(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) **World Intellectual Property Organization**
International Bureau

(43) **International Publication Date**
22 May 2025 (22.05.2025)

WIPO | PCT

(10) **International Publication Number**
WO 2025/106962 A1

(51) **International Patent Classification:**
B64C 29/00 (2006.01) *B64C 39/12* (2006.01)
B64C 3/38 (2006.01) *B64C 27/20* (2023.01)
B64C 27/52 (2006.01) *B64C 37/00* (2006.01)

(21) **International Application Number:**
PCT/US2024/056366

(22) **International Filing Date:**
18 November 2024 (18.11.2024)

(25) **Filing Language:** English

(26) **Publication Language:** English

(30) **Priority Data:**
63/599,870 16 November 2023 (16.11.2023) US

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(81) **Designated States** *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CV, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IQ, IR, IS, IT, JM, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, MG, MK, MN, MU, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) **Designated States** *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, CV, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SC, SD, SL, ST,

(54) **Title:** FORWARD SWEPT WING VTOL AIRCRAFT WITH EMBEDDED LIFT PROPULSORS

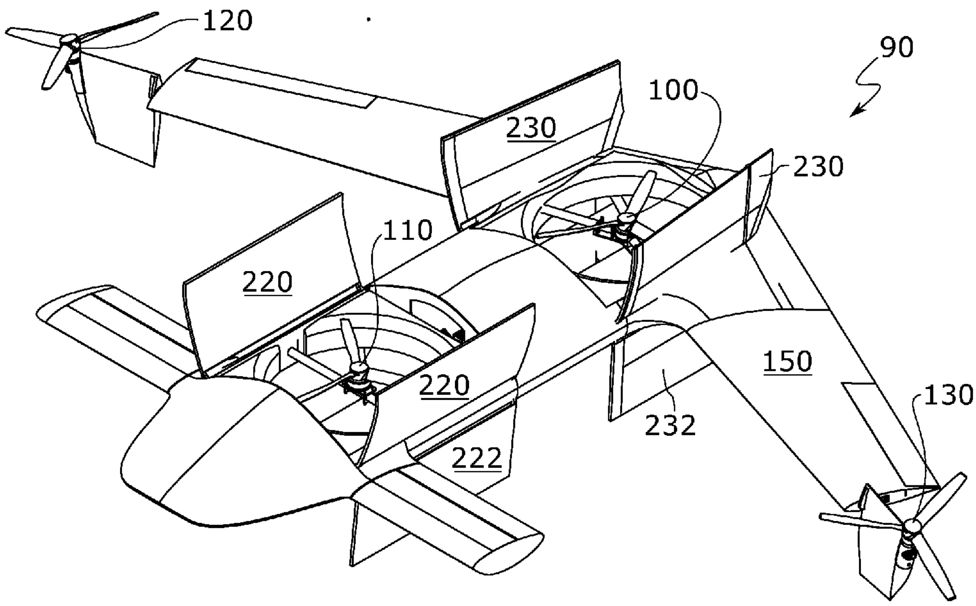

FIG. 2

(57) **Abstract:** An aircraft designed for vertical take-off and landing (VTOL) and fixed wing flight. The aircraft's structure includes a streamlined fuselage, forward swept wing and a canard, featuring a configuration of propulsors symmetrically embedded along the aircraft's longitudinal center of gravity and tilting propellers on the forward swept wingtips. Additionally, the fuselage includes doors to the propulsor ducts that can be opened for vertical flight and closed for forward flight.

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[Continued on next page]

SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, ME, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*
— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

Forward Swept Wing VTOL Aircraft with Embedded Lift Propulsors

RELATED APPLICATIONS

This application claims the benefit of U.S. provisional application no. 63/599,870 filed November 16, 2023, the contents of which are hereby incorporated by reference in their entirety.

TECHNICAL FIELD

The present invention relates to aircraft design. In one aspect, the present invention relates to a fixed wing vertical takeoff and landing forward swept wing aircraft design that incorporates tilting wingtip propulsors and embedded centerline propulsors to create a symmetrical layout of propulsors about the vehicle center of gravity during VTOL flight.

BACKGROUND ART

It is desirable to maximize aircraft handling qualities and disturbance rejection during VTOL flight, while minimizing coupling of control axis.

SUMMARY OF INVENTION

The present inventors have found that a symmetrical layout of propulsors about the aircraft center of gravity (CG) is desired. One method to achieve such a configuration is to use a combination of propulsors embedded in the fuselage along the vehicle centerline, and tilting wingtip propulsors for dual use in VTOL and fixed wing flight.

Such a configuration can be achieved using a forward swept wing, with the sweep angle selected such that the wingtip, and as a result wing tip propulsors, are laterally aligned with the vehicle center of gravity. Embedded lift propulsors are placed along the vehicle centerline to create longitudinal symmetry of propulsors about the CG.

The forward swept configuration combined with wingtip propulsors allows the aircraft to minimize drag producing effects caused by wingtip vortices, increasing the effective aspect ratio and efficiencies during fixed wing flight. Further, this combination reduces the risk of tip stall and enables excellent control authority at the high angles of attack required for maximum endurance flight conditions.

