



ДОКЛАД ОТ ПРОУЧВАНЕ		
с вх.№ СПИС-1004 от 19.09.2025г		
I. Уточнен класификационен индекс по МПК		
B64C3/00; B64C3/38; B64C3/56; B64C7/00; B64C13/40; B64C39/00		
I. Уточнен класификационен индекс по КПК		
B64C3/00; B64C3/38; B64C3/56; B64C7/00; B64C13/40; B64C39/00		
II. ОБЛАСТ НА ПРОУЧВАНЕ		
Минимален обхват на проучване		
Вид класификация:		Класификационен индекс:
МПК		B64C3; B64C7; B64C13; B64C39
КПК		B64C3; B64C7; B64C13; B64C39
Бази данни, в които е извършено проучването		
Espacenet, Epodoc		
III. Релевантни документи		
Категория	Цитиране на документите с посочване на релевантните части	Релевантни към претенция
A	US8800912B2, публикуван на 12-08-2014, OLIVER RICHARD DAVID [US]; OLIVER VTOL LLC [US]	1-20
A	WO2015089679A1, публикуван на 25-06-2015, CONCA-GARCIA RAPHAËL [CH]	1-20
A	US2010051742A1, публикуван на 04-03-20010, TERRAFUGIA INC [US]	1-20
A	BG65998B1, публикуван на 30-09-2010, ZAFIROV DIMO [BG]	1-20
A	US12162602B2, публикуван на 10-12-2024, JETZERO INC [US]	1-20
Категория на документа		
Х – документът е от особено значение; претендираното изобретение няма новост или изобретателска стъпка, когато документът се разглежда самостоятелно Y – документът е от особено значение; претендираното изобретение няма изобретателска стъпка, когато документът се комбинира с един или повече други документи и тази комбинация е очевидна за специалист в областта A – документ, отразяващ нивото на техниката, който не е от особено значение D – документ, цитиран в описанието О – неписмено разкриване, използване, прилагане, докладване или демонстриране P - документ, публикуван преди датата на подаване в България, но след приоритетната дата E – по-рано подадена българска заявка, но публикувана на или след датата на подаване L – документ, който може да предизвика съмнение относно приоритета на претенциите или който е цитиран с цел установяване датата на публикация на друг документ или друга специална причина (както е посочено) & - документ от една патентна фамилия		
ДАТА:26/09/2025	ИМЕ: Пламен Гончев	ПОДПИС:
		Пламен Гончев Старши експерт ДЕЗИПМПД

СТАНОВИЩЕ

ОТНОСНО: *Предварително проучване за новост на "Компактен многокорпусен самолет с неподвижни стреловидни крила със съгъваеми периферии без аеродинамични кормила, векторно управляван със скаларно контролирана тяга", съгласно искане с вх. № **СПИС-1004** от 19.09.2025г.*

Обектът на настоящото проучване е определен от една независима претенция и деветнадесет зависими претенции.

Съгласно първа независима претенция, компактен многокорпусен самолет с неподвижни стреловидни крила със съгъваеми периферии без аеродинамични кормила, векторно управляван със скаларно контролирана тяга, включващ секционирано крило с неподвижни секции (1) и подвижни секции (2), характеризиращ се с това, че има поне един самолетен корпус (3), към който са свързани основите на неподвижните секции на крилата (4), като към противоположния край на всяка основа (4) е шарнирно присъединена основата на периферната ѝ секция (5), а в задната част на всеки самолетен корпус (3) е монтиран поне един скаларно контролиран тягов агрегат (5), при което всеки контролиран тягов агрегат (5), през изпълнително устройство (6), е свързан с със съответен управленски извод от централен компютърен управленски блок (7), чиито команден вход е свързан с команден извод от команден център (8), а първият сигнален вход на централния компютърен управленски блок (7) е безжично свързан с датчик за текуща височина над терена (9), вторият му сигнален вход е безжично свързан с извод от комбиниран датчик за текущата самолетна скорост и посока на движение, спрямо терена (10), третият му сигнален вход е безжично свързан с извод от комбиниран датчик за атмосферните условия (11), четвъртият му сигнален вход е безжично свързан с извод от комбиниран датчик за близки препятствия около самолета (12), петият му сигнален вход е безжично свързан с извод от датчик за външно електромагнитно облъчване (13).

Съгласно 2-ра зависима претенция компактният многокорпусен самолет, съгласно претенция 1, се характеризира с това, че скаларно контролираният тягов агрегат (5) включва едно конвенционално витло.

Съгласно 3-та зависима претенция, компактният многокорпусен самолет съгласно претенции 1 и 2, се характеризира с това, че скаларно контролираният тягов агрегат (5) включва две противоположно въртящи се конвенционални витла.

Съгласно 4-та зависима претенция, компактният многокорпусен самолет съгласно претенции от 1 до 3, се характеризира с това, че скаларно контролираният тягов агрегат (5) включва две противоположно въртящи се тороидални витла.

Съгласно 5-та зависима претенция, компактният многокорпусен самолет съгласно претенции от 1 до 4, се характеризира с това, че скаларно контролираният тягов агрегат (5) включва едно тороидално витло.

Съгласно 6-та зависима претенция, компактният многокорпусен самолет съгласно претенции от 1 до 5, се характеризира с това, че скаларно контролираният тягов агрегат (5) включва турбореактивен двигател.

Съгласно 7-ма зависима претенция, компактният многокорпусен самолет съгласно претенции от 1 до 6, се характеризира с това, че скаларно контролираният тягов агрегат (5) включва ротационен ванкелов двигател.

Съгласно 8-ма зависима претенция, компактният многокорпусен самолет съгласно претенции от 1 до 7, се характеризира с това, че скаларно контролираният тягов агрегат (5) включва хибриден двигател.

Съгласно 9-та зависима претенция, компактният многокорпусен самолет съгласно претенции от 1 до 8, се характеризира с това, че скаларно контролираният тягов агрегат (5) включва ракетен двигател.

Съгласно 10-та зависима претенция, компактният многокорпусен самолет съгласно претенции от 1 до 9, се характеризира с това, че скаларно контролираният тягов агрегат (5) включва йонно-плазмен двигател.

Съгласно 11-та зависима претенция, компактният многокорпусен самолет съгласно претенции от 1 до 10, се характеризира с това, че всичките скаларно контролирани тягови агрегати (5) са еднакви.

Съгласно 12-та зависима претенция, компактният многокорпусен самолет съгласно претенции от 1 до 11, се характеризира с това, че всичките секционирани крила с неподвижни секции (1) са еднакви и успоредни помежду си.

Съгласно 13-та зависима претенция, компактният многокорпусен самолет съгласно претенции от 1 до 12, се характеризира с това, че всичките подвижни секции (2), са еднакви и съгъваеми надлъжно по самолетните корпуси (3).

Съгласно 14-та зависима претенция, компактният многокорпусен самолет съгласно претенции от 1 до 13, се характеризира с това, че неподвижните секции (1) и подвижните секции (2) и самолетните корпуси (3) са направени от материали с ниска радарна отражателност.

Съгласно 15-та зависима претенция, компактният многокорпусен самолет съгласно претенции от 1 до 14, се характеризира с това, че е без хора на борда.

Съгласно 16-та зависима претенция, компактният многокорпусен самолет съгласно претенции от 1 до 15, се характеризира с това, че е управляван от програмируем команден център (8) с изкуствен интелект за едновременно управление по множество командни канали.

Съгласно 17-та зависима претенция, компактният многокорпусен самолет съгласно претенции от 1 до 16, се характеризира с това, че командната връзка с командния център (8) е двупосочна и е кабелна.

Съгласно 18-та зависима претенция, компактният многокорпусен самолет съгласно претенции от 1 до 17, се характеризира с това, че командната връзка с командния център (8) е двупосочна и е безжична.

Съгласно 19-та зависима претенция, компактният многокорпусен самолет съгласно претенции от 1 до 18, се характеризира с това, че неподвижните секции (1) и подвижните секции (2) са с тесни геометрични размери и са изработени от материали поглъщащи електромагнитните вълни.

Съгласно 20-та зависима претенция, компактният многокорпусен самолет съгласно претенции от 1 до 18, се характеризира с това, че неподвижните секции (1), подвижните секции (2) и самолетните корпуси (3) са боядисани с бои, поглъщащи електромагнитните вълни.

При извършеното проучване са намерени документи, посочени в приложения доклад, релевантни на техническото решение на обекта от настоящото проучване, а именно:

Документът **US8800912B2**, публикуван на **12-08-2014**, се отнася до самолет с вертикално излитане и кацане, имащ поне три крила и поне шест двигателни агрегата, всеки от които е разположен радиално от два съседни двигателни агрегата, под равни или почти равни ъгли. Шестте двигателни агрегата заедно са разположени симетрично или в почти симетрични позиции около приблизителния център на тежестта на самолета, гледано отгоре. Може да се използва или да не се използва вертикален стабилизатор. Ако не се използва вертикален стабилизатор, управлението на отклонението от курса по време на хоризонтален полет може да се постигне чрез диференциална тяга, използваща поне шестте двигателни агрегата. Управлението на отклонението от курса по време на вертикален полет може да се осигури от множество панели за управление на отклонението от курса. При липса на панели за управление на отклонението от курса, управлението на отклонението от курса по време на вертикален полет може да се осигури, използвайки диференциални ъгли на наклона на двигателните агрегати.

В **WO2015089679A1**, публикуван на **25-06-2015**, се разкрива самолет с вертикално излитане (VTOL), който се състои от фюзелаж (10), две основни крила (41, 42), разположени от двете страни на задната част на фюзелажа (10), две витла (53, 54), като във всеки случай по едно витло (53, 54) е разположено на всяко основно крило (41, 42) така, че да може да се върти около хоризонтална надлъжна ос, и ротор (70) с поне две роторни лопатки (71, 72), като роторът (70) е разположен върху носач на ротора (60), монтиран на фюзелажа така, че да може да се върти около напречна ос. Тази конструкция е особено проста и следователно рентабилна за реализиране. Тя позволява самостабилизиране и по този начин лесно управление с надеждни полетни свойства. Роторът (70), благодарение на своята възможност за махване, може да се използва за подпомагане на задвижването и осигурява малко въздушно съпротивление при хоризонтален полет.

Документът **US2010051742A1**, публикуван на **04-03-2010**, се отнася до сгъваемо крило и заключващ механизъм. Подобрените механизми за сгъване и заключване на крило на самолет и управление на елероните на крилото чрез сгъване на крилото са мотивирани от разработването на самолет, подходящ за движение по пътищата. Приложими за по-широк клас самолети, тези механизми позволяват по-безопасно и по-леко решение за проблема със сгъването на крилото от наличното в момента. Системата за управление с кабел позволява външната секция на крилото да се движи едновременно със задействана вътрешна секция на крилото. Заклучващият механизъм позволява автоматизирана работа и визуална проверка. Механизмът за управление на елероните осигурява центриране и заключване в допълнение към управлението на полета чрез оста на шарнира.

В **BG65998B1**, публикуван на **30-09-2010**, се разкрива самолет със съчленено крило. Самолетът намира приложение при пилотирани и безпилотните самолети за спортни цели, гасене на пожари, мониторинг и предотвратяване на градушки. С прилагането му се постига висока маневреност чрез комбинирано управление на кормилата и вектора на тягата на двигателя, при което се постига директно и индиректно изменение на аеродинамичните сили. Възможно е да се извършва вертикално излитане и кацане. Съчлененото крило е устойчиво на претоварванията, възникващи при еволюциите. Самолетът се състои от предно крило с тяло (1) и задно крило (2), които имат елерони (10), предкрилки (8) и задкрилки (9), като крилата са свързани помежду си с обтекаеми силови елементи (3 и 4), двигател (5), захванат за централен силов елемент (3) посредством шарнири (6, 7) на рама (12). Обтекаемите силови елементи (4) имат кормила (11).

Документът **US12162602B2**, публикуван на **10-12-2024**, се отнася до системи и методи за сгъване на крила на самолет. Примерната система включва комбинирано тяло на крило, където комбинираното тяло на крило включва основно тяло и поне едно крило, панта, разположена на поне едно крило и конфигурирана да позволява сгъване на поне едно крило, система за задействане, конфигурирана да сгъва поне едно крило, и контролер, конфигуриран да управлява поне една система за задействане.

НОВОСТ

След извършен сравнителен анализ между обекта, предмет на настоящото проучване и намерените при проучването документи, се установи, че в нито един от намерените документи не е разкрит компактен многокорпусен самолет с неподвижни стреловидни крила със сгъваеми периферии без аеродинамични кормила, векторно управляван със скаларно контролирана тяга, който да включва всички технически признаци от описанието и претенциите на обекта на проучването. Следователно, обектът на настоящото проучване, съгласно така формулираните претенции, е нов по смисъла на чл. 8, ал. 1 от Закона за патентите и регистрацията на полезните модели (ЗПРПМ).

Пламен Гончев

Старши експерт от ДЕЗИПМПД



US012162602B2

(12) **United States Patent**
Rawdon

(10) **Patent No.: US 12,162,602 B2**
(45) **Date of Patent: Dec. 10, 2024**

(54) **SYSTEMS AND METHODS FOR FOLDING WINGS ON AN AIRCRAFT**

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- (71) Applicant: **JetZero, Inc.**, Long Beach, CA (US)
(72) Inventor: **Blaine Knight Rawdon**, Riverside, CA (US)
(73) Assignee: **JetZero, Inc.**, Long Beach, CA (US)
(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 29 days.

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(21) Appl. No.: **18/090,173**

(22) Filed: **Dec. 28, 2022**

(65) **Prior Publication Data**

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Related U.S. Application Data

(63) Continuation-in-part of application No. 17/502,428, filed on Oct. 15, 2021, now Pat. No. 11,591,066.

- (51) **Int. Cl.**
B64C 3/56 (2006.01)
B64C 13/40 (2006.01)
B64C 13/50 (2006.01)
B64C 39/10 (2006.01)

- (52) **U.S. Cl.**
CPC **B64C 3/56** (2013.01); **B64C 13/40** (2013.01); **B64C 13/50** (2013.01); **B64C 2039/105** (2013.01)

- (58) **Field of Classification Search**
CPC B64C 3/56; B64C 2039/105; B64D 2045/0085

See application file for complete search history.

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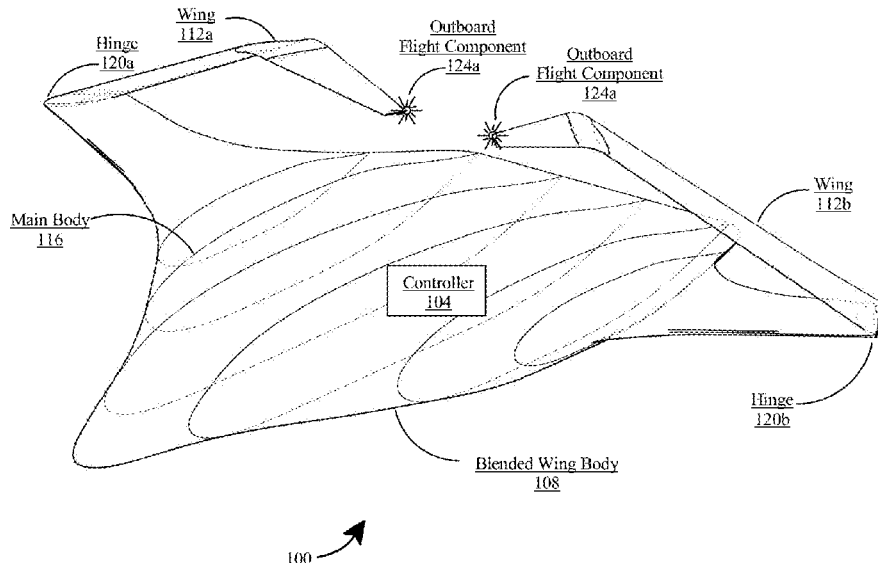
Primary Examiner — Valentina Xavier

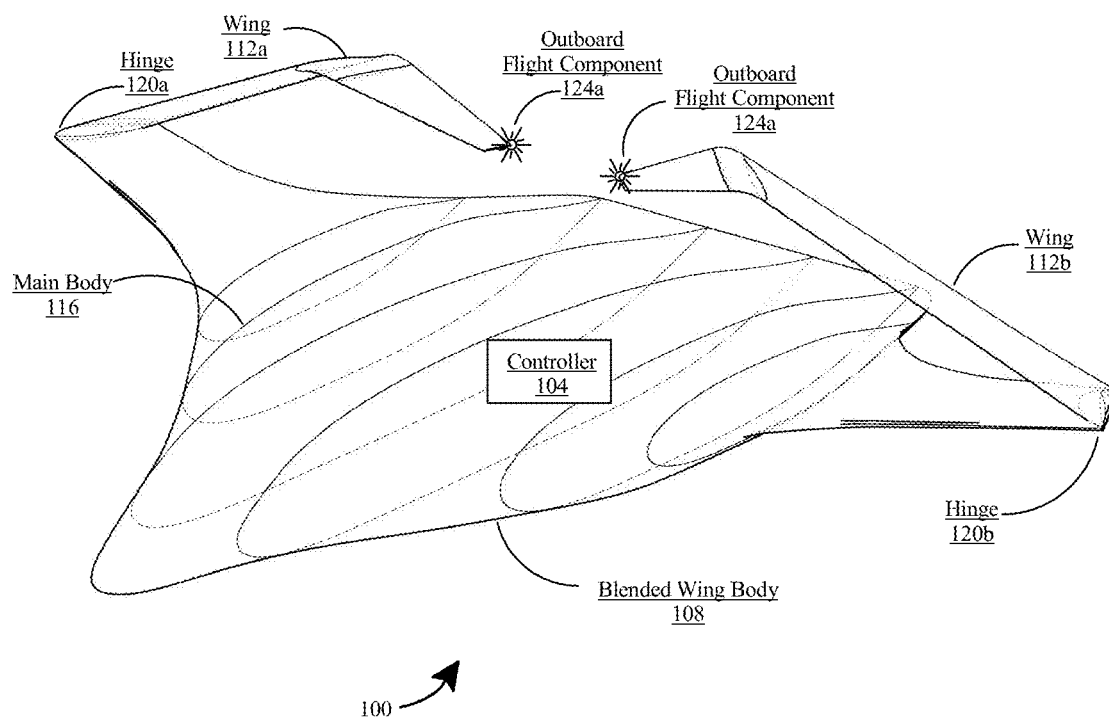
(74) *Attorney, Agent, or Firm* — Caldwell Intellectual Property Law

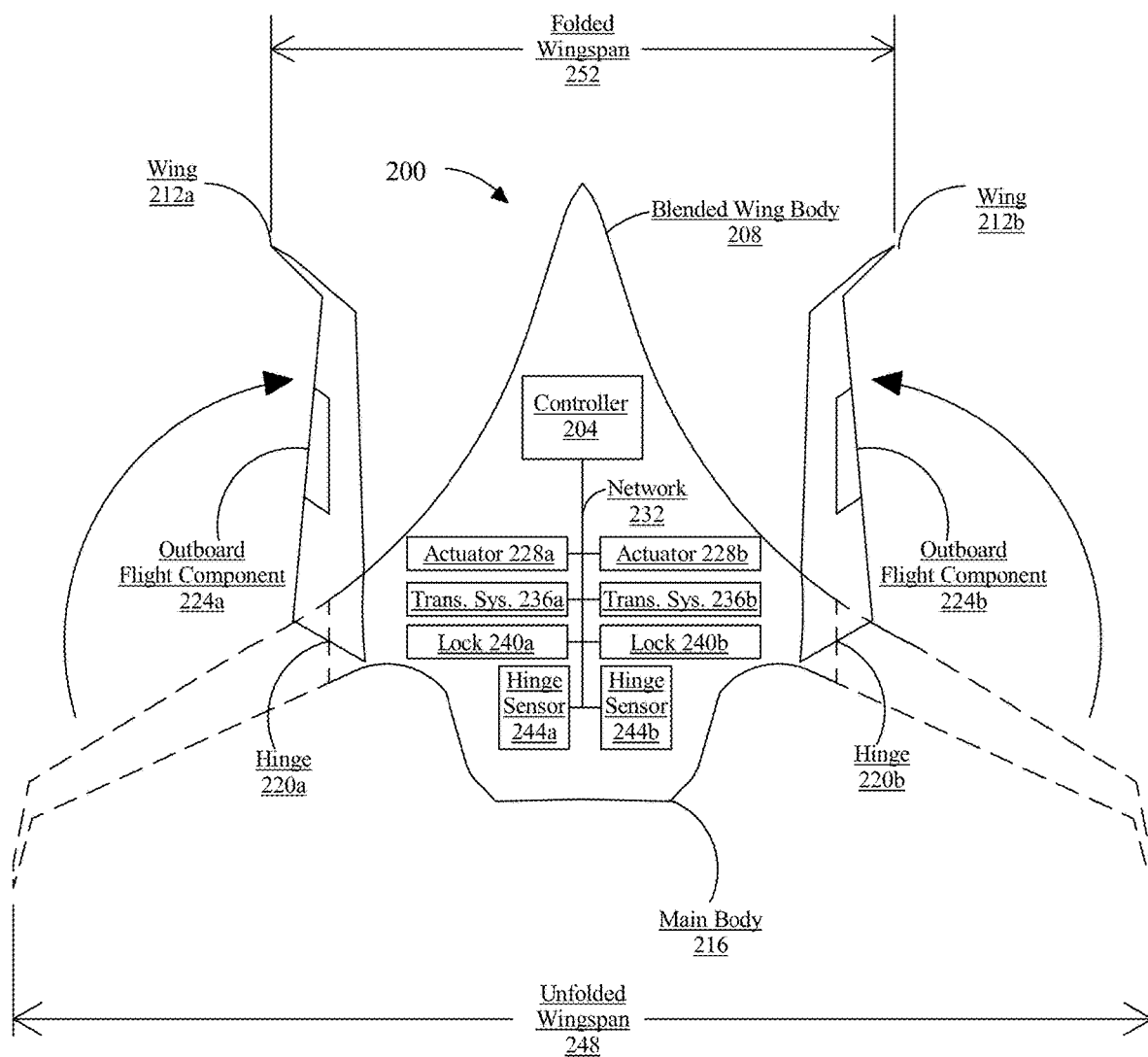
(57) **ABSTRACT**

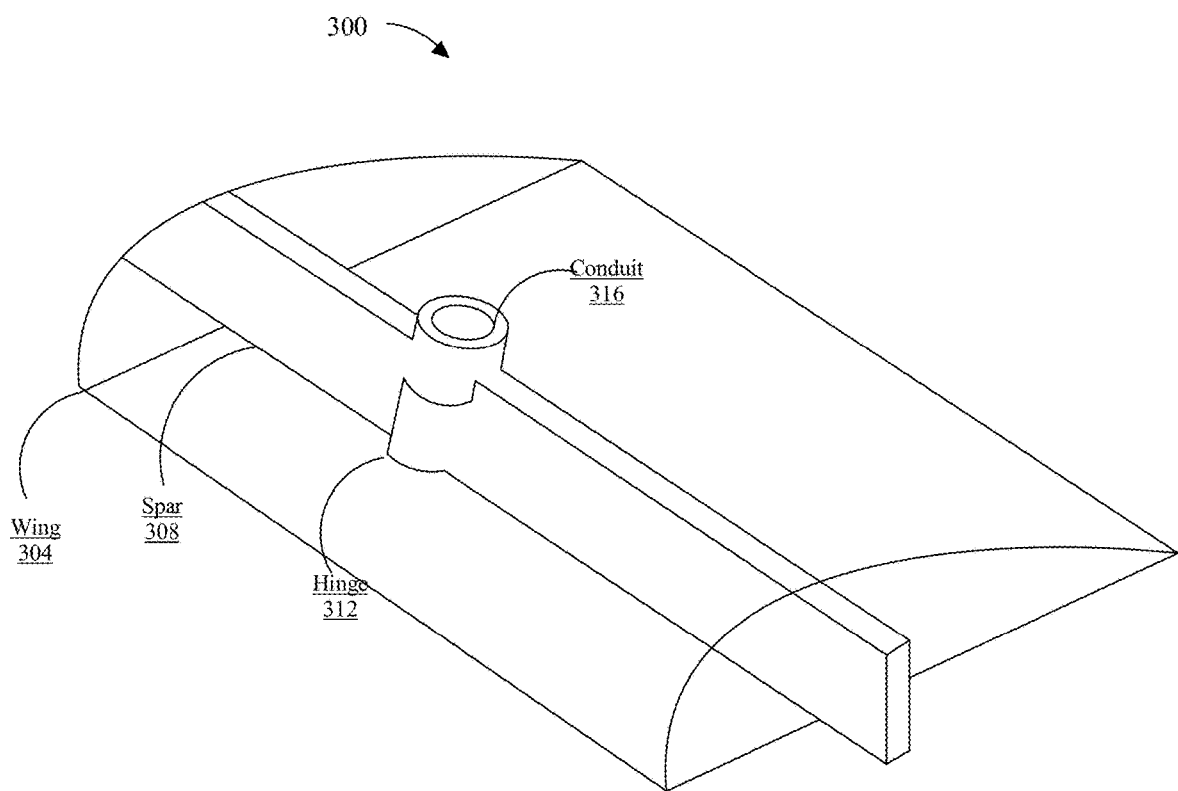
Aspects relate to systems and methods for folding wings on an aircraft. An exemplary system includes a blended wing body, where the blended wing body includes a main body and at least a wing, a hinge located on the at least a wing and configured to allow folding of the at least a wing, an actuation system configured to fold the at least a wing, and a controller configured to control the at least an actuation system.

18 Claims, 7 Drawing Sheets



**FIG. 1**

**FIG. 2**

**FIG. 3**

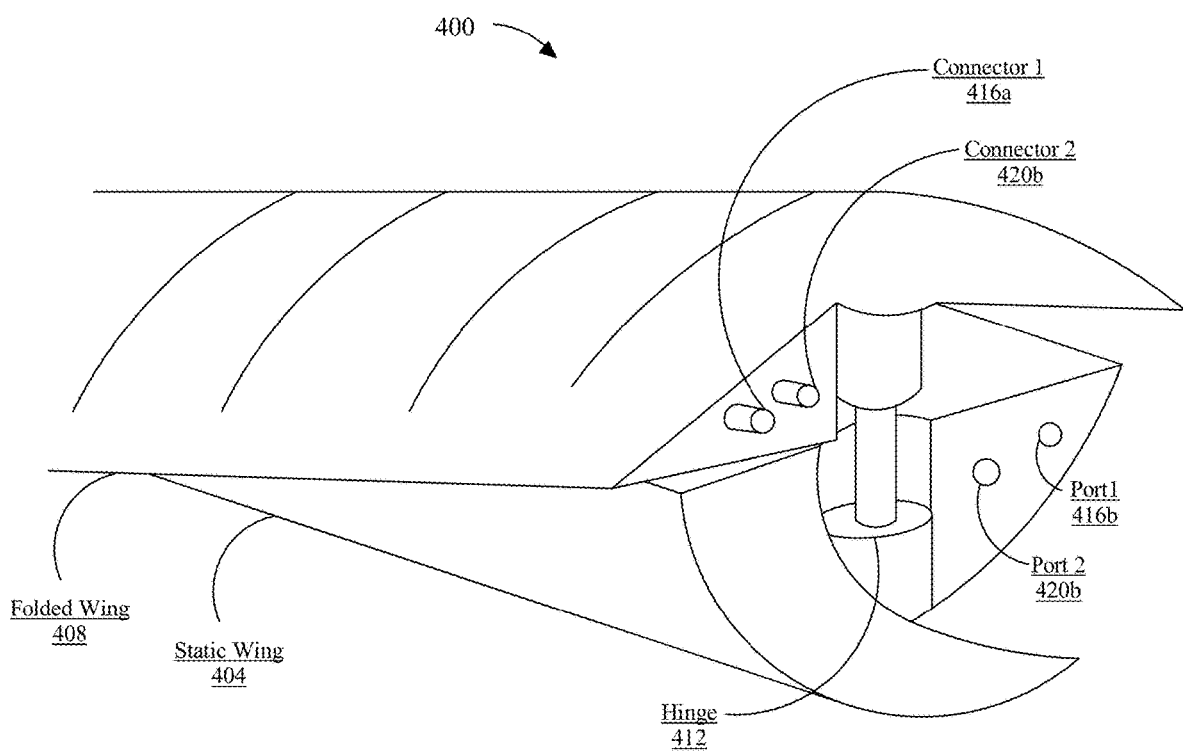


FIG. 4

33

limited to, a serial port, a USB connection, a FIREWIRE connection, a parallel connection, and any combinations thereof.

The foregoing has been a detailed description of illustrative embodiments of the invention. Various modifications and additions can be made without departing from the spirit and scope of this invention. Features of each of the various embodiments described above may be combined with features of other described embodiments as appropriate in order to provide a multiplicity of feature combinations in associated new embodiments. Furthermore, while the foregoing describes a number of separate embodiments, what has been described herein is merely illustrative of the application of the principles of the present invention. Additionally, although particular methods herein may be illustrated and/or described as being performed in a specific order, the ordering is highly variable within ordinary skill to achieve methods, systems, and software according to the present disclosure. Accordingly, this description is meant to be taken only by way of example, and not to otherwise limit the scope of this invention.

Exemplary embodiments have been disclosed above and illustrated in the accompanying drawings. It will be understood by those skilled in the art that various changes, omissions and additions may be made to that which is specifically disclosed herein without departing from the spirit and scope of the present invention.

What is claimed is:

1. A system for folding wings on an aircraft, the system comprising:

a blended wing body, wherein the blended wing body comprises:

a main body; and

at least a wing comprising an outboard flight component, wherein the outboard flight component comprises at least a flight control surface;

a hinge located on the blended wing body and configured to allow folding of the at least a wing, wherein the hinge is inboard relative to the outboard flight component;

an actuation system configured to fold the at least a wing; a controller configured to control the at least an actuation system; and

a transmission system comprising a connection wherein the connection disconnects as a function of folding of the at least a wing.

2. The system of claim 1, wherein the at least a connection comprises a selectably disconnectable communication system.

3. The system of claim 1, wherein the at least a connection comprises a fluidic connection.

4. The system of claim 1, wherein the at least a connection comprises an electrical connection.

5. The system of claim 1, wherein the transmission system is configured to facilitate communication with the outboard flight component, wherein the transmission system comprises a wireless communication component configured to transmit communication to the outboard flight component.

6. The system of claim 5, wherein the wireless communication component is further configured to transmit communication to the outboard flight component using a line-of-sight communication method.

34

munication to the outboard flight component using a line-of-sight communication method.

7. The system of claim 5, wherein the wireless communication component is further configured to transmit communication to the outboard flight component using radio communication.

8. The system of claim 1, further comprising a transmission system, wherein the transmission system comprises a slip ring.

9. The system of claim 1, further comprising a transmission system, wherein the hinge comprises a conduit, wherein the conduit is configured to contain at least a portion of the transmission system.

10. A method of folding wings on an aircraft comprising a blended wing body, wherein the blended wing body comprises a main body and at least a wing, the method comprising:

allowing, using a hinge located on the blended wing body and inboard relative to an outboard flight component of the at least a wing, folding of the at least a wing, wherein the outboard flight component comprises at least a flight control surface;

folding, using an actuation system, the at least a wing;

controlling, using a controller, the at least an actuation system; and

disconnecting a connection of a transmission system as a function of folding of the at least a wing.

11. The method of claim 10, wherein the at least a connection comprises a selectably disconnectable communication system.

12. The method of claim 10, wherein the at least a connection comprises a fluidic connection.

13. The method of claim 10, wherein the at least a connection comprises an electrical connection.

14. The method of claim 10, further comprising wirelessly communicating, using the transmission system, with the outboard flight component, wherein the transmission system comprises a wireless communication component configured to transmit communication to the outboard flight component.

15. The method of claim 14, wherein wirelessly communicating, using the transmission system, with the outboard flight component comprises transmitting communication to the outboard flight component using a line-of-sight communication method.

16. The method of claim 14, wherein wirelessly communicating, using the transmission system, with the outboard flight component comprises transmitting communication to the outboard flight component using radio communication.

17. The method of claim 10, further comprising communicating, using a transmission system, with the outboard flight component, wherein the transmission system comprises a slip ring.

18. The method of claim 10, further comprising communicating, using a transmission system, with the outboard flight component, wherein the hinge comprises a conduit, wherein the conduit is configured to contain at least a portion of the transmission system.

* * * * *



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(12) **United States Patent**
Oliver

(10) **Patent No.:** **US 8,800,912 B2**

(45) **Date of Patent:** ***Aug. 12, 2014**

(54) **THREE WING, SIX-TILT PROPULSION UNIT, VTOL AIRCRAFT**

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- (73) Assignee: **Oliver VTOL, LLC**, Bluffton, SC (US)
- (*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 417 days.
- This patent is subject to a terminal disclaimer.

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(22) Filed: **Sep. 12, 2011**

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(65) **Prior Publication Data**
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Related U.S. Application Data

- (63) Continuation-in-part of application No. 13/168,624, filed on Jun. 24, 2011, which is a continuation-in-part of application No. 12/900,790, filed on Oct. 8, 2010.
- (60) Provisional application No. 61/278,612, filed on Oct. 9, 2009.

(51) **Int. Cl.**
B64C 29/00 (2006.01)

(52) **U.S. Cl.**
USPC **244/12.4; 244/56; 244/66**

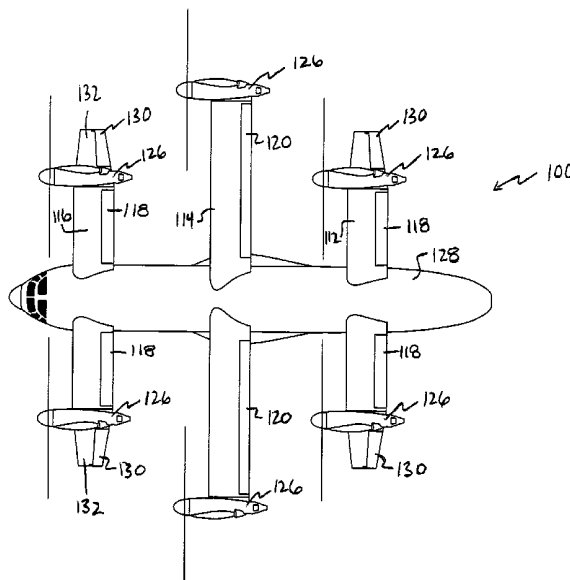
(58) **Field of Classification Search**
USPC .. 244/7 R, 7 C, 12.4, 12.5, 23 R, 23 B, 23 D, 244/56, 65, 66

See application file for complete search history.

ABSTRACT

(57) A vertical takeoff and landing aircraft having at least three wings and at least six propulsion units, each of which are located radially from two adjacent propulsion units, by equal or substantially equal angles. The at least six propulsion units together being located symmetrically, or at substantially symmetric positions, about the approximate center of gravity of the aircraft, when viewed from above. A vertical stabilizer may or may not be employed. If no vertical stabilizer is employed, yaw control during horizontal flight may be achieved through differential thrust using the at least six propulsion units. Yaw control during vertical flight may be provided by a plurality of yaw control panels. Absent yaw control panels, yaw control during vertical flight may be provided using differential propulsion unit tilt angles.

23 Claims, 12 Drawing Sheets



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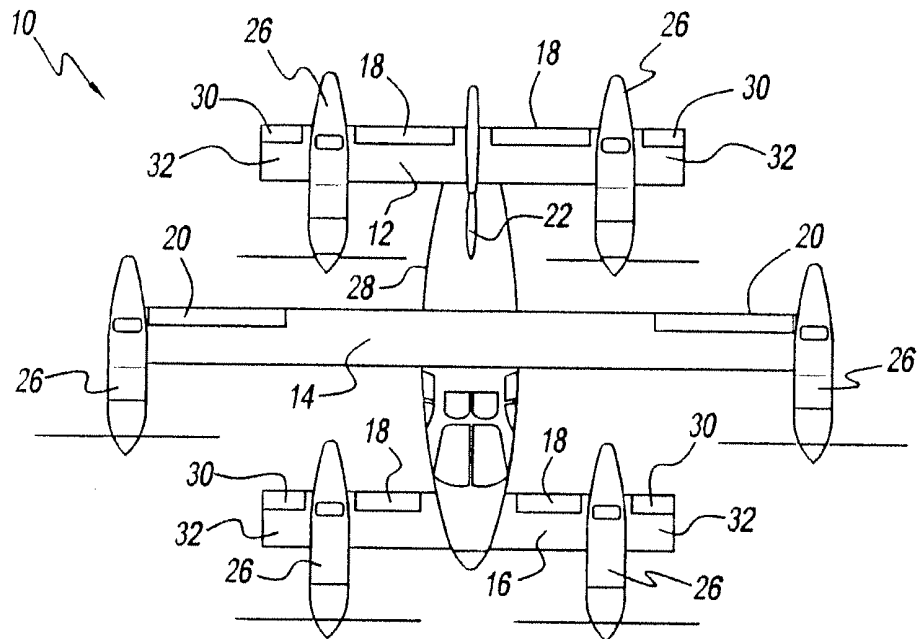


