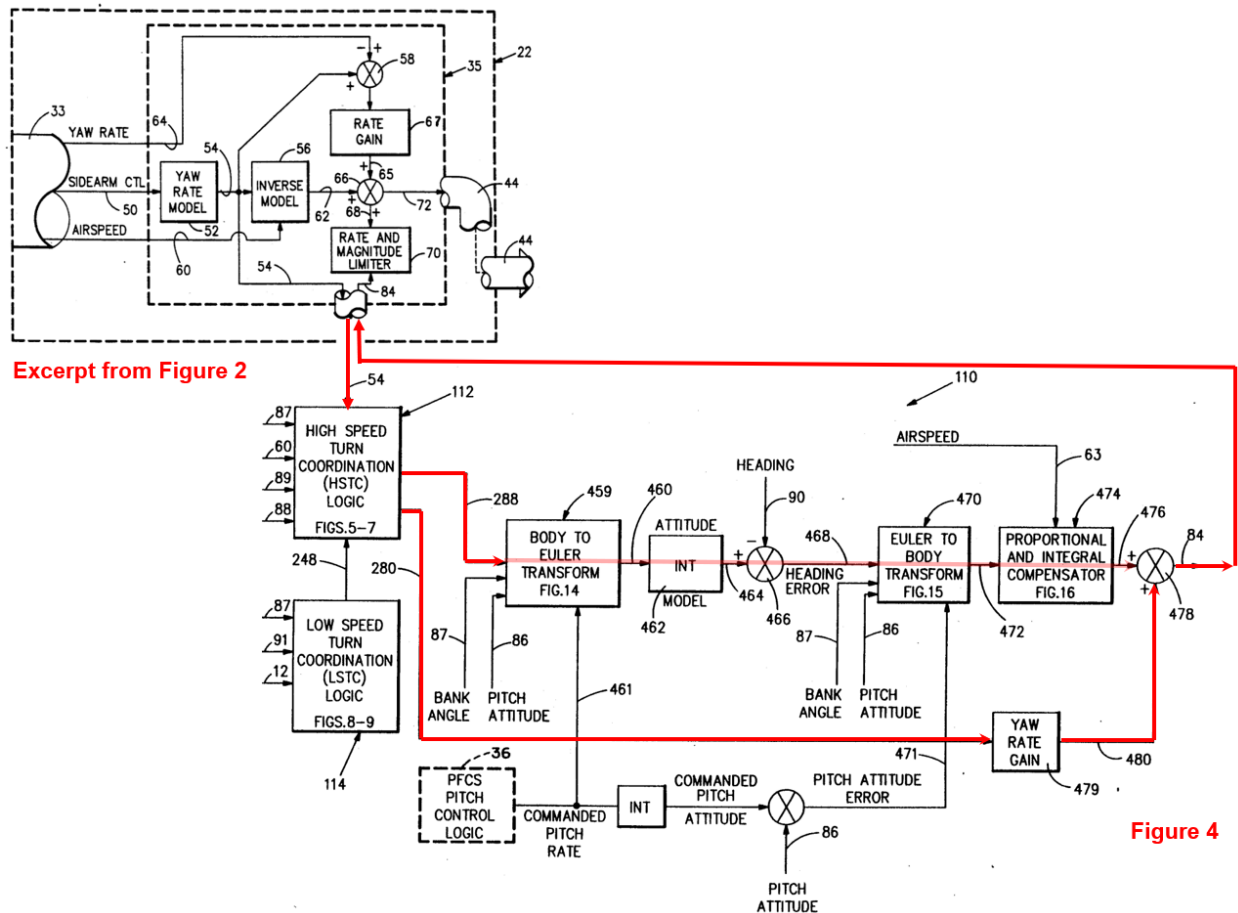
The aircraft heading error, described above, “is the second of two **feedback loops** around the tail rotor command signal.” (DJI-1006, 4:24-26.) Controlling the yaw rate is a way of controlling the directional heading. (DJI-1003, ¶194.) Accordingly, the “*directional control architecture*” of the combination of Gold and Skonieczny therefore includes “*a directional heading control loop*” [3A.1]/[13A]. (DJI-1003, ¶¶190-194.)