The present invention relates to an aircraft capable of VTOL and fixed wing flight, using a combination of thrust symmetrical embedded lift propulsors along the fuselage centerline and tilting wingtip propulsors. The aircraft is designed to provide a thrust symmetrical layout of propulsors about their respective axis during VTOL flight.

Embodiments of the present invention may use a forward swept wing, with the sweep angle of the wing selected such that the two wingtip motors are laterally aligned about the vehicle center of gravity. The wingtip propulsors augment lift of the vehicle in VTOL flight and provide control of the vehicle’s roll axis. The embedded lift propulsors consist of propellers shrouded by a duct, embedded in the fuselage, and located along the vehicle centerline, longitudinally symmetric about the center of gravity. The embedded lift propulsors provide the majority thrust during VTOL flight, and aid in pitch control.

The resulting VTOL flight control system decouples pitch and roll control axis. The embedded lift propulsors may provide pitch control, while the wingtip propulsors may stabilize the roll axis. The large lever arm provided by the wingtip propulsors further aids stability and disturbance rejection during VTOL maneuvers. The tilting actuation of the wingtip propulsors may allow for yaw control via thrust vectoring, as well as longitudinal velocity control.

During fixed wing flight, the aircraft may use tilting wingtip propulsors in a forward configuration to provide thrust. Retracting doors may be used to cover the ducts surrounding the embedded lift propulsors to reduce drag during fixed wing flight. A canard located near the front of the aircraft may provide a balancing moment, and the incidence angle of the entire surface can be adjusted for trim. Fixed wing flight controls are provided by control surfaces along the trailing edge of the main wing, adjustment of canard incidence angle, and differential thrust from the wingtip propulsors.

In some aspects, the techniques described herein relate to a vertical take-off and landing (VTOL) aircraft including: a fuselage defining fore and aft sections, left side and right side, topside and bottom side, and having a longitudinal centerline and a center of gravity; a forward swept wing extending from said left side and right side of the fuselage having a left wing tip and a right wingtip; a left wing tip propulsor and a right wing tip propulsor disposed at the left wing tip and right wing tip respectively, said left and right wing tip propulsors incrementally tiltable between a forward thrust position and a vertical thrust position; fore and aft vertical ducts, each having a top opening and a bottom opening; fore and aft propulsors disposed within the fore and aft vertical ducts, respectively, configured to provide vertical lift, wherein the fore and aft propulsors define a longitudinal axis through the center of gravity; a plurality of actuable doors configured to close the top openings and bottom openings of the fore and aft ducts; and a canard extending from the fuselage forward of the forward swept wing; wherein a sweep angle of the forward swept wing is such that the left wing tip propulsor and right wing tip propulsor, when in vertical thrust position, define a lateral axis through the center of gravity; wherein the aircraft is configurable in a VTOL flight mode having the doors in actuated in open positions and the left and right wingtip propulsors are tilted in vertical thrust positions; and wherein the aircraft is configurable in a fixed wing flight mode wherein the doors are actuated in closed positions and the left and right wingtip propulsors are tilted in a forward thrust position.

In some aspects, the techniques described herein relate to a VTOL aircraft wherein each of the propulsors is configured for direct drive from a respective motive source and the motive sources are electrically powered, use internal combustion, and/or use a hybrid power system.

In some aspects, the techniques described herein relate to a VTOL aircraft wherein each of the propulsors is mechanically coupled to a drive power source and a drive power source is electrically powered, uses internal combustion, and/or uses a hybrid power system.

In some aspects, the techniques described herein relate to a VTOL aircraft wherein the doors for each duct opening include a pair of doors pivotably hinged to the fuselage and may be operated by a door actuator mechanism having: a dual arm servo; a first lever arm coupled to a first door of a pair of doors; a second lever arm coupled to a second door of the pair of doors; and push/pull linkages coupling the first and second lever arms to the dual arm servo.

In some aspects, the techniques described herein relate to a VTOL aircraft wherein thrusts of the fore and aft propulsors are configured to be controlled independently to effect a pitch control of the aircraft; incremental tilting and thrust of the left and right wing tip propulsors are independently controllable to effect a yaw control of the aircraft; and thrust of the left and right wing tip propulsors are independently controllable to effect a roll control of the aircraft in the VTOL flight mode.

In some aspects, the techniques described herein relate to a VTOL aircraft, further including aircraft flight control surfaces along a trailing edge of the forward swept wings.

In some aspects, the techniques described herein relate to a VTOL aircraft, wherein the canard includes an elevator control surface and/or an incidence angle of the canard is adjustable.

In some aspects, the techniques described herein relate to a vertical take-off and landing (VTOL) aircraft including: a fuselage defining fore and aft sections, left side and right side, topside and bottom side, and having a longitudinal centerline and a center of gravity; a forward swept wing extending from said left side and right side of the fuselage having a left wing tip and a right wingtip; a left wing tip propulsor and a right wing tip propulsor disposed at the left wing tip and right wing tip respectively, said left and right wing tip propulsors incrementally tiltable between a forward thrust position and a vertical thrust position; fore and aft vertical ducts, each having a top opening and a bottom opening; fore and aft propulsors disposed within the fore and aft vertical ducts, respectively, configured to provide vertical lift, wherein the fore and aft propulsors define a longitudinal axis through the center of gravity; a canard extending from the fuselage forward of the forward swept wing; wherein a sweep angle of the forward swept wing is such that the left wing tip propulsor and right wing tip propulsor, when in vertical thrust position, define a lateral axis through the center of gravity; wherein the aircraft is configurable in a VTOL flight mode having the left and right wingtip propulsors are tilted in vertical thrust positions; and wherein the aircraft is configurable in a fixed wing flight mode wherein the left and right wingtip propulsors are tilted in a forward thrust position.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates a planform view of an exemplary embodiment of the aircraft in a VTOL configuration showing the layout of the aircraft and propulsors.