FIG. 1A

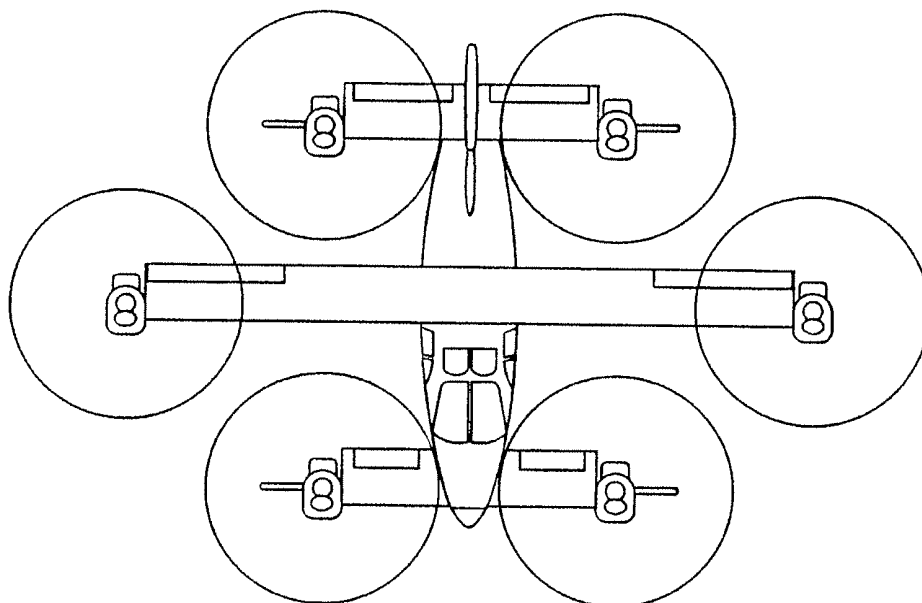


FIG. 1B

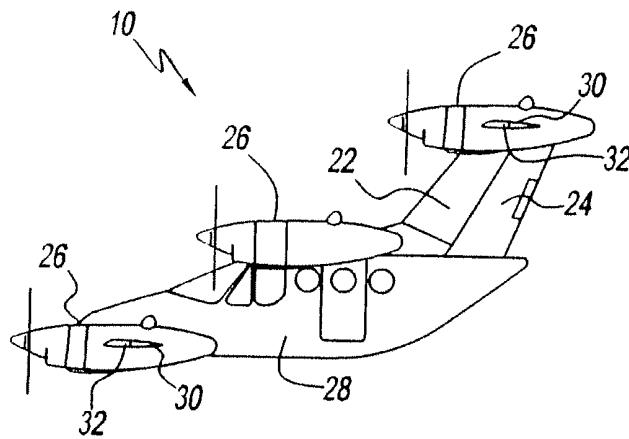


FIG. 2A

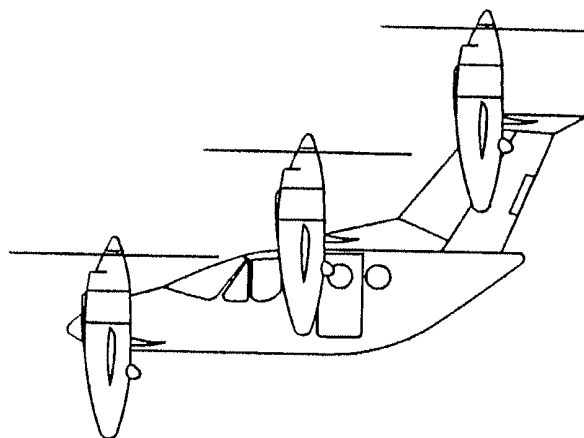


FIG. 2B

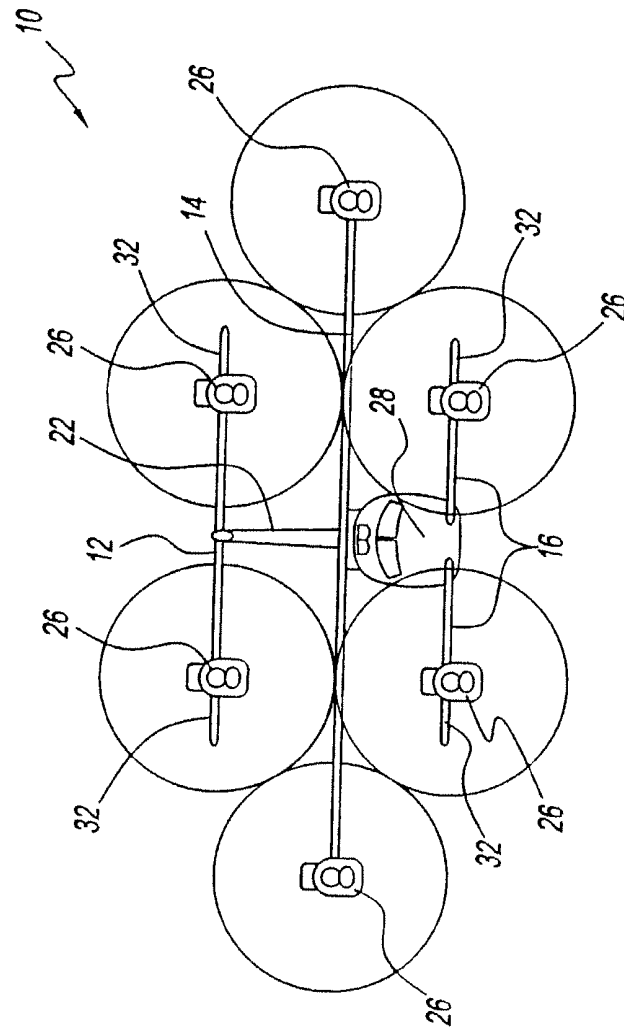


FIG. 3A

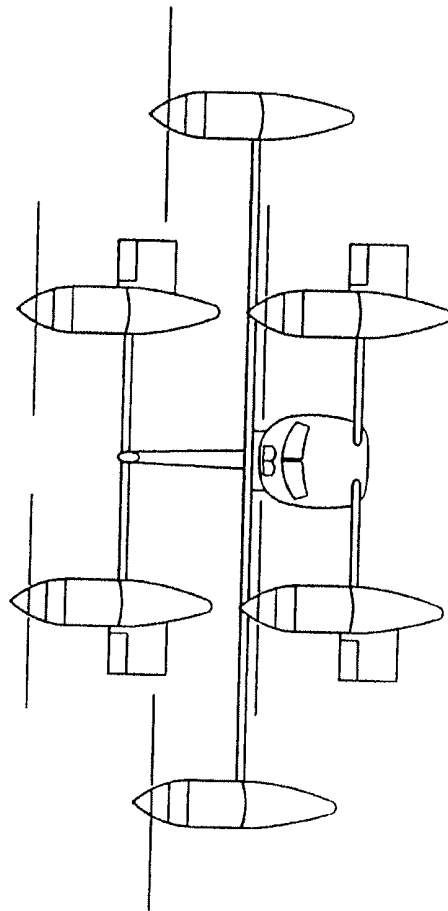


FIG. 3B

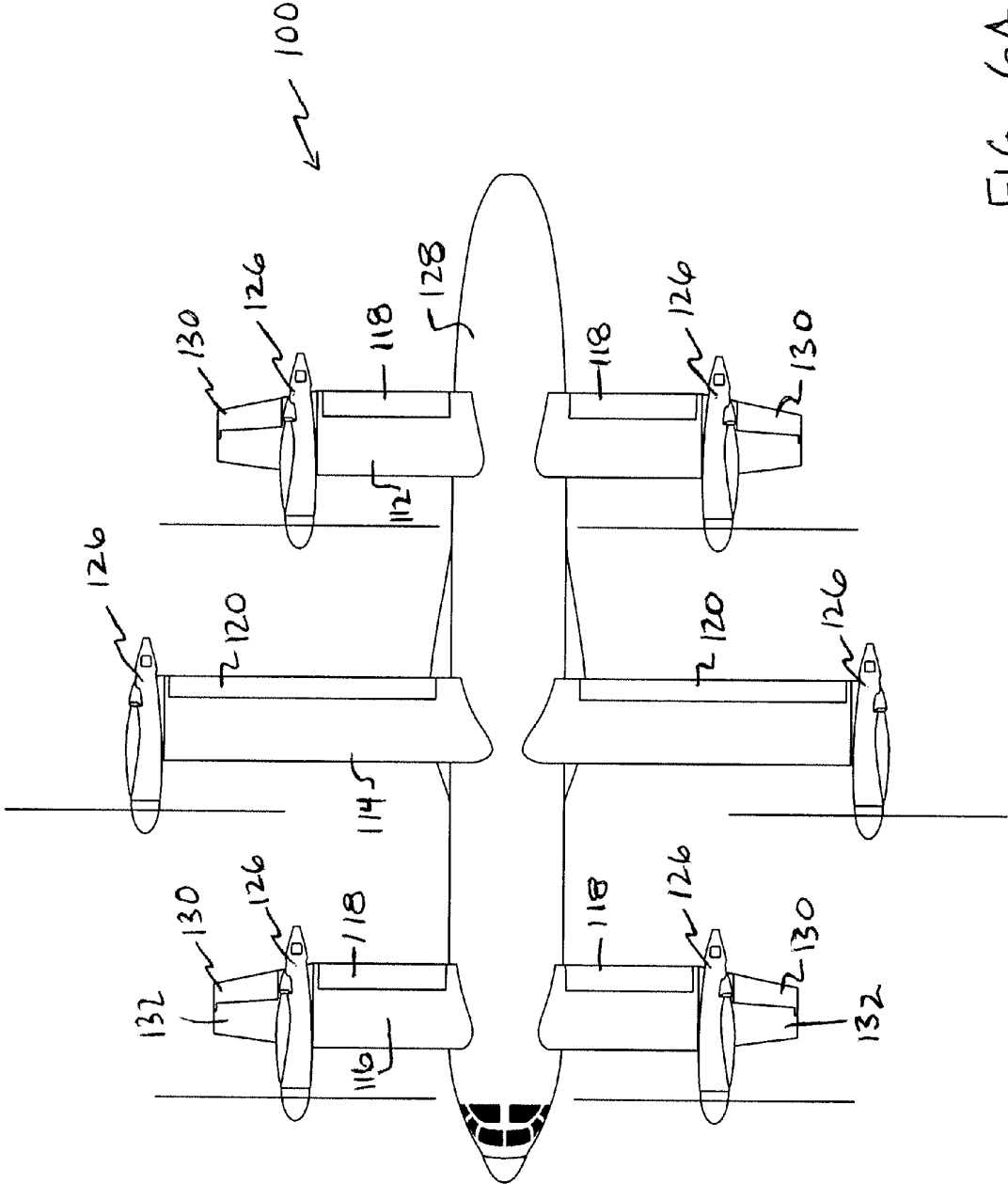


FIG. 6A

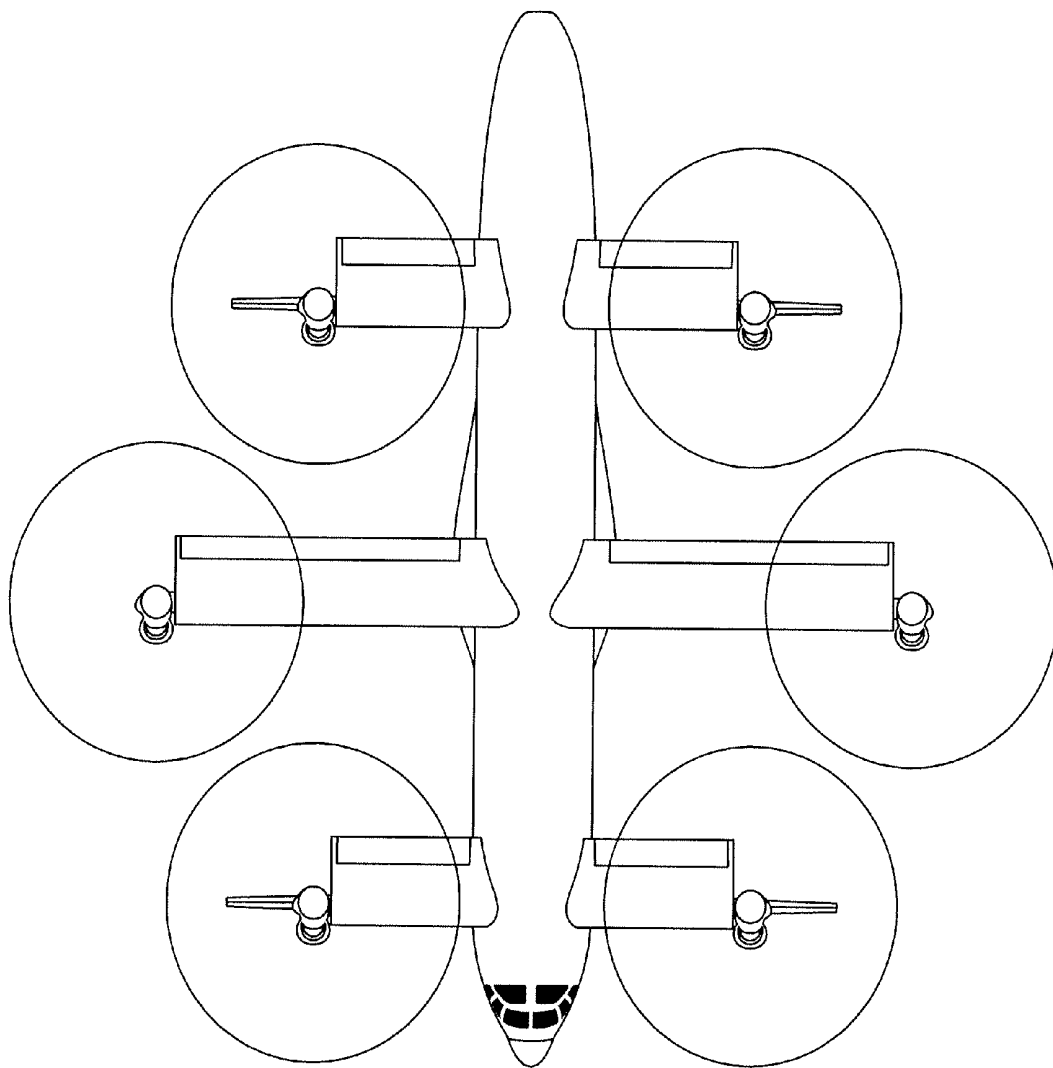


FIG. 6B

Individual propulsion unit fuel systems provide completely independent fuel systems, preventing failure of more than one unit due to a single problem. There are no fuel selectors or cross-feed controls planned, just fuel shutoff switches in the cockpit.

With the advent of Primary Flight Displays (PFDs) and Multifunction Displays (MFD) the availability of a highly reliable power source on the aircraft is mandatory. As a matter of fact the FAA demands it. Today the FAA considers alternators and batteries as power sources. This embodiment shown with six propulsion units has twelve (12) power sources. A properly designed electrical system can produce the fail safe power source for these and other important electronic systems including remote control and communication links for the UAV versions of this vehicle. The safety increase of having a virtually fail-proof power source is simply put, great.

Efficiencies

The rear wing of this configuration supports its share of the vehicle weight as opposed to conventional aircraft. Conventional aircraft normally use a less efficient un-cambered airfoil known as the horizontal stabilizer. The stabilizer operates with a downward force during normal flight. This force effectively adds additional weight reducing payload capability. It also creates drag due to this negative lift, known as "trim drag". The V22 Osprey uses a conventional horizontal stabilizer and elevator in its configuration. The supersonic Concord actually pumped fuel to a tank in its tail to reduce this trim drag.

The front wing is a cambered airfoil wing which operates as a lift producer and at the same time provides pitch control as a canard with elevator. So, rather than paying for the weight, trim drag, and negative lift of the horizontal stabilizer. The rear wing becomes part of the lift producing wing function as well as sharing pitch control with the front wing.

The location of the propulsion units near the wing ends can provide an end plate effect which reduces the normal magnitude of wing tip vortices and improving span efficiency factor, reducing induced drag and, therefore, increasing range.

A structural efficiency can be gained by distributing propulsion unit weight near the wing tips which reduces wing root bending loads and, therefore, wing weight.

The use of six propulsion units avoids the weight, complexity, and cost of a cross coupled engine drive shaft system. Industrial Applicability

The invention is applicable to aircraft and in particular VTOL aircraft. While there have been shown and described and pointed out the fundamental novel features of the invention as applied to the preferred embodiments, it will be understood that the foregoing is considered as illustrative only of the principles of the invention and not intended to be exhaustive or to limit the invention to the precise forms disclosed. Obvious modifications or variations are possible in light of the above teachings. The embodiments discussed were chosen and described to provide the best illustration of the principles of the invention and its practical application to enable one of ordinary skill in the art to utilize the invention in various embodiments and with various modifications as are suited to the particular use contemplated. All such modifications and variations are within the scope of the invention as determined by the appended claims when interpreted in accordance with the breadth to which they are entitled.

What is claimed is:

1. A vertical takeoff and landing aircraft comprising: a fuselage; three wings fixed to the fuselage, including a front wing, a middle wing and a rear wing; and

six rotatable propulsion units, wherein first and second propulsion units are fixed to the front wing, third and fourth propulsion units are fixed to the middle wing and fifth and sixth propulsion units are fixed to the rear wing, and

wherein each of the six propulsion units is located radially from each of two adjacent propulsion units by equal or substantially equal angles.

2. The vertical takeoff and landing aircraft of claim 1, wherein the six propulsion units are symmetrically positioned, or at substantially symmetric positions, about the approximate center of gravity of the aircraft.

3. The vertical takeoff and landing aircraft of claim 1, wherein each of the rotatable propulsion units are rotatable to first orientation during forward flight and to a second orientation during vertical flight.

4. The vertical takeoff and landing aircraft of claim 3, wherein the first and second propulsion units are fixed to a first and second outboard end of the front wing, respectively; the third and fourth propulsion units are fixed to a first and second outboard end of the middle wing, respectively; and the fifth and sixth propulsion units are fixed to a first and second end of the rear wing, respectively.

5. The vertical takeoff and landing aircraft of claim 4 further comprising: a plurality of yaw control panels.

6. The vertical takeoff and landing aircraft of claim 5, wherein the plurality of yaw control panels comprises a first, second, third and fourth yaw control panel located outboard of, fixed to and rotatable with the first, second, fifth and sixth propulsion unit, respectively.

7. The vertical takeoff and landing aircraft of claim 4 further comprising: differential propulsion unit tilt angle yaw control during vertical flight.

8. The vertical takeoff and landing aircraft of claim 1, wherein the front, middle and rear wings are vertically displaced relative to each other.

9. The vertical takeoff and landing aircraft of claim 8, wherein the middle wing is vertically displaced higher than the front wing, and the rear wing is vertically displaced higher than the middle wing.

10. The vertical takeoff and landing aircraft of claim 9, wherein the front wing exhibits a negative dihedral, the middle wing exhibits a neutral dihedral and the rear wing exhibits a positive dihedral.

11. The vertical takeoff and landing aircraft of claim 1 further comprising: differential thrust yaw control during horizontal flight.

12. The vertical takeoff and landing aircraft of claim 1 further comprising: a vertical stabilizer fixed to the fuselage.

13. A vertical takeoff and landing aircraft comprising: a fuselage; three wings fixed to the fuselage, including a front wing, a middle wing and a rear wing; and six propulsion units,

wherein first and second propulsion units are rotatably fixed to the front wing, third and fourth propulsion units are rotatably fixed to the middle wing and fifth and sixth propulsion units are rotatably fixed to the rear wing, wherein each of the six propulsion units is located radially from each of two adjacent propulsion units by equal or substantially equal angles, and

wherein each of the six propulsion units are rotatable to a first orientation during horizontal flight and rotatable to a second orientation during vertical flight.

21

14. The vertical takeoff and landing aircraft of claim 13, wherein the six propulsion units are symmetrically positioned, or at substantially symmetric positions, about the approximate center of gravity of the aircraft.

15. The vertical takeoff and landing aircraft of claim 13, wherein the first and second propulsion units are rotatably fixed to a first and second outboard end of the front wing, respectively; the third and fourth propulsion units are rotatably fixed to a first and second outboard end of the middle wing, respectively; and the fifth and sixth propulsion units are rotatably fixed to a first and second end of the rear wing, respectively.

16. The vertical takeoff and landing aircraft of claim 15 further comprising:

a plurality of yaw control panels.

17. The vertical takeoff and landing aircraft of claim 16, wherein the plurality of yaw control panels comprises:

a first yaw control panel and a second yaw control panel fixed to and rotatable with the first propulsion unit and the second propulsion unit, respectively; and

a third yaw control panel and a fourth yaw control panel fixed to and rotatable with the fifth propulsion unit and the sixth propulsion unit, respectively.

22

18. The vertical takeoff and landing aircraft of claim 15 further comprising:

differential propulsion unit tilt angle yaw control during vertical flight.

19. The vertical takeoff and landing aircraft of claim 13, wherein the front, middle and rear wings are vertically displaced relative to each other.

20. The vertical takeoff and landing aircraft of claim 19, wherein the middle wing is vertically displaced higher than the front wing, and the rear wing is vertically displaced higher than the middle wing.

21. The vertical takeoff and landing aircraft of claim 19, wherein the front wing exhibits a negative dihedral, the middle wing exhibits a neutral dihedral and the rear wing exhibits a positive dihedral.

22. The vertical takeoff and landing aircraft of claim 13 further comprising:

differential thrust yaw control during horizontal flight.

23. The vertical takeoff and landing aircraft of claim 13 further comprising:

a vertical stabilizer fixed to the fuselage.

* * * * *



US 20100051742A1

(19) **United States**(12) **Patent Application Publication**
Schweighart et al.(10) **Pub. No.: US 2010/0051742 A1**(43) **Pub. Date: Mar. 4, 2010**(54) **FOLDING WING & LOCKING MECHANISM**(22) Filed: **Jul. 22, 2008**(75) Inventors: **Samuel Adam Schweighart**,
Watertown, MA (US); **Carl Curtis**
Dietrich, Woburn, MA (US);
Andrew Heafitz, Cambridge, MA
(US); **Benjamin Zelnick**,
Cambridge, MA (US)**Publication Classification**(51) **Int. Cl.**
B64C 3/56 (2006.01)(52) **U.S. Cl.** **244/49**(57) **ABSTRACT**

Improved mechanisms for folding and locking an aircraft wing and controlling the wing's aileron through a wing fold have been motivated by development of a roadable aircraft. Applicable to a broader class of aircraft, these mechanisms allow for a safer, lighter-weight solution to the wing-folding challenge than currently available. The cable control system allows an outer wing section to be moved in concert with an actuated inner wing section. The locking mechanism allows for automated operation and visual inspection. The aileron control mechanism provides centering and locking in addition to flight control through the hinge axis.

Correspondence Address:

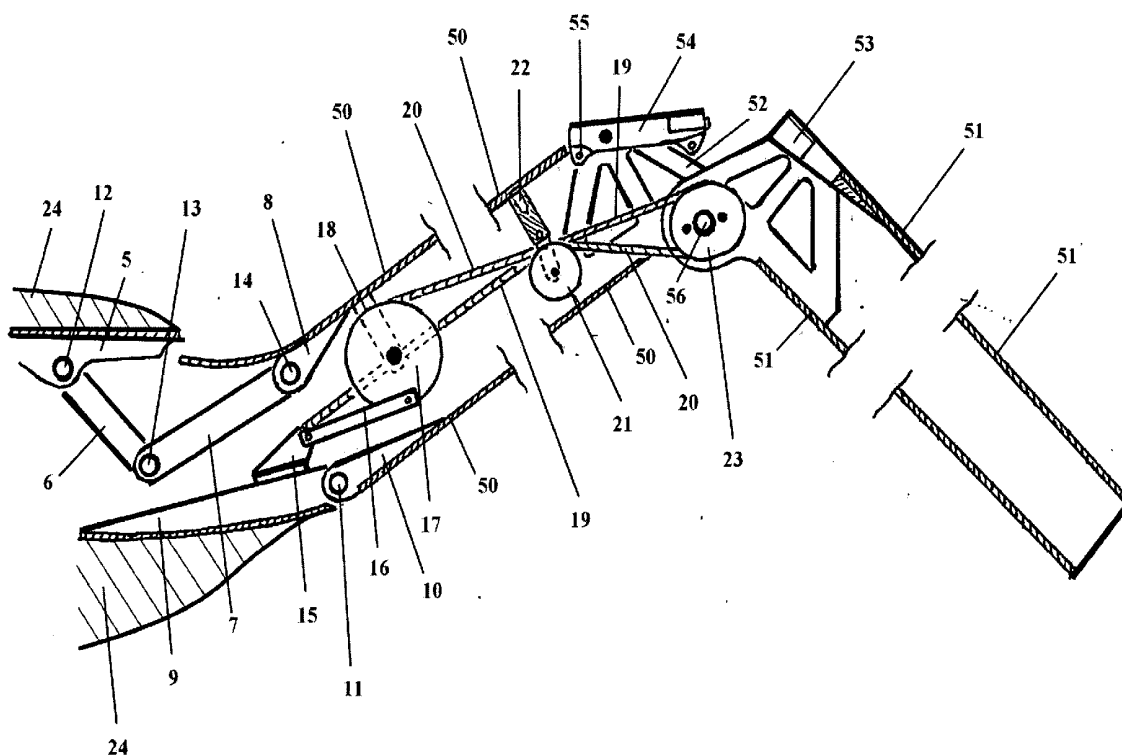
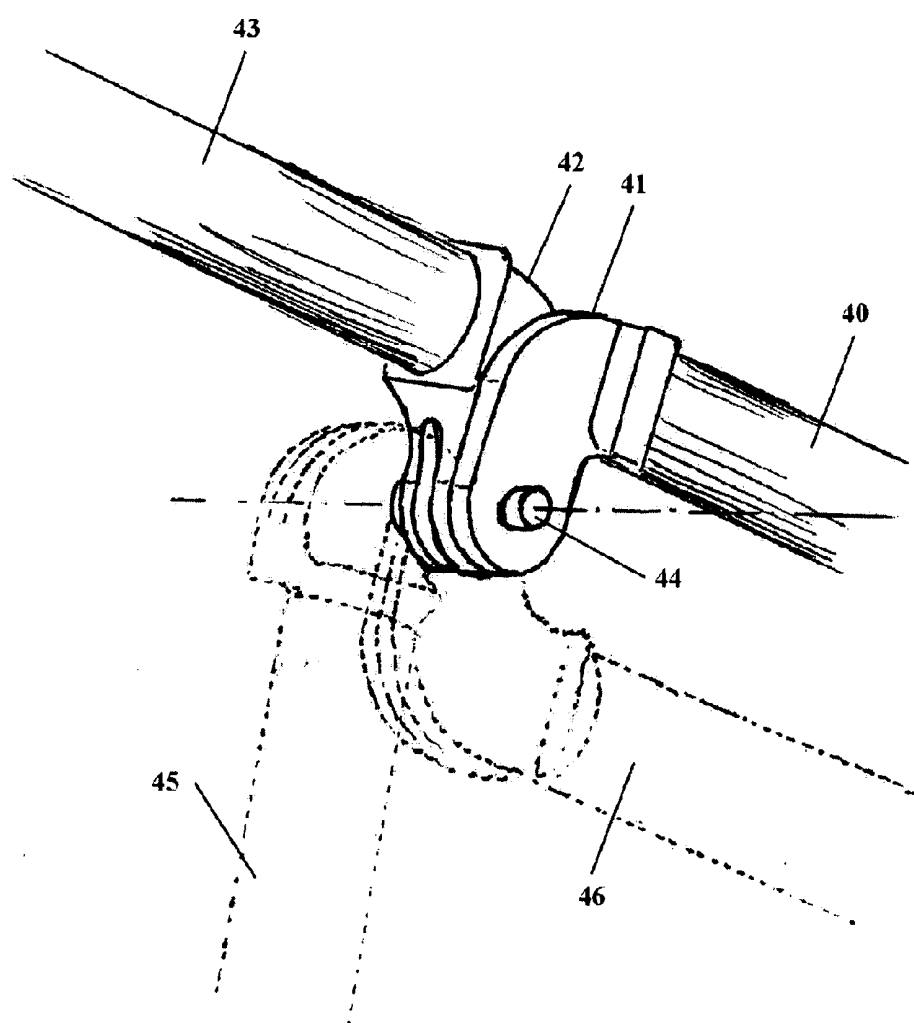
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BOSTON, MA 02109-2881 (US)(73) Assignee: **Terrafugia, Inc.,**, Woburn, MA
(US)(21) Appl. No.: **12/177,849**

Figure 3



(53). Step (58) is a feature on lever (54) which engages with a similarly shaped receptacle in outer wing latch receiver (53), and prevents (54) from overshooting its locked position in (53). In the locked position, in the preferred embodiment, the top surface of lever (54) is flush with the top surfaces of outer wing latch receiver (53) and inner wing latch mount (52) allowing smooth airflow over the inner wing (50) and the outer wing (51), and providing a visual and tactile indication that said wing panels are securely locked together. The lever (54) is directly visible, and no other device such as a sensor, window or indicator is required, although such devices could be added. In the unlocked position, part of lever (54) penetrates the surface plane of the inner wing (50), allowing a visual and tactile indicator that the wings are in an unlocked state. The sides of lever (54) may be painted a warning color such as red to enhance the visual indication of the unlocked state.

[0069] To unlock and re-fold the inner wing (50) and the outer wing (51), actuation cable (59) is pulled. In the preferred embodiment, actuation cable (59) is a cable that runs to a control lever in the cockpit, although (59) could be actuated by other means such as electrically, hydraulically etc., or (59) could be an actuator connected directly to lever (54). Actuation cable (59) provides more torque to lever (54) than to spring (57), causing (54) to rotate around lever pin (55) and disengage from outer wing latch receiver (53). Once lever head (62) and lever opposing face (63) are no longer engaged, inner wing latch mount (52) and outer wing latch receiver (53) are free to separate and the inner wing (50) and the outer wing (51) can rotate about the mid wing pivot (56) to move into the folded position. It should be observed that since the actuation cable (59) and the spring (57) are attached in the positions that they are, a break or failure in (59) will allow (57) to continue pulling lever (54) into the locked position: in case (59) fails the wing will remain locked in flight-capable configuration. In the preferred embodiment, actuation cable (59) is a push-pull cable, so in the event that spring (57) fails, lever (54) is still held in place. The double redundancy provides an extra level of safety when the wing is in use.

[0070] FIG. 3 shows the folding torque tube used to actuate the aileron in the preferred embodiment of the folding wing mechanism. This joint is located between the inner (50) and outer (51) wings in FIG. 3. The input torque tube (40) which is made of carbon fiber or other stiff material, is rigidly attached to the input hinge (41). The input hinge (41) and the output hinge (42) are allowed to pivot about the hinge pin (44), which is in line with the hinging axis of the wing. Output torque tube (43) is rigidly attached to output hinge (42). When the wing is folded, output torque tube (43) passes through mid position (45) and stops at folded position (46) when the wings are completely folded.

[0071] When the wings are in the open position, the output torque tube (43) and input torque tube (40) are collinear. Any rotational movement or force imparted by the input torque tube (40) goes through the hinge assembly and rotates or provides a force on the output torque tube (43), which transmits it to the aileron. In the preferred embodiment, the aileron is free to be moved by a mechanism linked to the control stick in the vehicle cockpit. When the wings are to be folded, the input torque tube (40) is moved to the center rotational position, so that the hinge pin (44) significantly aligns with the hinge axis of the inner and outer wing. The hinge is self centering over small angles, so small errors in alignment will be self correcting. Once the wing folds, the output torque tube

(43) will move to the folded position (46). In this position the aileron will be held rigidly in the center position, and the control stick will also be held rigidly in the center position.

[0072] When the wings are unfolded said torque tubes realign and are again free to rotate about their longitudinal axes.

We claim:

1) A bi-fold wing mechanism which provides relative rotation of an outer wing section to an inner wing section when said inner wing section rotates relative to a vehicle comprising:

- a) said vehicle,
- b) said inner wing section,
- c) an inner wing hinge connecting said inner wing section to said vehicle,
- d) said outer wing section,
- e) an outer wing hinge connecting said outer wing section to said inner wing section,
- f) a means for converting rotational motion of said inner wing relative to said vehicle to rotational motion of said outer wing relative to said inner wing whereby said outer wing rotates when said inner wing rotates.

2) A bi-fold wing mechanism which provides relative rotation of an outer wing section to an inner wing section when said inner wing section rotates relative to a vehicle comprising:

- a) said vehicle,
- b) said inner wing section,
- c) an inner wing hinge connecting said inner wing section to said vehicle,
- d) said outer wing section,
- e) an outer wing hinge connecting said outer wing section to said inner wing section,
- f) a first means for deploying said outer wing section when said inner wing section deploys,
- g) a second means for stowing said outer wing section when said inner wing section stows.

3) The mechanism in claim 2 wherein said first means and said second means are accomplished with one device.

4) The mechanism in claim 2 wherein said second means is comprised of a spring, bungee, gravity, or any other similar means that apply a biasing force or torque on said outer wing in a direction opposite of the force or torque applied by said first means.

5) The mechanism in claim 2 wherein said first means, said second means, or both said first means and said second means are comprised of:

- a) a cable or similar transmitter of linear motion,
- b) said cable connected at one end to said vehicle at a predetermined location, whereby said cable moves relative to said inner wing when said inner wing rotates relative to said vehicle,
- c) a pulley, or similar converter of linear motion to rotational motion,
- d) said pulley connected to said outer wing whereby rotational motion of said pulley is transmitted to said outer wing.
- e) said cable connected to said pulley
- f) whereby when said inner wing moves relative to said vehicle, said mechanism causes said outer wing to rotate.

6) The mechanism in claim 5 wherein said cable is a rod, chain, belt, push-pull cable, or similar device.

7) The mechanism in claim 5 wherein said pulley is a cam, offset pulley, linkage, lever, mounting location on said outer wing, or similar converter of linear motion to rotational motion.

8) The mechanism in claim 2 wherein said first means and/or said second means is comprised of:

- a) a linkage connected on one end to said vehicle,
- b) a first pulley with an axis of rotation fixed relative to said inner wing,
- c) a connection between said linkage and said first pulley whereby when said inner wing rotates relative to said vehicle, said linkage causes said first pulley to rotate with respect to said inner wing,
- d) a first cable or similar transmitter of linear motion,
- e) a connection between said first cable and said first pulley,
- f) a second pulley, or similar converter of linear motion to rotational motion,
- g) a connection between said second pulley and said outer wing whereby rotational motion of said second pulley is transmitted to said outer wing,
- h) a connection between said first cable and said second pulley, whereby when said inner wing rotates relative to said vehicle, said mechanism causes said outer wing to rotate with respect to said inner wing.

9) The mechanism in claim 8 wherein said cable is a rod, chain, belt, push-pull cable, or similar device.

10) The mechanism in claim 8 wherein said pulleys are cams, offset pulleys, linkages, levers, cable mounting location on said outer wing, similar converter of linear motion to rotational motion, or some combination thereof.

11) The mechanism in claim 8 wherein said mechanism includes:

- a) a second cable or similar transmitter of linear motion,
- b) a connection between said second cable and said first pulley, whereby said second cable moves relative to said inner wing when said inner wing rotates relative to said vehicle,
- c) a third means for converting linear force from said second cable into rotational motion of said outer wing whereby both said first cable and said second cable provide the means for rotating said outer wing in either direction.

12) The mechanism in claim 11 wherein said cables are rods, chains, belts, push-pull cables, similar device or some combination thereof.

13) The mechanism in claim 11 wherein said pulleys are cams, offset pulleys, linkages, levers, mounting location on said outer wing, similar converter of linear motion to rotational motion, or some combination thereof.

14) The mechanism in claim 11 wherein said mechanism includes a connection between said second cable and said second pulley whereby tension in said second cable causes said outer wing to rotate in a direction opposite to the direction said outer wing rotates when tension is applied to said first cable.

15) The mechanism in claim 11 wherein said cables are replaced by a singular belt or a plurality of belts or other transmitters of rotational motion.

16) The mechanism in claim 11 wherein said cables are replaced by a singular cable or a plurality of cables of other transmitters of linear motion.

17) The mechanism in claim 11 wherein said third means comprises of:

- a) a third pulley
- b) said third pulley connected to said outer wing whereby rotational motion of said pulley is transmitted to said outer wing,
- c) a connection between said second cable and said third pulley whereby tension in said second cable causes said outer wing to rotate in a direction opposite to the direction said outer wing rotates when tension is applied to said first cable.

18) The mechanism in claim 17 wherein said pulleys are cams, offset pulleys, linkages, levers, cable mounts on said outer wing, similar converter of linear motion to rotational motion, or some combination thereof.

19) The mechanism in claim 2 wherein

- a) said first means is comprised of:
 - i) a linkage connected on one end to said vehicle,
 - ii) a first pulley with an axis of rotation fixed relative to said inner wing,
 - iii) a connection between said linkage and said pulley whereby when said inner wing rotates relative to said vehicle, said linkage causes said pulley to rotate with respect to said inner wing,
 - iv) a first cable or similar transmitter of linear motion,
 - v) a connection between said first cable and said first pulley, whereby said first cable moves relative to said inner wing when said inner wing rotates relative to said vehicle,
 - vi) a second pulley,
 - vii) a connection between said second pulley to said outer wing whereby rotational motion of said second pulley is transmitted to said outer wing,
 - viii) said first cable connected to said second pulley, whereby when said inner wing moves relative to said vehicle, said outer wing rotates with respect to said inner wing.

b) said second means is comprised of:

- i) a second cable or similar transmitter of linear motion,
- ii) said second cable connected at one end to said vehicle at a predetermined location, whereby said second cable moves relative to said inner wing when said inner wing rotates relative to said vehicle,
- iii) a third pulley, or similar converter of linear motion to rotational motion,
- iv) said third pulley connected to said outer wing whereby rotational motion of said third pulley is transmitted to said outer wing,
- v) said second cable connected to said third pulley whereby when said inner wing moves relative to said vehicle, said outer wing rotates with respect to said inner wing.

20) The mechanism in claim 19 wherein said cables are rods, chains, belts, push-pull cables, similar device or some combination thereof.

21) The mechanism in claim 19 wherein said pulleys are cams, offset pulleys, linkages, levers, mounting location on said outer wing, similar converter of linear motion to rotational motion, or some combination thereof.

22) The mechanism in claim 2 wherein:

- a) said first, said second means is comprised of a cable, belt, chain or similar device for transmitting linear motion,
- b) said mechanism includes adjustment means for changing the path, length, tension or combination thereof of said cable or cables.

23) The mechanism in claim **22** wherein:

- a) said adjustment means is a pulley, cam, sprocket, slide, turnbuckle or other device in contact with said cable,
- b) said adjustment means has a variable position or orientation whereby the path, tension, length or combination thereof of said cable are adjusted.

24) The mechanism in claim **22** wherein the location or orientation of said adjustment means can be adjusted from outside the wing whereby the rotational orientation of said outer wing can be adjusted easily without disassembly of said mechanism.

25) A wing-fold lock mechanism comprising:

- a. a wing,
 - b. a body,
 - c. a hinge comprising of a first hinge half connected to said wing and a second hinge half connected to said body,
 - d. a first mechanical stop located on said wing,
 - e. a second mechanical stop located on said body,
 - f. a locking device that prevents one of said mechanical stops from moving away from said opposing mechanical stop
- whereby a combination of said mechanical stops and said locking mechanism prevent said wing from moving with respect to said body when said locking device is engaged.

26) The mechanism in claim **25** wherein said locking device is a lever comprising:

- a) a pivot axis located in one of said mechanical stops about which said lever pivots,
- b) an interlocking shape that interfaces with a corresponding recess in said opposing mechanical stop.

27) The mechanism in claim **26** wherein said hinge is located on the lower side of said wing, and said first mechanical stop is located on the top side of said wing.

28) The mechanism in claim **26** wherein said lever is shaped like the capital letter T, or the capital letter L, or any shape that prevents said first mechanical stop from moving with respect to said second mechanical stop.

29) The mechanism in claim **26** wherein said lever comes flush or nearly so with the outer surface of either or both said mechanical stops whereby said lever can be easily inspected to ensure that said lever is completely locked, and smooth airflow is maintained over the wing.

30) The mechanism in claim **26** wherein said mechanism includes means for returning said lever to the locked position.

31) The mechanism in claim **30** wherein said means is accomplished using a spring, bungee cord, electrical actuator, cable, rod, or any method that actively or passively returns said lever into the locked position.

32) The mechanism in claim **26** wherein said mechanism comprises of means for returning said lever to the unlocked position.

33) The mechanism in claim **32** wherein said means is accomplished using a spring, bungee cord, electrical actuator, cable, rod, or any method that actively or passively returns said lever into the unlocked position.

34) The mechanism in claim **26** wherein said lever has colored components only visible in the unlocked position to aid visual identification of an unlocked state.

35) A mechanism for articulating a control surface through a folding wing joint comprising:

- a) a wing assembly comprising:
 - i) an inner wing section or body,
 - ii) an outer wing section that folds with respect to said first wing section,
 - b) a first torque tube located adjacent to or inside said inner wing section,
 - c) a second torque tube located adjacent to or inside said outer wing section,
 - d) a hinge that:
 - i) connects said first torque tube with said second torque tube,
 - ii) has an axis of rotation that is substantially collinear with the axis of rotation between said inner and said outer wing section when said control surface is placed in a predetermined orientation with respect to said outer wing section,
 - e) a first means for attaching said second torque tube to said control surface,
 - f) a second means for controlling the axial orientation of said first torque tube whereby said aileron will be controlled during flight
- whereby said wing can be folded without the need for disconnecting said aileron, also said aileron is automatically held in a predetermined orientation when said wing is folded, and said mechanism transmits torque thereby controlling said aileron when wings are unfolded.

36) The mechanism in claim **35** wherein said mechanism includes a third means for ensuring said control surface is placed in a predetermined orientation before folding said wing.

37) The mechanism in claim **36** wherein said third means is comprised of:

- a) a control stick, yoke, or any similar device,
- b) a lock that holds said control stick in a predetermined position whereby said control surface is held in a predetermined orientation.

38) The mechanism in claim **35** wherein said hinge's axis of rotation is substantially perpendicular to, but not necessarily intersecting, the axis of rotation of said torque tubes whereby when a torque is applied to said torque tubes, there is no resulting force attempting to fold or unfold said hinge.

* * * * *


 ФЕДЕРАЛЬНАЯ СЛУЖБА
 ПО ИНТЕЛЛЕКТУАЛЬНОЙ СОБСТВЕННОСТИ
(12) ОПИСАНИЕ ИЗОБРЕТЕНИЯ К ПАТЕНТУ

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технического обеспечения имени генерала
армии А.В. Хрулева" Министерства обороны
Российской Федерации (RU)****(54) МЕТОД ОБНАРУЖЕНИЯ МАЛОГАБАРИТНЫХ БЕСПИЛОТНЫХ ЛЕТАТЕЛЬНЫХ АППАРАТОВ**

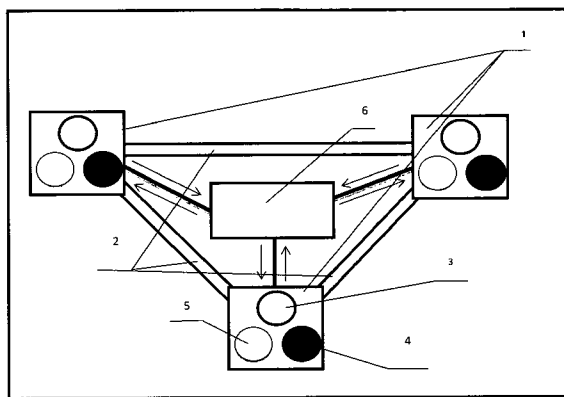
(57) Реферат:

Изобретение относится к области обнаружения и распознавания малогабаритных беспилотных летательных аппаратов (МБЛА). В заявленном способе применяются три и более изображений и сигналов в трех и более пространственно разнесенных точках на гиросtabilизирующих платформах, связанных между собой рабочими базами. Рабочие базы автоматически определяют расстояния между собой и свои пространственные координаты, что позволяет разместить в любых удобных местах как на подвижном, так и стационарном объекте. На каждой базе размещено по три датчика, работающих в оптическом (камеры кругового обзора), акустическом и в трех и более настраиваемых радиолокационных диапазонах электромагнитных волн. Управление работой

трех каналов и обработкой полученной информации и сигналов осуществляет ЭВМ с элементами искусственного интеллекта, которая сама выбирает наиболее эффективные каналы для более точного обнаружения и определения пространственных координат МБЛА в различных условиях ведения наблюдения, что позволяет построить объемное 3D изображение МБЛА и сравнить с известными изображениями для их распознавания и определения средств борьбы с МБЛА. Технический результат - разработка метода обнаружения МБЛА в различных условиях ведения наблюдения с использованием датчиков, работающих в оптическом, звуковом и радиолокационных диапазонах электромагнитных волн. 4 ил.

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Фиг.1



FEDERAL SERVICE
FOR INTELLECTUAL PROPERTY

(12) **ABSTRACT OF INVENTION**

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(54) **METHOD OF DETECTING SMALL UNMANNED AERIAL VEHICLES**

(57) Abstract:

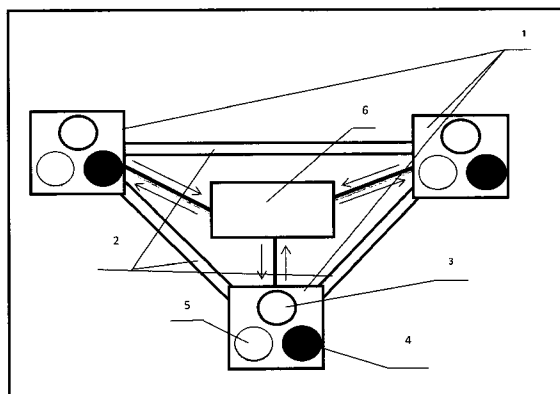
FIELD: physics, navigation.

SUBSTANCE: invention relates to detection and identification of small unmanned aerial vehicles (SUAV). The disclosed method employs three or more images and signals at three or more spaced-apart points on gyro-stabilised platforms connected to each other by operating bases. The operating bases automatically determine the distance between each other and their spatial coordinates, which enables positioning at any convenient places on both a mobile and fixed object. Each base has three sensors operating in an optical (all-round looking camera), acoustic and in three or more adjustable radar electromagnetic wave ranges. Control of the operation of the three channels and processing of the obtained information and signals is carried out by a computer with artificial intelligence elements, which selects the most efficient channel for more accurate detection and determination of spatial coordinates of the SUAV in different surveillance conditions, which enables to construct a 3D image of

the SUAV and compare with known images for identification thereof and determining means of counteracting the SUAV.

EFFECT: developing a method of detecting a SUAV in different surveillance conditions using sensors operating in the optical, audio and radar electromagnetic wave ranges.

4 dwg



Фиг.1

Изобретение относится к области обнаружения и распознавания малогабаритных беспилотных летательных аппаратов (МБЛА) и может быть использовано в военной технике.

Известны различные методы и технические решения для обнаружения летательных аппаратов с использованием способа кругового обзора матричным фотоприемным устройством и устройство для его осуществления (патент РФ №2445644), оптическим локатором кругового обзора (патент РФ №2352957) [1, 2]. Недостатками являются сложность конструкции, большие размеры, большая мощность двигателя для вращения камеры (кругового обзора) и соответственно ошибки в снятии результата.

Способ визуально-оптического контроля лазерного сканирования атмосферы (патент РФ №2489732). Недостатками являются активный метод обнаружения и минимальные турбулентные потоки из-за малых размеров и использования электродвигателей МБЛА [3].

Способ обнаружения объектов (патент РФ №2331084, прототип), заключающийся в селекции объекта на удаленном фоне, заключающийся в приеме и формировании двух изображений в двух пространственно разнесенных точках, а также одновременной регистрации сформированных цифровых изображений, отличающийся тем, что опорное и сравниваемое цифровые изображения регистрируют одномоментно для каждого фрагмента (пикселя) изображений двумя идентичными видеосистемами на основе многоэлементных высокоскоростных фотоприемников, например CMOS-матриц с объективами, которые предварительно фиксируют на небольшом по сравнению с удалением от предполагаемого места появления объекта расстоянии между собой параллельно друг другу в направлении на контролируемое пространство, а анализ изображений проводят при помощи определения величин смещения Δ характерных фрагментов сравниваемого изображения с аналогичными фрагментами опорного при максимально возможном их совпадении в направлении параллактического смещения и последующего выявления селектируемого и фоновых объектов из полученных смещений Δ и т.д. [4].