The heading error is one form of “*data*” communicated through and/or used by the “*directional heading control loop*.” (DJI-1003, ¶195.) As discussed above, the heading error is communicated through the “*directional heading control loop*” (illustrated by the purple lines in Singhose Figure C above). 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). (DJI-1003, ¶195.) The combination of Gold and Skonieczny therefore discloses “*communicating data* [e.g., heading error] *through a directional heading control loop*” [13A]. (DJI-1003, ¶195.)

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

The combination of Gold and Skonieczny discloses “*a directional turn coordination control loop*” [3A.2]/[13B], as shown in Singhose Figure D below which replaces the AFCS of Skonieczny Figure 2 with AFCS of Skonieczny Figure 4. (DJI-1003, ¶196.) 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, ¶¶196, 191; *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 the 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, ¶197.) 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;

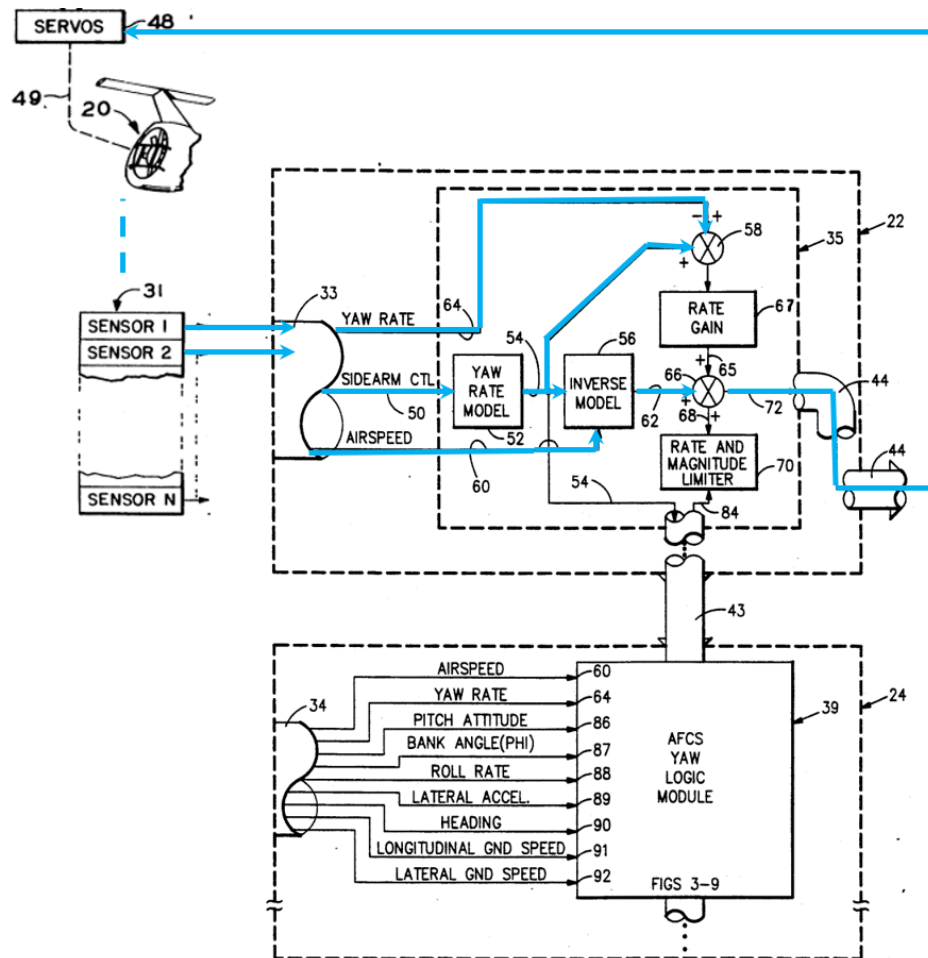
DJI-1003, ¶197.) After further processing, a yaw command modifying signal is provided to the yaw module of the PFCS. The “*directional control architecture*” of the combination of Gold and Skonieczny therefore includes “*a directional turn coordination loop*” [3A.2]/[13B]. (DJI-1003, ¶¶196-197.)

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, ¶198.) 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 and Skonieczny discloses “*communicating data through a directional turn coordination control loop*” [13B]. (*Id.*)

3. “*Directional Yaw Rate Control Loop*”

The combination of Gold and Skonieczny discloses “*a directional yaw rate control loop*” [3A.3]/[13C], highlighted by blue lines in annotated Skonieczny Figure 2 below which incorporates the servos and sensors from Figure 1. (DJI-1003, ¶199.) 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, ¶199.) Yaw rate model circuitry provides a commanded yaw rate signal on line 54 “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, ¶199.)