FIG. 2 illustrates an isometric view of an exemplary embodiment of the aircraft in a VTOL configuration.

FIG. 3 illustrates an isometric view of an exemplary embodiment of the aircraft in a fixed wing flight configuration.

FIG. 4 illustrates a detailed semi-transparent isometric view of the left wingtip propulsor tilt mechanism in an exemplary embodiment.

FIG. 5 illustrates a front section view along cut line 5-5 shown in FIG. 1 of the rear embedded lift propulsor mechanism in the fuselage in an exemplary embodiment.

DETAILED DESCRIPTION

As used herein any reference to an “embodiment” or “some embodiments” means that a particular element, feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment of the inventive concepts disclosed herein. The appearances of the phrase “in some embodiments” in various places in the specification are not necessarily all referring to the same embodiment, and embodiments of the inventive concepts disclosed may include one or more of the features expressly described or inherently present herein, or any combination of sub-combination of two or more such features, along with any other features which may not necessarily be expressly described or inherently present in the instant disclosure.

FIG. 1 is a planform view of an exemplary embodiment of the aircraft **90** in a VTOL configuration showing the layout of the aircraft and propulsors. The arrangement of the aft embedded lift propulsor **100** and forward embedded lift propulsor **110** within aft duct **102** and forward duct **112**, respectively, along the vehicle centerline can be seen with symmetric placement about the vehicle center of gravity **140**. The two embedded lift propulsors are shrouded by a duct and fully embedded in the fuselage. The forward swept wing **150** is shown, with the sweep angle of the wing selected such that the right wingtip motor **120** and left wingtip motor **130** are laterally aligned about the vehicle center of gravity **140**.

FIG. 2 is an isometric view of the aircraft **90** in a VTOL configuration. Here, the left wingtip propulsor **130** and right wingtip propulsor 120 are rotated into a vertical configuration to provide lift during VTOL flight and roll control. In one embodiment, the aircraft **90** may have forward upper duct doors **220**, forward lower duct doors **222**, aft lower duct doors **232**, and aft upper duct doors **230** illustrated here in an open position to enable air flow to and lift from the embedded lift propulsors **100** and **110**.

FIG. 3 is an isometric of the aircraft **90** in a fixed wing flight configuration. The aircraft **90** uses the propulsors **120** and **130** on the right wingtip tilt mechanism **300** and left wingtip tilt mechanism **310**, respectively, tilted forward to provide thrust and yaw control in fixed wing flight. During fixed wing flight, ailerons **320** located along the trailing edges of the wing **150** provide roll control. Forward upper duct doors **220** and forward lower duct doors **222** and aft upper duct doors **230** and aft lower duct doors **232** are used to cover duct **102** and duct **112** surrounding the embedded lift propulsors, creating a streamlined fuselage to reduce drag. A canard **350** is located near the front of the aircraft and may provide a balancing moment and trim the aircraft pitch axis. The entire canard **350** may rotate and/or an elevator **360** on a trailing edge of the canard may provide the balancing moment and aircraft pitch trim.

FIG. 4 is a semi-transparent isometric detail view of the left wingtip tilt mechanism **310**. The mechanism **310** may consist of a left wingtip propulsor **130** with attached wingtip propulsor fairing **400**. The propulsor **130** and fairing **400** rotate about a protruding cylindric spar **410** located at the end of the main portion of the swept wing **150**. Rotation is achieved by using a geared servo mechanism **430**. A right wingtip tilt mechanism is similar in design.

FIG. 5 is a front section view taken along cut-line 5-5 shown in FIG. 1 of an aft embedded propulsor door mechanism. A forward embedded propulsor door mechanism may be similar in design. Each mechanism may include a set of top doors **230** and bottom doors **232** of the fuselage. Operation of the doors may use a configuration of adjustable linkages **520** that push/pull lever arms **530** that are attached to each door segment. Actuation of the linkages may be made using a dual arm servo **540**.

While the present invention has been particularly shown and described with reference to exemplary embodiments thereof, by way of illustration and example only, it is clearly understood that the present invention is not to be construed as limiting the present invention, and various changes and modifications may be made by those skilled in the art within the protective scope of the invention without departing off the spirit of the present invention.