Известный способ имеет следующие недостатки: ограниченные функциональные возможности, связанные с невозможностью обнаружения МБЛА на 360° по горизонтали и на 180° по вертикали; ограниченную применимость видимым диапазоном работы видеокамер; невозможность использования в движении и создания достоверного трехмерного объемного изображения МБЛА и определения его дальнейшего направления движения.

Задачей, стоящей перед настоящим изобретением, является повышение возможности обнаружения МБЛА на 360° по горизонтали и на 180° по вертикали, параллельной работе в оптическом, звуковом и радиолокационном диапазоне электромагнитных волн, возможности размещения на подвижных объектах и создания достоверного трехмерного объемного изображения МБЛА и определения его дальнейшего направления движения.

Поставленная задача решается следующим образом.

В методе обнаружения МБЛА, заключающемся в приеме и формировании трех и более изображений и сигналов в трех и более пространственно разнесенных точках на гиросtabilизирующих платформах 1, связанных между собой рабочими базами 2, автоматически определяющими расстояния между собой и свои пространственные координаты, что позволяет разместить в любых удобных местах как на подвижном объекте, так и стационарном (фиг. 1). На каждой базе размещено по три датчика: датчик 3 (камера кругового обзора), работающий в оптическом диапазоне, датчик 4,

работающий в акустическом диапазоне, и датчик 5, работающий в трех и более настраиваемых радиолокационных диапазонах электромагнитных волн. Управление работой и обработкой полученной информации осуществляется ЭВМ 6 с элементами искусственного интеллекта, который сам выбирает наиболее эффективные датчики для более точного обнаружения и определения пространственных координат МБЛА в различных условиях. Одновременная регистрация кадров видеопоследовательности и определения геометрических и цветовых изменений сформированных изображений [5], согласно изобретению контрольное (наиболее ярко-выраженное) и сравниваемое цифровые изображения регистрируют одновременно для каждого фрагмента изображений тремя и более идентичными видеосистемами (датчиками) 3 на основе многоэлементных высокоскоростных фотоприемников 7 (фиг. 2). Анализ изображений проводится на ЭВМ 6 и определяются величины смещения P_1, P_2, P_3 (фиг. 3) характерных фрагментов 8 (фиг. 4) сравниваемого изображения с аналогичными фрагментами контрольного при максимально возможном их совпадении в направлении параллактического смещения 9. Сущность измерения расстояния до МБЛА заключается в суммарном определении линейного параллакса, которое рассчитывается между двумя датчиками 1-2 (2-3, 1-3 или 1-i), одновременно по трем и более базам (фиг. 2) по формуле $D=B/\text{tg} Y$ (стереоскопический базовый метод измерения дальности).

Дальность D_1 до точки 1 МБЛА определяется по величине параллактического угла Y^1 и по величине базы между датчиками B^{1-2} , определяемой суммой $Y_1 = Y_1^1 + Y_2^1 = P_1 / f + P_2 / f$ (фиг. 2). Соответственно также определяются расстояния до других точек МБЛА (D_2, D_3, D_4), что позволяет с помощью ЭВМ 6 построить объемное 3D изображение и сравнить с известными МБЛА с целью их распознавания. Определяя координаты датчиков 3 и углы направления Y_1^1, Y_2^1 , ЭВМ 6 рассчитывает пространственные координаты МБЛА в оптическом диапазоне электромагнитных волн. Определяя постоянно пространственные координаты, ЭВМ 6 определяет скорость и направление движения, что позволяет производить сопровождение МБЛА.

Для наиболее достоверного обнаружения МБЛА в условиях плохой видимости, когда оптический канал по выбору ЭВМ 6 не эффективно использовать (густой туман, полная темнота и т.д.), в процессе обнаружения используется звуковой и радиолокационный каналы. Датчики 4 и 5 размещены совместно на гиросtabilизирующих платформах 1 и параллельно фиксируют появления объекта, и также с помощью ЭВМ 6 определяют пространственные координаты МБЛА в звуковом и радиолокационном диапазонах электромагнитных волн.

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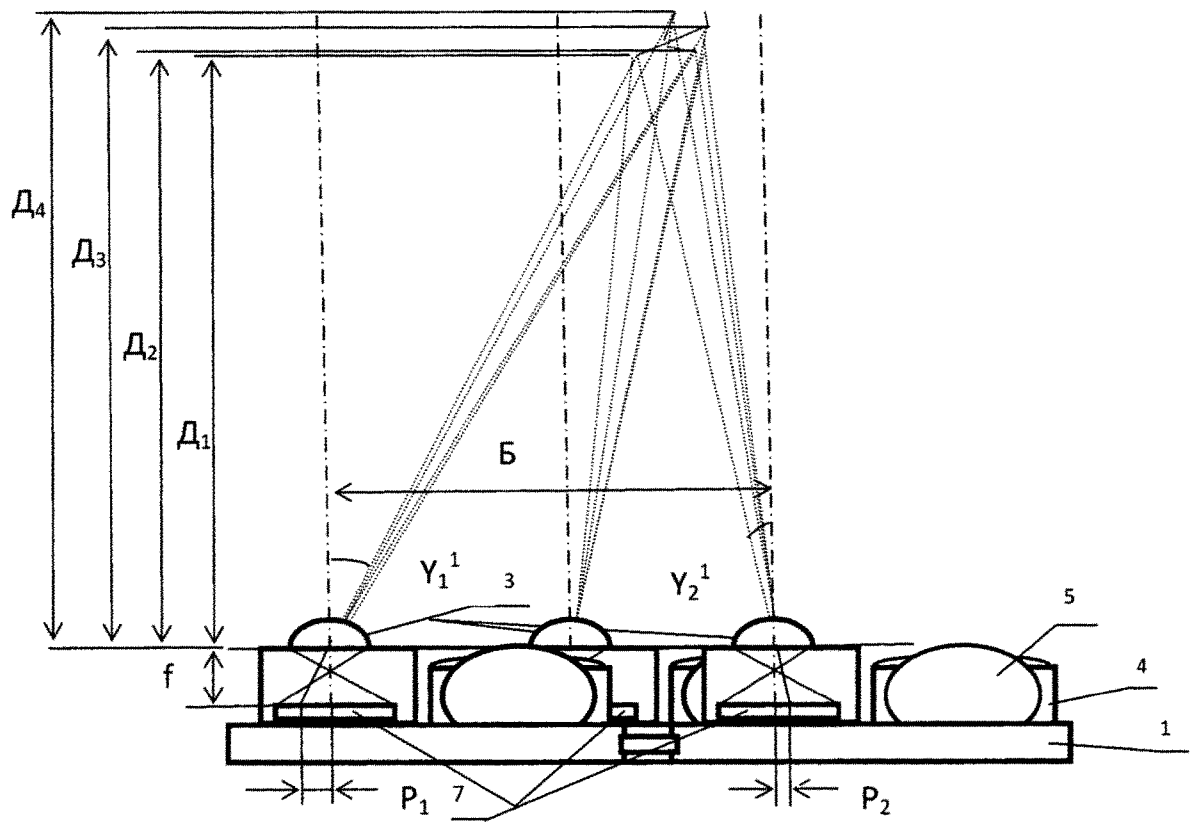
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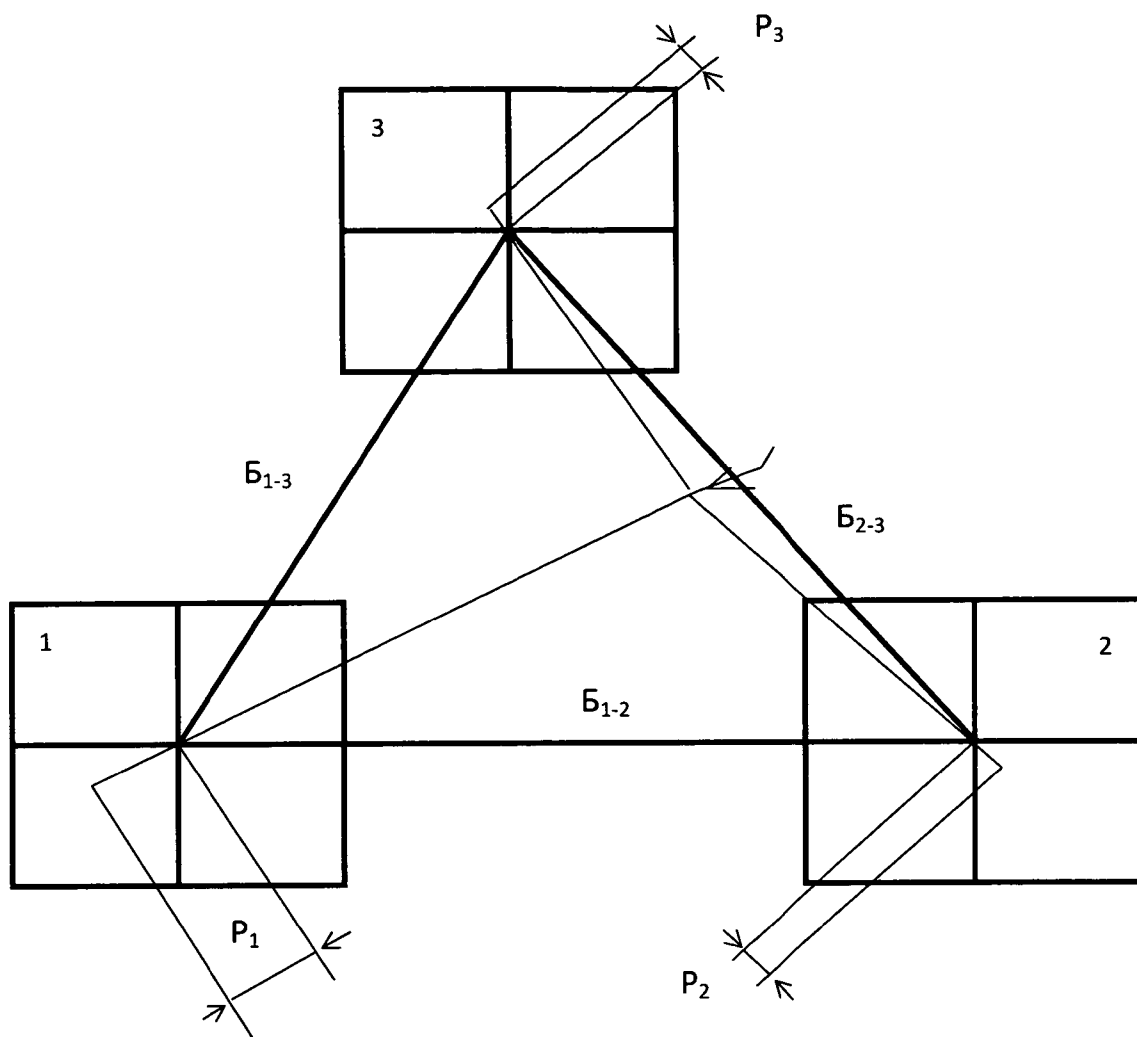
видеопоследовательности для обнаружения ДПЛА. / Музаи К., Устинов Е.М., Пархоменко А.В., Чернов Е.М., Щербаков А.С. /. Свидетельство о государственной регистрации программы для ЭВМ №2013611694, 31.01.13.

Формула изобретения

Метод обнаружения малогабаритных беспилотных летательных аппаратов (МБЛА), заключающийся в селекции объекта на удаленном фоне, в приеме и формировании изображений в пространственно разнесенных точках, а также одновременной регистрации сформированных цифровых изображений высокоскоростными фотоприемниками, анализ изображений проводят при помощи определения величин смещения характерных фрагментов сравниваемого изображения с аналогичными фрагментами опорного, отличающийся тем, что в приеме и формировании используются три и более изображений и сигналов в трех и более пространственно разнесенных точках на гиростабилизирующих платформах, связанных между собой рабочими базами, автоматически определяющими расстояния между собой и свои пространственные координаты, что позволяет разместить в любых удобных местах как на подвижном, так и стационарном объекте, на каждой базе размещено по три датчика, работающих в оптическом (камеры кругового обзора), акустическом и в трех и более настраиваемых радиолокационных диапазонах электромагнитных волн, управление работой трех каналов и обработкой полученной информации и сигналов осуществляет ЭВМ с элементами искусственного интеллекта, которая сама выбирает наиболее эффективные каналы для более точного обнаружения и определения пространственных координат МБЛА в различных условиях ведения наблюдения, что позволяет построить объемное 3D изображение МБЛА и сравнить с известными для их распознавания и определения средств борьбы с МБЛА.

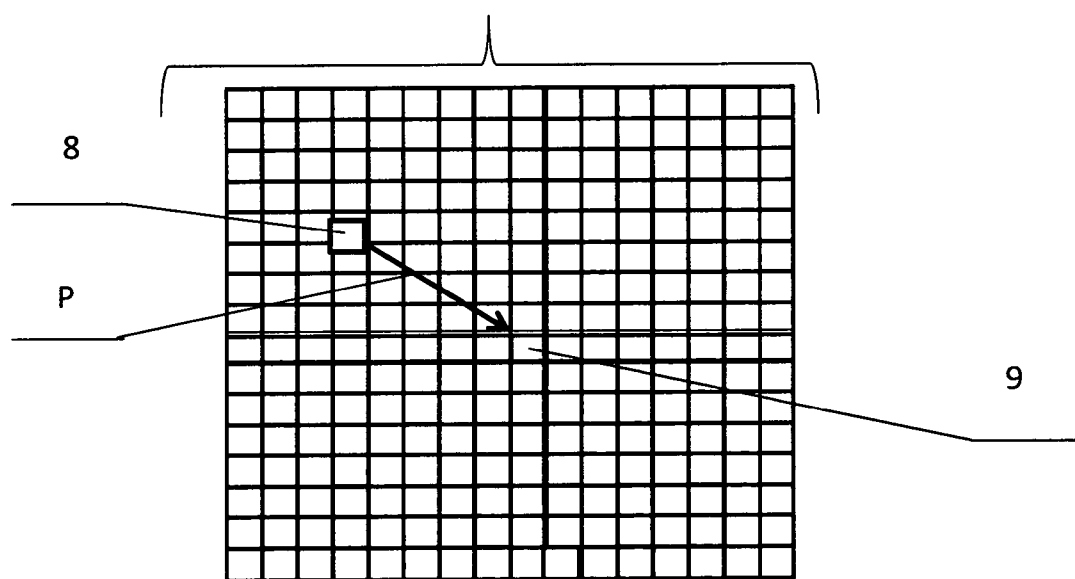


Фиг.2



Фиг.3

7



Фиг.4

РЕПУБЛИКА БЪЛГАРИЯ

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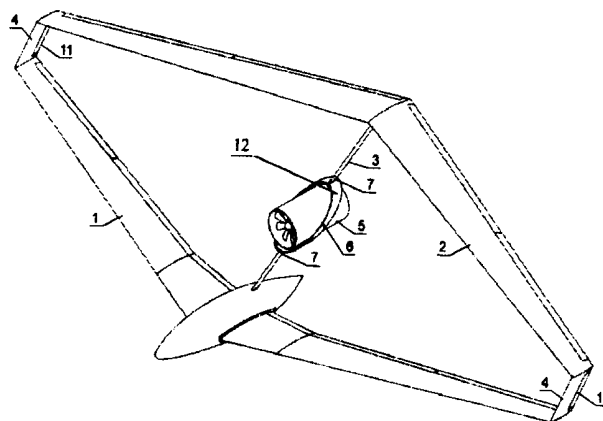
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(54) САМОЛЕТ СЪС СЪЧЛЕНЕНО КРИЛО

(57) Изобретението се отнася до високоманеврен самолет със съчленено крило, който може да намери приложение за извършване на полети, по-специално пилотирани или без пилот на борда за спортни цели, гасене на пожари, мониторинг и предотвратяване на градушки. Високата маневреност на самолета се постига чрез комбинирано управление на кормилата и вектора на тягата на двигателя, при което се постига директно и индиректно изменение на аеродинамичните сили. Съчлененото крило е устойчиво на претоварванията, възникващи при еволюиите. Високоманевреният самолет със съчленено крило се състои от предно (1) и задно (2) крило с елерони (10), предкрилки (8) и задкрилки (9), свързани помежду си с обтекаеми

силови елементи (3 и 4). Двигател (5) е захванат към централен силов елемент (3) посредством шарнири (6 и 7).

7 претенции, 3 фигури



BG 65998 B1

(54) САМОЛЕТ СЪС СЪЧЛЕНЕНО КРИЛО**Област на техниката**

Изобретението се отнася до самолет със съчленено крило, който може да намери приложение в пилотираната и безпилотна авиация, по-специално в летателните апарати, при които се изисква висока маневреност, устойчивост на високи претоварвания и директно управление на аеродинамичните сили.

Предшестващо състояние на техниката

Известен е самолет със съчленено крило, състоящ се от предно крило с тяло и задно крило, свързани помежду си със странични обтекаеми силови елементи предкрилки, задкрилки и с елерони, захванати за крилата и двигател и вертикален стабилизатор в задния му край. Предното крило е съединено с предната част на тялото, а задното крило е съединено с горния край на вертикален стабилизатор, като краищата на крилата са свързани помежду си посредством странични обтекаеми елементи (US 4365773).

Основният проблем е, че усилията между двете крила се предават през тялото и вертикалния стабилизатор, което ги утежнява, а също и че този самолет не притежава много висока маневреност поради твърдото захващане на двигателите, което не позволява управление на вектора на тягата.

Техническа същност на изобретението

Задачата на изобретението е да се създаде самолет, който да притежава висока маневреност, намалени размери и деформируемост, висока якост, подобрени аеродинамични характеристики и съкратени разбег и пробег.

Задачата е решена със самолет със съчленено крило, състоящ се от предно крило с тяло и задно крило, свързани помежду си със странични обтекаеми силови елементи предкрилки, задкрилки и с елерони, захванати за крилата и двигател. Съгласно изобретението, централните части на крилата са свързани чрез обтекаем централен силов елемент, образуващ с тях и страничните обтекаеми силови елементи пространствена рамка. Към централния обтекаем силов елемент посредством рамката / и шар-

нири е монтиран двигателят, при което векторът на тягата е през центъра на масата на самолета и е с възможност за отклоняване.

Съгласно вариант на изпълнение двигателят включва витло в дюза с двигател.

Двигателят може да бъде и реактивен двигател.

Обтекаемите силови елементи в края на крилата са поставени под ъгъл спрямо въздушния поток и имат кормила.

Кормилата, елероните и векторът на тягата на двигателя са с възможност за комбинирано отклоняване.

Предкрилките, задкрилките на предното и задното крило и двигателят са с възможност за комбинирано задействане, при повишаване на носещата способност и разширяване диапазона на центровките на самолета.

Предкрилките, задкрилките, елероните и векторът на тягата на двигателя са с възможност за комбинирано отклоняване.

Предимствата на самолета съгласно изобретението са:

Крилата могат да се използват комбинирано, в зависимост от изпълнявания маневър. При това задкрилките и елероните могат да изпълняват ролята на кормила за височина, за завой и директно управление на подемната и страничната сила.

Едновременното отклоняване на механизацията на двете крила самолетът позволява да се повиши рязко максималната му носеща способност, без да се създават допълнителни моменти, които трябва да бъдат балансирани, примерно чрез изменение на ъгъла на поставяне на хоризонтален стабилизатор. При синхронизирано отклонение на механизацията може значително да се разшири диапазона на експлоатационните центровки.

Шарнирното закрепване на двигателя позволява отклоняването му на големи ъгли и управление на вектора на тягата в хоризонталната и вертикалната равнина.

Едновременното комбинирано отклоняване на кормилата и двигателя позволява директно и индиректно управление на аеродинамичните сили и изпълнение на маневри с рязко изменение на посоката на движение и ъгловото положение на самолета.

Самолетът ще може да излита и каца при достатъчна тяговъоръженост и вертикално. Предлагаият самолет може да излита и само с един двигател, който осигурява и хоризонталния полет. Устойчивостта при излитане и кацане може да се осигури с малки отклонения на двигателя, така че векторът на тягата му винаги да минава през центъра на масата.

Самолетът може да се използва в пилотиран и безпилотен вариант. При пилотиран вариант могат да проектират самолети с много по-голям полезен товар, при еднакви размери със съществуващите до този момент.

Освен това съчлененото крило, заедно с централния силов елемент осигуряват възможност да се извършват маневри с много високи претоварвания, каквито са необходими за безпилотните самолети.

Обтекаемите странични силови елементи в края на крилата са поставени под ъгъл спрямо въздушния поток и осигуряват устойчивост срещу отклонения от курса и наклона. Те могат да имат кормила за завой и директно управление на страничната сила. Комбинираното отклоняване на кормилата и вектора на тягата от системата за управление придават на самолета свойствата свръхманевреност и пъргавост, т.е. той може да изпълнява маневри, които не са възможни за самолети с други схеми.

Полезният товар може да се помести в центропланите на крилата, формата на които се оформя в зависимост от необходимите за това обеми.

Обтекаемите силови елементи в края на крилата са поставени под ъгъл спрямо въздушния поток, което допринася за осигуряване на устойчивост срещу отклонения от курса и наклона. Те имат кормила за завой и директно управление на страничната сила. Освен това предкрилките, задкрилките на предното и задното крило и двигателят са с възможност за комбинирано задействане за повишаване на носещата способност и разширяване диапазона на центровките на самолета.

Използваното техническо решение намалява необходимата разпереност и масата на конструкцията на самолета, при което той има по-малка разпереност и собствено тегло, при сравнение с еквивалентни самолети от други схеми, което му осигурява предимства при летателната

и техническа експлоатация.

Други съществени предимства са, че самолетът може да бъде безпилотен, както и да излита и каца вертикално.

Пояснение на приложените фигури

Изобретението се пояснява с примерно изпълнение, показано на приложените фигури, от които:

фигура 1 представлява аксонометричен изглед отпред и отгоре на високоманеврения самолет със съчленено крило;

фигура 2 - поглед отгоре на самолета;

фигура 3 - поглед отпред на самолета.

Примери за изпълнение на изобретението

Високоманевреният самолет със съчленено крило, показан на фиг. 1, се състои от предно крило с тяло 1 и задно крило 2, съединени по средата с централен силов елемент 3, а в краищата със странични обтекаеми силови елементи 4. Към централния силов елемент 3 шарнирно е закрепен двигател 5, посредством рамка 12 с хоризонтален шарнир 6, за хоризонтално завъртане на двигателя 5 и наклонен шарнир 7, за движение на двигателя 5 по вертикала. Двигателят 5 включва витло в дюза и двигател или реактивен или ракетен двигател. Централният силов елемент 3, крилата 1, 2 и страничните обтекаеми силови елементи 4 образуват пространствената силова рамка, придаваща устойчивост на конструкцията. Предното 1 и задно 2 крило имат механизация, включваща предкрилки 8, задкрилки 9, елерони 10, а страничните обтекаеми силови елементи 4 имат кормила 11, които могат да се използват комбинирано, в зависимост от изпълнявания маневър. При това задкрилките 9, елероните 10 и кормилата 11 изпълняват ролята на кормила за височина, за завой и директно управление на подемната и страничната сила.

Възможни са варианти с няколко силови елемента 3, за които са захванати шарнирно няколко двигателя 5.

Приложение на изобретението

Самолетът със съчленено крило и управляем вектор на тягата може да се използва в пилотираната и безпилотна авиация за превоз на път-

ници и товари, спортни и учебни цели, за наблюдение, за гасене на пожари и предотвратяване на градушки.

Самолетът със съчленено крило е с управляем вектор на тягата, при което високата маневреност е необходима при акробатични спортни самолети и при самолети за гасене на пожари в планински местности.

При излитане и кацане като самолет (със засилване и изтъркаване) елементите на механизацията на предното 1 и задното 2 крило са спуснати, което увеличава коефициента на подемната сила, а двигателят 5, който е закрепен в центъра на масата, може да се завърти около хоризонталния шарнир 6, като създава допълнителна подемна сила и това позволява намаляване на пробегата и разбега, а при достатъчна тяговъоръженост, самолетът може да излита и каца вертикално.

Патентни претенции

1. Самолет със съчленено крило, състоящ се от предно крило с тяло и задно крило, свързани помежду си със странични обтекаеми силови елементи предкрилки, задкрилки и с елерони, захванати за крилата и двигател, характеризира се с това, че централните части на крилата (1 и 2) са свързани чрез обтекаем централен силов елемент (3), образуващ с тях и страничните обтекаеми силови елементи (4) пространствена рамка (12), като към централния обтекаем силов елемент (3) посредством рамката (12) и шарнири (6 и 7) е монтиран двигателят (5), при което векторът на тягата е през центъра на масата на самолета и е с възможност за отклоняване.

2. Самолет съгласно претенция 1, характеризира се с това, че двигателят (5) включва витло в дюза с двигател.

3. Самолет съгласно претенция 1, характеризира се с това, че двигателят (5) е реактивен двигател.

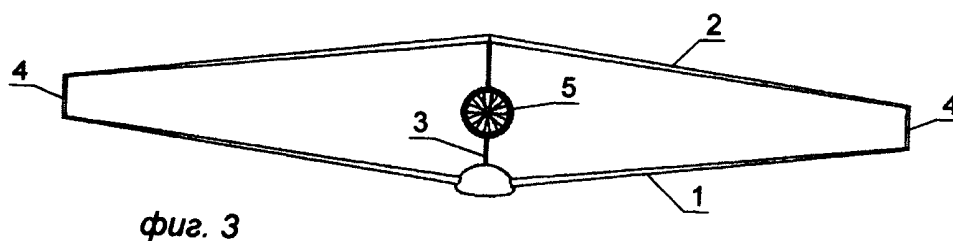
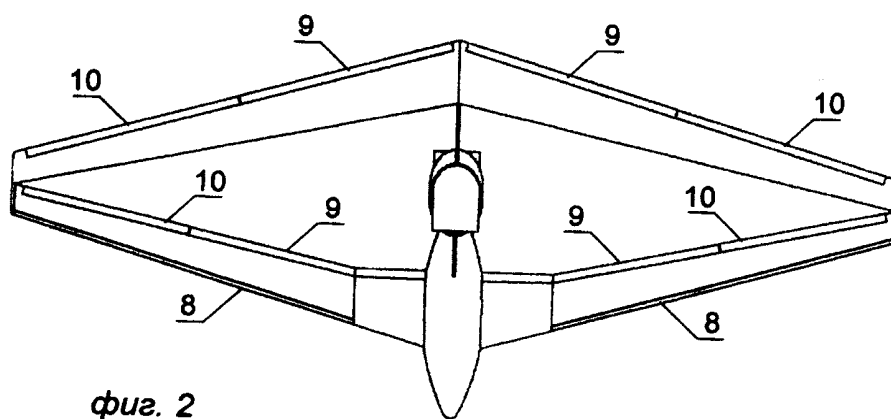
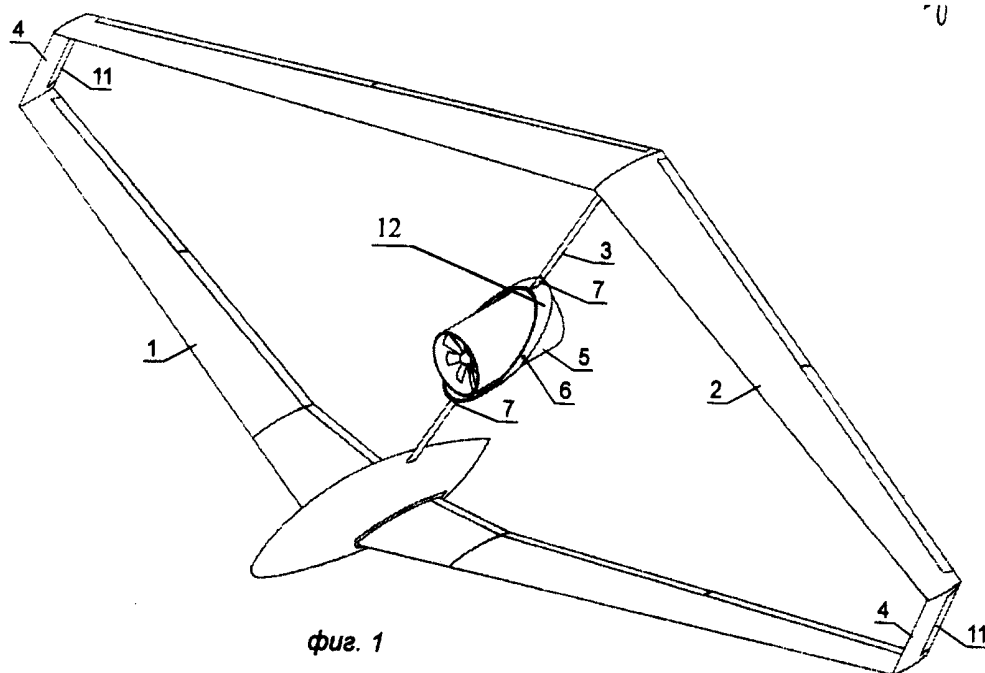
4. Самолет съгласно претенции от 1 до 3, характеризира се с това, че обтекаемите силови елементи (4) в края на крилата (1, 2) са поставени под ъгъл спрямо въздушния поток и имат кормила (11).

5. Самолет съгласно претенции от 1 до 4, характеризира се с това, че кормилата (11), елероните (10) и векторът на тягата на двигателя (5) са с възможност за комбинирано отклоняване.

6. Самолет съгласно претенции от 1 до 4, характеризира се с това, че предкрилките (8), задкрилките (9) на предното (1) и задното крило (2) и двигателят (5) са с възможност за комбинирано задействие, при повишаване на носещата способност и разширяване диапазона на центровките на самолета.

7. Самолет съгласно претенции от 1 до 4, характеризира се с това, че предкрилките (8), задкрилките (9), елероните (10) и векторът на тягата на двигателя (5) са с възможност за комбинирано отклоняване.

Приложение: 3 фигури



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(54) **TWIN BOOM VTOL ROTORCRAFT WITH
DISTRIBUTED PROPULSION**

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(72) Inventor: **Xi WANG**, Saint-Laurent (CA)

(21) Appl. No.: **17/827,706**

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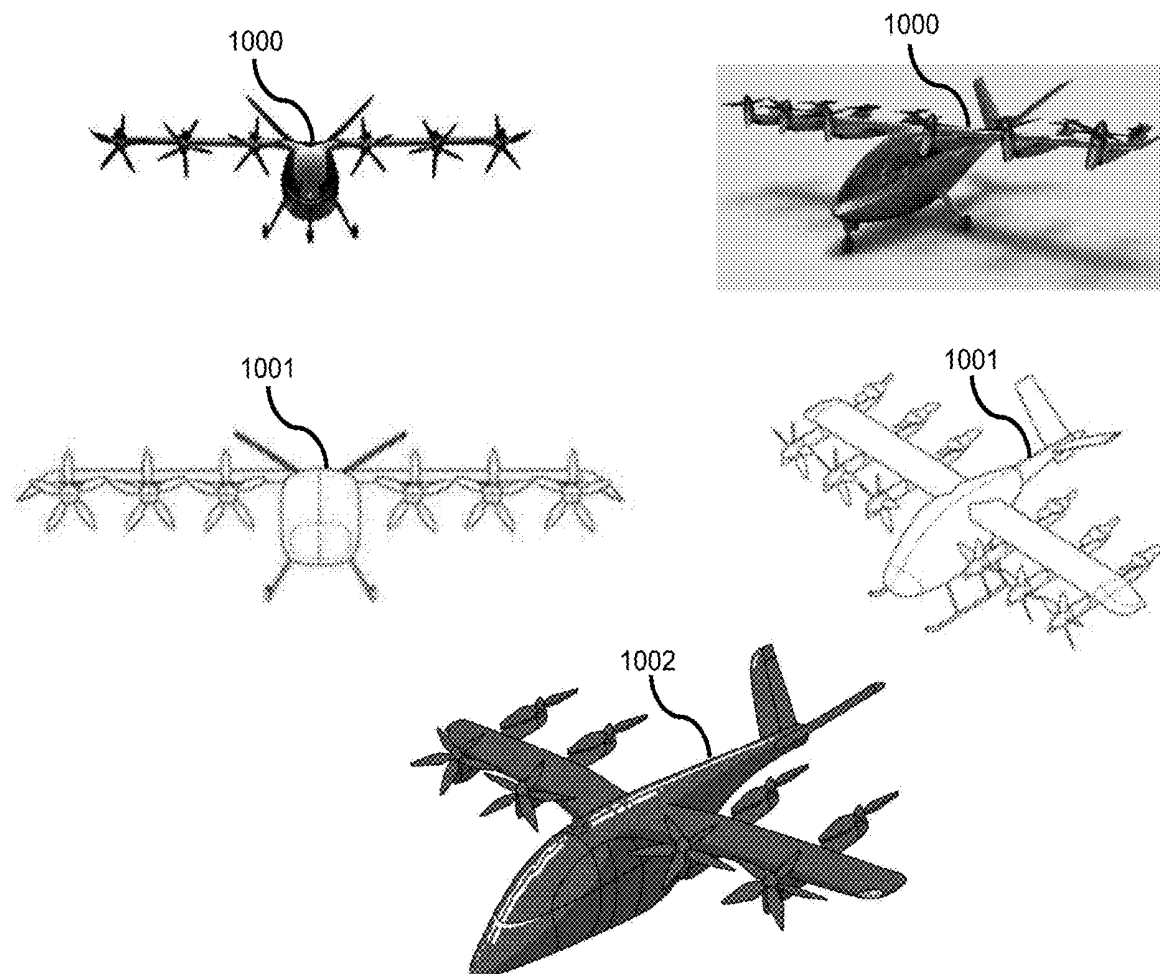
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CPC **B64C 29/0033** (2013.01); **B64C 5/02**
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(57) **ABSTRACT**

A VTOL (vertical take-off and landing) rotorcraft with distributed propulsion system having the capability to convert to airplane flight. The rotorcraft includes a short fuselage, a pair of wings, a pair of inboard booms, a plurality of outboard booms, an empennage, a plurality of lift rotors, and a plurality of proprotors. The fuselage, the wings, inboard booms and V-tail are mechanically coupled together. The plurality of outboard booms is mounted to the wings. Moreover, the proprotors and lift rotors are mounted on the inboard and outboard boom. The placement of the lift rotors allows the rotorcraft to benefit from the reliable and agile function of the quadcopter. The plurality of proprotors in a first configuration provides additional lift thrust for VTOL flight and a second configuration provides forward propulsive thrust in airplane flight.



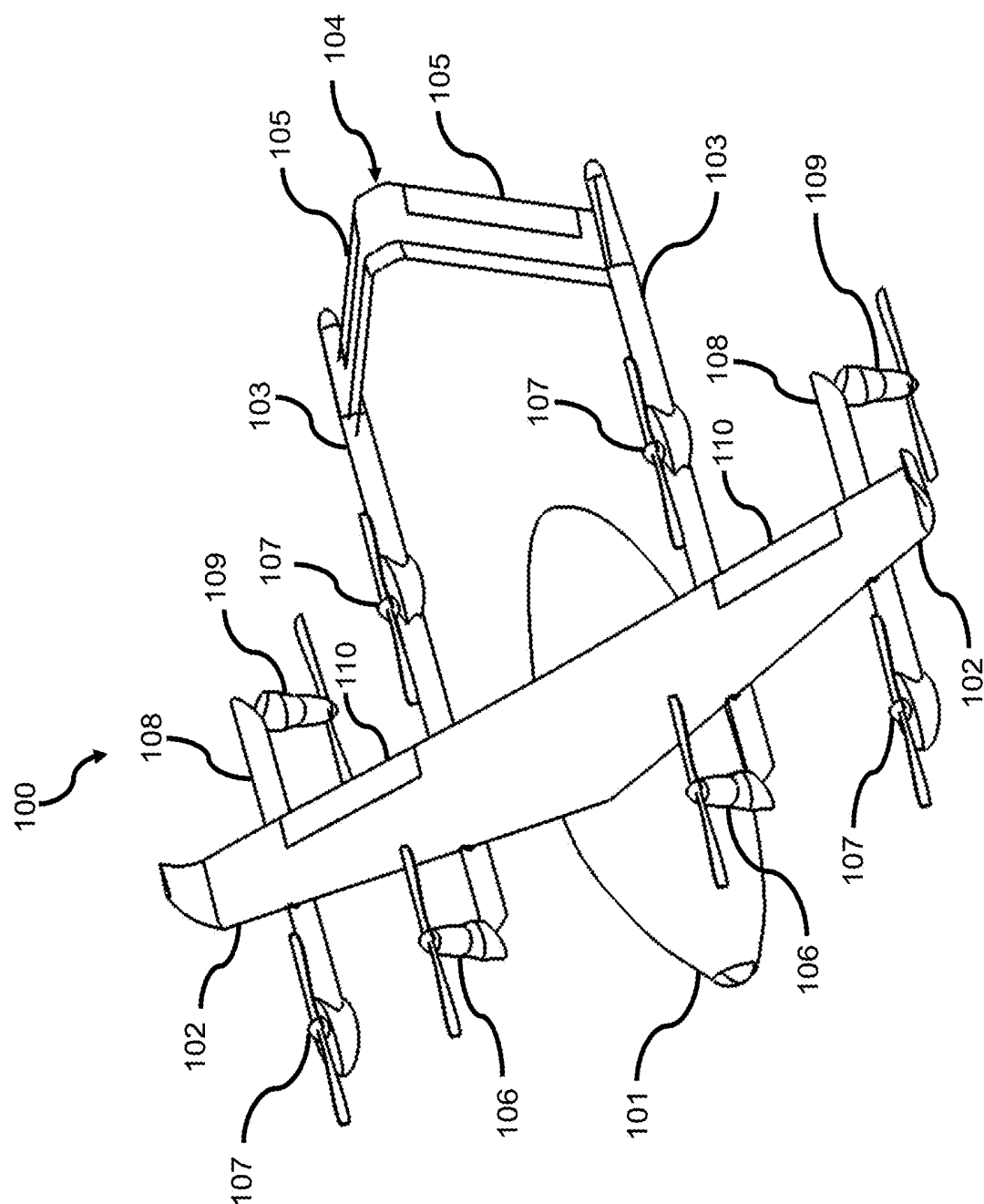
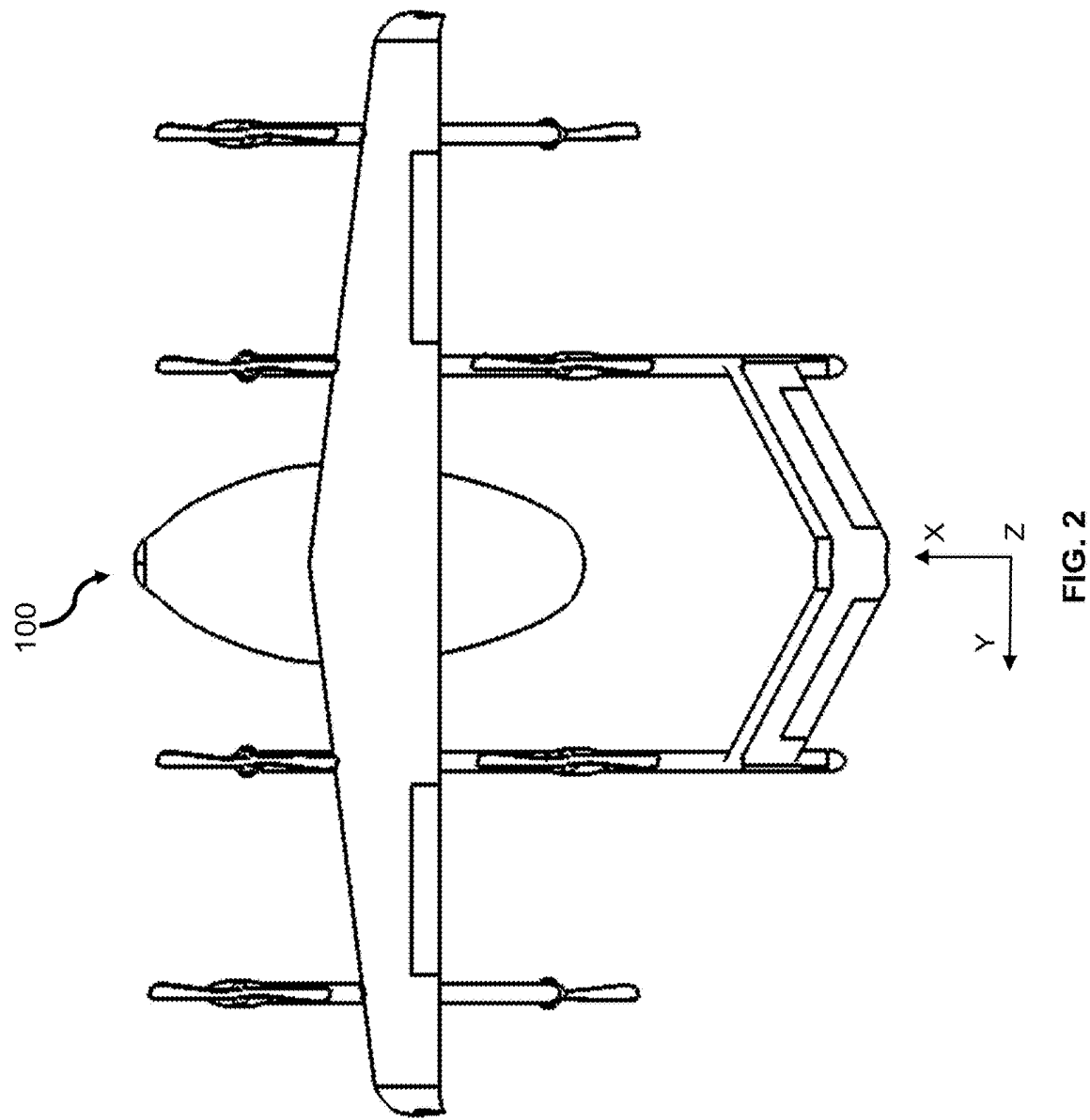