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 and Skonieczny therefore includes “*a directional yaw rate control loop*” [3A.3]/[13C]. (DJI-1003, ¶¶199-200.)

The yaw rate error signal is one form of “*data*” communicated through and used in the “*directional yaw rate control loop.*” (DJI-1003, ¶201.) 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, ¶¶201, 191.) The combination of Gold and Skonieczny therefore discloses “*communicating data through a directional yaw rate control loop*” [13C]. (DJI-1003, ¶201.)

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

The combination of Gold and Skonieczny discloses “*a directional control latch*” [4A]/[14A]. Gold provides “an aircraft velocity command 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.) In Gold, the flight control system activates a constant vector flat turn when the VCS is engaged and the pilot moves the directional controller out of the detent position.

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 module. (See, §V.B.) In the absence of a yaw command being generated by the pilot via the control stick, no shaped command is generated by the command module 72 and the flat turn motion is not activated in Gold. (DJI-1003, ¶204.) Therefore, the command model associated with the yaw control modules (“*directional control architecture*”) acts as a “*directional control latch*” in “*data communication with the directional control architecture*” that activates a constant vector flat turn as the pilot moves the directional controller out of a detent position. (*Id.*)

Accordingly, the combination of Gold and Skonieczny discloses “*a directional control latch in data communication with the directional control architecture*” [4A]/[14A] and “*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]. (DJI-1003, ¶¶204-205.)

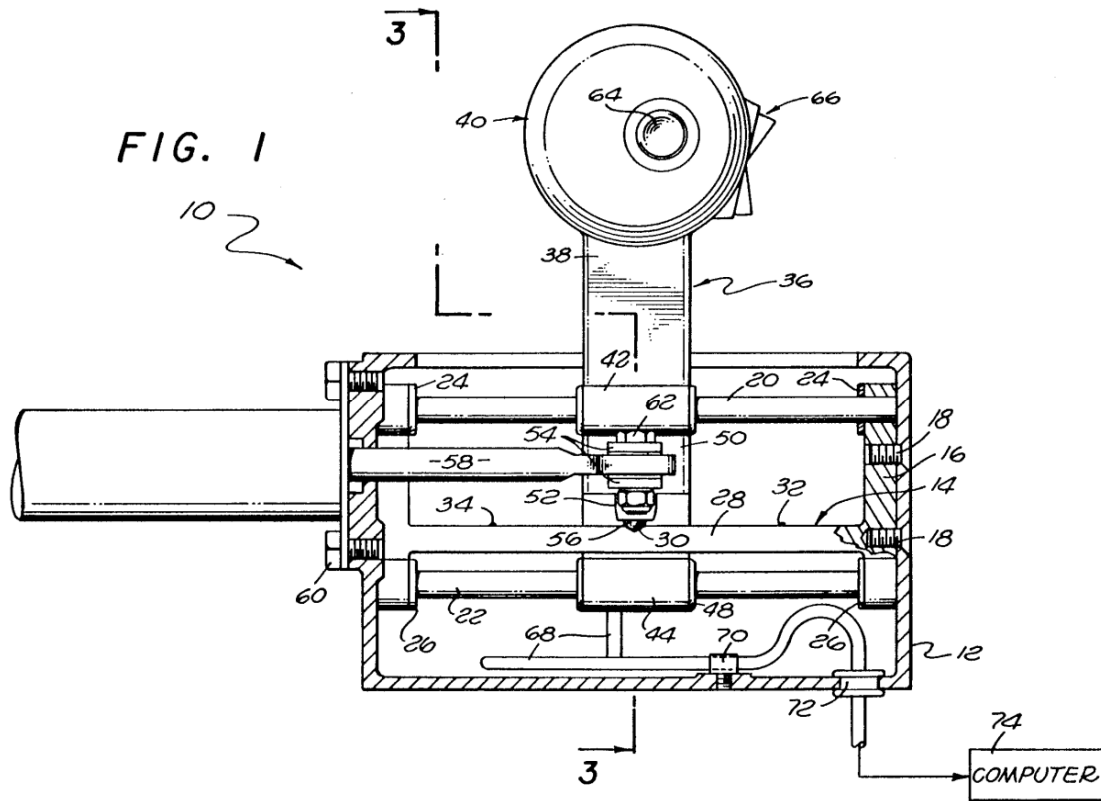
VII. GROUND 3: Combination of Gold and Adams renders claims 7, 10, 17, and 20 obvious.