WHAT IS CLAIMED IS:

1. A vertical take-off and landing (VTOL) aircraft comprising:

a fuselage defining fore and aft sections, left side and right side, topside and bottom side, and having a longitudinal centerline and a center of gravity;

a forward swept wing extending from said left side and right side of the fuselage having a left wing tip and a right wingtip;

a left wing tip propulsor and a right wing tip propulsor disposed at the left wing tip and right wing tip respectively, said left and right wing tip propulsors incrementally tiltable between a forward thrust position and a vertical thrust position;

fore and aft vertical ducts, each having a top opening and a bottom opening;

fore and aft propulsors disposed within the fore and aft vertical ducts, respectively, configured to provide vertical lift, wherein the fore and aft propulsors define a longitudinal axis through the center of gravity;

a plurality of actuable doors configured to close the top openings and bottom openings of the fore and aft ducts; and

a canard extending from the fuselage forward of the forward swept wing;

wherein a sweep angle of the forward swept wing is such that the left wing tip propulsor and right wing tip propulsor, when in vertical thrust position, define a lateral axis through the center of gravity;

wherein the aircraft is configurable in a VTOL flight mode having the doors in actuated in open positions and the left and right wingtip propulsors are tilted in vertical thrust positions; and

wherein the aircraft is configurable in a fixed wing flight mode wherein the doors are actuated in closed positions and the left and right wingtip propulsors are tilted in a forward thrust position.

2. The VTOL aircraft of claim 1 wherein each of the propulsors is configured for direct drive from a respective motive source.

3. The VTOL aircraft of claim 2 wherein the motive sources are electrically powered.

4. The VTOL aircraft of claim 2 wherein the motive sources use internal combustion.

5. The VTOL aircraft of claim 2 wherein the motive sources use a hybrid power system.

6. The VTOL aircraft of claim 1 wherein each of the propulsors is mechanically coupled to a drive power source.

7. The VTOL aircraft of claim 6 wherein a drive power source is electrically powered.

8. The VTOL aircraft of claim 6 wherein a drive power source uses internal combustion.

9. The VTOL aircraft of claim 6 wherein a drive power source uses a hybrid power system.

10. The VTOL aircraft according to claim 1 wherein the doors for each duct opening comprise a pair of doors pivotably hinged to the fuselage.

11. The VTOL aircraft according to claim 10, further comprising a door actuator mechanism having:

a dual arm servo;

a first lever arm coupled to a first door of a pair of doors;

a second lever arm coupled to a second door of the pair of doors; and

push/pull linkages coupling the first and second lever arms to the dual arm servo.

12. The VTOL aircraft according to claim 1 wherein thrusts of the fore and aft propulsors are configured to be controlled independently to effect a pitch control of the aircraft.

13. The VTOL aircraft according to claim 1, further comprising aircraft flight control surfaces along a trailing edge of the forward swept wings.

14. The VTOL aircraft according to claim 1, wherein the canard comprises an elevator control surface.

15. The VTOL aircraft according to claim 1, wherein an incidence angle of the canard is adjustable.

16. The VTOL aircraft according to claim 1, wherein incremental tilting and thrust of the left and right wing tip propulsors are independently controllable to effect a yaw control of the aircraft.

17. The VTOL aircraft according to claim 1, wherein thrust of the left and right wing tip propulsors are independently controllable to effect a roll control of the aircraft in the VTOL flight mode.

18. A vertical take-off and landing (VTOL) aircraft comprising:

a fuselage defining fore and aft sections, left side and right side, topside and bottom side, and having a longitudinal centerline and a center of gravity;

a forward swept wing extending from said left side and right side of the fuselage having a left wing tip and a right wingtip;

a left wing tip propulsor and a right wing tip propulsor disposed at the left wing tip and right wing tip respectively, said left and right wing tip propulsors incrementally tiltable between a forward thrust position and a vertical thrust position;

fore and aft vertical ducts, each having a top opening and a bottom opening;

fore and aft propulsors disposed within the fore and aft vertical ducts, respectively, configured to provide vertical lift, wherein the fore and aft propulsors define a longitudinal axis through the center of gravity;

a canard extending from the fuselage forward of the forward swept wing;

wherein a sweep angle of the forward swept wing is such that the left wing tip propulsor and right wing tip propulsor, when in vertical thrust position, define a lateral axis through the center of gravity;

wherein the aircraft is configurable in a VTOL flight mode having the left and right wingtip propulsors are tilted in vertical thrust positions; and

wherein the aircraft is configurable in a fixed wing flight mode wherein the left and right wingtip propulsors are tilted in a forward thrust position.

19. The VTOL aircraft of claim 18 wherein each of the propulsors is configured for direct drive from a respective motive source.

20. The VTOL aircraft of claim 19 wherein the motive sources are electrically powered.

21. The VTOL aircraft of claim 19 wherein the motive sources use internal combustion.

22. The VTOL aircraft of claim 19 wherein the motive sources use a hybrid power system.

23. The VTOL aircraft of claim 18 wherein each of the propulsors is mechanically coupled to a drive power source.

24. The VTOL aircraft of claim 23 wherein a drive power source is electrically powered.

25. The VTOL aircraft of claim 23 wherein a drive power source uses internal combustion.

26. The VTOL aircraft of claim 23 wherein a drive power source uses a hybrid power system.

27. The VTOL aircraft according to claim 18 wherein thrusts of the fore and aft propulsors are configured to be controlled independently to effect a pitch control of the aircraft.