FIG. 1



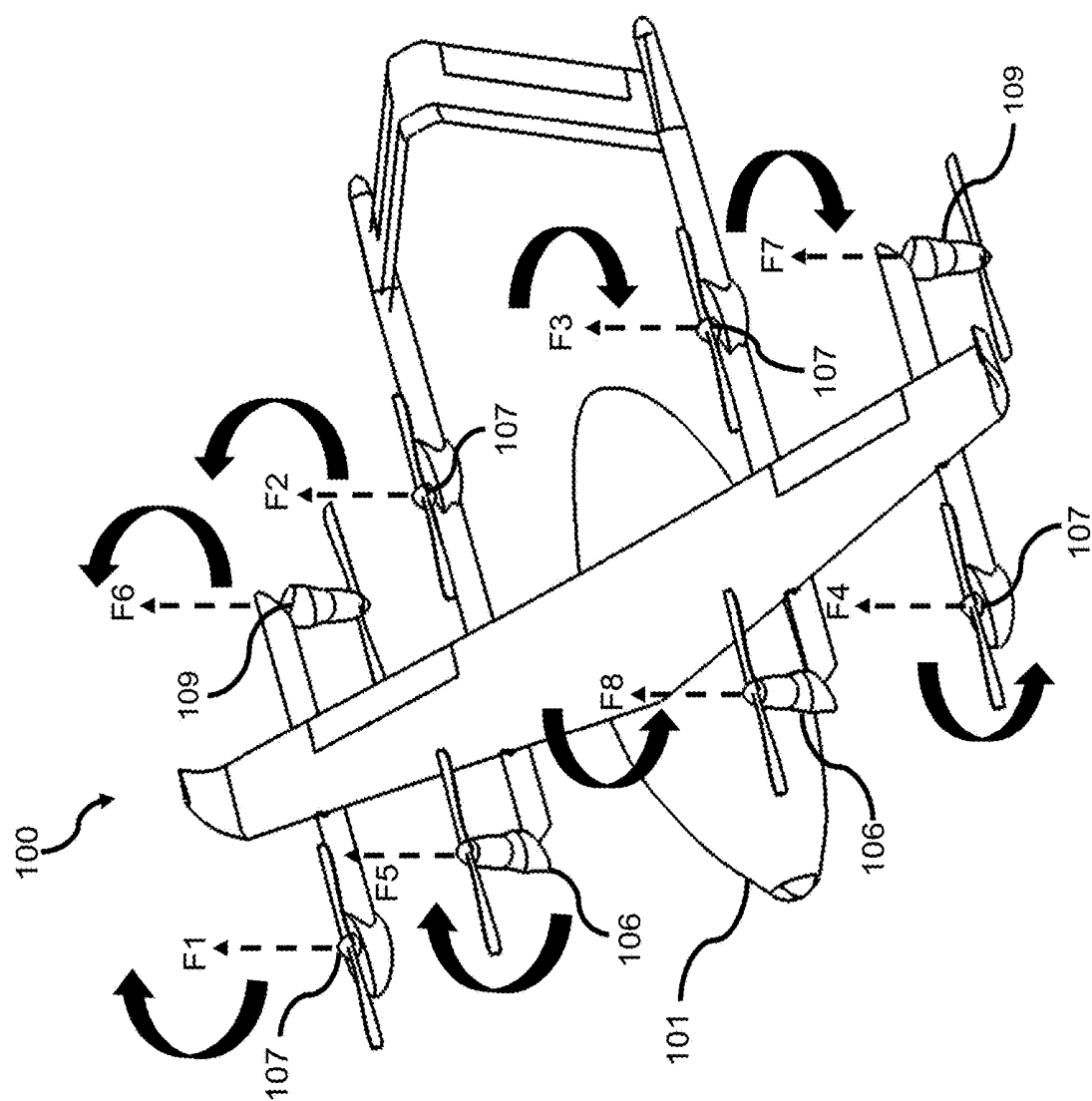


FIG. 3

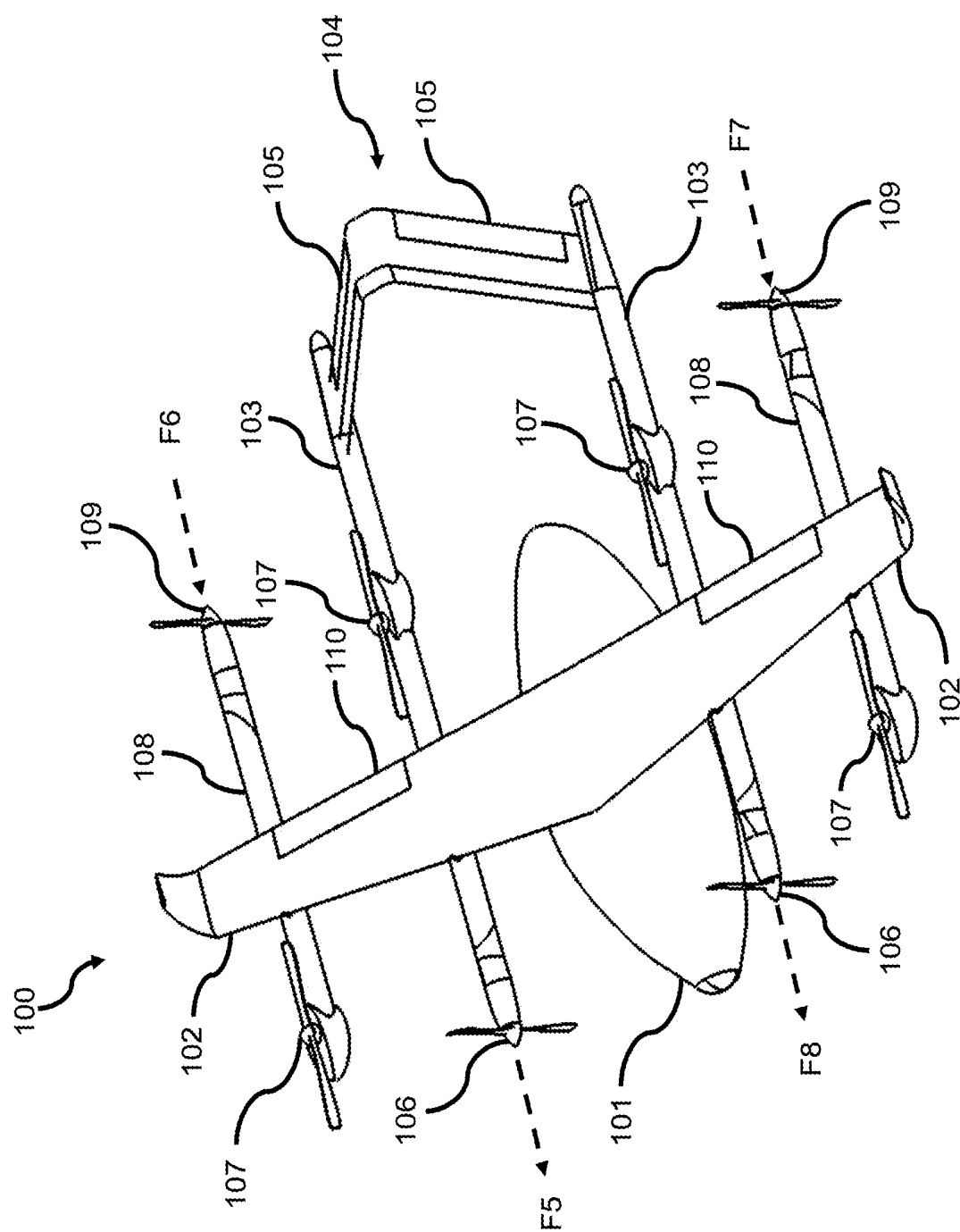
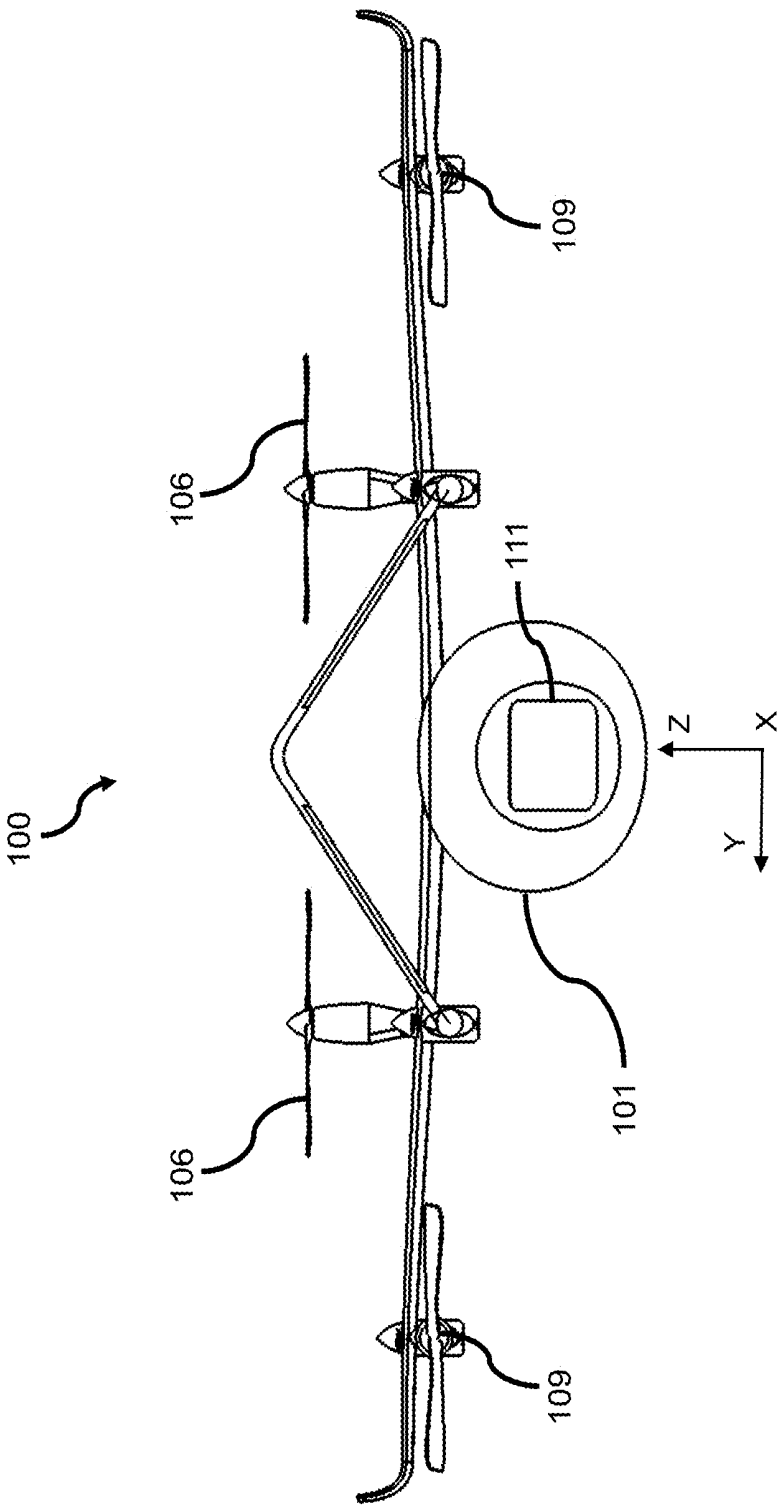


FIG. 4



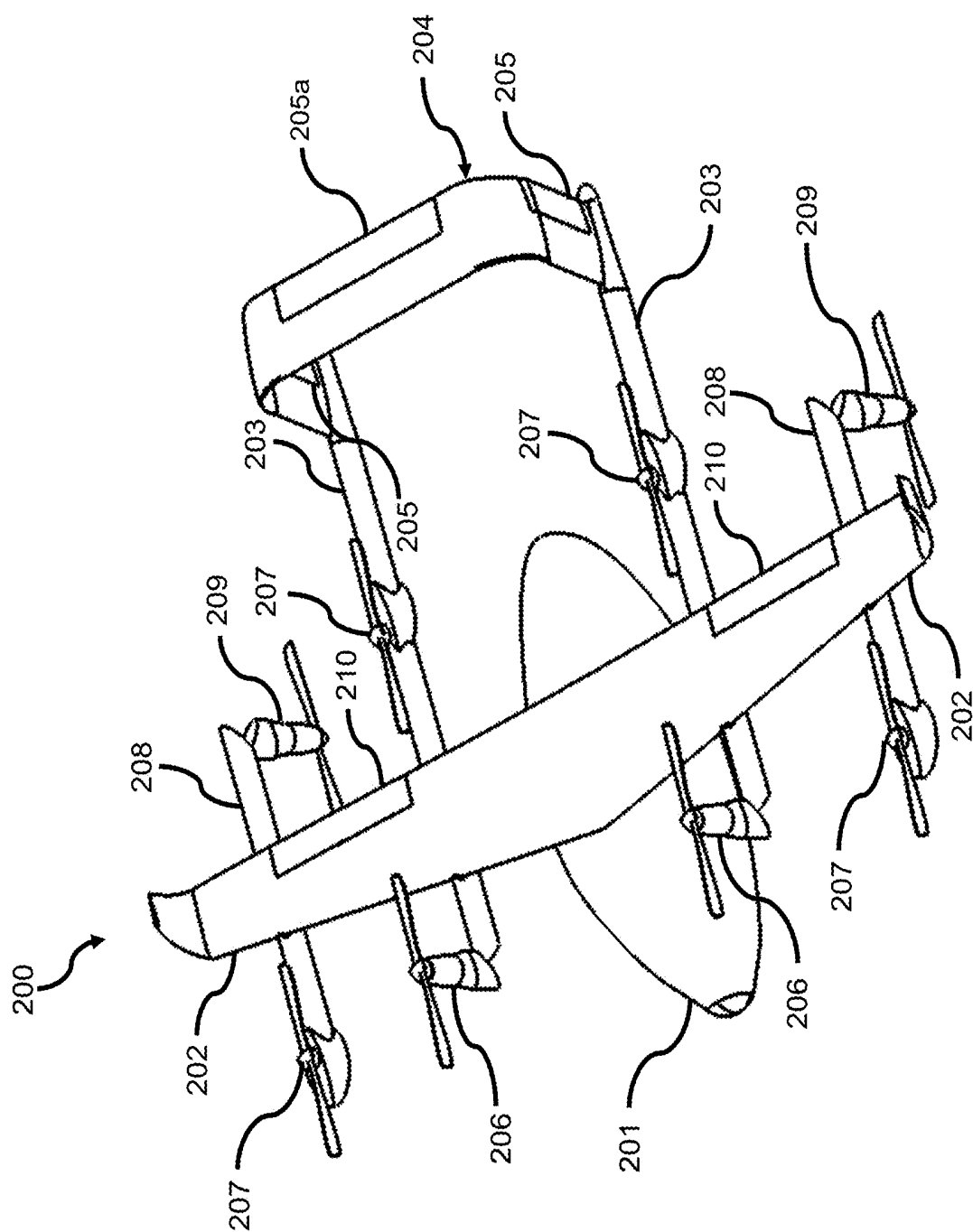
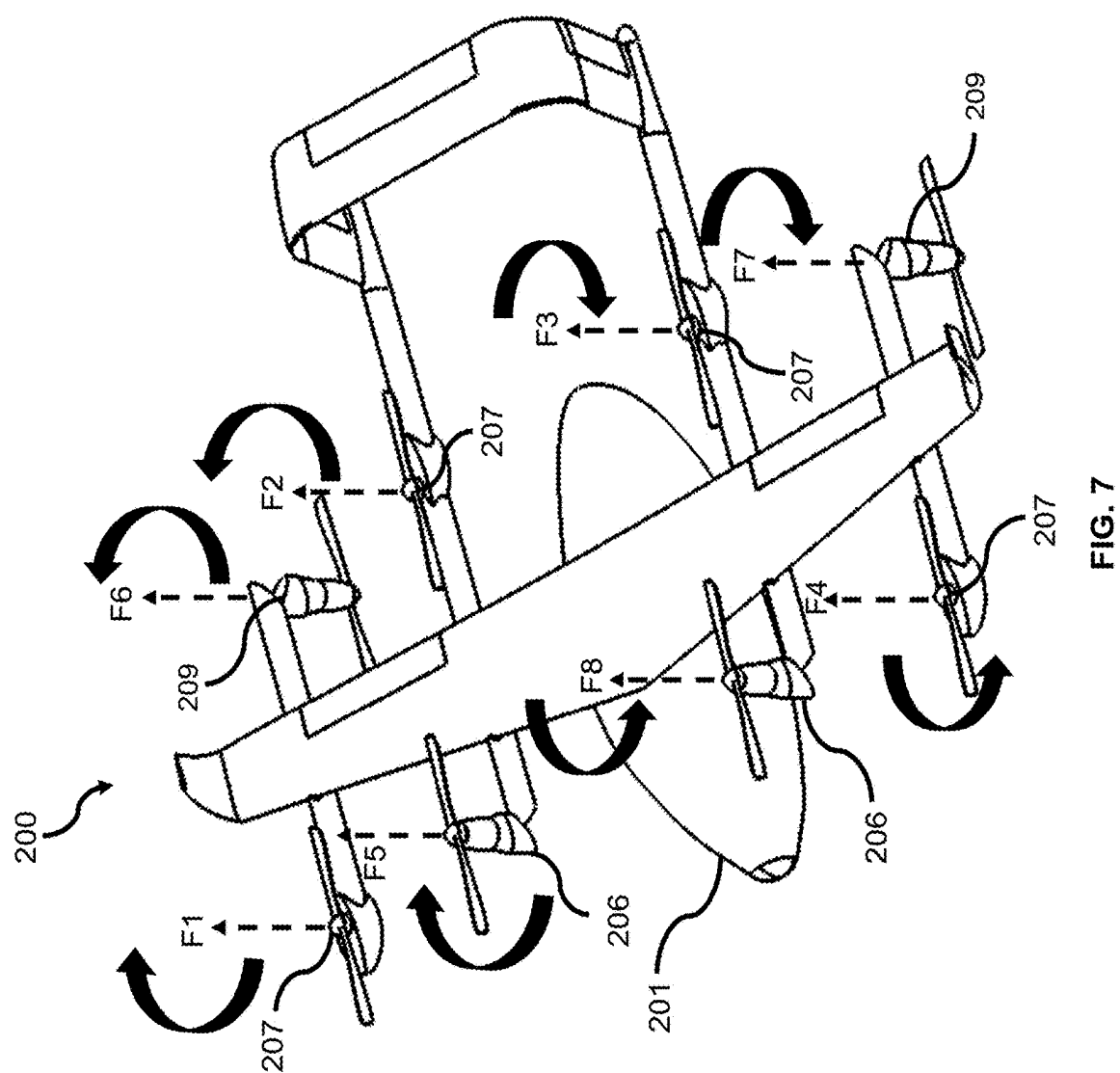


FIG. 6



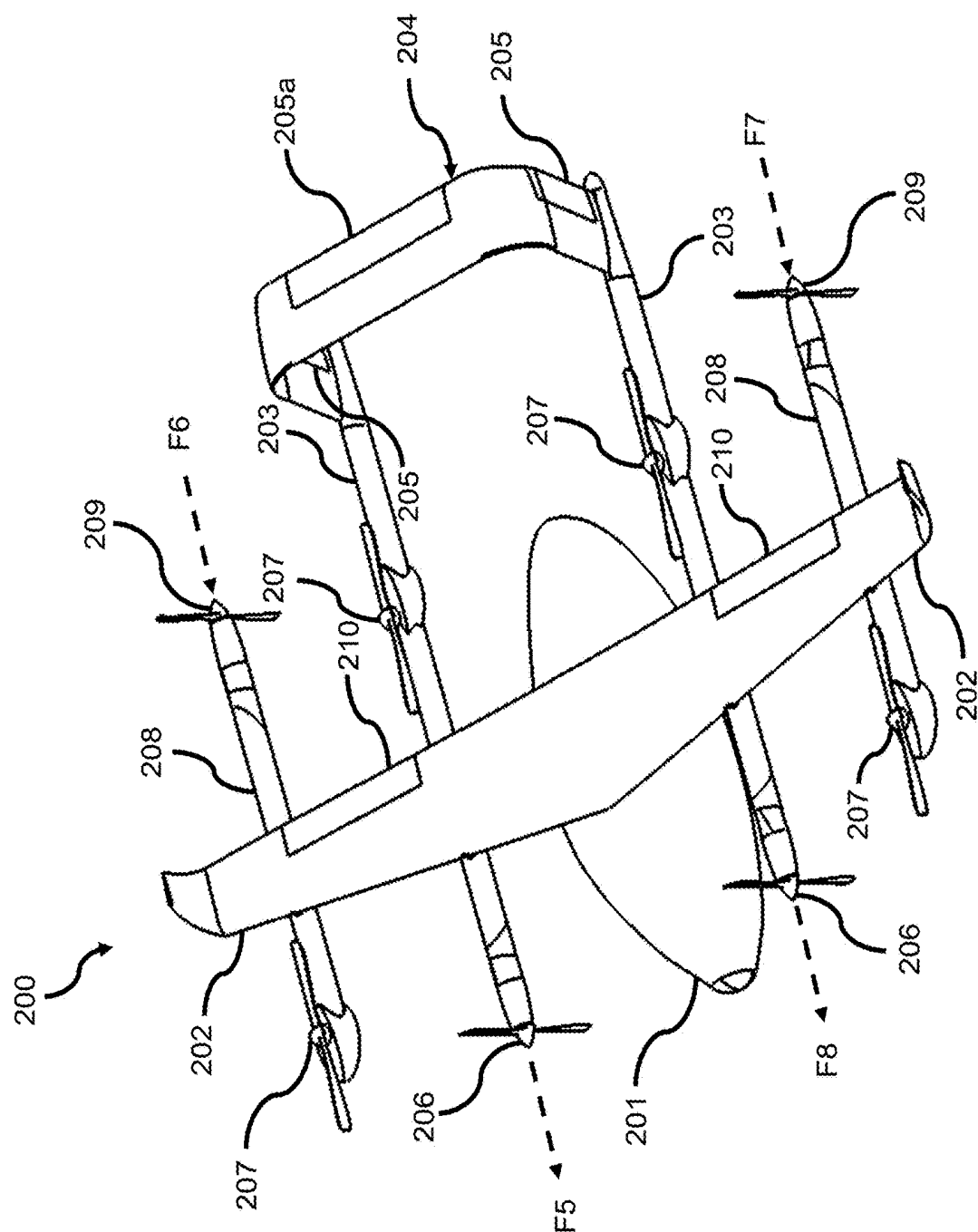


FIG. 8

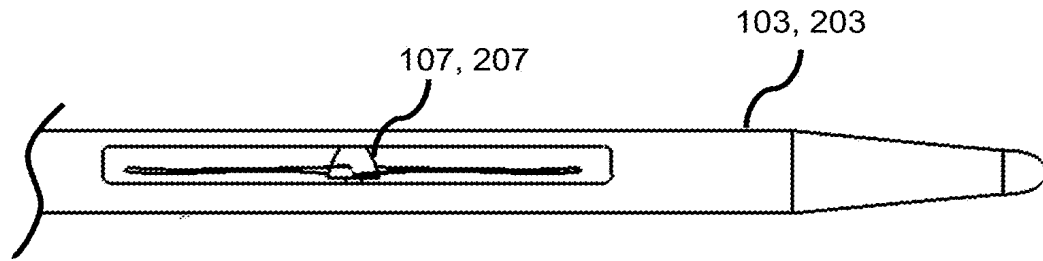


FIG. 9

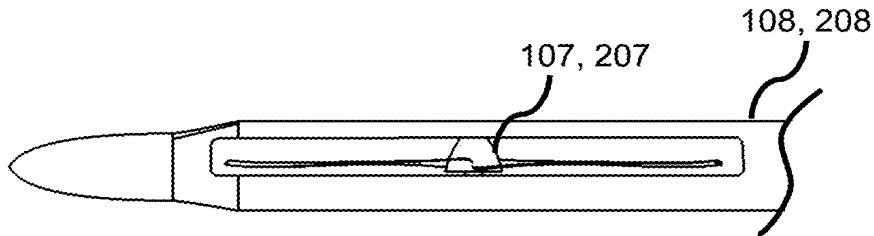


FIG. 10

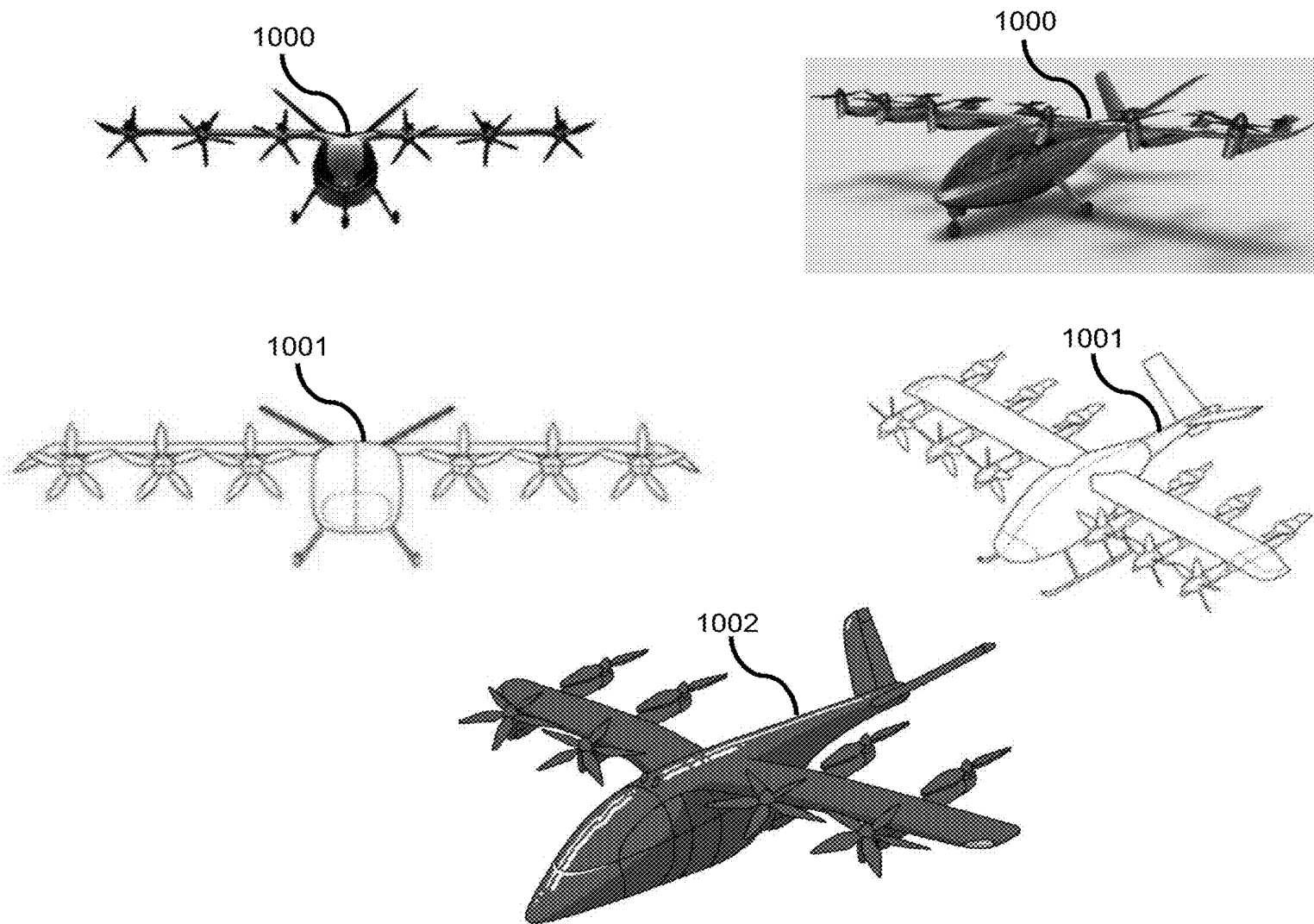


FIG. 11

TWIN BOOM VTOL ROTORCRAFT WITH DISTRIBUTED PROPULSION

REFERENCE TO RELATED PATENTS

[0001]

U.S. Pat. No. 6,655,631 B2	Dec. 2, 2003	John Frederick Austen-Brown	B64C11/28, B64C29/0033
U.S. Pat. No. 9,120,560 B1	Oct. 01, 2015	Charles Justin Ammer	B64C29/0008, B64C27/26, B64C29/0016, B64C29/0025, B64C39/04, B64C29/0033
US 2018/0155021 A1	Jun. 7, 2018	Michael D. Patterson	B64D29/02, B64C29/0025
US 10,364,036 B2	Jul. 30, 2019	James Joseph Tighe	B64C29/0033
US 2021/0362849 A1	Nov. 25, 2021	BOWER, Geoffrey C.	B64C27/26, B64C27/28, B64C29/00, B64C29/0025
US 11,208,203 B2	Dec. 28, 2021	Robert W. Parks	B64C27/26
US 2022/0126996 A1	Apr. 28, 2022	Geoffrey Alan Long	B64C29/0033

BACKGROUND OF THE INVENTION

[0002] The helicopter is an essential modern air transportation vehicle. Rotorcraft and rotary-wing vehicle are the technical term designated for aircraft equipped with rotating wing, which provides lift, propulsion and steering control. Rotorcraft can land and take-off without the presence of a long runway. However, travelling in a helicopter is expensive, due to the high operational cost. Moreover, helicopter with fossil fuel engine flying over an urban area is known to be a source of noise and air pollution.

[0003] The world of aviation is under pressure to reduce emission. As a result, there is numerous new designs of E-VTOL (electrical vertical take-off and landing) rotorcraft in progress, and the term “Air Taxi”, UAM (urban air mobility) or AMM (Advanced Air Mobility) are adopted for this type of personal or cargo aerial transportation. An E-VTOL rotorcraft is quiet, emission free and low operational cost.

[0004] As the traffic is increasingly congested in the global urban area, an affordable E-VTOL rotorcraft is the solution for daily commuter to avoid the congestion on the road. Without traffic delay, an affordable E-VTOL rotorcraft can also serve as law enforcement vehicle, ambulance and medical cargo transporter.

[0005] Since the weight of electrical energy storage accounts for a large fraction of the total weight of the E-VTOL rotorcraft, it is paramount to design an electrical rotorcraft with higher propulsive thrust and lift thrust efficiency. The electrical energy storage for electrical rotorcraft is not limited to electrical battery or fuel cell. Based on the momentum theory of propeller, small disc area with high disc loading leads to lower lift thrust efficiency. Therefore, higher power is required to lift the rotorcraft and more energy is consumed to hover. The best demonstration of this theory can be found in human powered rotorcraft. The human powered rotorcraft with multiple giant rotors is as large as the size of a basketball court. The disc area must be very large, in order to reduce the disc loading and increase

lift thrust efficiency, therefore a person can provide the required power to hover the rotorcraft. However, long light weight rotor blade has limited strength and non-practical for landing on a small area. Moreover, the longer rotor blade increases of the risk of impact surrounding obstacle and human.

SUMMARY OF THE INVENTION

[0006] The primary objective of the present invention is to disclose a VTOL rotorcraft with distributed propulsion, which is suitable for larger and heavier aerial vehicle application. The distributed propulsion includes at least four lift rotors and at least four propellers to benefit from the reliable and agile function of a quadcopter. The propellers provide lift thrust and flight forward thrust. Moreover, the four lift rotors can be stowed during horizontal flight to reduce drag.

[0007] 1. In one embodiment of the VTOL rotorcraft is provided, comprising of the fuselage, the opposing wing, a pair of opposing inboard booms, at least one pair of opposing outboard booms, an inverted V-tail, a plurality of propellers, and a plurality of lift rotors.

[0008] 2. In one embodiment of the VTOL rotorcraft is provided, comprising of the fuselage, the opposing wing, a pair of opposing inboard booms, at least one pair of opposing outboard booms, a high-tail, a plurality of propellers, and a plurality of lift rotors.

OBJECT OF THE INVENTION

[0009] The primary object of the present invention is an aerial vehicle with the capability to convert between VTOL flight to airplane flight.

PRIOR ART

[0010] Traditionally, helicopter is equipped with a single large rotor for lift, propulsion and steering control. Helicopter is distinctive by the tail rotor to balance the torque effect of the main rotor. A significant amount of energy is wasted in the tail rotor in hover and low-speed flight. In order to eliminate the need for the tail rotor, the contra-rotating rotors were introduced in helicopter design. The contra-rotating rotors can balance the torque effect and increase power without increase in disc frontal diameter. A light weight civilian helicopter with large main rotor is known to have lower disk loading. As a result, the lift thrust efficiency is the highest among the VTOL (vertical take-off and landing) vehicle. The fact that helicopter has large main rotor with high inertia, it is not possible to modulate the rotational speed to vary the output thrust. As a result, helicopter's rotor operates at constant speed, and the pitch of the rotor blade is changed by the swash plate mechanism. The swash plate mechanism is linked to the collector and cyclic to steer the helicopter, which is a complex and heavy equipment. Naturally, both single rotor or contra-rotating rotary wings have the complex mechanical swash plate system.

[0011] The arrival of distributed electrical propulsion system allows modern multirotor to substitute the single main rotor helicopter. The electrical propulsion system is equipped with multiple independent rotors of smaller disc area to provide lift, propulsion and steering control. Quad-rotorcraft is a popular design for electrical rotorcraft, since it contains four moving parts, which are the four rotating rotors. The fixed pitch rotor with small diameter has low inertia, therefore it can rapidly change the output thrust by

modulating the rotational speed of the rotor. The change of the output thrust of the four rotors creates the thrust vector for lift, propulsion and steering control. The distributed electrical propulsion architecture decreases rotor loading by increasing the number of lift rotor.

[0012] Advantageously, VTOL (vertical take-off and landing) vehicle can operate without a runway. However, an aerial vehicle operating in VTOL mode requires significantly higher amount of energy than an airplane with fixed wing to maintain forward flight. Therefore, the usefulness of the VTOL vehicle is limited to short-range flight. The modern VTOL vehicle is commonly designed with electrical power plant. In order to reduce the weight of electrical energy storage, a viable VTOL vehicle can adapt to airplane mode for long range forward flight. The proprotor is a rotor which can provide lift thrust and forward thrust. The proprotor has the advantage to reduce drag during horizontal flight and reduce the overall weight of the rotorcraft. FIG. 11 provides examples of designs known to the art from Archer Aviation 1000, Wisk Aero 1001 and Vertical Aerospace 1002. The examples depict a VTOL vehicle design with a plurality of booms coupled on the wings, and the booms are provided with a plurality of proprotors and a plurality of lift rotors. In this example, a plurality of proprotors is positioned forward of the center of gravity and a plurality of lift rotors is positioned aftward of the center of gravity. Consequently, from the failure of the plurality of proprotors, the plurality of lift rotors alone is inadequate to provide flight control authority to the vehicle in the pitch plane.

BRIEF DESCRIPTION OF DRAWINGS

[0013] It should be observed that three mutual orthogonal directions X, Y, and Z are shown in some of the FIGS. The first direction X is said to be “longitudinal”, and the forward side is referenced to be positive. A rotational movement around the longitudinal direction is known as roll. The second direction Y is said to be “transverse”, and the port side is referenced to be positive. A rotational movement around the transverse direction is known as pitch. Finally, the third direction Z is said to be “vertical”, and the up side is referenced to be positive. A rotational movement around the vertical direction is known as yaw. Moreover, it should be observed that force vector is shown in dash lead arrow and the direction of movement is shown in bold lead arrow.

[0014] FIG. 1 shows a perspective view of the embodiment of the twin boom rotorcraft in VTOL mode and hover mode.

[0015] FIG. 2 shows a top orthogonal view of the embodiment of FIG. 1.

[0016] FIG. 3 shows a perspective view of the embodiment of FIG. 1 with forces acting thereon.

[0017] FIG. 4 shows a perspective view of the embodiment of the twin boom rotorcraft in airplane mode with forces acting thereon.

[0018] FIG. 5 shows a back orthogonal view of the embodiment of the twin boom rotorcraft in landed configuration.

[0019] FIG. 6 shows a perspective view of another embodiment of the twin boom rotorcraft in VTOL mode and hover mode.

[0020] FIG. 7 shows a perspective view of the embodiment of FIG. 6 with forces acting thereon.

[0021] FIG. 8 shows a perspective view of the embodiment of the twin boom rotorcraft in airplane mode with forces acting thereon.

[0022] FIG. 9 shows a side orthogonal view of the embodiment of an optional configuration of the inboard boom provided with the lift rotor.

[0023] FIG. 10 shows a side orthogonal view of the embodiment of an optional configuration of the outboard boom provided with the lift rotor.

[0024] FIG. 11 are photos of existing or proposed VTOL rotorcraft design known in the art.

DETAILED DESCRIPTION OF THE INVENTION

[0025] Regarding the invention disclosure, the feature and advantage of the invention are particularly pointed and distinctly claimed in the claims. Detailed description and methods are given to provide further comprehension of the functionality of the invention. In the disclosure of the invention, the technical term “rotor” is referred as the rotating blade with airfoil to generate thrust by moving air. Moreover, the technical term “proprotor” is referred as the rotating blade with airfoil to generate thrust by moving air as an airplane-style propeller and helicopter-style rotor. Moreover, the term “opposing” is used to describe a component, feature, or element which is symmetrical with respecting to median plane of the rotorcraft. It is further understood that the terms “includes”, “including”, “comprises”, “comprising”, “couples”, “coupled”, “mounts”, and “mounted”, when used herein, specify the presence of stated features, components and elements, without the further detail on the method of mechanical interconnection. In addition, it is also understood that the singularity form “a”, “an”, and “the” used throughout the description are intended to include plural forms as well, unless the context clearly specifies otherwise.

[0026] FIG. 1 shows a perspective view of the embodiment of the twin boom rotorcraft 100 in VTOL and hover mode. The rotorcraft 100 comprising of the fuselage 101, the wings 102, the inboard booms 103, the outboard booms 108, the inverted V-tail 104, the rudders 105, a plurality of proprotors 106 and 109, a plurality of lift rotors 107, and the ailerons 110. The proximal ends of the transversely extended opposing wings 102 are coupled to the longitudinally extended fuselage 101. Naturally, the center of the wings is positioned near the center of gravity of the rotorcraft along the longitudinal direction. The wings 102 are provided with the first longitudinally extended inboard booms 103 and second longitudinally extended outboard booms 108. The inboard booms 103 and outboard booms 108 comprises of a structure forward of the wings 102, and a structure aftward of the wings 102. The V-tail 104 includes a pair of opposing diagonal stabilizers. The aftward structure of the inboard booms 103 are coupled to the proximal ends of the V-tail 104. The distal ends of the diagonal stabilizers of the V-tail 104 are coupled together. The diagonal stabilizers of the V-tail 104 are provided with the rudders 105. The structure of the inboard booms 103 forward of the wings 102 is coupled through a tilt mechanism to the proprotor 106. The structure of the inboard booms 103 aftward of the wings 102 is provided with the lift rotor 107. The structure of the outboard boom 108 forward of the wings 102 is provided with the lift rotor 107. The structure of the outboard boom 108 aftward of the wings 102 is coupled through a tilt

mechanism to the proprotor 109. The proprotors 106 and 109 may be provided with more than two blades with variable collective pitch capability. Moreover, the lift rotors 107 may be provided with two blades or a pair of two blades in coaxial corotating arrangement. The proprotors 106 and 109 can tilt in the pitch axis to vector rotor thrust in the vertical direction for VTOL and hover mode. The thrust of the lift rotors 107 is also contributing for vertical flight. The axis of the rotation of the lift rotors 107 and proprotor 106 or 109 may be canted from the vertical axis to minimize the damage resulting from a blade failure event (commonly referred to as rotor burst). In detail, the canted configuration allows rotor burst trajectory to avoid impacting the fuselage 101, adjacence propulsion unit and flight critical components. The opposing wings 102 are provided with the ailerons 110.

[0027] FIG. 2 shows a top orthogonal view of the twin boom rotorcraft 100 in VTOL and hover mode.

[0028] FIG. 3 shows a perspective view of the embodiment of the twin boom rotorcraft 100 in VTOL and hover mode shown with the propulsive forces. It can be observed that each one of the lift rotors 107 is configured to generate vertical lift vector F1, F2, F3, and F4. During stable vertical flight and hover, the sum of the lifting vector F1, F2, F3, and F4 generated thereby passes approximately through the center of gravity of rotorcraft 100. Similar to a quadcopter architecture, some of the lift rotors 107 rotate in opposite directions, as indicated by the curved bold arrows. As a result, the torque effect generated by lift rotors 107 substantially cancel each other out. Also shown in FIG. 3, the output thrust of the proprotor 106 and 109 is oriented vertically, therefore the thrust is represented by vertical lift vector F5, F6, F7, and F8. The sum of the lifting vector F5, F6, F7, and F8 generated thereby passes approximately through the center of gravity of the rotorcraft 100, during stable vertical flight and hover. Some of the proprotor 106 and 109 rotate in opposite directions, as indicated by the bold curved arrows, so that the torque effect generated by proprotor 106 and 109 substantially cancel each other out. Naturally, during stable vertical flight and hover, the sum of the eight lift forces F1 to F8 is intersecting the center of gravity of the rotorcraft 100. Finally, flight movements such as maintaining leveled hover, tilting in the pitch axis to fly forwards or backwards, tilting in the roll axis to fly sideways and yawing along the vertical axis can be accomplished by modulating the magnitude of the thrust of each individual rotor.

[0029] FIG. 4. shows a perspective view of the embodiment of the twin boom rotorcraft 100 in airplane mode with the propulsive forces. The rotorcraft 100 is depending on the forward speed to generate airfoil lift from the wings 102. The axis of rotation of the proprotors 106 and 109 is oriented horizontally, therefore the output thrust F5, F6, F7, and F8 are propelling the rotorcraft 100 forward. The proprotors 106 is in tractor configuration and the proprotors 109 is in pusher configuration. The lift rotors 107 are inactive and the blades are locked in position to minimized frontal area exposure to reduce drag during forward flight. The rudders 105 and ailerons 110 function as flight control surfaces to provide pitch, roll and yaw authority to the rotorcraft 100.

[0030] FIG. 5. shows a back orthogonal view of the of the embodiment of the twin boom rotorcraft 100 landed on ground. The proprotors 106 is oriented vertically and the proprotors 109 are oriented horizontally. This configuration

of proprotors 106 and 109 allows easy ingress and egress to fuselage 101 and rear door 111.

[0031] FIG. 6 shows a perspective view of the embodiment of the twin boom rotorcraft 200 in VTOL and hover mode. The rotorcraft 200 comprising of the fuselage 201, the wings 202, the inboard booms 203, the outboard booms 208, the high-tail 204, the rudders 205, the elevator 205a, a plurality of proprotors 206 and 209, a plurality of lift rotors 207, and the ailerons 210. The proximal ends of the transversely extended opposing wings 202 are coupled to the longitudinally extended fuselage 201. Naturally, the center of the wings is positioned near the center of gravity of the rotorcraft along the longitudinal direction. The wings 202 are provided with the first longitudinally extended inboard booms 203 and second longitudinally extended outboard booms 208. The inboard booms 203 and outboard booms 208 comprises of a structure forward of the wings 202, and a structure aftward of the wings 202. The high-tail 204 includes a horizontal stabilizer and a pair of opposing vertical stabilizers. The aftward structure of the inboard booms 203 are coupled to the proximal ends of the high-tail 204. The horizontal stabilizer is coupled between the distal ends of the vertical stabilizers. The opposing vertical stabilizers of the high-tail 204 are provided with the rudders 205. The horizontal stabilizer of the high-tail 204 is provided with the elevator 205a. The structure of the inboard booms 203 forward of the wings 202 is coupled through a tilt mechanism to the proprotor 206. The structure of the inboard booms 203 aftward of the wings 202 is provided with the lift rotor 207. The structure of the outboard boom 208 forward of the wings 202 is provided with the lift rotor 207. The structure of the outboard boom 208 aftward of the wings 202 is coupled through a tilt mechanism to the proprotor 209. The proprotors 206 and 209 may be provided with more than two blades with variable collective pitch capability. Moreover, the lift rotors 207 may be provided with two blades or a pair of two blades in coaxial corotating arrangement. The proprotors 206 and 209 can tilt in the pitch axis to vector rotor thrust in the vertical direction for VTOL and hover mode. The thrust of the lift rotors 207 is also contributing for vertical flight. The axis of the rotation of the lift rotors 207 and proprotor 206 or 209 may be canted away from the vertical axis to minimize the damage resulting from a blade failure event (commonly referred to as rotor burst). In detail, the canted configuration allows rotor burst trajectory to avoid impacting the fuselage 201, adjacence propulsion unit and flight critical components. The opposing wings 202 are provided with the ailerons 210.