Gold renders independent claims 1 and 11 obvious. However, Gold does not explicitly disclose “*lateral control latch*” for “*resetting a lateral speed hold*” or a “*longitudinal control latch*” for “*resetting a longitudinal speed hold.*” Adams discloses these limitations.

A. Combination Overview

1. Adams

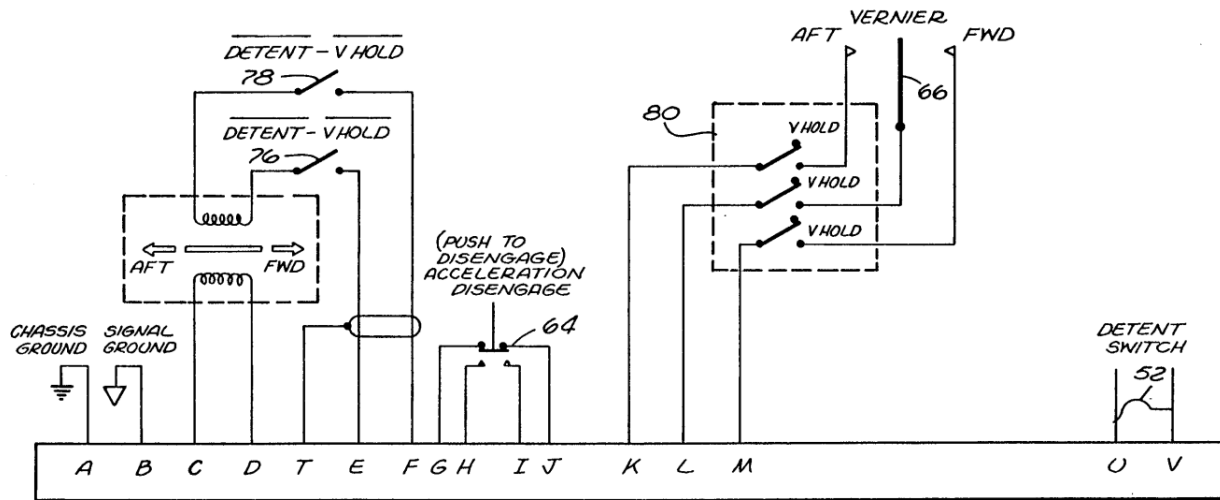
Adams describes a “controller used to command acceleration and deceleration rates and for maintaining a selected velocity.” (DJI-1007, 1:6-9.) Adams’ controller, illustrated in Figure 1, has a movable handle 36 with a shaft 38 including a protrusion 50 that “supports a detent switch 52.” (DJI-1007, 3:36-38.) Handle grip 40 “includes a velocity hold switch 64.” (DJI-1007, 3:45-46.) Wiring connects the switches to a computer 74 for the aircraft. (DJI-1007, 3:49-56.)



Adams, Figure 1

At the start of operation, Adams' handle 36 is in the 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 aircraft operating mode and use of a detent switch to disengage the mode with Gold’s sidearm controller and flight control system. (DJI-1003, ¶211.) Adams and Gold are in the same field of endeavor as the ’505 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 Gold’s 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 longitudinal 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. (*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 any details regarding how velocity stabilization mode is engaged or disengaged. 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, ¶212.) Moreover, a POSITA would have been motivated to combine Gold 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 stabilization mode); (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. (DJI-1003, ¶212.)