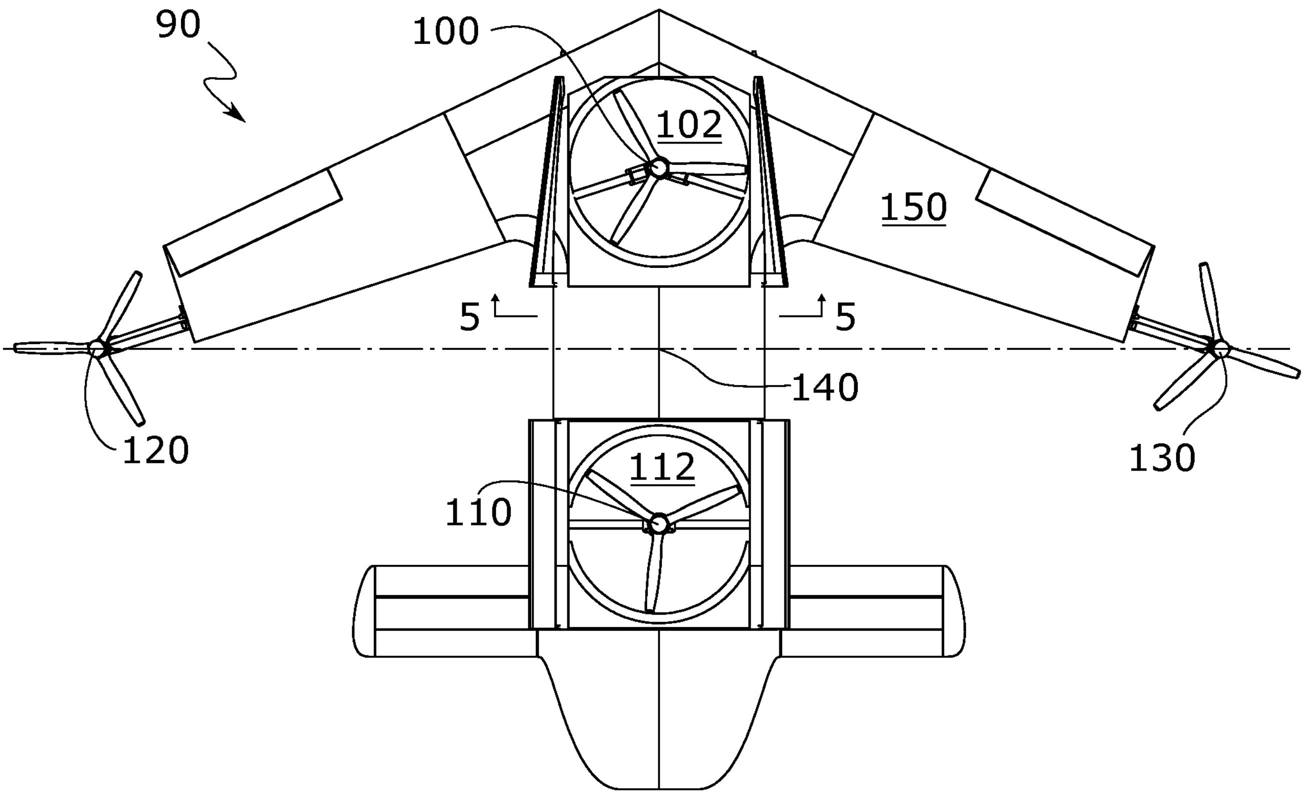
28. The VTOL aircraft according to claim 18, further comprising aircraft flight control surfaces along a trailing edge of the forward swept wings.

29. The VTOL aircraft according to claim 18, wherein the canard comprises an elevator control surface.

30. The VTOL aircraft according to claim 18, wherein an incidence angle of the canard is adjustable.

31. The VTOL aircraft according to claim 18, wherein incremental tilting and thrust of the left and right wing tip propulsors are independently controllable to effect a yaw control of the aircraft.

32. The VTOL aircraft according to claim 18, wherein thrust of the left and right wing tip propulsors are independently controllable to effect a roll control of the aircraft in the VTOL flight mode.


90
100
102
150
5
5
140
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112
110