[0032] FIG. 7 shows a perspective view of the embodiment of the twin boom rotorcraft 200 in VTOL and hover mode with the propulsive forces. It can be observed that each one of the lift rotors 207 is configured to generate vertical lift vector F1, F2, F3, and F4. Moreover, each of the proprotors 206 and 209 is configured to generate vertical lift vector F5, F6, F7, and F8. The rotorcraft 200 shares the same propulsive characteristic as rotorcraft 100 in VTOL and hover mode.

[0033] FIG. 8. shows a perspective view of the embodiment of the twin boom rotorcraft 200 in airplane mode with the propulsive forces. The rotorcraft 200 is depending on the forward speed to generate airfoil lift from the wings 202. The axis of rotation of the proprotors 206 and 209 is oriented horizontally, therefore the output thrust F5, F6, F7, and F8 are propelling the rotorcraft 200 forward. The lift rotors 207

are inactive and the blades are locked in position to minimized frontal area exposure to reduce drag during forward flight. The rudders **205**, elevator **205a** and ailerons **210** function as flight control surfaces to provide pitch, roll and yaw authority to the rotorcraft **200**.

[0034] FIG. 9. shows a side orthogonal view of an optional embodiment of the inboard boom **103** or **203** provided with lift rotor **107** or **207**. It can be observed that lift rotor **107** or **207** is integrated within the structure of the inboard boom **103** or **203**. During airplane mode, the stowed lift rotor **107** or **207** is hidden inside the structure of the inboard boom **103** or **203**, as a result a further drag reduction is achieved. Moreover, inboard boom **103** or **203** can be provided with an optional door to fully encapsule the stowed lift rotor **107** or **207**.

[0035] FIG. 10. shows a side orthogonal view of an optional embodiment of the outboard boom **108** or **208** provided with lift rotor **107** or **207**. It can be observed that lift rotor **107** or **207** is integrated within the structure of the outboard boom **203** or **203**. During airplane mode, the stowed lift rotor **107** or **207** is hidden inside the structure of the outboard boom **108** or **208**, as a result a further drag reduction is achieved. Moreover, outboard boom **108** or **208** can be provided with an optional door to fully encapsule the stowed lift rotor **107** or **207**.

[0036] FIG. 11. are photos of existing or proposed VTOL rotorcraft designs known in the art. The examples show the possible choices of VTOL rotorcraft design from Archer Aviation **1000**, Wisk Aero **1001** and Vertical Aerospace **1002**. In general, the aerial vehicle design is shown with a plurality of booms coupled on the wings, and the booms are provided with a plurality of proprotors and a plurality of lift rotors.

[0037] Naturally, there are numerous variations, modifications and configurations which may be made hereto without departing from the scope of the disclosure invention. It should be understood that the embodiments are for illustrative and explanatory purpose and it is not conceivable to identify exhaustively all possible embodiments. Many other embodiments will be apparent to those of skill in the art upon reviewing the above description. During VTOL and hover flight, the placement of the four lift rotors permanently allows the rotorcraft to benefit from the reliable and agile function of a quadcopter. Moreover, the twin boom design allows an unobstructed access path to the rear door.

1. A rotorcraft adapted for vertical take-off, vertical landing and horizontal flight comprising:

- a longitudinally extended fuselage;
- a pair of opposing wings, each of said opposing wings having a wing proximal end and a wing distal end, wherein the proximal end of each of the wings is coupled to the fuselage;
- a pair of opposing inboard booms, each of said inboard booms having a longitudinal structure forward of the wings and a longitudinal structure aftward of the wings, wherein each of the inboard booms is coupled closely to the proximal end of each wing, and the fuselage is positioned between the inboard booms;

at least one pair of opposing outboard booms, each of said outboard booms having a longitudinal structure forward of the wings and a longitudinal structure aftward of the wings, wherein each of the outboard booms is coupled closely to the distal end of each wing, and the fuselage is positioned between the outboard booms;

An inverted V-tail, wherein the inverted V-tail having opposing diagonal stabilizers with the proximal ends coupled to the aftward structure of the inboard booms, and the distal ends coupled together;

A first plurality of proprotors, wherein the proprotor is coupled on the forward structure of the inboard booms by a tilt mechanism configured to rotate between VTOL and airplane mode;

A second plurality of proprotors, wherein the proprotor is coupled on the aftward structure of the outboard booms by a tilt mechanism configured to rotate between VTOL and airplane mode;

A first plurality of lift rotors, wherein the lift rotor is coupled on the aftward structure of the inboard booms between the wings and the V-tail;

A second plurality of lift rotors, wherein the lift rotor is coupled on the forward structure of the outboard booms;

A pair of ailerons, wherein the ailerons are coupled to the wings by a pivot mechanism;

A pair of rudders, wherein the rudders are coupled to the diagonal stabilizers by a pivot mechanism.

2. A rotorcraft as set forth in claim 1, wherein said a plurality of proprotors can tilt on the pitch axis to direct the output thrust to the vertical direction in the VTOL configuration.

3. A rotorcraft as set forth in claim 1, wherein said a plurality of proprotors may have blades with variable collective pitch capability.

4. A rotorcraft as set forth in claim 1, wherein said a plurality of proprotors in the VTOL configuration and a plurality of lift rotors provide the vertical thrust to hover, fly up, fly down, fly forward, fly backward, fly sideway and change yaw heading.

5. A rotorcraft as set forth in claim 1, wherein said a plurality of lift rotors and proprotors in the VTOL and hover configuration can have the axis of rotation canted from the vertical axis to direct rotor burst trajectory away from critical flight components and passenger.

6. A rotorcraft as set forth in claim 1, wherein said a plurality of proprotors in the VTOL configuration has the function to improve propulsive efficiency by reducing collective disc loading.

7. A rotorcraft as set forth in claim 1, wherein said a plurality of proprotor can pivot on the pitch axis to direct the output thrust to the horizontal direction in the airplane configuration.

8. A rotorcraft as set forth in claim 1, wherein said a plurality of proprotors in airplane configuration provides the thrust for horizontal flight and said wings provide the lift force to maintain airborne.

9. A rotorcraft as set forth in claim 1, wherein said a pair of ailerons and a pair of rudders provide the flight control for pitch, roll and yaw in airplane mode.

10. A rotorcraft as set forth in claim 1, wherein said a plurality of lift rotors can be integrated within the structure of the supportive booms.

11. A rotorcraft adapted for vertical take-off and horizontal flight comprising:

- a longitudinally extended fuselage;
- a pair of opposing wings, each of said opposing wings having a wing proximal end and a wing distal end, wherein the proximal end of each of the wings is coupled to the fuselage;

a pair of opposing inboard booms, each of said inboard booms having a longitudinal structure forward of the wings and a longitudinal structure aftward of the wings, wherein each of the inboard booms is coupled closely to the proximal end of each wing, and the fuselage is positioned between the inboard booms;

at least one pair of opposing outboard booms, each of said outboard booms having a longitudinal structure forward of the wings and a longitudinal structure aftward of the wings, wherein each of the outboard booms is coupled closely to the distal end of each wing, and the fuselage is positioned between the outboard booms;

A high-tail, wherein the high-tail having a horizontal stabilizer and the opposing vertical stabilizers, wherein the vertical stabilizers having proximal ends coupled to the aftward structure of the inboard booms, and wherein the horizontal stabilizer is coupled to the distal ends of the vertical stabilizers;

A first plurality of propellers, wherein the propeller is coupled on the forward structure of the inboard booms by a tilt mechanism configured to rotate between VTOL and airplane mode;

A second plurality of propellers, wherein the propeller is coupled on the aftward structure of the outboard booms by a tilt mechanism configured to rotate between VTOL and airplane mode;

A first plurality of lift rotors, wherein the lift rotor is coupled on the aftward structure of the inboard booms between the wings and the high-tail;

A second plurality of lift rotors, wherein the lift rotor is coupled on the forward structure of the outboard booms;

A pair of ailerons, wherein the ailerons are coupled to the wings by a pivot mechanism;

A pair of rudders, wherein the rudders are coupled to the vertical stabilizers by a pivot mechanism;

An elevator, wherein the elevator is coupled to the horizontal stabilizer by a pivot mechanism.

12. A rotorcraft as set forth in claim 11, wherein said a plurality of propellers can tilt on the pitch axis to direct the output thrust to the vertical direction in the VTOL configuration.

13. A rotorcraft as set forth in claim 11, wherein said a plurality of propellers may have blades with variable collective pitch capability.

14. A rotorcraft as set forth in claim 11, wherein said a plurality of propellers in the VTOL configuration and a plurality of lift rotors provide the vertical thrust to hover, fly up, fly down, fly forward, fly backward, fly sideway and change yaw heading.

15. A rotorcraft as set forth in claim 11, wherein said a plurality of lift rotors and propellers in the VTOL and hover configuration can have the axis of rotation canted from the vertical axis to direct rotor burst trajectory away from critical flight components and passenger.

16. A rotorcraft as set forth in claim 11, wherein said a plurality of propellers in the VTOL configuration has the function to improve propulsive efficiency by reducing collective disc loading.

17. A rotorcraft as set forth in claim 11, wherein said a plurality of propellers can pivot on the pitch axis to direct the output thrust to the horizontal direction in the airplane configuration.

18. A rotorcraft as set forth in claim 11, wherein said a plurality of propellers in airplane configuration provides the thrust for horizontal flight and said wings provide the lift force to maintain airborne.

19. A rotorcraft as set forth in claim 11, wherein said a pair of rudders, elevators and a pair of ailerons provide the flight control for pitch, roll and yaw in airplane mode.

20. A rotorcraft as set forth in claim 11, wherein said a plurality of lift rotors can be integrated within the structure of the supportive booms.

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(19) **United States**(12) **Patent Application Publication****Tighe et al.**(10) **Pub. No.: US 2018/0105279 A1**(43) **Pub. Date: Apr. 19, 2018**(54) **MULTICOPTER WITH BOOM-MOUNTED ROTORS**(71) Applicant: **Kitty Hawk Corporation**, Mountain View, CA (US)(72) Inventors: **James Joseph Tighe**, San Jose, CA (US); **Eric Allison**, Mountain View, CA (US)(21) Appl. No.: **15/297,035**(22) Filed: **Oct. 18, 2016****Publication Classification**

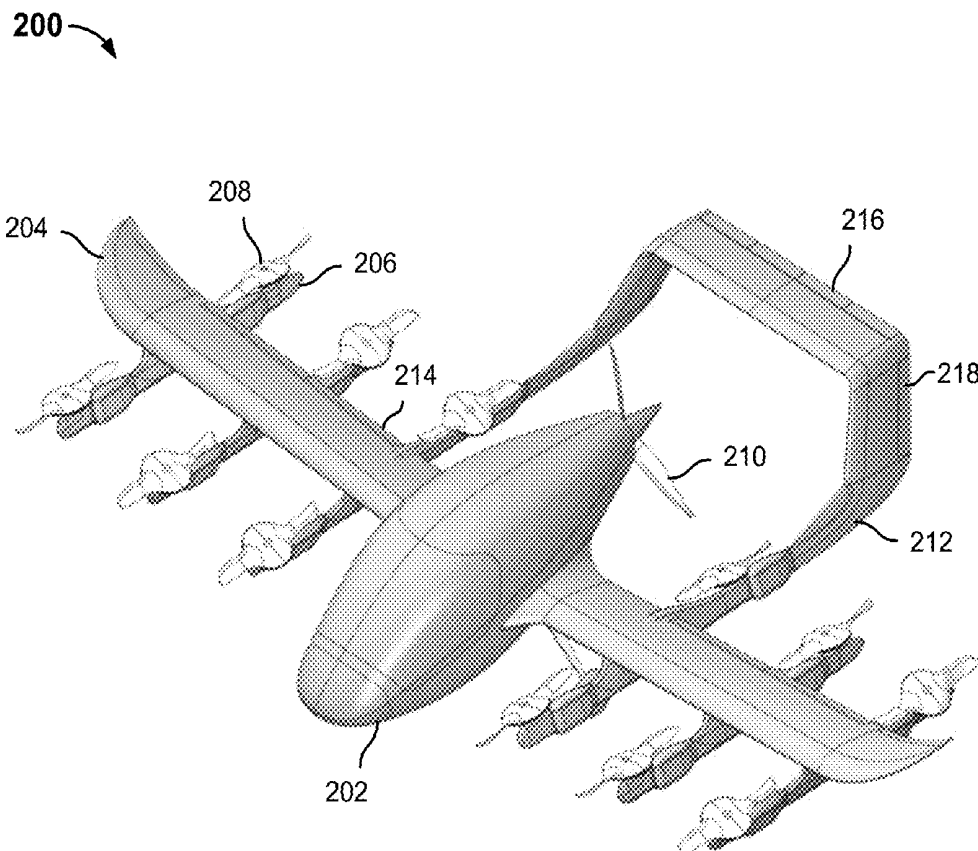
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B64D 27/24 (2006.01)
B64C 5/08 (2006.01)

(52) **U.S. Cl.**CPC **B64D 29/02** (2013.01); **B64C 5/08** (2013.01); **B64D 27/24** (2013.01); **B64C 29/0025** (2013.01)

(57)

ABSTRACT

A multicopter aircraft with boom-mounted rotors is disclosed. In various embodiments, a multicopter as disclosed herein includes a fuselage; a port side wing coupled to the fuselage; and a starboard side wing coupled to the fuselage. Each of the wings has mounted thereto one or more booms, each boom having a forward end extending forward of a corresponding wing to which the boom is mounted and an after end extending aft of said corresponding wing to which the boom is mounted. The aircraft further includes a first plurality of lift rotors, each rotor in said first plurality being mounted on a forward end of a corresponding one or said booms; and a second plurality of lift rotors, each rotor in said second plurality being mounted on an after end of a corresponding one or said booms. Each rotor produces vertical thrust independent of the thrust produced by the other rotors.



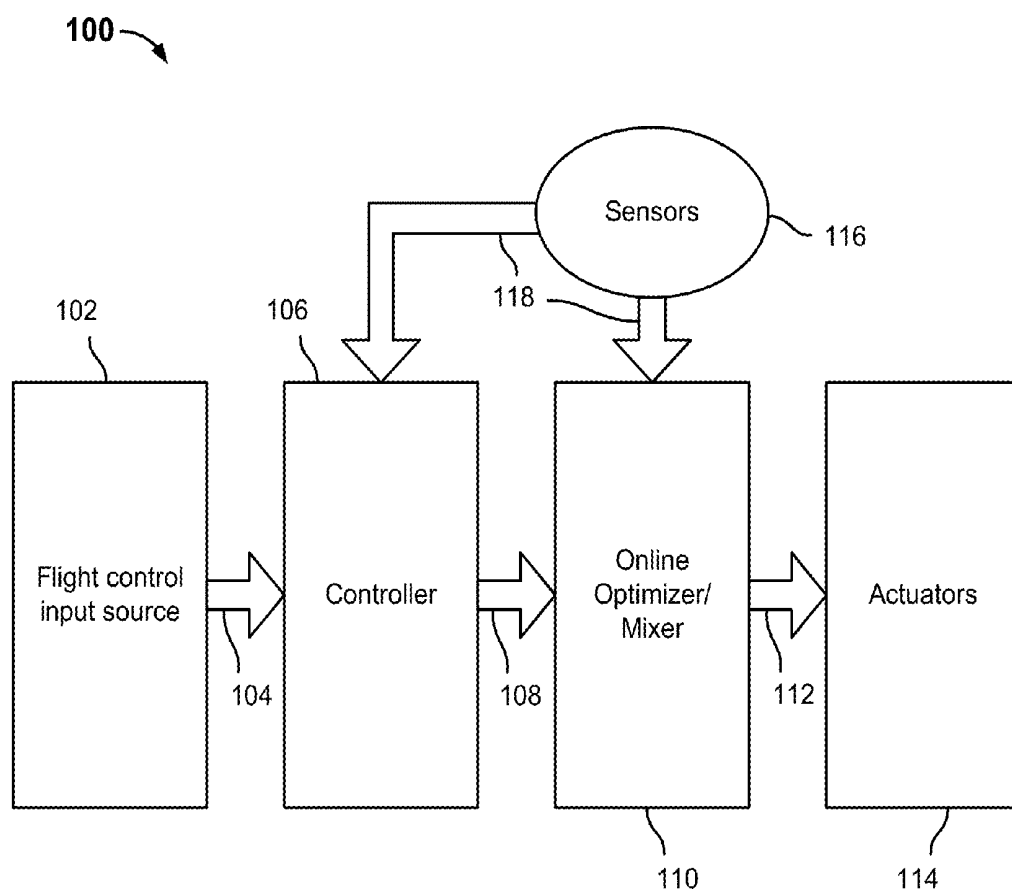


FIG. 1

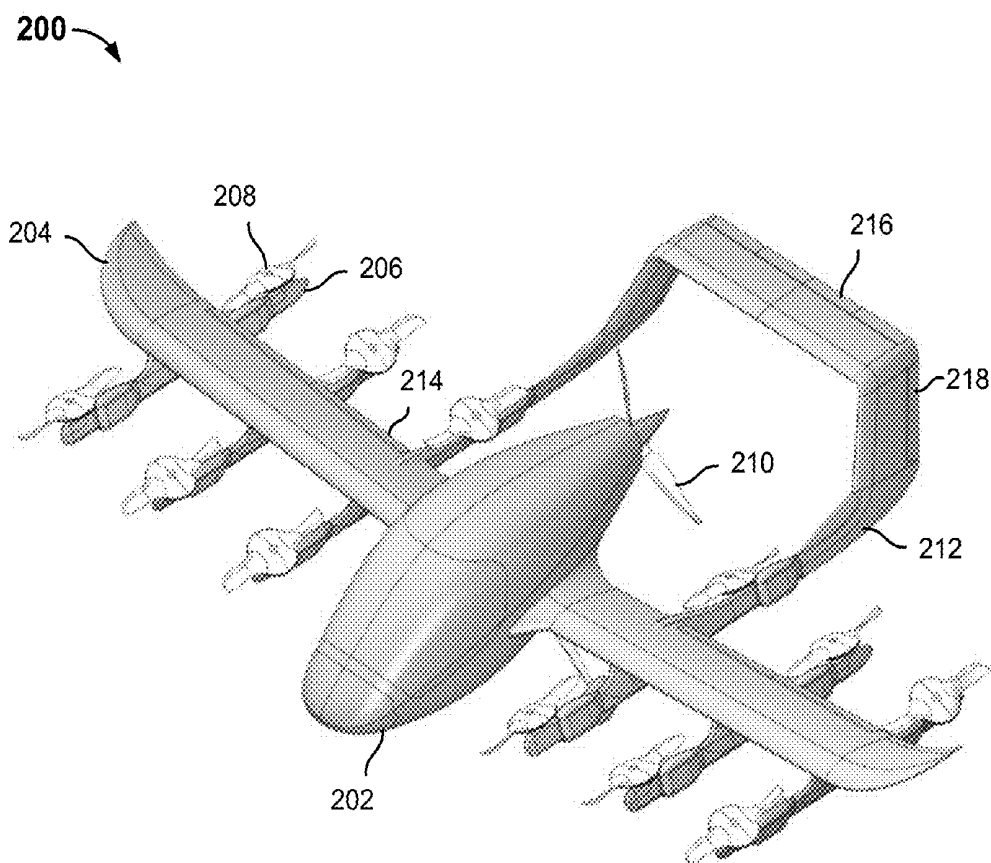


FIG. 2A

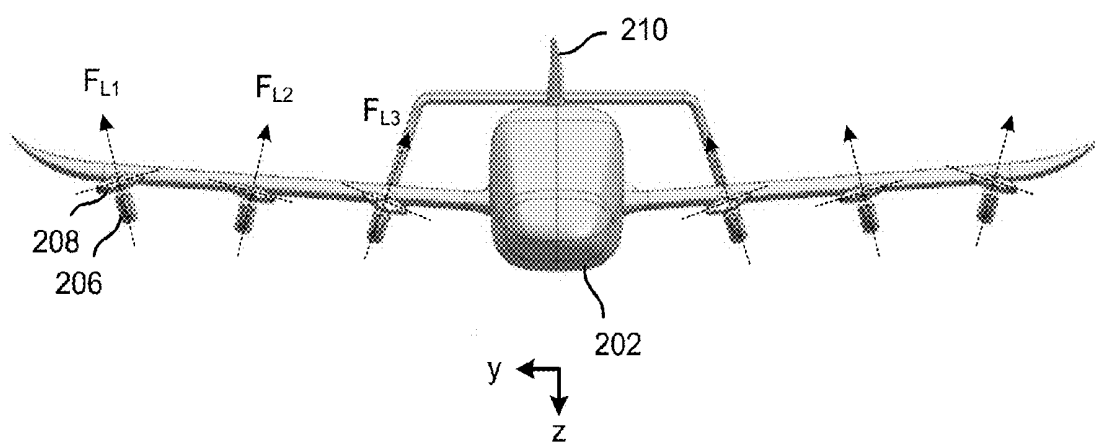


FIG. 2B

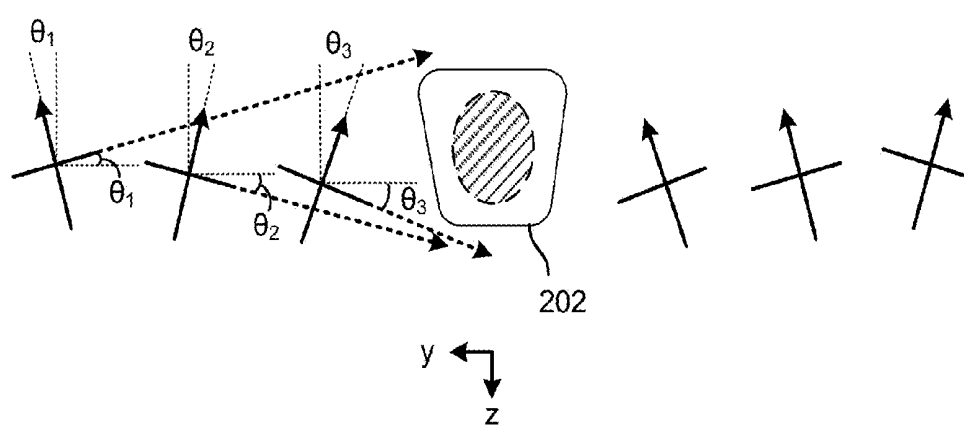


FIG. 2C

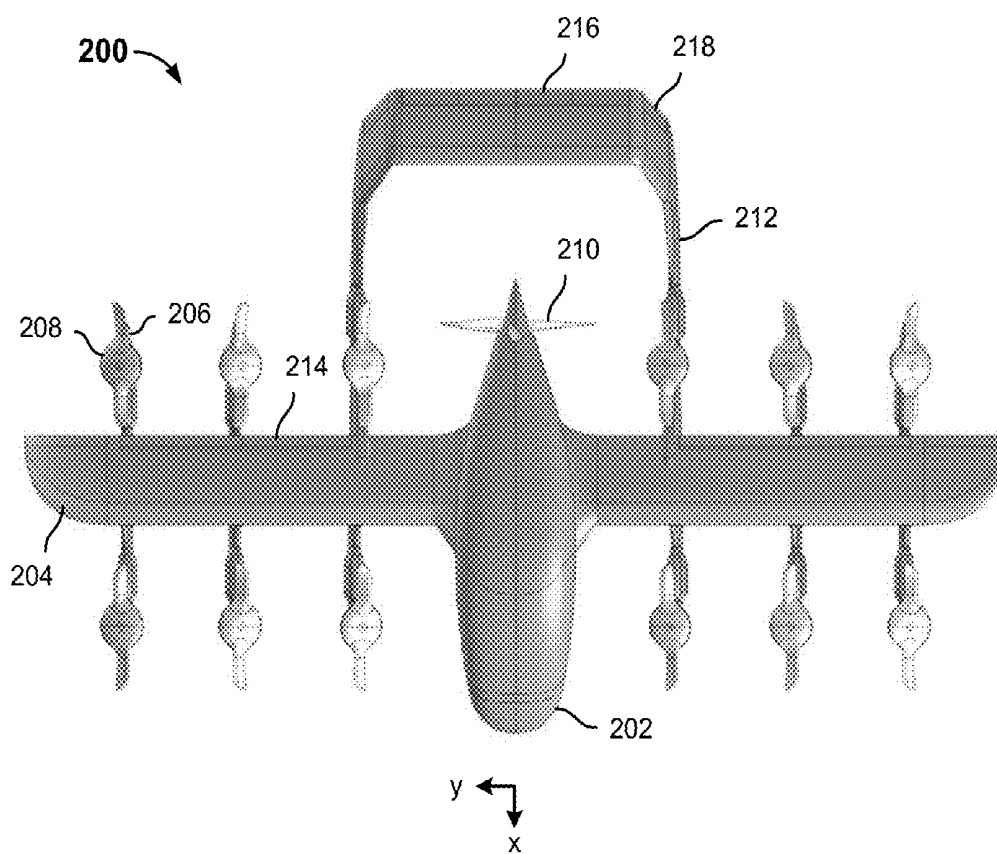


FIG. 2D

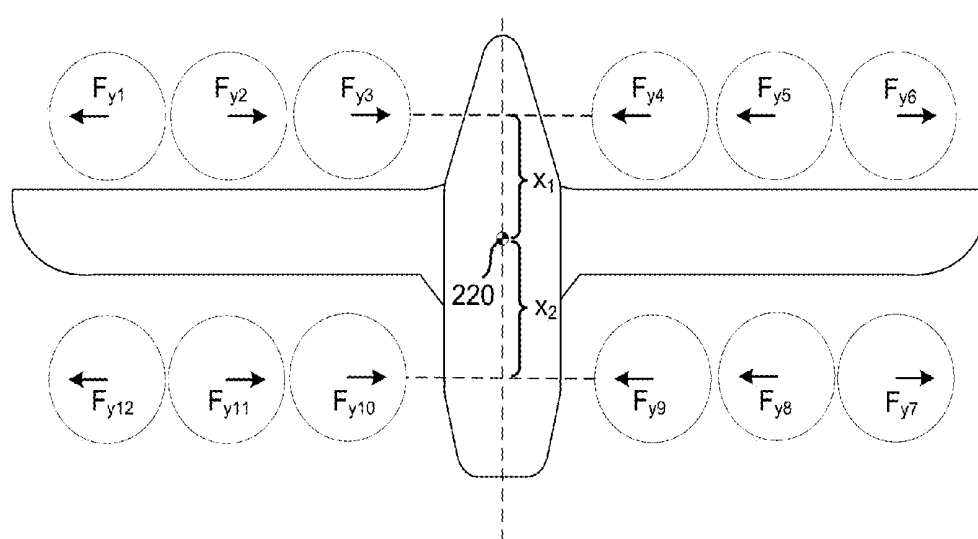


FIG. 2E

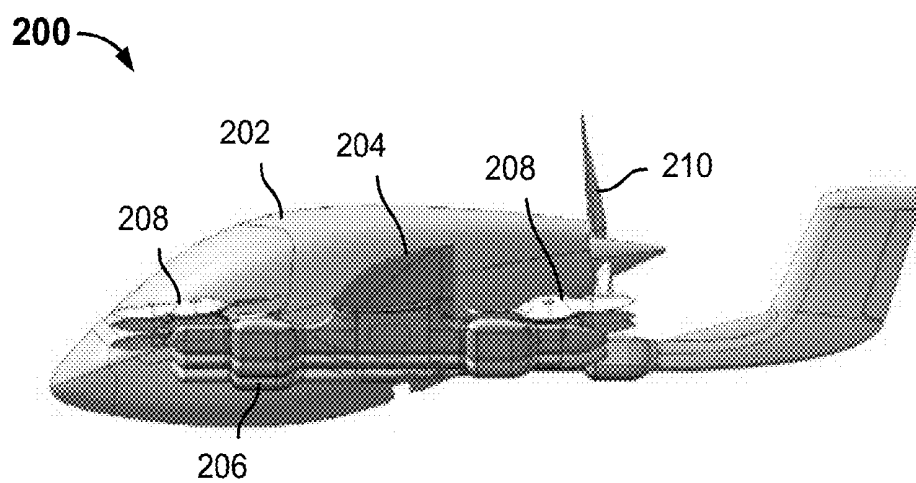


FIG. 2F

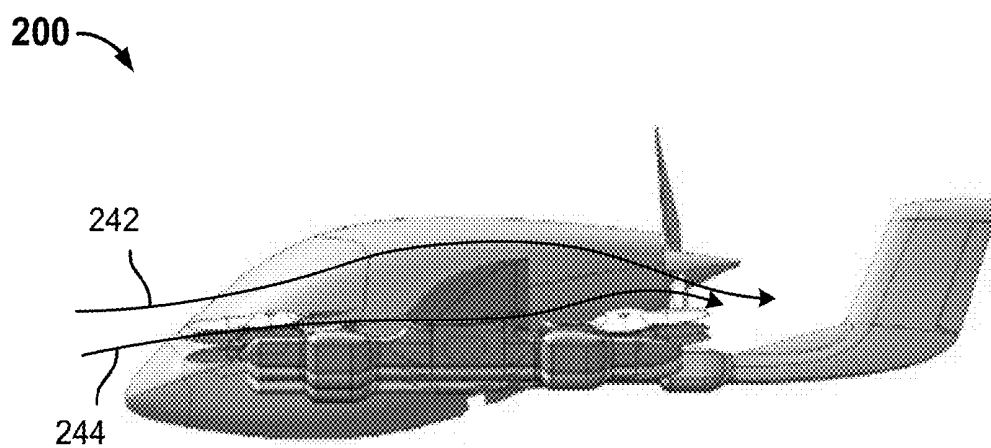


FIG. 2G

MULTICOPTER WITH BOOM-MOUNTED ROTORS

BACKGROUND OF THE INVENTION

[0001] Multicopter aircraft typically include a plurality of horizontally oriented rotors, sometimes referred to as “lift fans,” to provide lift, stability, and control. A flight control system, sometimes referred to as a “flight controller” or “flight computer”, may be provided to translate pilot or other operator input, and/or corrections computed by an onboard computer, e.g., based on sensor data, into forces and moments and/or to further translate such forces and moments into a set of actuator (e.g., lift rotors; propellers; control surfaces, such as ailerons; etc.) and/or associated parameters (e.g., lift fan power, speed, or torque) to provide the required forces and moments.

[0002] For example, pilot or other operator inputs may indicate a desired change in the aircraft's speed, direction, and/or orientation, and/or wind or other forces may act on the aircraft, requiring the lift fans and/or other actuators to be used to maintain a desired aircraft attitude (roll/pitch/yaw), speed, and/or altitude.

[0003] An aircraft typically is considered to have six degrees of freedom of movement, including forces in the forward/back, side/side, and up/down directions (e.g., F_x , F_y , and F_z) and moments about the longitudinal (roll) axis, the transverse (pitch) axis, and the vertical (yaw) axis (e.g., M_x , M_y , and M_z). If an aircraft has more actuators than degrees of freedom, it must be determined how the various actuators will be used to act on the aircraft in response to commands received via manual and/or automated controls. For a given set of one or more pilot commands under given circumstances, some combinations of actuators capable of acting on the aircraft to achieve the result indicated by the pilot command(s) may be more effective and/or efficient than others. For example, some may consume more or less power and/or fuel than others, provide a more smooth transition from a current state than others, etc.

[0004] Rotors may spin at a high rate and could pose a risk to an occupant of a manned multicopter and/or to equipment housed in a fuselage or other structure comprising the multicopter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] Various embodiments of the invention are disclosed in the following detailed description and the accompanying drawings.

[0006] FIG. 1 is a block diagram illustrating an embodiment of a flight control system.

[0007] FIG. 2A is a block diagram illustrating an embodiment of a multicopter aircraft with angled rotors.

[0008] FIG. 2B is a block diagram showing a front view of the multicopter aircraft 200 of FIG. 2A.

[0009] FIG. 2C is a block diagram illustrating an example of angled rotors as implemented in an embodiment of a multicopter aircraft with angled rotors.

[0010] FIG. 2D is a block diagram illustrating a top view of an embodiment of a multicopter aircraft with angled rotors.

[0011] FIG. 2E is a block diagram illustrating an example of forces and moments capable of being generated by angled rotors in an embodiment of a multicopter aircraft with angled rotors.

[0012] FIG. 2F is a block diagram showing a side view of the multicopter aircraft 200 of FIG. 2A.

[0013] FIG. 2G is a block diagram showing a side view of the multicopter aircraft 200 of FIG. 2A.

DETAILED DESCRIPTION

[0014] The invention can be implemented in numerous ways, including as a process; an apparatus; a system; a composition of matter; a computer program product embodied on a computer readable storage medium; and/or a processor, such as a processor configured to execute instructions stored on and/or provided by a memory coupled to the processor. In this specification, these implementations, or any other form that the invention may take, may be referred to as techniques. In general, the order of the steps of disclosed processes may be altered within the scope of the invention. Unless stated otherwise, a component such as a processor or a memory described as being configured to perform a task may be implemented as a general component that is temporarily configured to perform the task at a given time or a specific component that is manufactured to perform the task. As used herein, the term ‘processor’ refers to one or more devices, circuits, and/or processing cores configured to process data, such as computer program instructions.

[0015] A detailed description of one or more embodiments of the invention is provided below along with accompanying figures that illustrate the principles of the invention. The invention is described in connection with such embodiments, but the invention is not limited to any embodiment. The scope of the invention is limited only by the claims and the invention encompasses numerous alternatives, modifications and equivalents. Numerous specific details are set forth in the following description in order to provide a thorough understanding of the invention. These details are provided for the purpose of example and the invention may be practiced according to the claims without some or all of these specific details. For the purpose of clarity, technical material that is known in the technical fields related to the invention has not been described in detail so that the invention is not unnecessarily obscured.

[0016] A multicopter aircraft with angled rotors is disclosed. In various embodiments, a multicopter aircraft as disclosed herein includes a plurality of lift fans or other rotors disposed in a configuration around a fuselage and/or other centrally-located structure of the aircraft. In some embodiments, a first subset of the rotors may be disposed on a one side of the aircraft and a second subset of the rotors may be disposed on an opposite side of the aircraft. In various embodiments, each of at least a subset of the rotors is mounted at a corresponding non-zero angle off of a horizontal plane of the aircraft. In some embodiments, the angle at which each rotor is mounted is determined at least in part by a location of the rotor relative to the fuselage and/or a human or other occupied portion thereof, the angle being determined at least in part to ensure that a plane in which the rotor primarily rotates does not intersect the fuselage and/or a human or other occupied portion thereof. In various embodiments, the respective angles at which at least a subset of the rotors are mounted may be determined at least in part to provide the ability to generate lateral force components in the horizontal plane of the aircraft at rotor mount locations that are offset in the horizontal plane from a center of gravity of the aircraft, so as to provide an ability

to use the rotors to control yaw of the aircraft (i.e., rotation about a vertical axis of the aircraft) by applying moments about the vertical axis.

[0017] FIG. 1 is a block diagram illustrating an embodiment of a flight control system. In the example shown, flight control system 100 includes a source of flight control inputs 102 configured to provide flight control inputs 104 to a controller 106, e.g., a flight control computer. In some embodiments, source of inputs 102 may comprise one or both of pilot input, e.g., via manual flight controls, and auto-pilot or other self-piloting technologies. For example, in a self-piloting aircraft inputs 104 may be generated by a self-piloting program/computer 102. In various embodiments, source of inputs 102 may include manual input devices (sometimes referred to as “inceptors”), such as stick, throttle, rudder, collective, joystick, thumb stick, and/or other manual control/input devices configured to be manipulated by a pilot or other operator to control the flight of an aircraft. Such inceptor devices and/or associated electronics, and/or a self-piloting program, computer, or module, may be configured to provide as input signals 104 one or more of a roll direction, roll rate, yaw direction, yaw rate, pitch angle, pitch rate, altitude, altitude rate and/or forward or other thrust input signal. In the example shown, controller 106 also receives sensor data 118, e.g., wind speed, air temperature, etc., from sensors 116. Flight controller 106 translates, aggregates, and/or otherwise processes and/or interprets the received flight control inputs 104 and/or sensor data 118 to generate and provide as output associated forces and/or moments 108 to be applied to the aircraft via its control assets (e.g., propellers, rotors, lift fans, aerodynamic control surfaces, etc.; sometimes referred to herein as “actuators”) to maneuver the aircraft in a manner determined based at least in part on the flight control inputs 104 and/or sensor data 118. In various embodiments, forces/moments 108 may include forces and/or moments along and/or about one or more axes of the aircraft, such as x, y, and z axes, corresponding to longitudinal, transverse, and vertical axes of the aircraft, respectively, in various embodiments.

[0018] Referring further to FIG. 1, the flight control system 100 includes an online optimizer/mixer 110 configured to receive forces/moments 108. Online optimizer/mixer 110 receives as input forces/moments 108 and computes dynamically (online) a set of actuators and associated commands/parameters 112 to achieve the requested forces/moments 108. In some embodiments, the optimizer minimizes total power given a desired combination of forces and moments. Actuators 114 are configured to operate in response to actuator commands/parameters 112 provided by online optimizer/mixer 110.

[0019] In the example shown, sensors 116 provide sensor data 118 to online optimizer/mixer 110. Examples of sensors 116 and/or sensor data 118 may include one or more of airspeed, temperature, or other environmental conditions; actuator availability, failure, and/or health information; aircraft attitude, altitude, and/or other position information; presence/absence of other aircraft, debris, or other obstacles in the vicinity of the aircraft; actuator position information; etc. In various embodiments, online optimizer/mixer 110 may be configured to take sensor data 118 into account in determining an optimal mix of actuators and associated parameters to achieve a requested set of forces and moments. For example, in some embodiments, six or more lift fans may be provided to lift an aircraft into the air, enable

the aircraft to hover, control aircraft attitude relative to the horizontal, etc. In some embodiments, failure of a lift fan may be reflected in sensor data 118, resulting in a seamless response by online optimizer/mixer 110, which provides an optimal set of actuators and parameters 112 that omits (does not rely on) the failed lift fan. Likewise, in some embodiments, sensor data reflecting diminished power/performance, overheating, etc., may be taken into consideration, such as by adjusting a mapping of actuator parameter to expected effect on the aircraft for affected actuators.

[0020] FIG. 2A is a block diagram illustrating an embodiment of a multicopter aircraft with angled rotors. In various embodiments, a flight control system such as flight control system 100 of FIG. 1 may be embodied in an aircraft such as aircraft 200 of FIG. 2A. In the example shown, aircraft 200 includes a fuselage (body) 202 and wings 204. A set of three underwing booms 206 is provided under each wing. Each boom 206 has two lift fans 208 mounted thereon, one forward of the wing and one aft. Each lift fan 208 may be driven by an associated drive mechanism, such as a dedicated electric motor. One or more batteries (not shown) and/or onboard power generators (e.g., small gas turbine) may be used to drive the lift fans 208 and/or charge/recharge onboard batteries.

[0021] In various embodiments, each boom 206 is positioned at an angle relative to a vertical axis of the aircraft such that the lift fans 208 are mounted thereon at an associated angle, as described more fully in connection with FIGS. 2B-2E.

[0022] In the example shown in FIG. 2A, a propeller 210 is mounted on the fuselage 202 and configured to push the aircraft through the air in the forward (e.g., x axis) direction. The propeller 210 is positioned between a pair of tail booms 212 that extend aft and are joined at their aft end by a tail structure on which aerodynamic control surfaces including elevators 216 and rudder 218 are mounted. In various embodiments, each of the inboard booms 206 forms at least in part an integral part of the corresponding port/starboard side tail boom 212. In some embodiments, the tail booms 212 comprise extensions aft from the respective inboard booms 206. For example, the tail booms 212 may be formed as part of or fastened (e.g., bolted) to an aft end of the corresponding inboard boom 206. Additional control surfaces include ailerons 214 mounted on the trailing edge of wings 204.

[0023] In the example shown, four ailerons 214 are included, e.g., to provide redundancy. In some embodiments, if a single aileron 214 is lost or fails the remaining three ailerons 214 are sufficient to control the aircraft. Likewise, in some embodiments, loss of one rudder 218 results in one remaining rudder to provide a degree of yaw control, along with the lift fans. Finally, in some embodiments four elevators 216 are provided for loss/failure tolerance.

[0024] In some embodiments, an aircraft 200 as shown in FIG. 2A may have the following approximate dimensions:

Wingspan:	36.0 feet
Nose to tail	21.4 feet
Centerline to first boom	6.1 feet
Distance between inner booms	12.2 feet
Spacing between booms (same wing)	4.0 feet
Push propeller sweep	6.5 feet

-continued

Lift fan sweep	4.2 feet
Distance between fan centers (same boom)	8.7 feet

[0025] FIG. 2B is a block diagram showing a front view of the multicopter aircraft 200 of FIG. 2A. Coordinate axes in the z (vertical) and y (side) direction are indicated. The front view shown in FIG. 2B illustrates the respective angles off the vertical axis (z axis as labeled), sometimes referred to herein as “cant angles”, at which the outboard, middle, and inboard pairs of lift fans 206 are oriented. In various embodiments, angling the lift fans, as indicated, may provide additional options to control the aircraft, especially at or near hover. For example, different combinations of fans may be used to exercise yaw control (e.g., rotate around z axis), to slip sideways or counteract the force of wind while in a hover (y axis), etc.

[0026] In various embodiments, the respective angles at which lift fans 208 may be oriented may be determined based at least in part on safety considerations, such as to increase the likelihood that debris thrown centrifugally from a lift fan, e.g., should the lift fan break apart, would be propelled on a trajectory and/or in a plane that does not intersect a human-occupied portion of fuselage 202. In some embodiments, two side by side seats are provided for passengers in a forward part of fuselage 202. Batteries to power the lift fans 208 and/or push propeller 210 may be located in a central/over wing part of the fuselage 202, and in some embodiments both the human-occupied and battery occupied parts of the fuselage are protected at least in part by canting the booms/lift fans as disclosed herein.

[0027] In some embodiments, lift fan cant angles may be determined at least in part via a constrained optimization design process. The fan cants (e.g., roll and pitch fan angles) may be determined by an optimization process in which an object is to minimize the amount of torque required by any individual motor for a variety of trimmed or equilibrium conditions including: angular accelerations, any individual fan failure, crosswinds, and center of gravity variations. In some embodiments, the optimization is subject to constraints of preventing the plane of the fan blade from intersecting the crew in the event of catastrophic failure of a fan. Another example of a constraint that may be applied is ensuring that the fans are aligned to the local flow angle for forward flight with the fans stopped and aligned with the boom.