A POSITA would have had reasonable expectation of success and the results of the combination would have been predictable because both relate to pilots' controllers. (DJI-1003, ¶213.) 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, ¶213.) Moreover, Gold’s sidearm controller was well-known in the art before the earliest possible priority date of the ’505 patent. Therefore, a POSITA would have understood and been able to apply Adams’ teachings to the controller architecture of Gold. (*Id.*)

B. “*Lateral Control Latch*” (Claims 7 and 17)

The combination of Gold and Adams discloses “*a lateral control latch*”⁷ that “*resets a lateral speed hold.*” (DJI-1003, ¶215.) In the combined system of Gold and Adams, 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 control computer (1) indicating the direction of controller movement and rate of acceleration and (2) 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 and Adams discloses “*a lateral control [l]atch in data communication with the control system*” [7A], “*as the lateral controller is moved out of a detent position, the lateral control latch resets a lateral speed*

⁷ Claims 7 and 17 include an apparent typographical error: “*lateral control hatch.*” Solely for purposes of this IPR, Petitioner assumes the claims recite a “*lateral control latch.*”

hold” [7B], and “*resetting a lateral speed hold with a lateral control [l]atch 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 of Gold and Adams fails to disclose a “*control system*” comprising “*a lateral control [l]atch*” as recited in claim 7, the claims of the ’505 patent do not support such an argument. Claim 6 recites that 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. (DJI-1003, ¶216.)

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

The combination of Gold and Adams discloses “*a longitudinal control latch*”⁸ that “*resets a longitudinal speed hold.*” (DJI-1003, ¶218.) In the combined system of Gold and Adams, when the “*longitudinal controller is moved out of a*

⁸ Claims 10 and 20 include an apparent typographical error: “*longitudinal control hatch.*” Solely for purposes of this IPR, Petitioner assumes the claims recite a “*longitudinal control latch.*”

detent position” by moving the sidearm controller forward or backward, the detent detection capability activates, sending a signal to the flight control computer (1) indicating direction of controller movement and rate of acceleration and (2) commanding the system to disengage velocity stabilization mode to maintain the reference velocity. (*Id.*) This process resets the longitudinal speed hold in place during velocity stabilization mode. (*Id.*) Thus, the combination of Gold and Adams discloses “a longitudinal control [l]atch 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 [l]atch 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 of Gold and Adams fails to disclose a “control system” comprising “a longitudinal control [l]atch” as recited in claim 10, the claims of the ’505 patent do not support such an argument. Claim 9 recites that 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, as discussed above, 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. (DJI-1003, ¶219.)

VIII. Discretionary Denial Is Not Appropriate

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.) The allegedly novel feature of the ’505 patent is the recited “*wherein the aircraft continuously moves in a yaw direction while maintaining the constant vector heading*” which was added during prosecution to obtain allowance of the claims. (See, e.g., IV.D.) However, the concept of an aircraft continuously moving in a yaw direction while maintaining a constant ground track was known and disclosed by Gold, as Petitioner establishes herein. Indeed, the EP Examiner found that “maintaining a constant vector heading across a ground surface while the aircraft flies with a crab angle greater than zero is the subject-matter of document D1!” (DJI-1012, 110.) And PO amended the specification of its corresponding EP application to summarize Gold:

An example velocity command system is described in US 5553812, in which an aircraft flight path referenced velocities are determined with respect to an inertial frame of reference, the flight path referenced velocities are held constant during pilot commanded yaw maneuvers so that **the aircraft maintains a fixed inertial referenced flight path regardless of the pointing direction of the aircraft.**

(DJI-1012, 122-123.) This addition to the European patent, especially the portions emphasized above, are an admission by PO that Gold discloses the alleged novel feature of the '505 patent claims.

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 DJI's knowledge, the '505 patent has been involved in the following district court litigations:

- *Textron Innovations, Inc. v. SZ DJI Technology Co., Ltd. et al*, 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 20005-3960, 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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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), DJI hereby certifies that portions of the above-captioned Petition for *Inter Partes* Review of U.S. Patent No. 8,682,505, 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 13,253. 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 8,682,505 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] A control system for an aircraft, comprising:

[1A] a lateral control architecture configured to control lateral motion of the aircraft; and

[1B] a longitudinal control architecture configured to control longitudinal motion of the aircraft;

[1C] wherein the control system utilizes the lateral control architecture and the longitudinal control architecture to control yaw movement of the aircraft while the aircraft maintains a constant vector heading across a ground surface; and

[1D] wherein the aircraft continuously moves in a yaw direction while maintaining the constant vector heading.

[11P] A method, comprising:

[11A] sensing a directional movement of an aircraft;

[11B] determining lateral and longitudinal movements of the aircraft; and

[11C] selectively controlling flat yaw movement of the aircraft while maintaining a constant vector flat turn relative to a ground surface;

[11D] wherein the aircraft continuously moves in a yaw direction while maintaining the constant vector heading.