FIG. 1

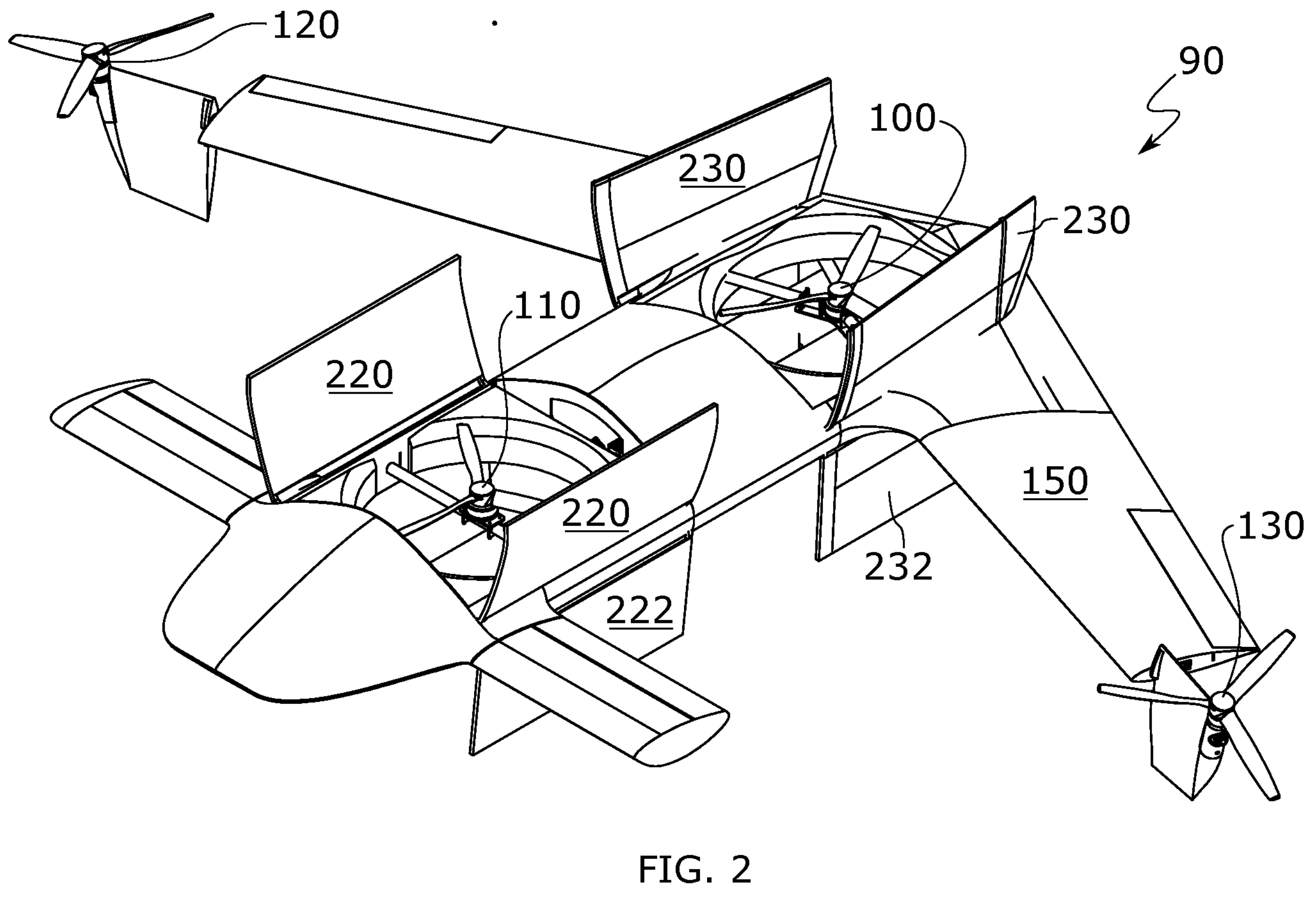
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FIG. 2

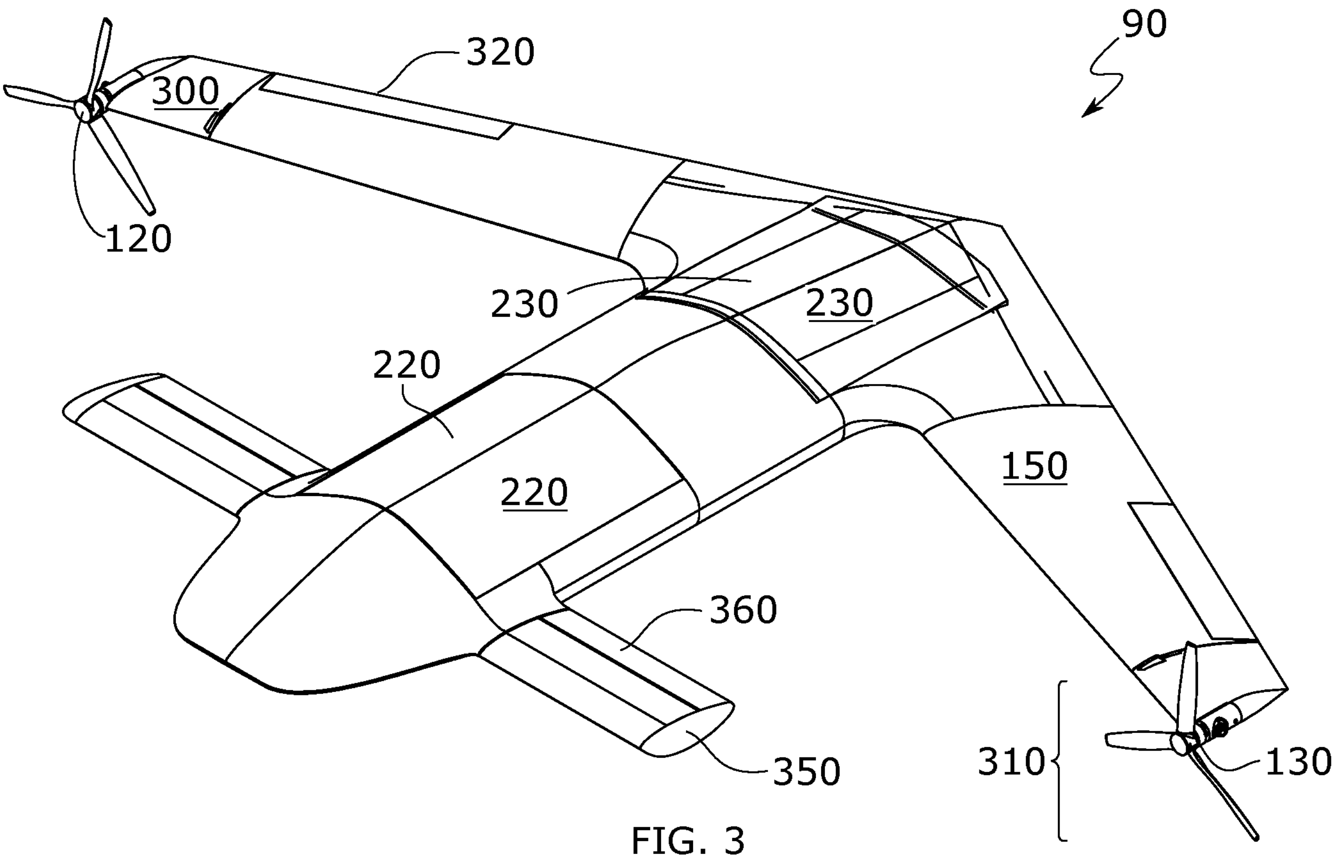
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FIG. 3