[0028] In various embodiments, the effective forces and moments capable of being provided by each respective lift fan may be stored onboard the aircraft 200 in a memory or other data storage device associated with the onboard flight control system. In various embodiments, a matrix, table, database, or other data structure may be used.

[0029] In some embodiments, effectiveness under different operating conditions may be stored. For example, effectiveness of a lift fan or control surface may be different depending on conditions such as airspeed, temperature, etc. In some embodiments, forces and moments expected to be generated by a lift fan or other actuator under given conditions may be discounted or otherwise reduced, e.g., by a factor determined based at least in part on an environmental or other variable, such as a measure of lift fan motor health.

[0030] In an aircraft having angled lift fans as in the example shown in FIG. 2B, the forces and moments capable

of being generated by a given lift fan may reflect the angle at which each lift fan is mounted. For example, lift fans mounted at an angle relative to the horizontal plane of the aircraft would generate a horizontal force component and a vertical force component, and each force may generate a corresponding moment about one or more axes of the aircraft, depending on the location at which the fan is mounted relative to the center of gravity of the aircraft.

[0031] FIG. 2C is a block diagram illustrating an example of angled rotors as implemented in an embodiment of a multicopter aircraft with angled rotors. In the example shown, the approximate angles at which the left side (as viewed from the front) rotors of the aircraft 200 as shown in FIGS. 2A and 2B are mounted are shown. In particular, the left most (outboard) lift fan is shown to be mounted at an angle θ_1 to the vertical (and, therefore, horizontal/lateral) axis of the aircraft, tilting away from fuselage 202, resulting in a plane of rotation of the lift fan, indicated by the dashed arrow extending away from the lift fan, not intersecting the fuselage 202. In some embodiments, the plane of rotation may intersect the fuselage but not a human-occupied or otherwise critical portion thereof.

[0032] Similarly, in the example shown the middle lift fan and the inboard lift fan have been angled in towards the fuselage 202, resulting in their respective planes of rotation being rotated downward by corresponding angles, such that they do not intersect the fuselage 202.

[0033] In various embodiments, angling lift fans or other rotors towards or away from a fuselage or critical portion thereof, and/or other critical structures, may decrease the risk that debris thrown centrifugally from the rotor would hit the fuselage or other structure.

[0034] FIG. 2D is a block diagram illustrating a top view of an embodiment of a multicopter aircraft with angled rotors. Specifically, in FIG. 2D a top view off aircraft 200 of FIG. 2A is shown. Coordinate axes in the x (forward) and y (side) direction are indicated. In the example shown, the aircraft 200 includes twelve lift fans 208, six on either side of the fuselage 202. On each side of the fuselage 202, three lift fans are mounted forward of the wing 204 and three aft. The lift fans 208 are mounted in pairs on corresponding booms 206 mounted under the wings 204. The outermost booms are tilted away from the fuselage 202 and the middle and inner booms are tilted towards the fuselage, as shown in FIGS. 2B and 2C.

[0035] FIG. 2E is a block diagram illustrating an example of forces and moments capable of being generated by angled rotors in an embodiment of a multicopter aircraft with angled rotors. In FIG. 2E, the fuselage 202 of the aircraft 200 of FIG. 2D is shown to have a center of gravity 220. The circles in FIG. 2E each represent a corresponding one of the lift fans 208. The arrows labeled F_{y1} , F_{y2} , etc. represent the respective lateral (y-axis) components of the force generated by the angled lift fans 208 by virtue of their being mounted at angles, and shown in FIGS. 2A-2D. The rear (aft) fans are shown to be mounted at an x-axis distance x_1 from center of gravity 220. As a result, the y-axis components of the rear lift fans, as shown, would result in corresponding moments of magnitudes proportional to the distance x_1 being applied to the aircraft about the vertical axis (z-axis, using the convention shown in FIGS. 2A-2E). The moment contributed by any given one of the rear lift fans would be determined by the lift force generated by the lift fan as actuated by the flight control system, with the direction

(counter-clockwise or clockwise) depending on the position of the lift fan and whether it was tilted away from or towards the fuselage 202. For example, the rear leftmost lift fan would contribute a lateral force F_{y1} resulting in contributing a counter-clockwise moment component about the center of gravity 220. The right side (as shown in FIG. 2E) rear inner and middle lift fans (F_{y4} , F_{y5}) similarly would contribute a counter-clockwise moment component. By contrast, the lift fans associated with lateral force components F_{y2} , F_{y3} , and F_{y6} would contribute clockwise moment components.

[0036] Similar to the rear lift fans, the forward lift fans (associated with lateral force components F_{y7} - F_{y12} , in this example) would contribute moment components proportional to the x-axis distance x_2 at which they are mounted relative to the center of gravity 220.

[0037] In various embodiments, the respective lift fans 208 may be rotated in alternating clockwise or counterclockwise rotations, e.g., to balance side forces associated with rotation direction. In the example shown in FIGS. 2A-2E, a total of twelve lift fans 208 are included. In various embodiments, an even number of lift fans including at least four lift fans may be included and distributed evenly on each side of the fuselage. Upon loss or failure of a lift fan, a corresponding lift fan on an opposite side of the aircraft may be de-activated, to maintain balance. For example, loss of a clockwise rotating lift fan on a forward end of an innermost boom on a port side of the aircraft may result in a counter-clockwise rotating lift fan in a complementary position on the opposite side, such as the aft end of the innermost boom on the opposite side, may be shut down and omitted from use (e.g., zero RPM/torque added as a constraint for that lift fan) in subsequent optimization computations to determine mixes of actuators and associated parameters to achieve desired forces and moments.

[0038] FIG. 2F is a block diagram showing a side view of the multicopter aircraft 200 of FIG. 2A. In the example shown, the lift fans 208 are mounted at a prescribed forward tilt relative to a horizontal plane of the aircraft 200. The booms 206 are shown to be mounted substantially aligned with the horizontal plane of the aircraft 200 when in level flight. The wings 204 sweep up slightly as they extend away from the fuselage 202. In various embodiments, the angle at which the lift fans 208 are tilted forward may be determined at least in part on the same considerations as the angles illustrated in FIGS. 2B and 2C, i.e., to ensure that debris thrown centrifugally from a lift fan if it were to break apart would not intersect at least a human-occupied or otherwise critical portion of a cockpit or cabin portion of fuselage 202. In some embodiments, the angle at which the lift fans 208 are tilted forward may be selected at least in part to minimize drag, turbulence, or other undesirable aerodynamic effects of the lift fans when the aircraft 200 is in forward flight, e.g., being propelled by push propeller 210.

[0039] FIG. 2G is a block diagram showing a side view of the multicopter aircraft 200 of FIG. 2A. In the example shown, approximate airflow patterns are illustrated by arrows 242 and 244. Arrow 242 shows air flowing with minimal resistance over the forward lift fans 208 and, due in part to the forward tilt of the forward lift fans 242, continuing relatively unimpeded over wing 204, and clearing the aft lift fans 208 (or, in some embodiments, flowing over them in a relatively low drag path, due in part to their forward tilt). Arrow 244 shows air flowing under/through the forward lift fans 208, under the wing 204, and flowing over the aft lift

fans 208 in a relatively low drag manner, due at least in part to the forward tilt of the aft lift fans 208.

[0040] In some embodiments, the wing 204 may not sweep upward to the same extent as shown in FIGS. 2F and 2G, and in some such embodiments the aft lift fans may be more within a same horizontal plane as the forward lift fans 208 and wing 204. In some such embodiments, the aft lift fans 208 may be tilted back slightly, instead of forward, to provide a continuous, relatively low drag pathway for air to flow over the forward lift fans 208, the wing 204, and the after lift fans 208, e.g., when the aircraft 200 is in forward flight mode.

[0041] In various embodiments, a flight control system, such as flight control system 100 of FIG. 1, is configured to determine a mix of actuators and corresponding actuator parameters, including of lift fans 208, to achieve required forces and moments, including by taking into consideration the moments about the z-axis that would be generated and applied to the aircraft 200 by virtue of the lift fans being mounted at angles, as disclosed herein.

[0042] In various embodiments, techniques disclosed herein may be used to provide a multicopter aircraft having angled lift fans and/or rotors. Each rotor may be mounted at an angle such that debris thrown centrifugally from the lift fan, in a plane of rotation of the lift fan, would not intersect the fuselage or other critical structure of the aircraft. In various embodiments, angling rotors as disclosed herein may provide a degree of authority over (ability to control or influence) yaw of the aircraft, e.g., during hover or vertical takeoff (lift) or landing operations.

[0043] Although the foregoing embodiments have been described in some detail for purposes of clarity of understanding, the invention is not limited to the details provided. There are many alternative ways of implementing the invention. The disclosed embodiments are illustrative and not restrictive.

What is claimed is:

1. An aircraft, comprising:

a fuselage;

a port side wing coupled to the fuselage;

a starboard side wing coupled to the fuselage;

wherein each of said wings has mounted thereto one or more booms, each boom having a forward end extending forward of a corresponding wing to which the boom is mounted and an after end extending aft of said corresponding wing to which the boom is mounted;

a first plurality of lift rotors, each rotor in said first plurality being mounted on a forward end of a corresponding one or said booms; and

a second plurality of lift rotors, each rotor in said second plurality being mounted on an after end of a corresponding one or said booms;

wherein each rotor in said first plurality and each rotor in said second plurality produces an amount of vertical thrust independent of levels of vertical thrust produced by the other rotors.

2. The aircraft of claim 1, wherein each of said pylons is mounted to said port side wing or said starboard side wing at a non-zero angle relative to a substantially vertical axis of the aircraft.

3. The aircraft of claim 1, wherein a first subset of said pylons each is mounted to said port side wing or said starboard side wing at a non-zero angle relative to a sub-

stantially vertical axis of the aircraft such that the pylon is tilted inboard towards the fuselage.

4. The aircraft of claim 3, wherein a second subset of said pylons each is mounted to said port side wing or said starboard side wing at a non-zero angle relative to a substantially vertical axis of the aircraft such that the pylon is tilted outboard away from the fuselage.

5. The aircraft of claim 1, wherein the port side wing and the starboard side wing each has three pylons mounted thereto and wherein the first plurality of lift rotors is 6 and the second plurality of lift rotors is 6.

6. The aircraft of claim 1, wherein the lift rotors in the first and second plurality of lift rotors are driven by electric motors.

7. The aircraft of claim 1, wherein the port side wing and the starboard side wing comprise a single wing structure mounted to the fuselage such that said port said wing

comprises a port side portion of said single wing structure extending to the port side of the fuselage and said starboard said wing comprises a starboard side portion of said single wing structure extending to the starboard side of the fuselage.

8. The aircraft of claim 1, further comprising a split boom structure extending after from each of an inboard pair of said pylons, the split boom structure comprising a port side boom and a starboard side boom extending aft of the fuselage and being joined at an after end of the split boom structure by a tail structure.

9. The aircraft of claim 8, wherein each of said pylons comprising the inboard pair of pylons forms at least in part an integral part of a corresponding one of said port side boom and said starboard side boom.

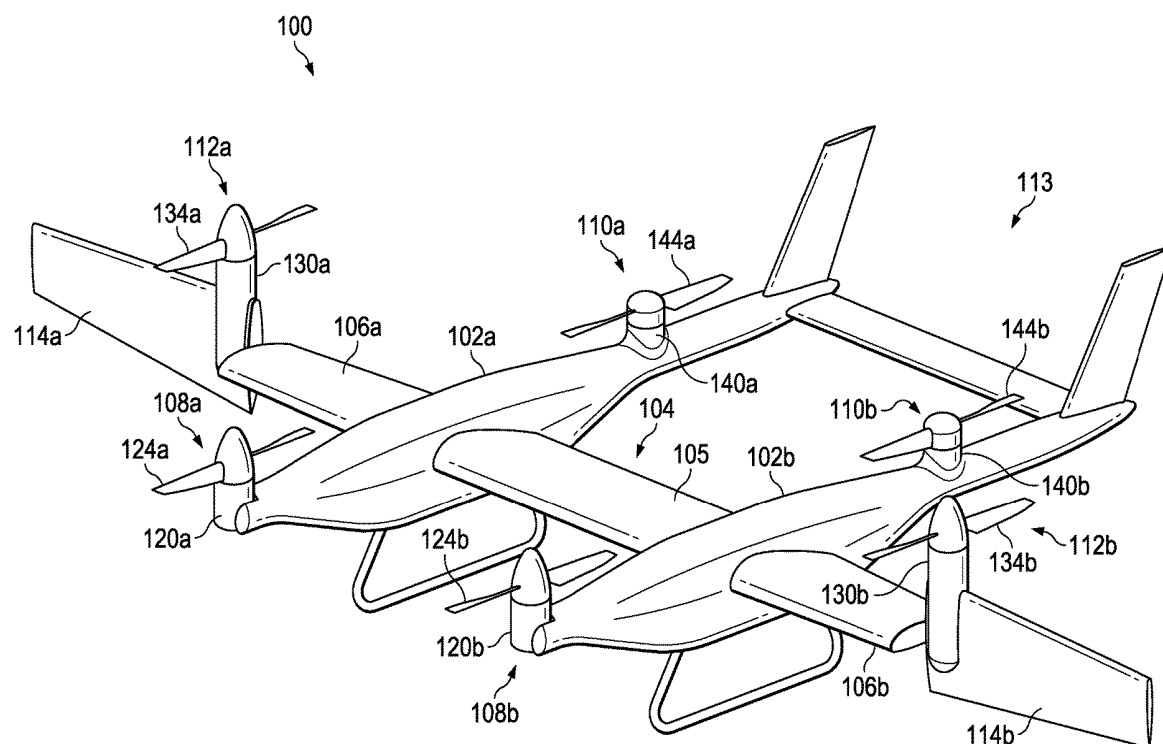
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(19) **United States**(12) **Patent Application Publication** (10) **Pub. No.: US 2023/0150659 A1**
Ivans et al. (43) **Pub. Date: May 18, 2023**(54) **TWIN FUSELAGE TILTROTOR AIRCRAFT**(52) **U.S. Cl.**(71) Applicant: **Bell Textron Inc.**, Fort Worth, TX (US)CPC **B64C 29/0033** (2013.01); **B64C 39/04**
(2013.01)(72) Inventors: **Steven R. Ivans**, Ponder, TX (US);
Robert Roe, Fort Worth, TX (US)(57) **ABSTRACT**(21) Appl. No.: **17/528,989**(22) Filed: **Nov. 17, 2021****Publication Classification**(51) **Int. Cl.**
B64C 29/00 (2006.01)
B64C 39/04 (2006.01)

One embodiment is an aircraft including first and second fuselages; a wing assembly connecting the first and second fuselages, wherein the first and second fuselages are parallel to one another; first and second forward propulsion systems tiltably attached to forward ends of the first and second fuselages; and first and second aft propulsion systems fixedly attached proximate aft ends of the first and second fuselages.



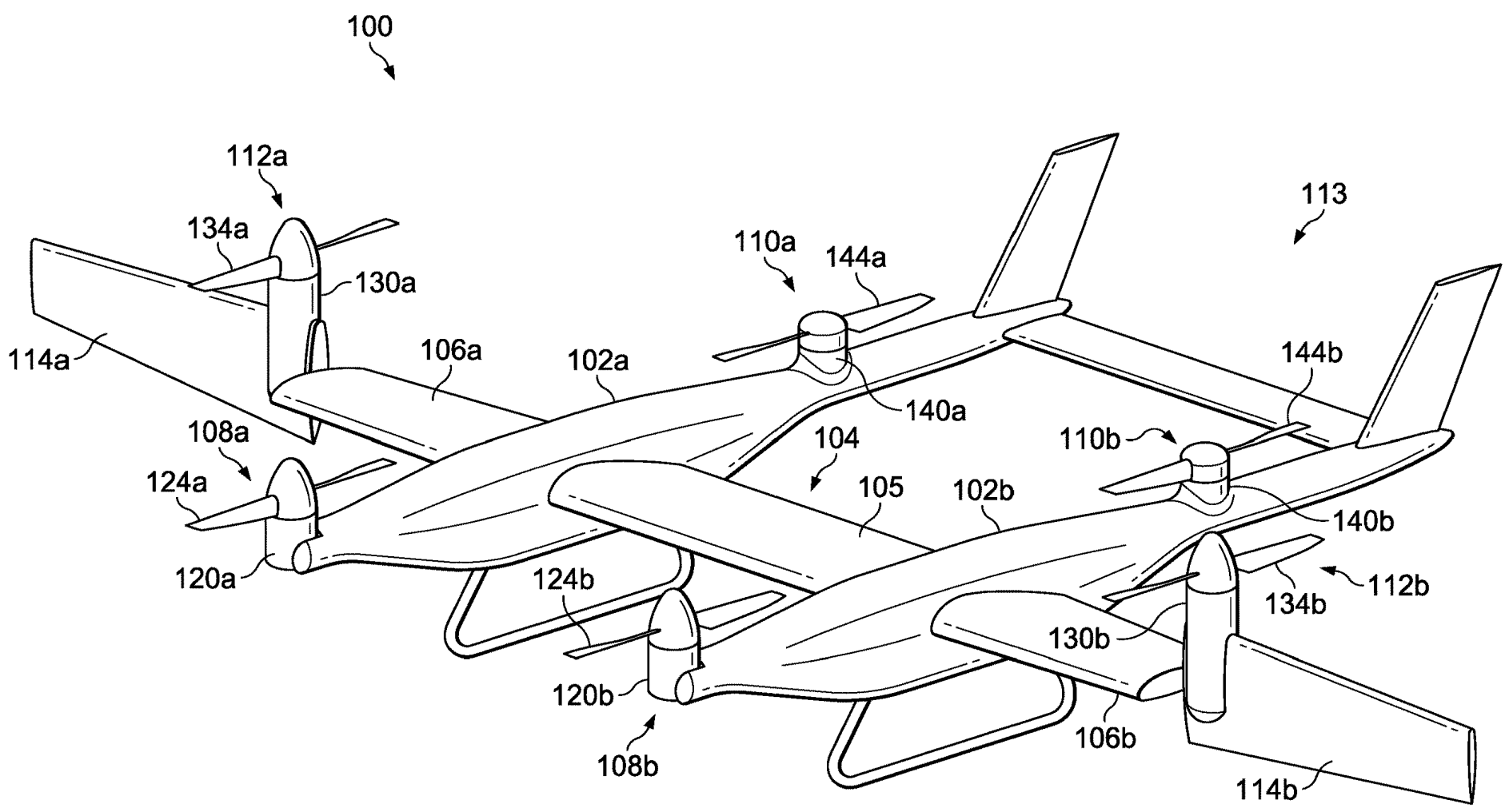


FIG. 1A

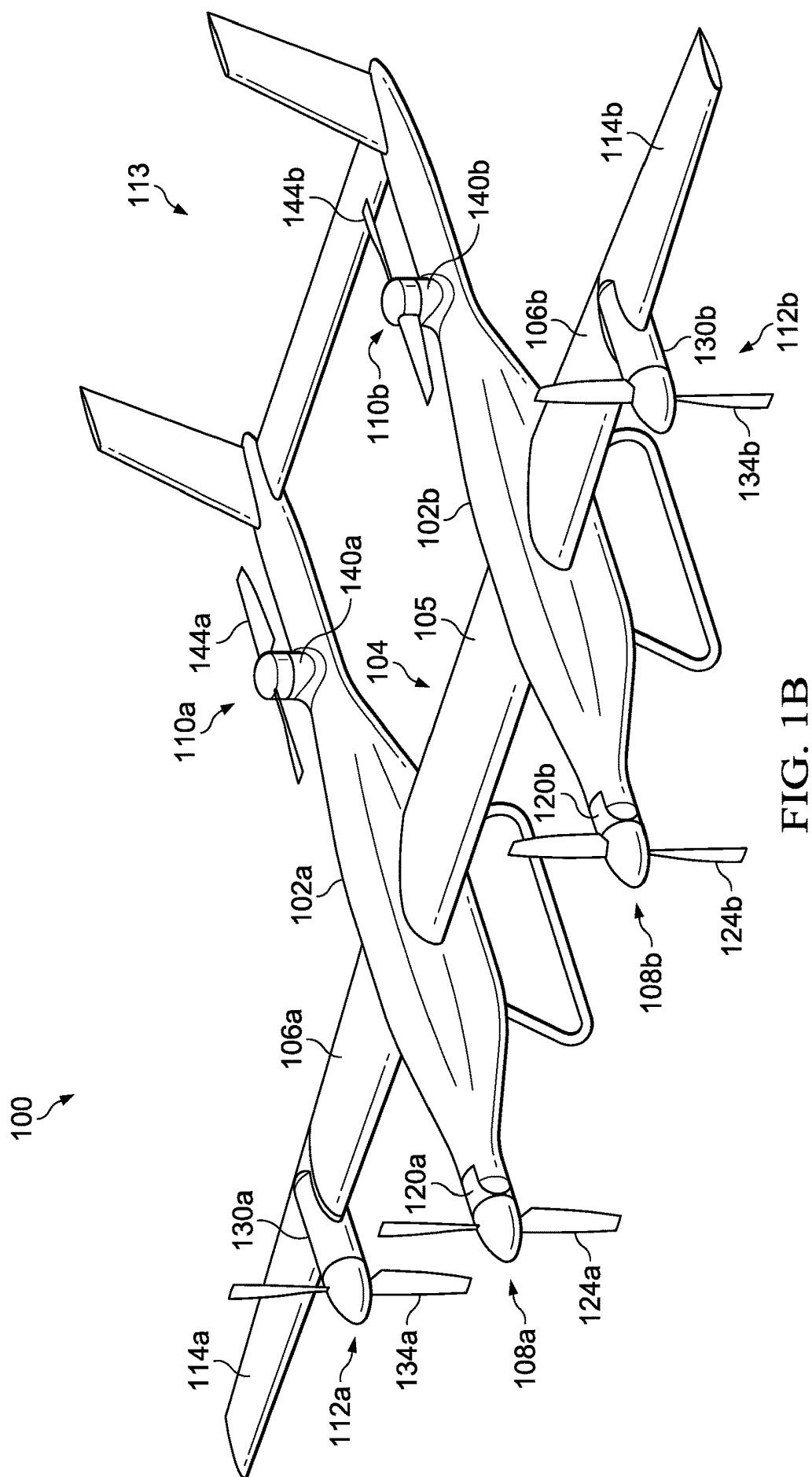
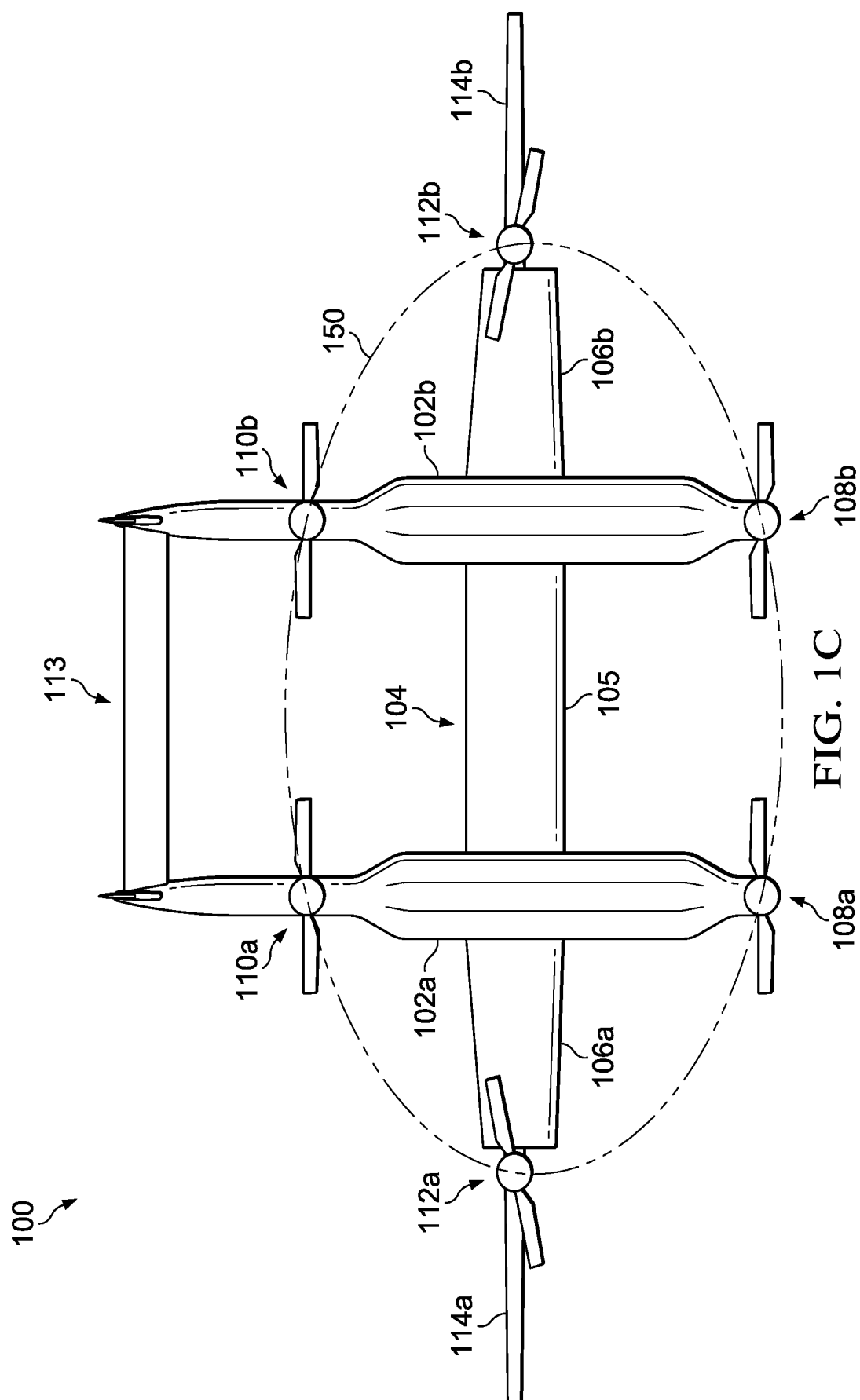


FIG. 1B



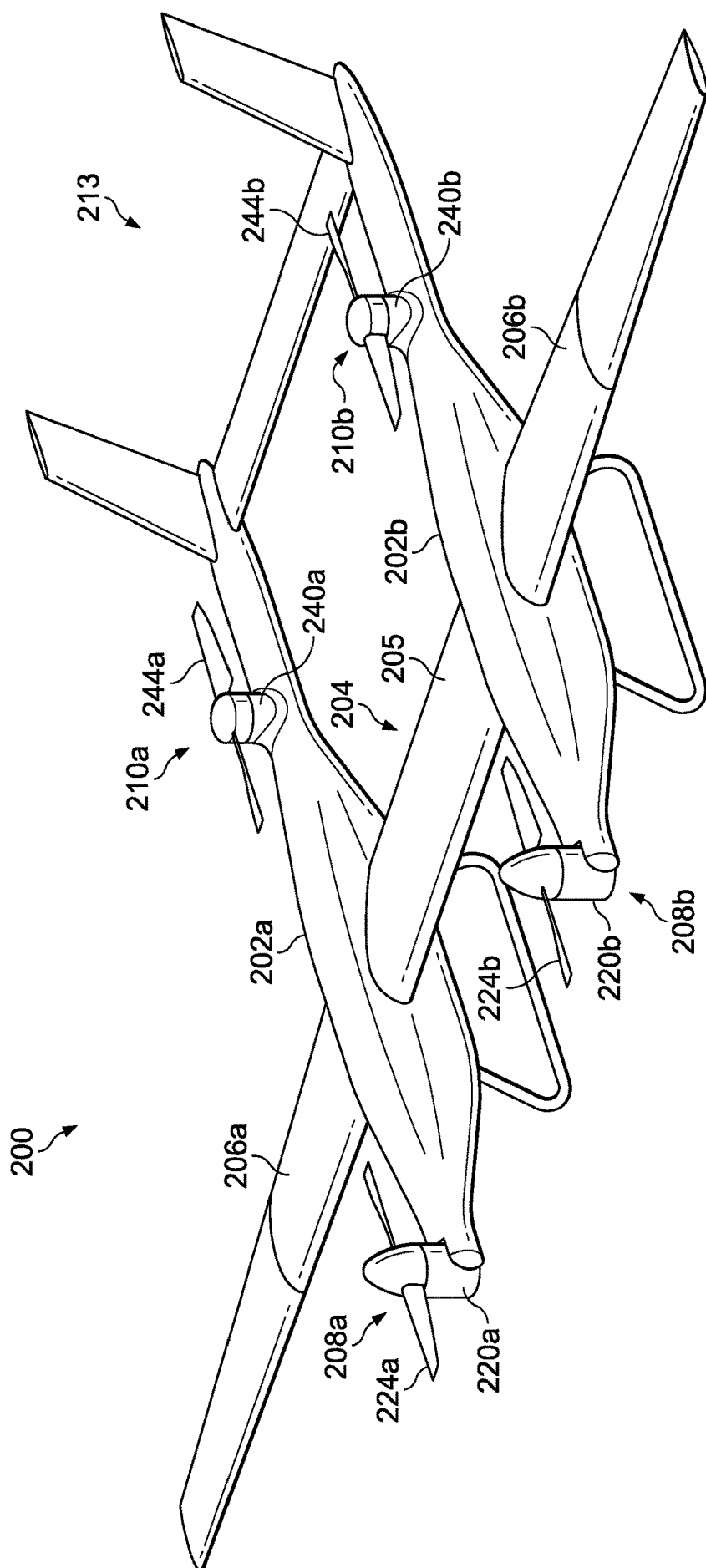


FIG. 2A

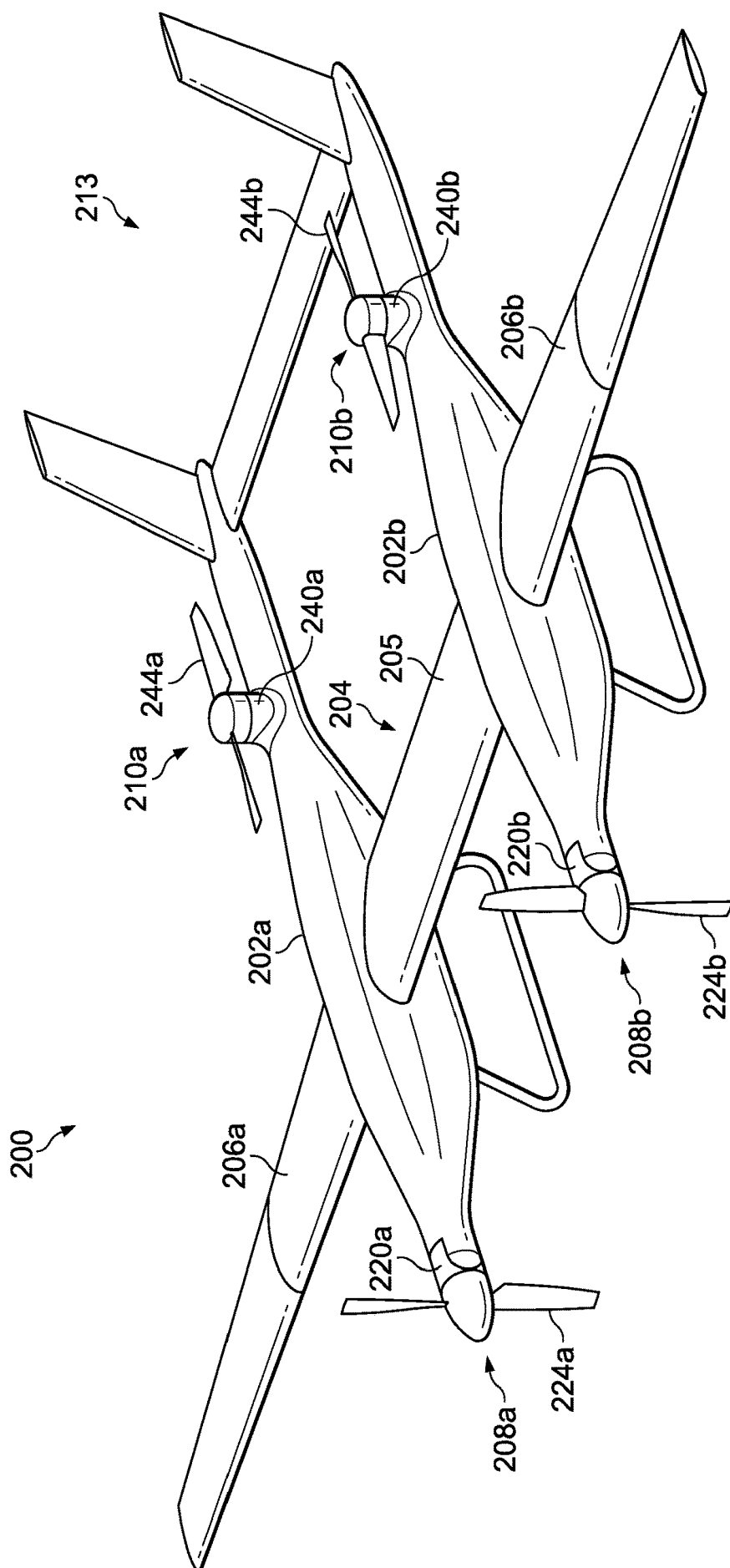


FIG. 2B

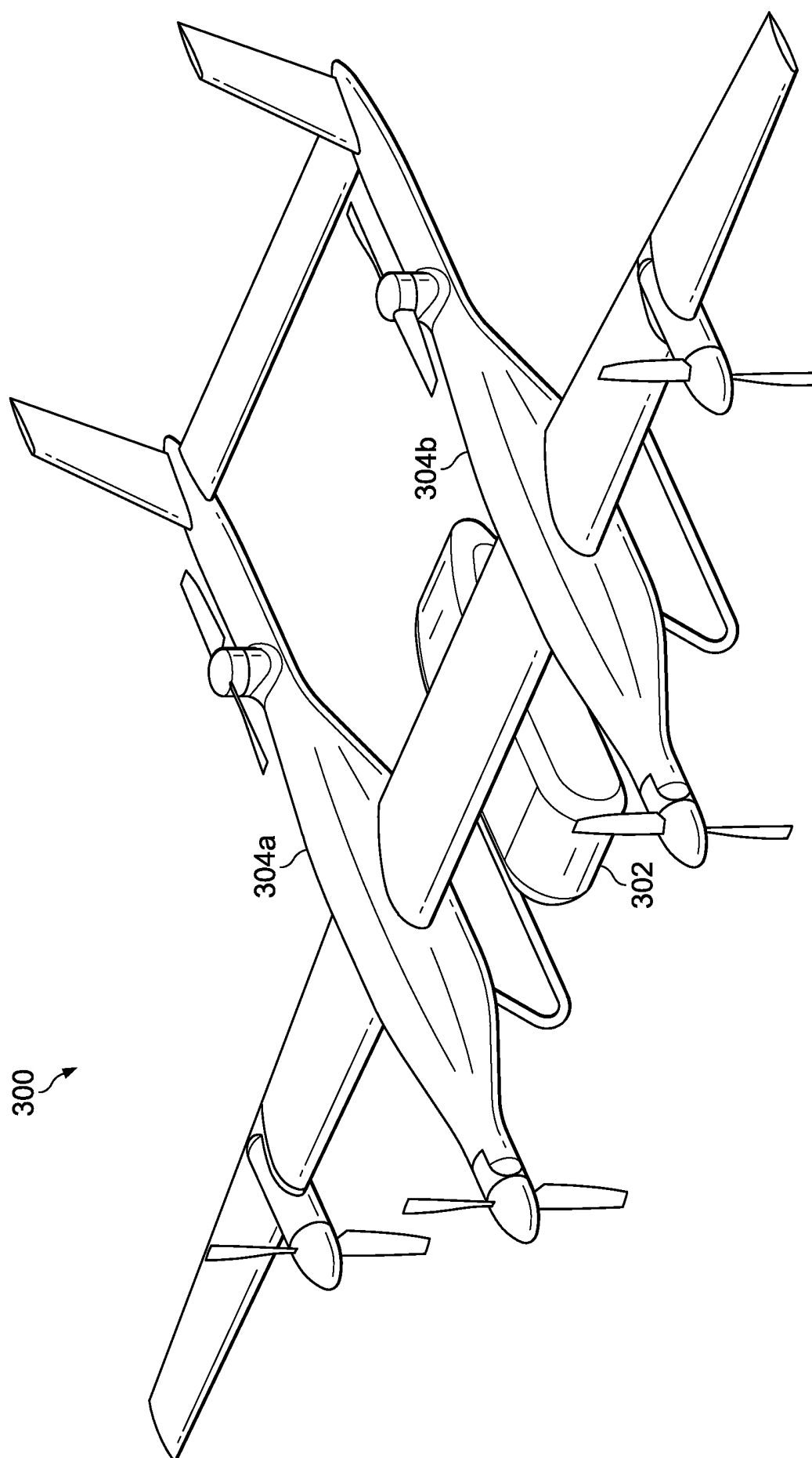


FIG. 3A

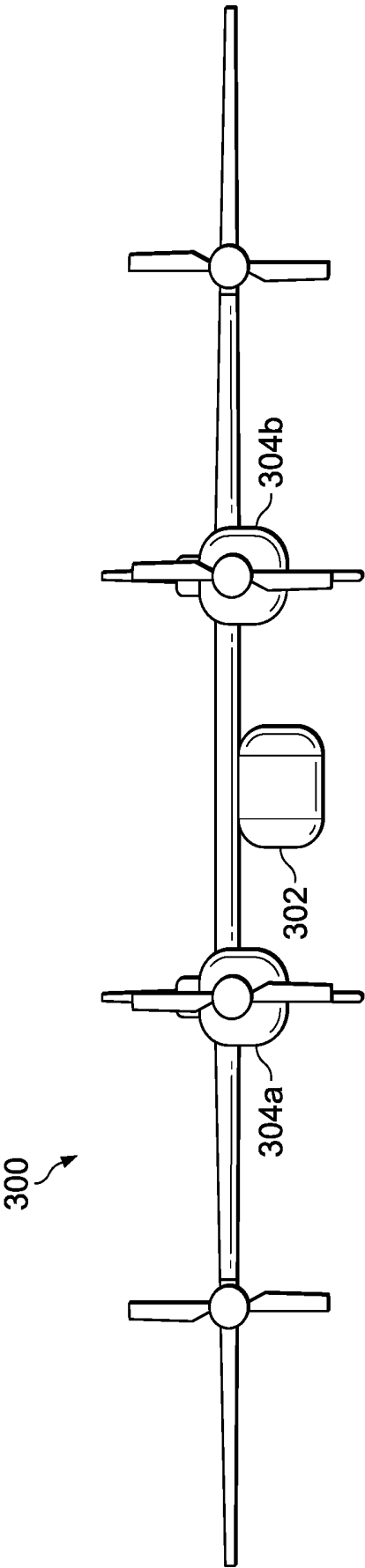


FIG. 3B

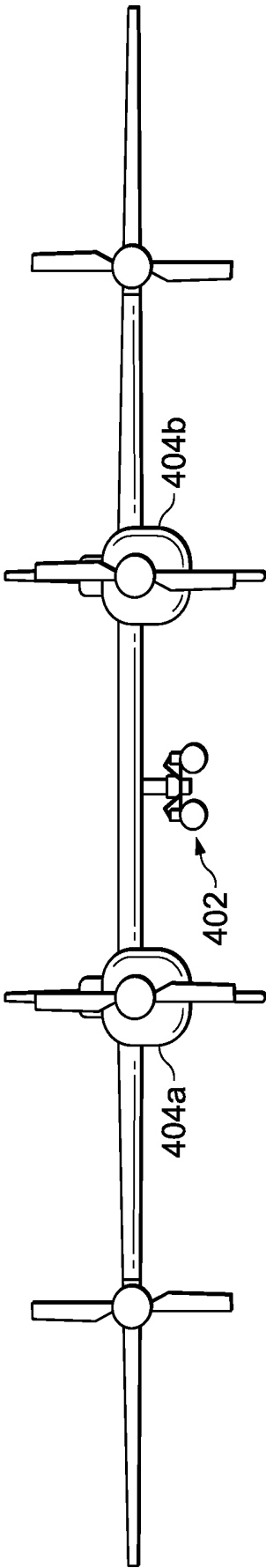


FIG. 4B

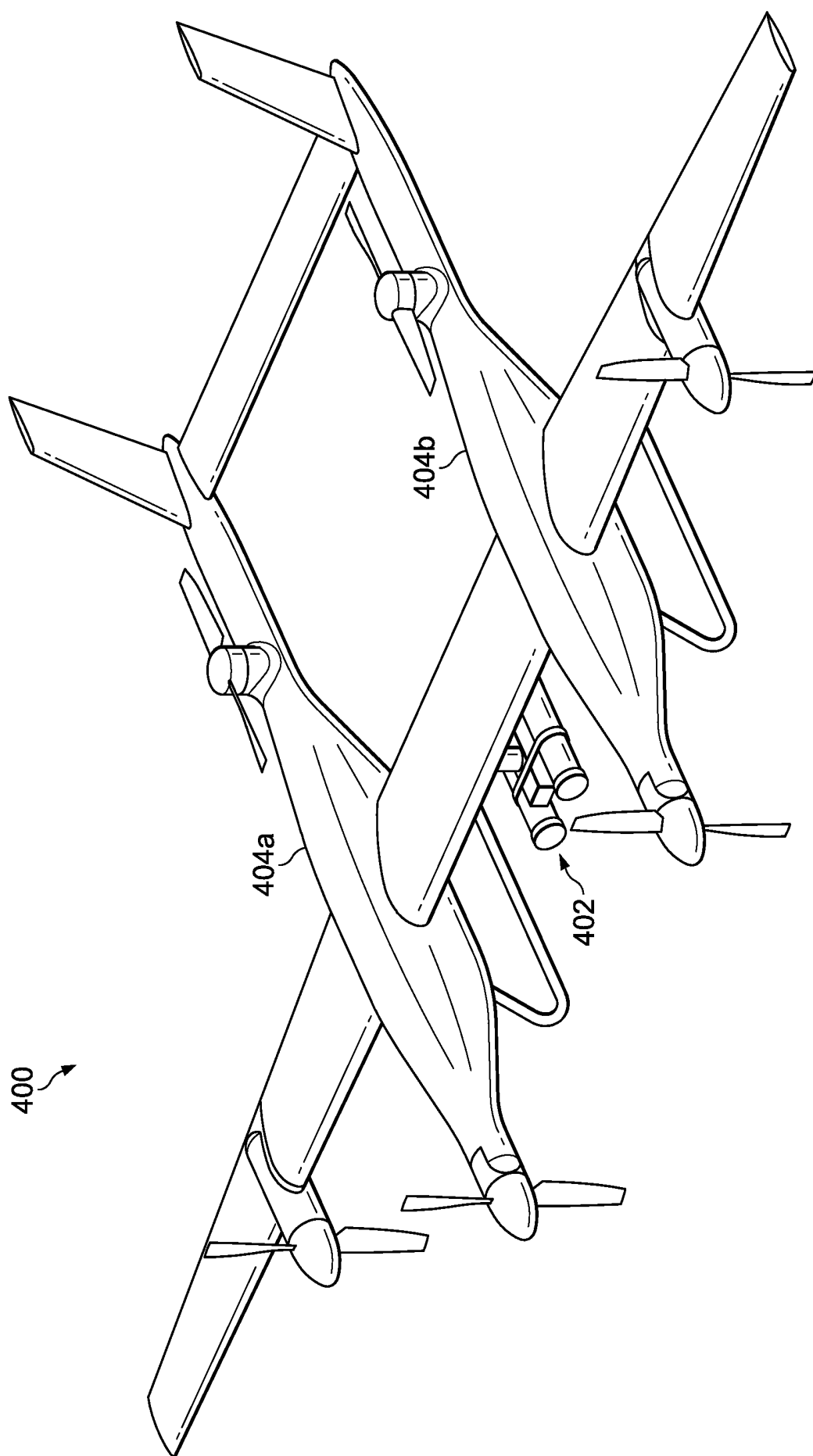


FIG. 4A

TWIN FUSELAGE TILTROTOR AIRCRAFT

TECHNICAL FIELD

[0001] This disclosure relates in general to the field of tiltrotor aircraft and, more particularly, though not exclusively, to twin fuselage arrangements for such aircraft.

BACKGROUND

[0002] An electric vertical takeoff and landing (eVTOL) aircraft is a type of aircraft that uses electric power to supply rotational energy through electric motor(s) to props, rotors, or fans in an aircraft propulsion system for enabling the aircraft to hover, take off, and land vertically. Because of their versatility and lack of a need for a runway, eVTOL aircraft are particularly useful for providing urban air mobility. As used herein, the term eVTOL also includes VTOL aircraft that use hybrid-electric (with an engine running a generator producing electricity and battery stored power) or turbo electric (an engine running a generator providing all power required) propulsion systems. One particular type of eVTOL aircraft is an electric tiltrotor aircraft.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] To provide a more complete understanding of the present disclosure and features and advantages thereof, reference is made to the following description, taken in conjunction with the accompanying figures, in which like reference numerals represent like elements:

[0004] FIGS. 1A-1B illustrate a tiltrotor aircraft having a twin fuselage hexrotor configuration in accordance with embodiments described herein;

[0005] FIG. 1C illustrates a hexrotor arc arrangement of rotors of the tiltrotor aircraft of FIGS. 1A and 1B;

[0006] FIGS. 2A-2B illustrate a tiltrotor aircraft having a twin fuselage quadrotor configuration in accordance with embodiments described herein;

[0007] FIGS. 3A-3B illustrate a tiltrotor aircraft having a twin fuselage hexrotor configuration including a cargo pod between the fuselages in accordance with embodiments described herein; and

[0008] FIGS. 4A-4B illustrate a tiltrotor aircraft having a twin fuselage hexrotor configuration including a weapons assembly between the fuselages in accordance with embodiments described herein.

DETAILED DESCRIPTION

[0009] The following disclosure describes various illustrative embodiments and examples for implementing the features and functionality of the present disclosure. While particular components, arrangements, and/or features are described below in connection with various example embodiments, these are merely examples used to simplify the present disclosure and are not intended to be limiting. It will of course be appreciated that in the development of any actual embodiment, numerous implementation-specific decisions must be made to achieve the developer's specific goals, including compliance with system, business, and/or legal constraints, which may vary from one implementation to another. Moreover, it will be appreciated that, while such a development effort might be complex and time-consuming; it would nevertheless be a routine undertaking for those of ordinary skill in the art having the benefit of this disclosure.

[0010] In the specification, reference may be made to the spatial relationships between various components and to the spatial orientation of various aspects of components as depicted in the attached drawings. However, as will be recognized by those skilled in the art after a complete reading of the present disclosure, the devices, components, members, apparatuses, etc. described herein may be positioned in any desired orientation. Thus, the use of terms such as "above", "below", "upper", "lower", "top", "bottom", or other similar terms to describe a spatial relationship between various components or to describe the spatial orientation of aspects of such components, should be understood to describe a relative relationship between the components or a spatial orientation of aspects of such components, respectively, as the components described herein may be oriented in any desired direction. When used to describe a range of dimensions or other characteristics (e.g., time, pressure, temperature, length, width, etc.) of an element, operations, and/or conditions, the phrase "between X and Y" represents a range that includes X and Y.

[0011] Additionally, as referred to herein in this specification, the terms "forward", "aft", "inboard", and "outboard" may be used to describe relative relationship(s) between components and/or spatial orientation of aspect(s) of a component or components. The term "forward" may refer to a spatial direction that is closer to a front of an aircraft relative to another component or component aspect (s). The term "aft" may refer to a spatial direction that is closer to a rear of an aircraft relative to another component or component aspect(s). The term "inboard" may refer to a location of a component that is within the fuselage(s) of an aircraft and/or a spatial direction that is closer to or along a centerline of the aircraft (wherein the centerline runs between the front and the rear of the aircraft) or other point of reference relative to another component or component aspect. The term "outboard" may refer to a location of a component that is outside the fuselage(s) of an aircraft and/or a spatial direction that farther from the centerline of the aircraft or other point of reference relative to another component or component aspect.

[0012] Further, the present disclosure may repeat reference numerals and/or letters in the various examples. This repetition is for the purpose of simplicity and clarity and does not in itself dictate a relationship between the various embodiments and/or configurations discussed. Example embodiments that may be used to implement the features and functionality of this disclosure will now be described with more particular reference to the accompanying figures.

[0013] Described herein are various configurations for twin fuselage tiltrotor aircraft. In particular, both hexrotor and quadrotor configurations are disclosed. Embodiments of tiltrotor aircraft described herein may be suitable for use in a variety of unmanned aircraft applications, including but not limited to unmanned logistics operations, joint surveillance and target attack radar system (JSTAR) applications, and military and other unmanned aerial systems (UAS) applications, to name a few. Embodiments described herein distribute propulsion around the aircraft to achieve large center of gravity (CG) envelopes and employ a long wing to facilitate efficient cruise operation. Twin fuselages may be used for packaging aircraft components and/or to support landing gear, which may include but is not limited to skids, fixed wheels, and retractable wheels, to name a few. Modular payload, such as a cargo pod, a weapons assembly and/or

one or more sensors, may be mounted to the underside of a center wing section between the fuselages. In certain embodiments, twin fuselages may be implemented as twin booms. A distinguishing feature of embodiments described herein is the lack of a center boom/fuselage between the twin (outboard) fuselages.

[0014] FIGS. 1A and 1B illustrate an example tiltrotor aircraft 100 that is convertible between a VTOL or hover (also commonly referred to as helicopter) mode (shown in FIG. 1A), which allows for vertical takeoff and landing, hovering, and low speed directional movement, and a cruise (also commonly referred to as airplane) mode (shown in FIG. 1B), which allows for forward flight. Aircraft 100 includes two fuselages 102a, 102b, and a wing assembly 104 including a center wing section 105 extending between and interconnecting fuselages 102a, 102b, and outboard wing portions 106a, 106b, extending outboard of fuselages 102a, 102b. In accordance with features of embodiments described herein, aircraft 100 further includes three pairs of propulsion systems, including forward propulsion systems 108a, 108b, connected to the forward ends of the fuselages 102a, 102b, aft propulsion systems 110a, 110b, connected proximate the aft ends of the fuselages 102a, 102b, and a pair of wing-mounted propulsion systems 112a, 112b, proximate opposite ends of wing assembly 104. In particular, in accordance with features of embodiments described herein, and as illustrated in FIGS. 1A and 1B, wing-mounted propulsion systems 112a, 112b, are connected to inboard ends of wing tips 114a, 114b, disposed on outboard ends of outboard wing portions 106a, 106b. As shown in FIGS. 1A and 1B, aircraft 100 further includes a tail assembly 113 connected to aft ends of fuselages 102a, 102b. Although as shown in FIGS. 1A and 1B, tail assembly 113 is illustrated as including a pair of boom-mounted stabilizers, other tail assembly configurations may be implemented without departing from the spirit or scope of embodiments described herein.

[0015] In the illustrated embodiment, each forward propulsion system 108a, 108b, includes a drive system housing comprising a pylon 120a, 120b, and a rotatable open rotor assembly comprising a plurality of rotor blades 124a, 124b, connected to a rotor shaft and configured to rotate about a rotor axis. As shown in FIGS. 1A and 1B, the rotor assemblies of forward propulsion systems 108a, 108b, include two (2) rotor blades; however, it should be recognized that more blades may be implemented without departing from the spirit and the scope of the embodiments described. Rotation of rotor blades 124a, 124b, generates lift while operating in helicopter mode and thrust while operating in airplane mode. Each pylon 120a, 120b, may house one or more electric motors therein configured to produce rotational energy that drives the rotation of the rotor assembly. Alternatively, each pylon 120a, 120b, may house a gearbox therein that drives the rotation of the rotor assembly, wherein the gearbox receives rotational energy from a driveshaft.

[0016] In the illustrated embodiment, each wing-mounted propulsion system 112a, 112b, includes a drive system housing comprising a pylon 130a, 130b, and a rotatable open rotor assembly comprising a plurality of rotor blades 134a, 134b, connected to a rotor shaft and configured to rotate about a rotor axis. As shown in FIGS. 1A and 1B, the rotor assemblies of propulsion systems 112a, 112b, include two (2) rotor blades; however, it should be recognized that more blades may be implemented without departing from the spirit and the scope of the embodiments described. It

should also be recognized that rotor assemblies of propulsion systems 112a, 112b, may include a different number of rotor blades than rotor assemblies of propulsion systems 108a, 108b. Rotation of rotor blades 134a, 134b, generates lift while operating in helicopter mode and thrust while operating in airplane mode. Each pylon 130a, 130b, may house one or more electric motors therein configured to produce rotational energy that drives the rotation of the rotor assembly. Alternatively, each pylon 130a, 130b, may house a gearbox therein that drives the rotation of the rotor assembly, wherein the gearbox receives rotational energy from a driveshaft.

[0017] In the illustrated embodiment, each aft propulsion system 110a, 110b, includes a drive system housing comprising a pylon 140a, 140b, and a rotatable open rotor assembly comprising a plurality of rotor blades 144a, 144b, connected to a rotor shaft and configured to rotate about a rotor axis. As shown in FIGS. 1A and 1B, the rotor assemblies of propulsion systems 110a, 110b, include two (2) rotor blades; however, it should be recognized that more blades may be implemented without departing from the spirit and the scope of the embodiments described. It should also be recognized that rotor assemblies of propulsion systems 110a, 110b, may include a different number of rotor blades than rotor assemblies of propulsion systems 108a, 108b, 112a, 112b.

[0018] Rotation of rotor blades 144a, 144b generates lift while operating in helicopter mode. Each pylon 140a, 140b, may house one or more electric motors therein configured to produce rotational energy that drives the rotation of the rotor assembly. Alternatively, each pylon 140a, 140b, may house a gearbox therein that drives the rotation of the rotor assembly, wherein the gearbox receives rotational energy from a driveshaft.

[0019] In accordance with features of embodiments described herein, and as illustrated in FIGS. 1A and 1B, wing-mounted propulsion systems 112a, 112b, are connected to inboard ends of wing tips 114a, 114b, attached to outboard ends of wing assembly 104. Wing tips 114a, 114b, together with wing-mounted propulsion systems 112a, 112b, tilt relative to wing assembly 104 between a first position (FIG. 1A), in which propulsion systems 112a, 112b, and wing tips 114a, 114b, are configured in a hover mode, and a second position (FIG. 1B), in which propulsion systems 112a, 112b, and wing tips 114a, 114b, are configured in a cruise mode. It will be recognized that wing tips 114a, 114b, are not necessary and that in alternative embodiments, wing tips are omitted.

[0020] In accordance with features of embodiments described herein, forward propulsion systems 108a, 108b, (and more specifically, pylons 120a, 120b) are tiltably connected to forward ends of fuselages 102a, 102b, such that they may be tilted between a first position (FIG. 1A), in which propulsion systems 108a, 108b, are configured in a hover mode, and a second position (FIG. 1B), in which propulsion systems 108a, 108b, are configured in a cruise mode.

[0021] In accordance with features of embodiments described herein, aft propulsion systems 110a, 110b, are fixedly attached to fuselages 102a, 102b, proximate aft ends thereof (forward of tail assembly 113) and do not convert between hover mode (FIG. 1A) and cruise mode (FIG. 1B).

[0022] The position of the rotor assemblies of the forward propulsion systems 108a, 108b, and wing-mounted propul-

sion systems **112a**, **112b**, as well as the pitch of individual rotor blades **124a**, **124b**, **134a**, **134b**, **144a**, **144b**, can be selectively controlled in order to selectively control direction, thrust, and lift of aircraft **100**. As previously noted, propulsion systems **108a**, **108b**, **112a**, **112b**, are each convertible, relative to fuselages **102a**, **102b**, between a vertical position, as shown in FIG. 1A, and a horizontal position, as shown in FIG. 1B. Propulsion systems **108a**, **108b**, **112a**, **112b**, are in the vertical position during vertical takeoff and landing mode. Vertical takeoff and landing mode may be considered to include hover operations of aircraft **100**. Propulsion systems **108a**, **108b**, **112a**, **112b**, are in the horizontal position during forward flight mode, in which aircraft **100** is in forward flight. In forward flight mode, propulsion systems **108a**, **108b**, **112a**, **112b**, direct their respective thrusts in the aft direction to propel aircraft **100** forward. Aircraft **100** is operable to fly in all directions during the vertical takeoff and landing mode configuration of FIG. 1A, although faster forward flight is achievable while in the forward flight mode configuration of FIG. 1B. Propulsion systems **108a**, **108b**, **112a**, **112b**, may be tiltable between the vertical and horizontal positions by actuators (not shown) that are tiltable in response to commands originating from a pilot and/or a flight control system. Each of the propulsion systems **108a**, **108b**, **110a**, **110b**, **112a**, **112b**, may utilize an electric motor and gearbox unit disposed within a respective pylon **120a**, **120b**, **130a**, **130b**, **140a**, **140b** or a direct drive motor of group of motors on the same shaft as a power source to rotate the respective rotor assembly about the rotor axis via the rotor shaft.

[0023] It should be noted that, although propulsion systems **108a**, **108b**, are shown and described as being tiltable between cruise and hover positions, those propulsion systems may be fixed in the hover positions, similarly to propulsion systems **110a**, **110b**. Additionally and/or alternatively, propulsion systems **112a**, **112b**, may be connected to opposite ends of the wing assembly **104** such that only pylons **130a**, **130b**, or a portion thereof, are tiltable relative to the wing assembly **104**. The tiltable pylons **120a**, **120b** and **130a** and **130b** may also be differentially tiltable and may vary in power to control yaw of the aircraft whereas different thrust for roll and pitch is controlled through differential blade pitch, rpm, and motor power.

[0024] In accordance with features of embodiments described herein, when aircraft **100** is in cruise mode, the rotor assemblies of aft propulsion systems **110a**, **110b**, may cease rotation. In embodiments in which forward propulsion systems **108a**, **108b**, are also fixed (i.e., do not convert between hover and cruise modes), rotor assemblies of propulsion systems **108a**, **108b**, may also cease rotation when aircraft **100** is in cruise mode. Fewer active rotor assemblies in cruise mode improves blade loading and propulsive efficiency of the props. In addition, stopping or slowing the aft rotors reduces drag. The lift is accomplished with the wings so lift from rotors **110a**, **110b**, is not necessary. With six rotor assemblies, a rotor assembly can be lost while still allowing aircraft **100** to hover even without motor redundancy per rotor assembly. In the event of a rotor failure, the rotor on the opposite side of the aircraft would be powered down, allowing the aircraft to hover as a quad copter with the four remaining rotors operating at elevated power levels. In accordance with features of embodiments described herein, if the aft left rotor were to fail, the forward right rotor would also be powered down, allowing the thrust on the

remaining rotors to balance. Electric power to the motors allows the distributed nature of the aircraft **100** to stay weight efficient without requiring extensive cross-connects.

[0025] Because the aircraft **100** includes six (6) rotor assemblies, the aircraft may be referred to as a “hexrotor aircraft.” FIG. 1C illustrates a hexrotor arc arrangement **150** when aircraft **100** is in hover mode. In particular, to allow the minimum number of rotors and still allow loss of a rotor as a recoverable failure mechanism in a hover, the rotors are arranged in an arc arrangement both side-to-side and forward-to-aft. As a result, when one rotor is lost and a second rotor is powered down, the aircraft can still be balanced as a quad arrangement on the remaining rotors. If a linear arrangement were used, the power and balance requirements would prevent recovery on just four rotors. Multi-copters with more than six rotors may recover by offsetting opposing rotors, but six in the illustrated arc arrangement is the minimum to allow a recovery after failure and result in significant weight savings due to fewer redundant motors and rotors.

[0026] FIGS. 2A and 2B illustrate an example tiltrotor aircraft **200** that is convertible between a VTOL or hover (also commonly referred to as helicopter) mode (shown in FIG. 2A), which allows for vertical takeoff and landing, hovering, and low speed directional movement, and a cruise (also commonly referred to as airplane) mode (shown in FIG. 2B), which allows for forward flight. Aircraft **200** includes two fuselages **202a**, **202b**, and a wing assembly **204** including a center wing section **205** extending between and interconnecting fuselages **202a**, **202b**, and outboard wing portions **206a**, **206b**, extending outboard of fuselages **202a**, **202b**. In accordance with features of embodiments described herein, aircraft **200** further includes two pairs of propulsion systems, including forward propulsion systems **208a**, **208b**, connected to the forward ends of the fuselages **202a**, **202b**, and aft propulsion systems **210a**, **210b**, connected proximate the aft ends of the fuselages **202a**, **202b**. As shown in FIGS. 2A and 2B, aircraft **200** further includes a tail assembly **213** connected to aft ends of fuselages **202a**, **202b**. Although as shown in FIGS. 2A and 2B, tail assembly **213** is illustrated as including a pair of boom-mounted stabilizers, other tail assembly configurations may be implemented without departing from the spirit or scope of embodiments described herein.

[0027] In the illustrated embodiment, each forward propulsion system **208a**, **208b**, includes a drive system housing comprising a pylon **220a**, **220b**, and a rotatable open rotor assembly comprising a plurality of rotor blades **224a**, **224b**, connected to a rotor shaft and configured to rotate about a rotor axis. As shown in FIGS. 2A and 2B, the rotor assemblies of forward propulsion systems **208a**, **208b**, include two (2) rotor blades; however, it should be recognized that more blades may be implemented without departing from the spirit and the scope of the embodiments described. Rotation of rotor blades **224a**, **224b**, generates lift while operating in helicopter mode and thrust while operating in airplane mode. Each pylon **220a**, **220b**, may house one or more electric motors therein configured to produce rotational energy that drives the rotation of the rotor assembly. Alternatively, each pylon **220a**, **220b**, may house a gearbox therein that drives the rotation of the rotor assembly, wherein the gearbox receives rotational energy from a driveshaft.

[0028] In the illustrated embodiment, each aft propulsion system **210a**, **210b**, includes a drive system housing com-

prising a pylon **240a**, **240b**, and a rotatable open rotor assembly comprising a plurality of rotor blades **244a**, **244b**, connected to a rotor shaft and configured to rotate about a rotor axis. As shown in FIGS. **2A** and **2B**, the rotor assemblies of propulsion systems **210a**, **210b**, include two (2) rotor blades; however, it should be recognized that more blades may be implemented without departing from the spirit and the scope of the embodiments described. It should also be recognized that rotor assemblies of propulsion systems **210a**, **210b**, may include a different number of rotor blades than rotor assemblies of propulsion systems **208a**, **208b**.

[0029] Rotation of rotor blades **244a**, **244b** generates lift while operating in helicopter mode. Each pylon **240a**, **240b**, may house one or more electric motors therein configured to produce rotational energy that drives the rotation of the rotor assembly. Alternatively, each pylon **240a**, **240b**, may house a gearbox therein that drives the rotation of the rotor assembly, wherein the gearbox receives rotational energy from a driveshaft.

[0030] In accordance with features of embodiments described herein, forward propulsion systems **208a**, **208b**, (and more specifically, pylons **220a**, **220b**) are tiltably connected to forward ends of fuselages **202a**, **202b**, such that they may be tilted between a first position (FIG. **2A**), in which propulsion systems **208a**, **208b**, are configured in a hover mode, and a second position (FIG. **2B**), in which propulsion systems **208a**, **208b**, are configured in a cruise mode. In accordance with features of embodiments described herein, aft propulsion systems **210a**, **210b**, are fixedly attached to fuselages **202a**, **202b**, proximate aft ends thereof (forward of tail assembly **213**) and do not convert between hover mode (FIG. **2A**) and cruise mode (FIG. **2B**).

[0031] The position of the rotor assemblies of the forward propulsion systems **208a**, **208b**, as well as the pitch of individual rotor blades **224a**, **224b**, **244a**, **244b**, can be selectively controlled in order to selectively control direction, thrust, and lift of aircraft **200**. As previously noted, propulsion systems **208a**, **208b**, are each convertible, relative to fuselages **202a**, **202b**, between a vertical position, as shown in FIG. **2A**, and a horizontal position, as shown in FIG. **2B**. Propulsion systems **208a**, **208b**, are in the vertical position during vertical takeoff and landing mode. Vertical takeoff and landing mode may be considered to include hover operations of aircraft **200**. Propulsion systems **208a**, **208b**, are in the horizontal position during forward flight mode, in which aircraft **200** is in forward flight. In forward flight mode, propulsion systems **208a**, **208b**, direct their respective thrusts in the aft direction to propel aircraft **200** forward. Aircraft **200** is operable to fly in all directions during the vertical takeoff and landing mode configuration of FIG. **2A**, although faster forward flight is achievable while in the forward flight mode configuration of FIG. **2B**. Propulsion systems **208a**, **208b**, may be tiltable between the vertical and horizontal positions by actuators (not shown) that are tiltable in response to commands originating from a pilot and/or a flight control system. Each of the propulsion systems **208a**, **208b**, **210a**, **210b**, may utilize an electric motor and gearbox unit disposed within a respective pylon **220a**, **220b**, **240a**, **240b** or a direct drive motor or group of motors on the same shaft as a power source to rotate the respective rotor assembly about the rotor axis via the rotor shaft.

[0032] The tiltable pylons **220a**, **220b**, may be differentially tiltable and may vary in power to control yaw of the aircraft whereas different thrust for roll and pitch is controlled through differential blade pitch, rpm, and motor power.

[0033] In accordance with features of embodiments described herein, when aircraft **200** is in cruise mode, the rotor assemblies of aft propulsion systems **210a**, **210b**, may cease rotation or rotate slower. Fewer active rotor assemblies in cruise mode improves blade loading and propulsive efficiency of the props. In addition, stopping or slowing the aft rotors reduces drag. The lift is accomplished with the wings so lift from rotors **210a**, **210b** is not necessary.

[0034] Because the aircraft **200** includes four (4) rotor assemblies, the aircraft may be referred to as a “quadrotor aircraft.”

[0035] FIGS. **3A-3B** illustrate an example tiltrotor aircraft **300** that is convertible between a VTOL or hover (also commonly referred to as helicopter) mode (shown in FIG. **3A**), which allows for vertical takeoff and landing, hovering, and low speed directional movement, and a cruise (also commonly referred to as airplane) mode (shown in FIG. **3B**), which allows for forward flight. The aircraft **300** is substantially identical to the aircraft **100** (FIGS. **1A-1B**) except that the aircraft **300** includes a cargo pod **302** connected to the underside of wing assembly between twin fuselages **304a**, **304b**.

[0036] FIGS. **4A-4B** illustrate an example tiltrotor aircraft **400** that is convertible between a VTOL or hover (also commonly referred to as helicopter) mode (shown in FIG. **4A**), which allows for vertical takeoff and landing, hovering, and low speed directional movement, and a cruise (also commonly referred to as airplane) mode (shown in FIG. **4B**), which allows for forward flight. The aircraft **400** is substantially identical to the aircraft **100** (FIGS. **1A-1B**) except that the aircraft **400** includes a weapons assembly **402** disposed between twin fuselages **404a**, **404b**. It will be recognized that other types of external cargo, such as sensors, may be supported between the fuselages as shown in FIGS. **3A**, **3B**, **4A**, and **4B**.

[0037] It should be appreciated that aircraft illustrated herein, such as aircraft **100**, is merely illustrative of a variety of aircraft that can implement the embodiments disclosed herein. Indeed, the various embodiments of the electric drive system line replaceable unit described herein may be used on any aircraft that utilizes motors. Other aircraft implementations can include hybrid aircraft, tiltrotor aircraft, quad tiltrotor aircraft, unmanned aircraft, gyrocopters, airplanes, helicopters, commuter aircraft, electric aircraft, hybrid-electric aircraft, and the like. As such, those skilled in the art will recognize that the embodiments described herein for an electric drive system line replaceable unit can be integrated into a variety of aircraft configurations. It should be appreciated that even though aircraft are particularly well-suited to implement the embodiments of the present disclosure, non-aircraft vehicles and devices can also implement the embodiments.

[0038] The components of rotor assemblies described herein may comprise any materials suitable for use with an aircraft rotor. For example, rotor blades and other components may comprise carbon fiber, fiberglass, or aluminum; and rotor shafts and other components may comprise steel, aluminum, or titanium.

[0039] Example 1 provides an aircraft comprising first and second fuselages; a wing assembly connecting the first and second fuselages, wherein the first and second fuselages are parallel to one another; first and second forward propulsion systems tiltably attached to forward ends of the first and second fuselages; and first and second aft propulsion systems fixedly attached proximate aft ends of the first and second fuselages.

[0040] Example 2 provides the aircraft of example 1, further comprising a tail assembly attached to the aft ends of the first and second fuselages.

[0041] Example 3 provides the aircraft of any of examples 1-2, further comprising first and second wing-mounted propulsion systems tiltably connected to outboard ends of the wing assembly.

[0042] Example 4 provides the aircraft of example 3, further comprising first and second wing tips fixedly connected to outboard sides of the first and second wing-mounted propulsion systems.

[0043] Example 5 provides the aircraft of example 4, wherein the first and second wing-mounted propulsion systems and the first and second wing tips are collectively tiltable between a first position when the aircraft is in a hover mode and a second position when the aircraft is in a cruise mode.

[0044] Example 6 provides the aircraft of any of examples 1-5, wherein each of the propulsion systems includes a rotor assembly comprising a plurality of rotor blades.

[0045] Example 7 provides the aircraft of example 6, wherein the rotor assemblies of the first and second aft propulsion systems rotate when the aircraft is in the hover mode and cease to rotate when the aircraft is in the cruise mode.

[0046] Example 8 provides the aircraft of any of examples 1-7, wherein the first and second forward propulsion systems are tiltably connected to the forward ends of the first and second fuselages such that the first and second forward propulsion systems are tiltable between a first position when the aircraft is in the hover mode and a second position when the aircraft is in the cruise mode.

[0047] Example 9 provides the aircraft of any of examples 1-8, wherein the propulsion systems collectively comprise a hexrotor arc when the aircraft is in the hover mode.

[0048] Example 10 provides the aircraft of any of examples 1-9, further comprising a cargo pod between the first and second fuselages.

[0049] Example 11 provides the aircraft of example 10, wherein the cargo pod is connected to an underside of the wing assembly.

[0050] Example 12 provides the aircraft of any of examples 1-11, further comprising external payload between the first and second fuselages.

[0051] Example 13 provides the aircraft of example 12, wherein the external payload is connected to an underside of the wing assembly.

[0052] Example 14 provides the aircraft of example 12, wherein the external payload comprises at least one of a weapons assembly and a sensor.

[0053] Example 15 provides an eVTOL selectively convertible between a hover mode and a cruise mode, the eVTOL comprising a first fuselage; a second fuselage parallel to the first fuselage; a wing assembly connecting the first and second fuselages; first and second forward propulsion systems attached to forward ends of the first and second

fuselages, the first and second forward propulsion systems comprising first and second pylons tiltably relative to the first and second fuselages between a first position when the aircraft is in a hover mode and a second position when the aircraft is in a cruise mode, wherein each of the pylons houses a drive system for providing rotational power to rotor assemblies of the forward propulsion systems; and first and second aft propulsion systems fixedly attached proximate aft ends of the first and second fuselages.

[0054] Example 16 provides the eVTOL of example 15, further comprising first and second wing-mounted propulsion systems tiltably connected to outboard ends of the wing assembly.

[0055] Example 17 provides the eVTOL of example 16, further comprising first and second wing tips fixedly connected to outboard sides of the first and second wing-mounted propulsion systems.

[0056] Example 18 provides the eVTOL of example 17, wherein the first and second wing-mounted propulsion systems and the first and second wing tips are collectively tiltable between a first position when the aircraft is in a hover mode and a second position when the aircraft is in a cruise mode.

[0057] Example 19 provides the eVTOL of any of examples 16-18, wherein each of the propulsion systems includes a rotor assembly comprising a plurality of rotor blades.

[0058] Example 20 provides the eVTOL of example 19, wherein the rotor assemblies of the first and second aft propulsion systems rotate when the aircraft is in the hover mode and cease to rotate when the aircraft is in the cruise mode.

[0059] At least one embodiment is disclosed, and variations, combinations, and/or modifications of the embodiment(s) and/or features of the embodiment(s) made by a person having ordinary skill in the art are within the scope of the disclosure. Alternative embodiments that result from combining, integrating, and/or omitting features of the embodiment(s) are also within the scope of the disclosure. Where numerical ranges or limitations are expressly stated, such express ranges or limitations should be understood to include iterative ranges or limitations of like magnitude falling within the expressly stated ranges or limitations (e.g., from about 1 to about 10 includes, 2, 3, 4, etc.; greater than 0.10 includes 0.11, 0.12, 0.13, etc.). For example, whenever a numerical range with a lower limit, RI, and an upper limit, Ru, is disclosed, any number falling within the range is specifically disclosed. In particular, the following numbers within the range are specifically disclosed: $R=RI+k*(Ru-RI)$, wherein k is a variable ranging from 1 percent to 100 percent with a 1 percent increment, i.e., k is 1 percent, 2 percent, 3 percent, 4 percent, 5 percent, . . . 50 percent, 51 percent, 52 percent, . . . 95 percent, 96 percent, 97 percent, 98 percent, 99 percent, or 100 percent. Moreover, any numerical range defined by two R numbers as defined in the above is also specifically disclosed. Use of the term "optionally" with respect to any element of a claim means that the element is required, or alternatively, the element is not required, both alternatives being within the scope of the claim. Use of broader terms such as comprises, includes, and having should be understood to provide support for narrower terms such as consisting of, consisting essentially of, and comprised substantially of. Accordingly, the scope of protection is not limited by the description set out above but is

defined by the claims that follow, that scope including all equivalents of the subject matter of the claims. Each and every claim is incorporated as further disclosure into the specification and the claims are embodiment(s) of the present invention. Also, the phrases “at least one of A, B, and C” and “A and/or B and/or C” should each be interpreted to include only A, only B, only C, or any combination of A, B, and C.

[0060] The diagrams in the FIGURES illustrate the architecture, functionality, and/or operation of possible implementations of various embodiments of the present disclosure. Although several embodiments have been illustrated and described in detail, numerous other changes, substitutions, variations, alterations, and/or modifications are possible without departing from the spirit and scope of the present disclosure, as defined by the appended claims. The particular embodiments described herein are illustrative only and may be modified and practiced in different but equivalent manners, as would be apparent to those of ordinary skill in the art having the benefit of the teachings herein. Those of ordinary skill in the art would appreciate that the present disclosure may be readily used as a basis for designing or modifying other embodiments for carrying out the same purposes and/or achieving the same advantages of the embodiments introduced herein. For example, certain embodiments may be implemented using more, less, and/or other components than those described herein. Moreover, in certain embodiments, some components may be implemented separately, consolidated into one or more integrated components, and/or omitted. Similarly, methods associated with certain embodiments may be implemented using more, less, and/or other steps than those described herein, and their steps may be performed in any suitable order.

[0061] Numerous other changes, substitutions, variations, alterations, and modifications may be ascertained to one of ordinary skill in the art and it is intended that the present disclosure encompass all such changes, substitutions, variations, alterations, and modifications as falling within the scope of the appended claims.

[0062] One or more advantages mentioned herein do not in any way suggest that any one of the embodiments described herein necessarily provides all the described advantages or that all the embodiments of the present disclosure necessarily provide any one of the described advantages. Note that in this specification, references to various features included in “one embodiment”, “example embodiment”, “an embodiment”, “another embodiment”, “certain embodiments”, “some embodiments”, “various embodiments”, “other embodiments”, “alternative embodiment”, and the like are intended to mean that any such features are included in one or more embodiments of the present disclosure but may or may not necessarily be combined in the same embodiments.

[0063] As used herein, unless expressly stated to the contrary, use of the phrase “at least one of”, “one or more of” and “and/or” are open ended expressions that are both conjunctive and disjunctive in operation for any combination of named elements, conditions, or activities. For example, each of the expressions “at least one of X, Y and Z”, “at least one of X, Y or Z”, “one or more of X, Y and Z”, “one or more of X, Y or Z” and “A, B and/or C” can mean any of the following: 1) X, but not Y and not Z; 2) Y, but not X and not Z; 3) Z, but not X and not Y; 4) X and Y, but not Z; 5) X and Z, but not Y; 6) Y and Z, but not X; or 7) X, Y,

and Z. Additionally, unless expressly stated to the contrary, the terms “first”, “second”, “third”, etc., are intended to distinguish the particular nouns (e.g., blade, rotor, element, device, condition, module, activity, operation, etc.) they modify. Unless expressly stated to the contrary, the use of these terms is not intended to indicate any type of order, rank, importance, temporal sequence, or hierarchy of the modified noun. For example, “first X” and “second X” are intended to designate two X elements that are not necessarily limited by any order, rank, importance, temporal sequence, or hierarchy of the two elements. As referred to herein, “at least one of”, “one or more of”, and the like can be represented using the “(s)” nomenclature (e.g., one or more element(s)).

[0064] In order to assist the United States Patent and Trademark Office (USPTO) and, additionally, any readers of any patent issued on this application in interpreting the claims appended hereto, Applicant wishes to note that the Applicant: (a) does not intend any of the appended claims to invoke paragraph (f) of 35 U.S.C. Section 112 as it exists on the date of the filing hereof unless the words “means for” or “step for” are specifically used in the particular claims; and (b) does not intend, by any statement in the specification, to limit this disclosure in any way that is not otherwise reflected in the appended claims.

1. An aircraft comprising:

first and second fuselages;

a wing assembly connecting the first and second fuselages, wherein the first and second fuselages are parallel to one another;

first and second forward propulsion systems tiltably attached to forward ends of the first and second fuselages such that the first and second propulsion systems are tiltable between a first orientation in which rotor blades of the first and second forward propulsion systems are disposed above the first and second fuselages and a second orientation in which the rotor blades of the first and second forward propulsion systems are disposed forward of forward ends of the first and second fuselages; and

first and second aft propulsion systems fixedly attached to the first and second fuselages proximate aft ends thereof such that rotor blades of the first and second aft propulsion systems are rotatable in a plane substantially parallel with longitudinal axes of the first and second fuselages, wherein the first and second aft propulsion systems comprise pylons attached directly to upper surfaces of the first and second fuselages.

2. The aircraft of claim 1, further comprising a tail assembly attached to the aft ends of the first and second fuselages.

3. The aircraft of claim 1, further comprising first and second wing-mounted propulsion systems tiltably connected to outboard ends of the wing assembly.

4. The aircraft of claim 3, further comprising first and second wing tips fixedly connected to outboard sides of the first and second wing-mounted propulsion systems.

5. The aircraft of claim 4, wherein the first and second wing-mounted propulsion systems and the first and second wing tips are collectively tiltable between a first position when the aircraft is in a hover mode and a second position when the aircraft is in a cruise mode.

6. The aircraft of claim 1, wherein each of the propulsion systems includes a rotor assembly comprising a plurality of rotor blades.

7. The aircraft of claim 6, wherein the rotor assemblies of the first and second aft propulsion systems rotate when the aircraft is in the hover mode and cease to rotate when the aircraft is in the cruise mode.

8. The aircraft of claim 1, wherein the first and second forward propulsion systems are tiltably connected to the forward ends of the first and second fuselages such that the first and second forward propulsion systems are tiltable between a first position when the aircraft is in the hover mode and a second position when the aircraft is in the cruise mode.

9. The aircraft of claim 1, wherein the propulsion systems collectively comprise a hexrotor arc when the aircraft is in the hover mode.

10. The aircraft of claim 1, further comprising a cargo pod between the first and second fuselages.

11. The aircraft of claim 10, wherein the cargo pod is connected to an underside of the wing assembly.

12. The aircraft of claim 1, further comprising an external payload between the first and second fuselages, wherein the external payload is modular.

13. The aircraft of claim 12, wherein the external payload is connected to an underside of the wing assembly.

14. The aircraft of claim 12, wherein the external payload comprises at least one of a weapons assembly and a sensor.

15. An electric vertical takeoff and landing aircraft (eVTOL) selectively convertible between a hover mode and a cruise mode, the eVTOL comprising:

a first fuselage;

a second fuselage parallel to the first fuselage;

a wing assembly connecting the first and second fuselages;

first and second forward propulsion systems attached to forward ends of the first and second fuselages, the first and second forward propulsion systems comprising first and second pylons tiltable relative to the first and

second fuselages between a first position when the aircraft is in a hover mode, in which rotor blades of the first and second forward propulsion systems are disposed above the first and second fuselages, and a second position when the aircraft is in a cruise mode, in which the rotor blades of the first and second forward propulsion systems are disposed forward of forward ends of the first and second fuselages, wherein each of the pylons houses a drive system for providing rotational power to rotor assemblies of the forward propulsion systems; and

first and second aft propulsion systems fixedly attached to the first and second fuselages proximate aft ends thereof such that rotor blades of the first and second aft propulsion systems are rotatable in a plane substantially parallel with longitudinal axes of the first and second fuselages, wherein the first and second aft propulsion systems comprise pylons attached directly to upper surfaces of the first and second fuselages

16. The eVTOL of claim 15, further comprising first and second wing-mounted propulsion systems tiltably connected to outboard ends of the wing assembly.

17. The eVTOL of claim 16, further comprising first and second wing tips fixedly connected to outboard sides of the first and second wing-mounted propulsion systems.

18. The eVTOL of claim 17, wherein the first and second wing-mounted propulsion systems and the first and second wing tips are collectively tiltable between a first position when the aircraft is in a hover mode and a second position when the aircraft is in a cruise mode.

19. The eVTOL of claim 15, wherein each of the propulsion systems includes a rotor assembly comprising a plurality of rotor blades.

20. The eVTOL of claim 19, wherein the rotor assemblies of the first and second aft propulsion systems rotate when the aircraft is in the hover mode and cease to rotate when the aircraft is in the cruise mode.

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(54) **AMPHIBIOUS AIRCRAFT**

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12.2-12.5; B64C 1/00, 35/00

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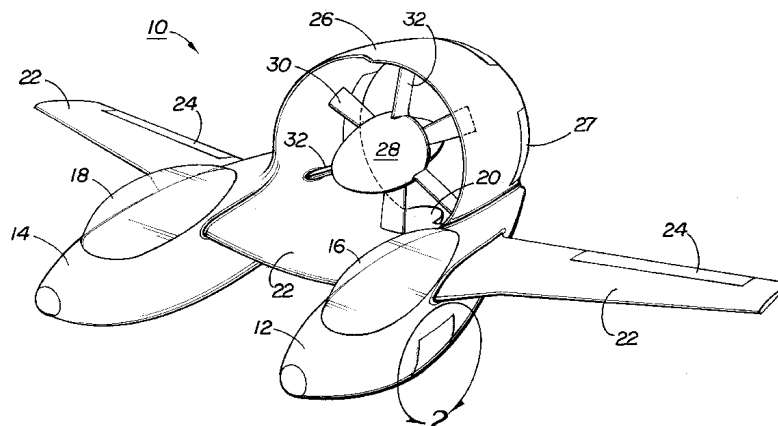
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ABSTRACT

General aviation class amphibious aircraft which include two fuselages, each having a hydrodynamic surface, the fuselages connected via a primary flight surface and a ducted power plant located aft and above the fuselages. The power plant location removes the fan/propeller arc from water and spray during water-borne taxiing, takeoff and landing. The combination of fuselages, lifting surface and ducting provides an aerodynamically efficient design with a lower center of gravity and protected powerplant for yielding improved performance including increased range and airspeed, together with favorable maneuverability, stability and control characteristics both aerodynamically and hydrodynamically.