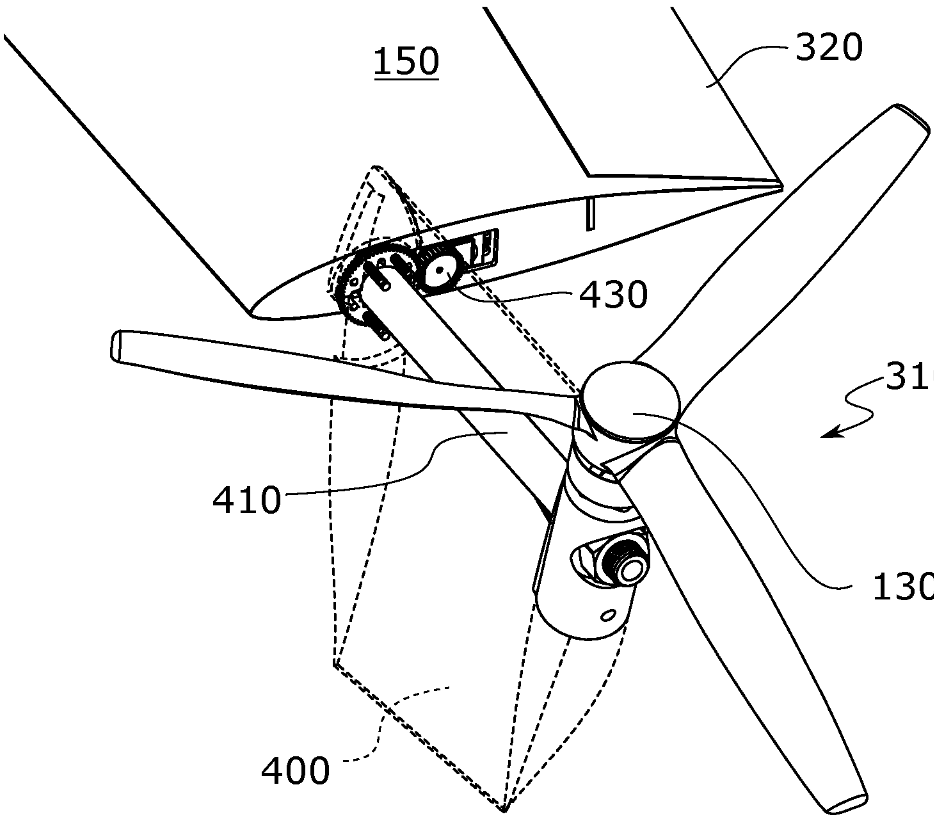
150
320
430
310
410
130
400

FIG. 4

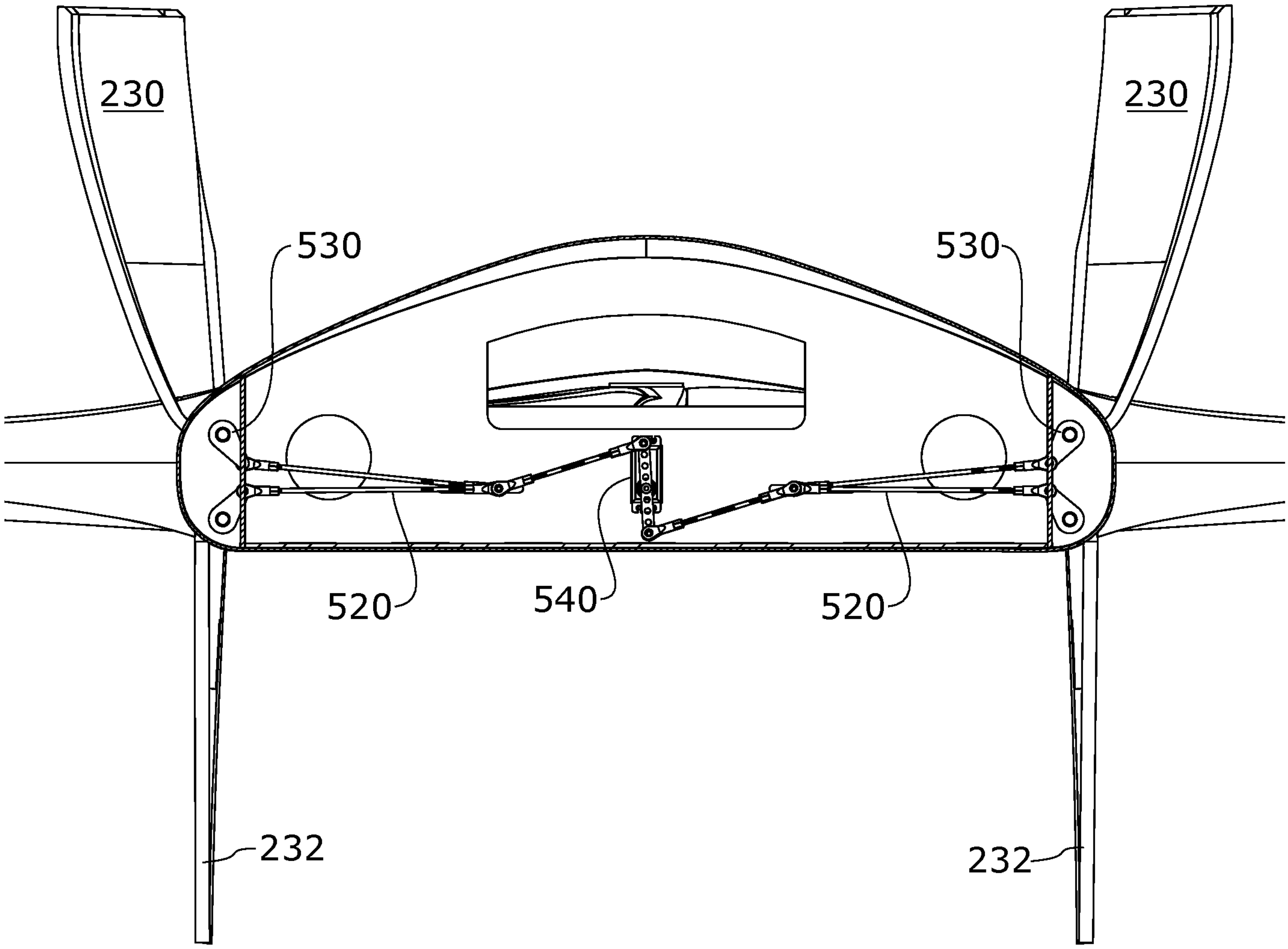

FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2024/056366

A. CLASSIFICATION OF SUBJECT MATTER

IPC: ***B64C 29/00*** (2025.01); ***B64C 3/38*** (2025.01); ***B64C 27/52*** (2025.01); *B64C 39/12* (2025.01); *B64C 27/20* (2025.01); *B64C 37/00* (2025.01)

CPC: ***B64C 29/0033; B64C 29/0025; B64C 29/0016; B64C 29/0008; B64C 3/385; B64C 3/38; B64C 27/52;*** *B64U 30/294; B64U 30/295; B64U 30/297; B64C 39/12; B64C 11/001; B64C 27/20; B64C 37/00*

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

See Search History Document

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

See Search History Document

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

See Search History Document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	US 2004/0026563 A1 (Moller) 12 February 2004 (12.02.2004)	
Y	Figs 2-3, 12a, 12e, 13a, abstract, Para [0044], Para [0048], Para [0066], Para [0067], Para [0080],	1-10, 12-32
A	entire document	11
	US 2018/0354613 A1 (Airbus Defense and Space GmbH) 13 December 2018 (13.12.2018)	
Y	Fig 1, Para [0054]	1-10, 12, 15-27, 30-32
A	entire document	11
	US 2023/0257114 A1 (Poh et al.) 17 August 2023 (17.08.2023)	
Y	Figs 1H, 1i, Para [0036], Para [0040]	1, 13-14, 18, 28-29
	US 10,696,390 B2 (Winston) 30 June 2020 (30.06.2020)	
Y	abstract, Col 2, ln 67 – Col 3, ln 2	3, 5, 20, 22

☑ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
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- "P" document published prior to the international filing date but later than the priority date claimed
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- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- "&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
18 April 2025 (18.04.2025)	**05 May 2025 (05.05.2025)**

Name and mailing address of the ISA/US	Authorized officer
COMMISSIONER FOR PATENTS **MAIL STOP PCT, ATTN: ISA/US** **P.O. Box 1450** **Alexandria, VA 22313-1450** **UNITED STATES OF AMERICA**	**KARI RODRIQUEZ**
Facsimile No. **571-273-8300**	Telephone No. **PCT Help Desk: 571-272-4300**

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2024/056366

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2019/0144107 A1 (Bell Helicopter Textron Inc.) 16 May 2019 (16.05.2019) Para [0023], Para [0025]	6-7, 23-24
Y	US 2019/0270517 A1 (Mono Aerospace IP LTD) 05 September 2019 (05.09.2019) Fig 2, Para [0050]	6, 8-9, 23, 25-26
Y A	US 2021/0300540 A1 (Textron Innovations Inc.) 30 September 2021 (30.09.2021) Fig 1a, Para [0026], Para [0027] entire document	1-10, 12-17 11
A	US 2015/0274289 A1 (The Boeing Corporation) 01 October 2015 (01.10.2015) entire document	1-32
A	US 2021/0031909 A1 (ROLLS - ROYCE plc) 04 February 2021 (04.02.2021) entire document	1-32