18 Claims, 4 Drawing Sheets

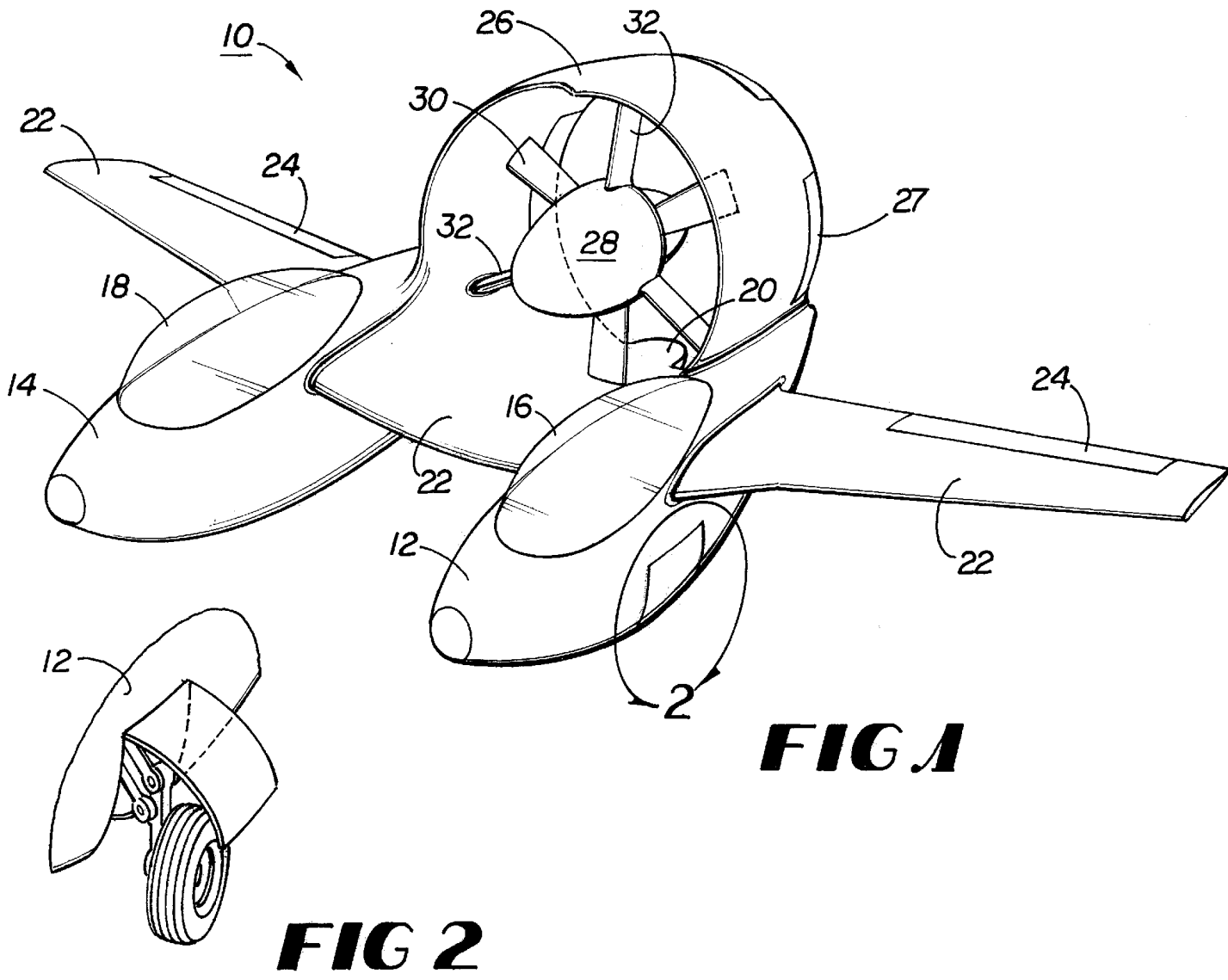


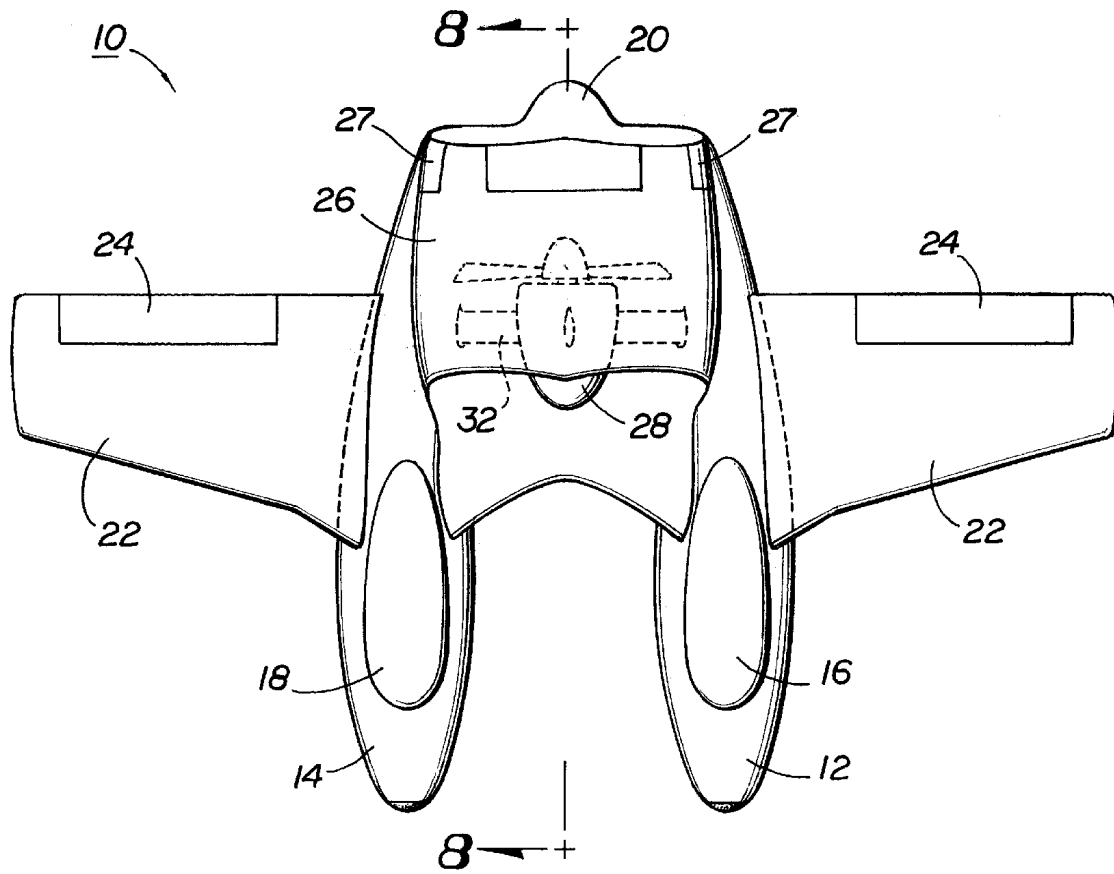
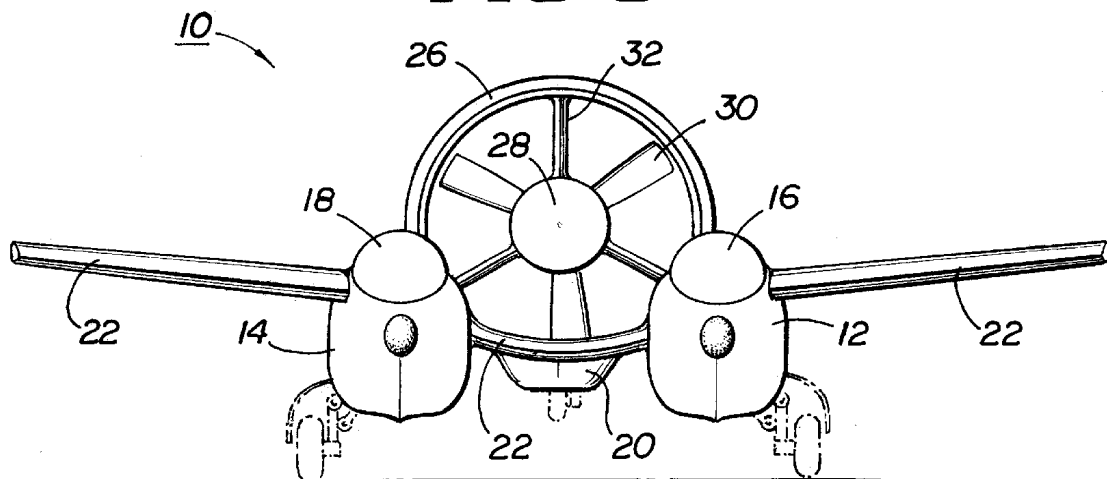
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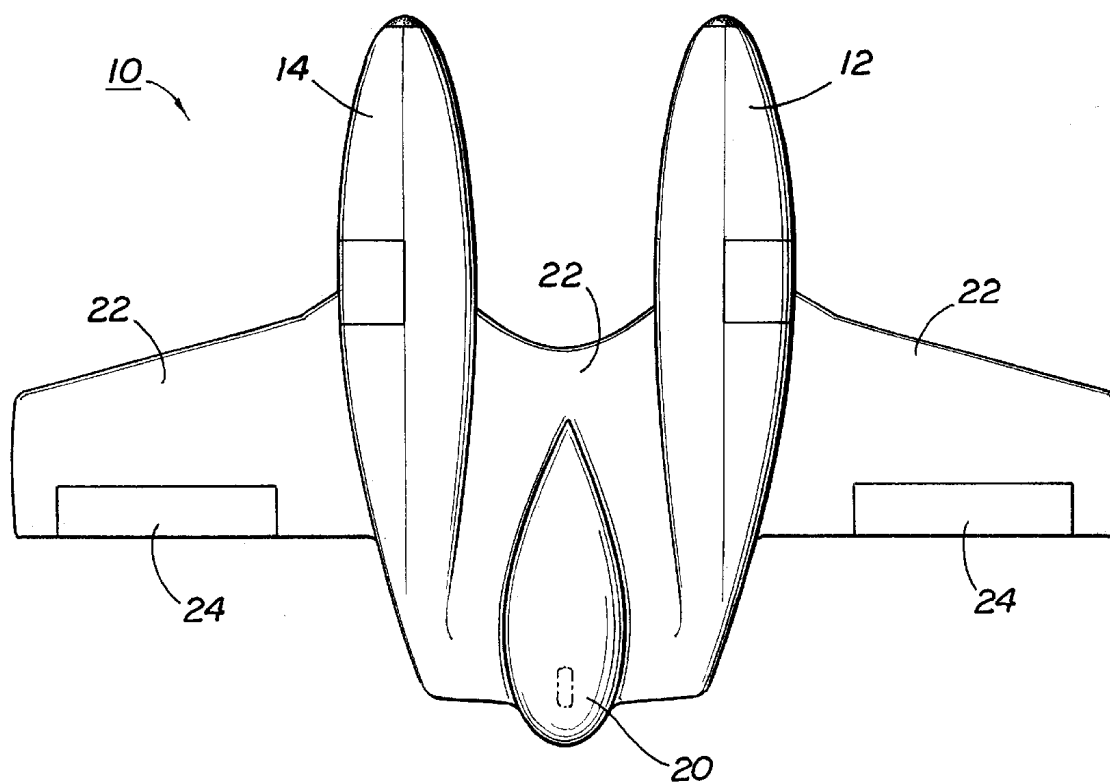
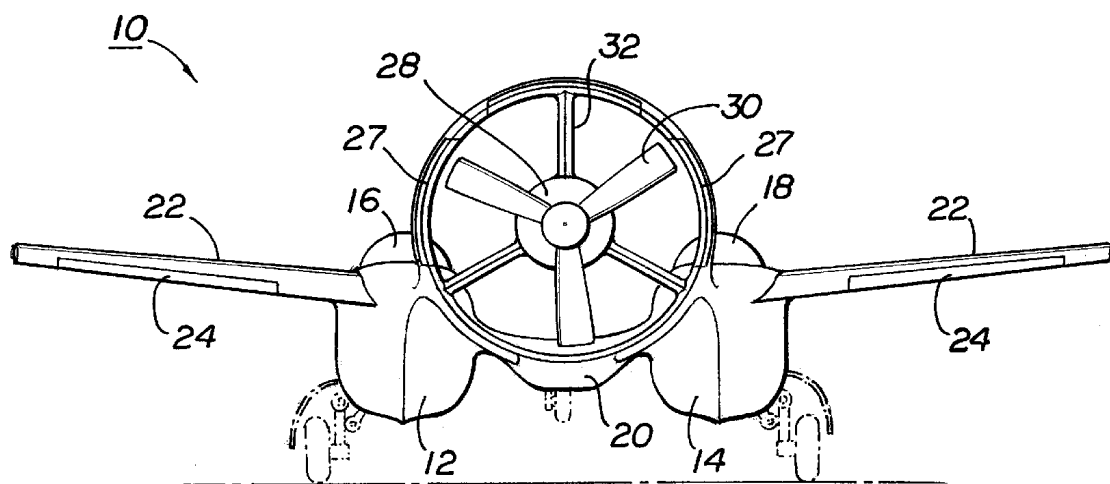
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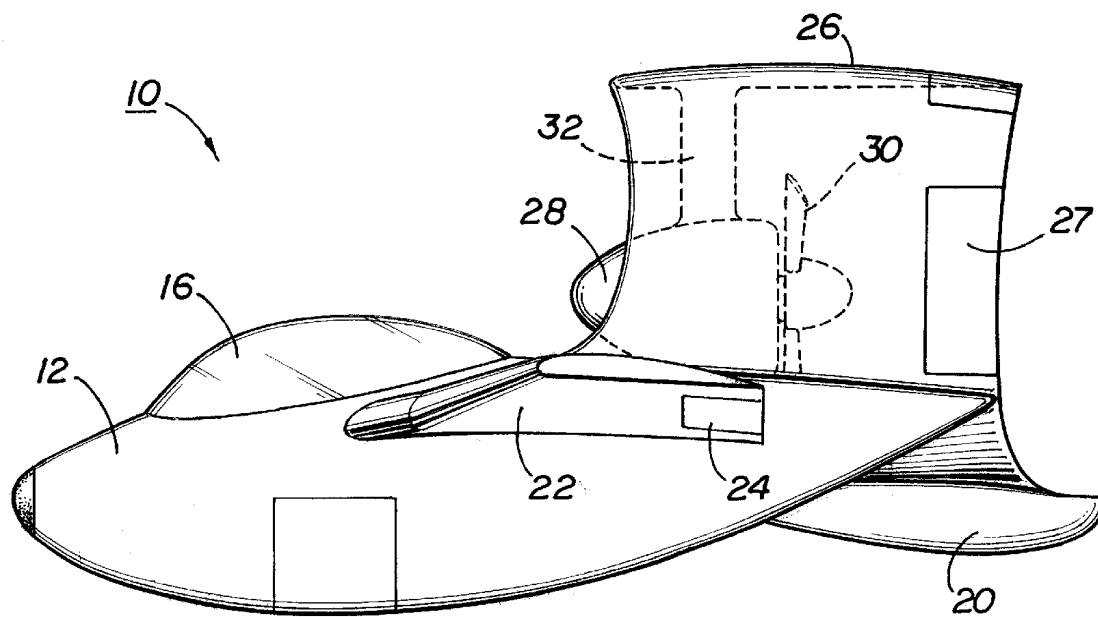
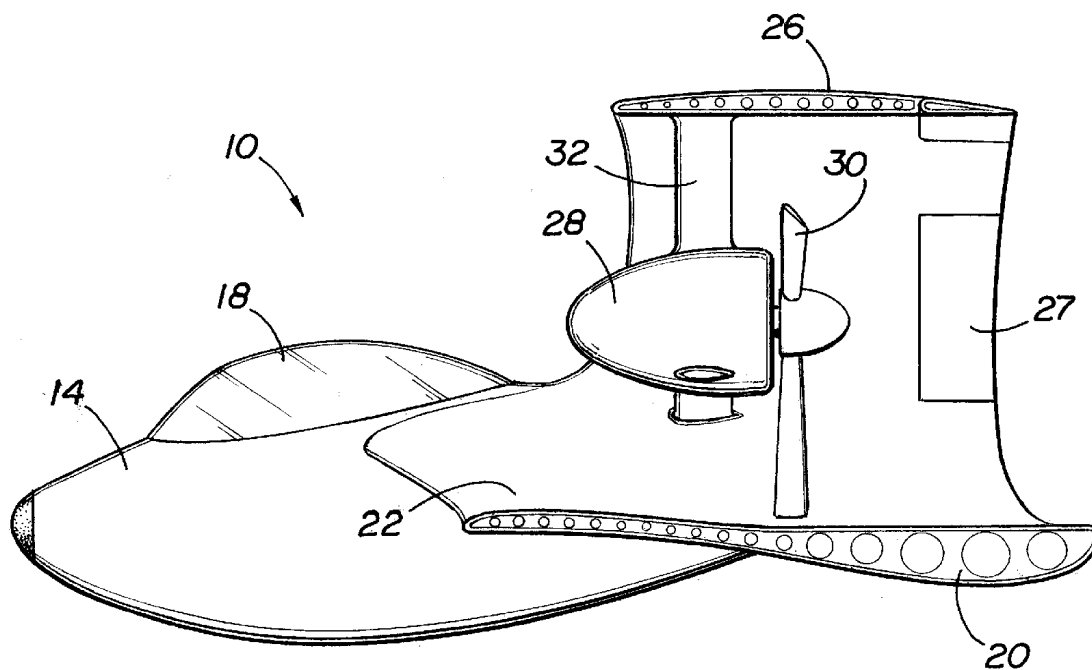
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**FIG 3****FIG 4**

**FIG 5****FIG 6**

**FIG 7****FIG 8**

1

AMPHIBIOUS AIRCRAFT

BRIEF DESCRIPTION

Aircraft which can take off and land on the water have populated the skies for many years, since the dawn of powered aviation. Such aircraft have been considered seaplanes if unable also to take off and land on the ground, and amphibious if able to take off and land both on the ground and water. For purposes of this document, seaplanes are included in and considered a subcategory of amphibious aircraft, as amphibious aircraft which do not feature or have not been fitted with the sort of landing gear which allows takeoff and landing on the ground.

Amphibious aircraft have typically been of two general types. The first general type includes single fuselage designs in which the fuselage serves as flotation and usually includes appropriate hydrodynamic contouring. A prime example is the PBY Catalina multiengine aircraft in wide use in the mid-20th century. The second general type also has a single fuselage, but the fuselage is supported on floats or pontoons. Examples include any number of conventional aircraft which have been fitted with floats.

The single fuselage/hull amphibious aircraft have generally taken the form of larger, high-winged, multi-engine designs in an effort to position engine intakes and propeller arcs above water and spray. Lake Aircraft models, however, feature a single fuselage/hull design with high wing and a powerplant mounted on a strut above the fuselage. Other float design general aviation class aircraft avoid the spray issue by dimensioning the float struts of sufficient length to raise the fuselage and propeller arc of the typically forward-mounted engine above water line, spray being less of an issue since the engine is forward of the floats.

A significant issue with conventional float designs is the considerable additional aerodynamic drag created by the floats. That drag not only reduces range and airspeed, but it also creates additional moments of inertia about all of the yaw, pitch, and roll axes of the aircraft, and can thus degrade maneuverability of the aircraft. For smaller aircraft, the inventor has found that the designs featuring powerplants mounted too great a distance above the fuselage introduce stability issues, particularly on the water as well as in situations requiring radical power changes, as well as maneuverability issues which may arise as a result of the thrust axis being located an excessive distance above the center of gravity.

Twin fuselage aircraft have also been designed and used for various purposes, including the P38 Lightning, the P51 Mustang twin fuselage version and the B26 bomber designs widely used in World War II. Those designs typically offer an additional site at the forward end of a fuselage for a power plant and/or armament, together with additional stability at least about the roll axis. Similar designs include the single cockpit/twin tailboom aircraft such as the P61 Black Widow and the C119 Flying Boxcar.

One aspect of certain embodiments according to the present invention is to provide general aviation class amphibious aircraft which avoid any or all of aerodynamic drag and concomitant issues presented by pontoons and floats as well as structural, control and maneuverability issues presented by fuselage supported high engine designs, and which leverage the advantages of a twin fuselage, twin hull design in which the power plant is located aft and positioned advantageously with respect to water and spray.

Another aspect of certain embodiments according to the present invention is to provide amphibious aircraft in the

2

general aviation class with any or all of increased range, speed and maneuverability, among other advantages, relative to conventional smaller float amphibious aircraft.

Another aspect of certain embodiments according to the present invention is to provide amphibious aircraft in the general aviation class which are eminently stable during take off, landing and taxiing phases on the water.

Other objects, features and advantages of the invention and embodiments thereof will become apparent with respect to the remainder of this document.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of a first embodiment of an amphibious aircraft according to the present invention.

FIG. 2 is a view of a portion of the embodiment of FIG. 1.

FIG. 3 is a top plan view of the embodiment of FIG. 1.

FIG. 4 is a front elevational view of the embodiment of FIG. 1.

FIG. 5 is a bottom plan view of the embodiment of FIG. 1.

FIG. 6 is a rear elevational view of the embodiment of FIG. 1.

FIG. 7 is a cross sectional view of the embodiment of FIG. 1.

FIG. 8 is another cross sectional view of the embodiment of FIG. 1.

DETAILED DESCRIPTION

FIGS. 1–8 all show a preferred embodiment of an amphibious aircraft according to a preferred embodiment of the present invention. This embodiment features a twin fuselage, twin hull design with aft mounted, ducted propeller power plant. The first and second fuselages, 12 and 14 respectively, can each contain any or all of pilot/co-pilot/passenger accommodations. Pilot and copilot flight controls may be located in any number of permutations. For example, the port cockpit 16 might contain primary flight controls for the pilot in command and the starboard cockpit controls for a co-pilot. This configuration could be reversed, no co-pilot controls need be included, or both of pilot and co-pilot controls could be placed in either of cockpits 16 or 18 with additional passenger space in either or both of those cockpits as desired.

Each fuselage 10, 12 is preferably faired and configured for appropriate hydrodynamic effects, both statically and dynamically during all phases of taxing, takeoff and landing. The fuselages may feature any desired shape, length, width and height to accomplish the result of appropriate aerodynamic and hydrodynamic performance for a general aviation class amphibious aircraft with favorable stability, airspeed, range, and maneuverability characteristics. An aft hydrodynamic stabilizer 20 may be included as shown in these figures. The stabilizer generally affects performance during taxing, takeoff and landing on the water. Retractable or non-retractable landing gear 21 may also be included.

Primary lifting surface 22 of this particular embodiment is a generally cantilevered, preferably positive dihedral design with a significant aerodynamically active portion located between the fuselages 12 and 14. The lifting surface 22 might be of any desired structural design, swept or unswept, any desired combination of camber, chord, airfoil, aspect ratio and any length and structural configuration. Short Takeoff/Landing or other variable lift/wing performance

structures may be chosen as appropriate and can include configurable surfaces such as slats and/or flaps in addition to flight control surfaces such as ailerons, flaps, combination flaps/ailerons, elevators, combination ailerons and elevators, trim tabs and other appropriate surfaces. Any and/or all of these surfaces may be manually controlled, computer controlled, or a combination of the two. In addition to primary lifting surface **22**, canards (not shown) can be employed. Additionally, surfaces on the fuselages and the ducting described hereafter can contribute to the lift produced by the aerodynamic structure of aircraft **10**.

Flight control surfaces in the forms of combination flaps/ailerons **24** are shown in FIGS. **1**, **3** and **5**.

The power plant in the particular embodiment shown in FIGS. **1-8** is a reciprocating propeller/fan design surrounded by duct **26**. Duct **26** may provide lift and may contain elevators and/or rudder flight control surfaces, together with other flight control surfaces as desired. The power plant **28** may be of any desired manufacture or design, including reciprocating or jet. The fan or propeller may be constant speed or variable speed, controllable pitch or otherwise. One particular form of ducted powerplant design which is appropriate is a fanjet or jet engine with high bypass ratio, which may be used with or without other ducting structure **26** of the sort shown in the drawings; in that the cowling around the fan serves as the duct.

Power plant **28** and prop/fan **30** may be supported within duct **26** by appropriate structure such as web **32** extending from both fuselages **12**, **14**, and assisting in support of duct **26**.

Fuel tanks may be located within fuselages **12**, **14**, lifting surface **22** or duct **26** or a combination, appropriate weight and balance, maneuverability and fuel flow issues taken into account.

Any or all components including structural components and surfaces of embodiments according to the present invention may be formed of conventional materials including metallic materials and/or composites, preferably with appropriate corrosion-resistant characteristics for operation in salt water aggressive environments.

The fuselages **12**, **14** may be positioned relative to each other at sufficient distance for optimum maneuverability and control, together with appropriate performance on the water and structural integrity. The fuselages **12**, **14** preferably act in combination with the lifting surface **22** and the ducting **26** to provide favorable aerodynamic performance with or without power applied, thus providing smooth transition into an engine out mode, and smooth performance as power is applied such as for takeoff.

The low center of gravity together with the positioning of the ducted prop/fan power plant, in combination with lifting surface **22** interposed between the fuselages **12**, **14** allows any or all of at least these advantages:

- (1) substantially removing the power plant **28** and the prop/fan **30** from water and spray;
- (2) improved hydrodynamic performance combined with aerodynamic performance relative to conventional float/pontoon designs;
- (3) favorable stability and maneuverability on the water, and stable control in landing and takeoff modes whether on the water or on the ground.
- (4) improved speed and range relative to comparably sized and power amphibious aircraft;
- (5) favorable comfort and visibility for operators and passengers, due in part to cockpits placed well forward of the power plant.

What is claimed:

1. A general aviation class amphibious aircraft adapted to take off and land on water, comprising:

- (a) a pair of fuselages joined by a cantilevered lifting surface, each fuselage containing a cockpit and hydrodynamic fairing;
- (b) a power plant mounted on a web supported by each of the fuselages, the power plant located adjacent to portions of the fuselages and connected to at least one of a propeller or fan;
- (c) a duct surrounding the power plant and connected to the fuselages for improving efficiency of the power-plant and providing lift.

2. An aircraft according to claim **1** in which the lifting surface includes elevators and aileron surfaces and the duct includes rudder surfaces.

3. An aircraft according to claim **1** in which one cockpit contains primary flight controls and the other cockpit contains secondary flight controls.

4. An aircraft according to claim **1** in which the lifting surface contains combination flap and aileron flight surfaces.

5. An aircraft according to claim **1** in which the duct contains elevator and rudder flight control surfaces.

6. An aircraft according to claim **1** in which the duct includes flight surfaces which perform a combination of elevator and rudder functions.

7. An aircraft according to claim **1** in which the power plant is reciprocating.

8. An aircraft according to claim **1** in which the power plant includes a turbojet.

9. An aircraft according to claim **1** in which all external surfaces are formed of composites.

10. A general aviation class aircraft adapted to land and take off on water, comprising:

- (a) a pair of fuselages joined by a cantilevered lifting surface, each fuselage containing a cockpit and hydrodynamic fairing, each fuselage adapted at least partially to float the aircraft on water in order to allow take off, taxiing and landing operations;
- (b) a power plant mounted on a web supported by each of the fuselages, the power plant located adjacent to portions of the fuselages and connected to at least one of a propeller or fan;
- (c) a duct surrounding the power plant and connected to the fuselages for improving efficiency of the power-plant and providing lift, wherein
- (d) the duct includes at least one flight control surface adapted to affect rotation of the aircraft about at least one of the yaw and the pitch axes.

11. An aircraft according to claim **10** in which the duct contains elevator and rudder flight control surfaces.

12. An aircraft according to claim **10** in which the duct includes flight control surfaces which perform a combination of elevator and rudder functions.

13. An aircraft according to claim **10** in which the lifting surface includes elevators and aileron surfaces and the duct includes rudder surfaces.

14. An aircraft according to claim **11** in which one cockpit contains primary flight-controls and the other cockpit contains secondary flight controls.

15. An aircraft according to claim **10** in which the lifting surface contains combination flap and, aileron flight surfaces.

16. An aircraft according to claim **10** in which the power plant is reciprocating.

17. An aircraft according to claim **10** in which the power plant includes a turbojet.

5

18. A general aviation class aircraft adapted to take off and land on water, comprising:

- (a) a pair of fuselages joined by a cantilevered lifting surface, each fuselage containing a cockpit and hydrodynamic fairing;
- (b) a power plant mounted on a web supported by each of the fuselages, the power plant located adjacent to portions of the fuselages and connected to at least one of a propeller or fan;

5

6

- (c) a generally tubular duct surrounding the power plant and structurally connecting the fuselages, for improving efficiency of the powerplant, adding structural integrity to the aircraft and providing lift, wherein
- (d) the duct includes at least one flight control surface adapted to affect rotation of the aircraft about each of the yaw and the pitch axes.

* * * * *

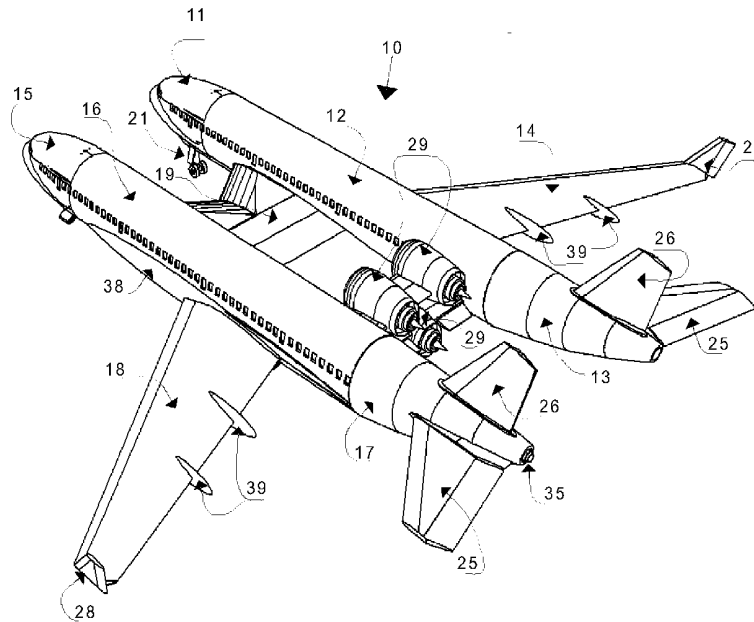


US 20140263831A1

(19) **United States**(12) **Patent Application Publication**
Mitchell, JR.(10) **Pub. No.: US 2014/0263831 A1**(43) **Pub. Date: Sep. 18, 2014**(54) **CROSS-WING TWIN-FUSELAGE AIRCRAFT**(71) Applicant: **Lawrence C. Mitchell, JR.**, Yarrow
Point, WA (US)(72) Inventor: **Lawrence C. Mitchell, JR.**, Yarrow
Point, WA (US)(21) Appl. No.: **13/800,975**(22) Filed: **Mar. 13, 2013****Publication Classification**(51) **Int. Cl.****B64C 39/04** (2006.01)**B64D 11/00** (2006.01)**B64D 27/12** (2006.01)(52) **U.S. Cl.**CPC **B64C 39/04** (2013.01); **B64D 27/12**
(2013.01); **B64D 11/00** (2013.01)USPC **244/1 N**(57) **ABSTRACT**

A dimensionally size-efficient aircraft being of a twin-fuse-lage configuration that addresses long-range high-capacity passenger commercial or military application needs, unique in that propelling engines (two, three, or four engine arrange-ments) are centrally mounted aft of a central cross-wing sec-tion, that section addressing the structural requirements of fuselage attachment with a means of passage between fuse-lages, the outer main wings being free from hanging append-ages, thereby enabling efficient aerodynamic-lift wing design, the configuration using a split stabilizer and a split vertical tail for stable aerodynamic control. Engine locations are biased high and aft with the central and outer wings providing ground noise abatement while in flight, passenger cabin noise low due to aft engine locations.

Efficiencies of operation derive from: 1) a low overall weight/ revenue seat ratio, 2) large and adaptable passenger floor plans, 3) compatibility with existing ground terminal facili-ties, 4) multiple engine configuration selections enabled by this aircraft layout, both turbo-fan and turbo-prop, and 5) opportunities of growth within this configuration. It is a low wave-drag configuration that better approaches the cross-sectional frontal-area shape ideal for minimum drag at near transonic speeds. This disclosure represents a general design concept and not a specific point design.

**TABLE #1**

Design Point	
Range: n.mi.	8,300
Seating capacity	470
Takeoff weight: (lbs)	818,000
Payload: (lbs)	97,000

Disclosure Aircraft	
Wingspan: (ft)	223
Length: (ft)	207
Height: (ft)	45
Thrust: (lbs)	192,000
Fuel Capacity: (lbs)	375,000
Max Payload: (lbs)	200,000
Max. Seating Capacity	640

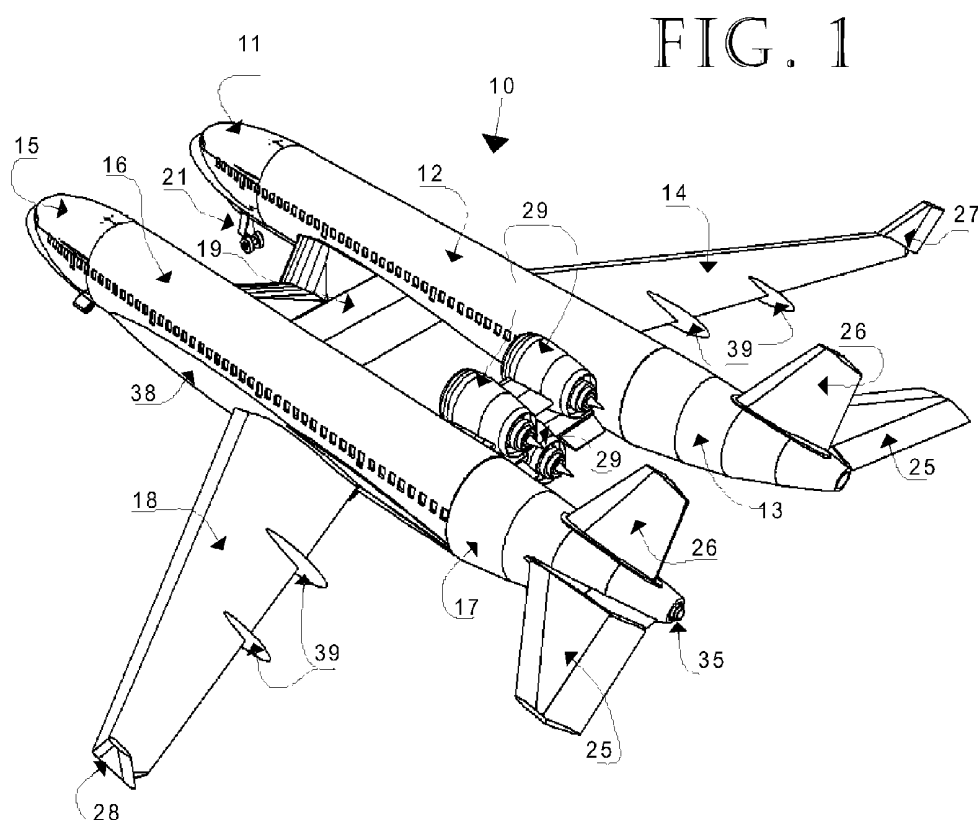


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FIG. 2

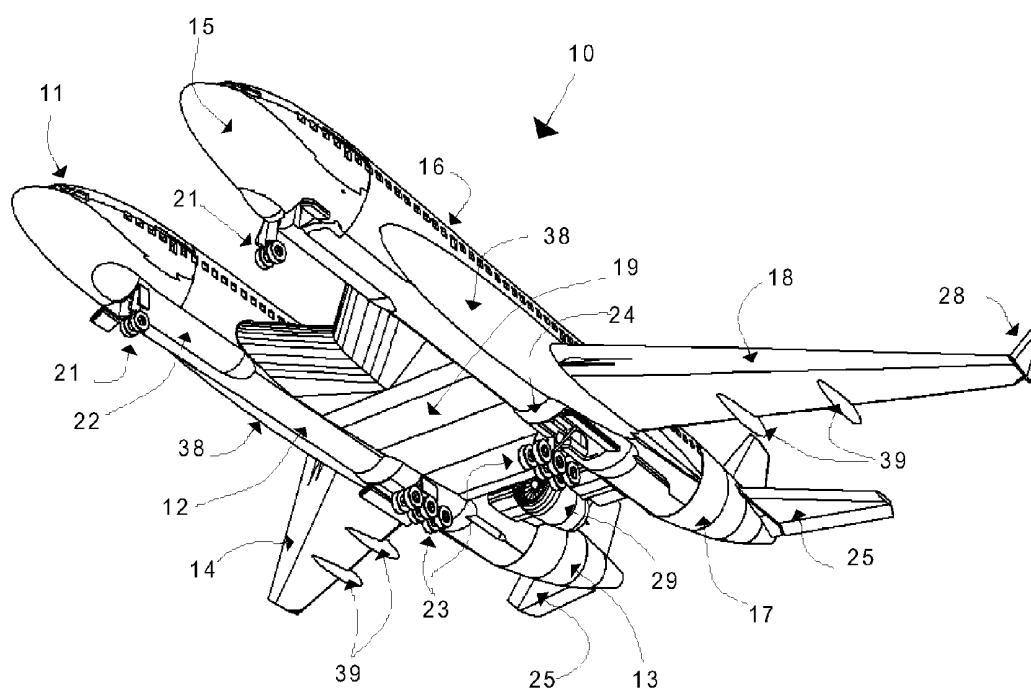
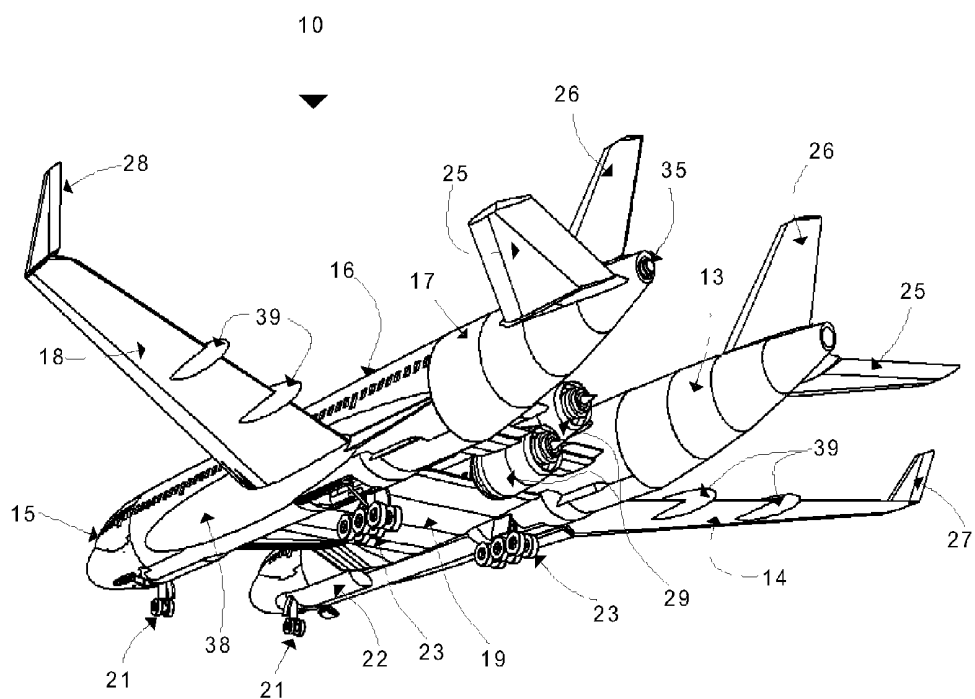


FIG. 3



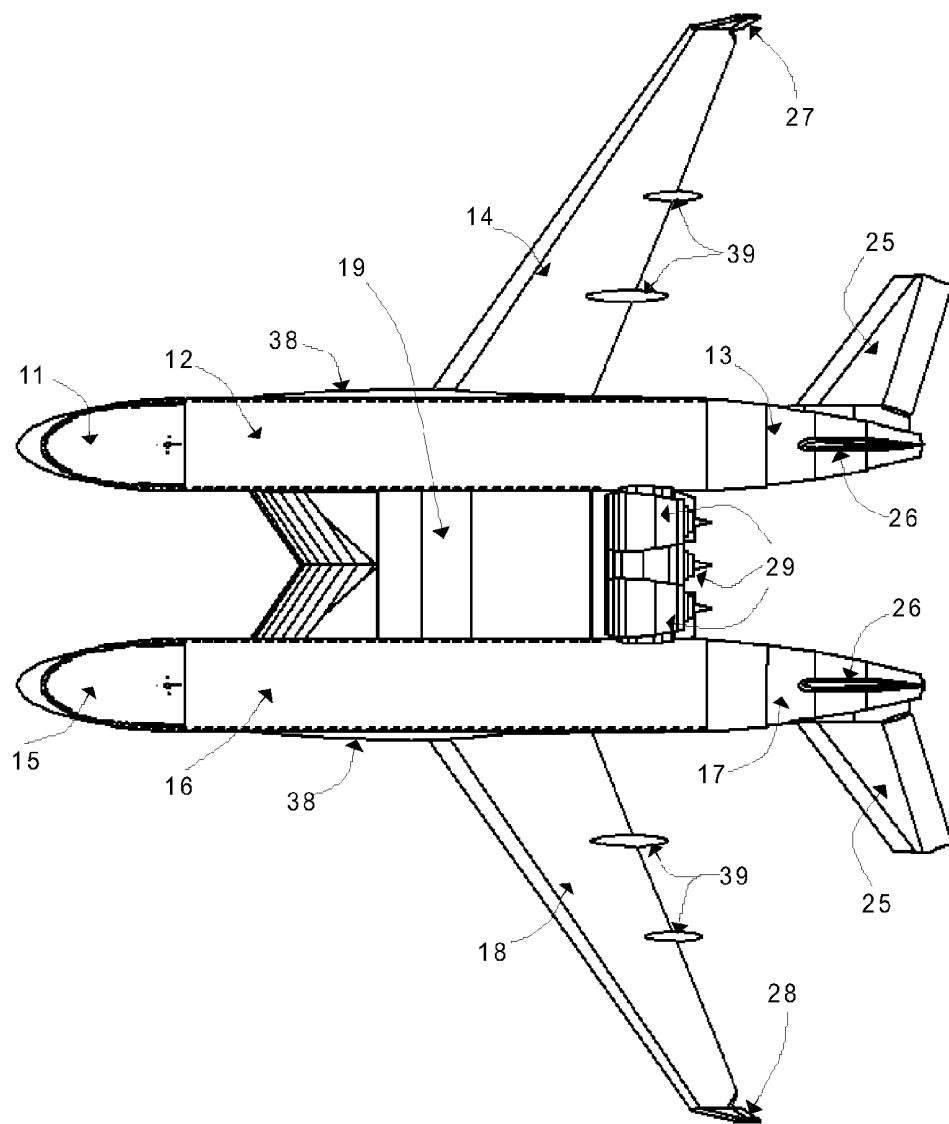


FIG. 5

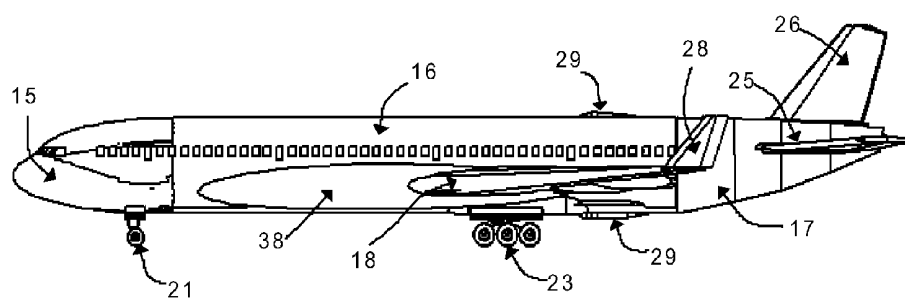


FIG. 6

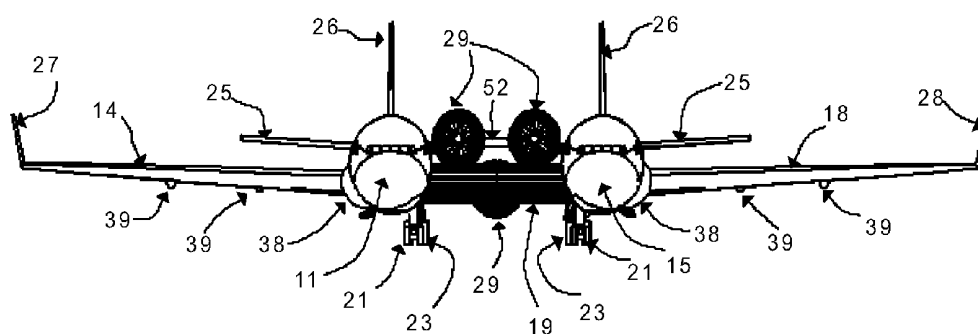


FIG. 7

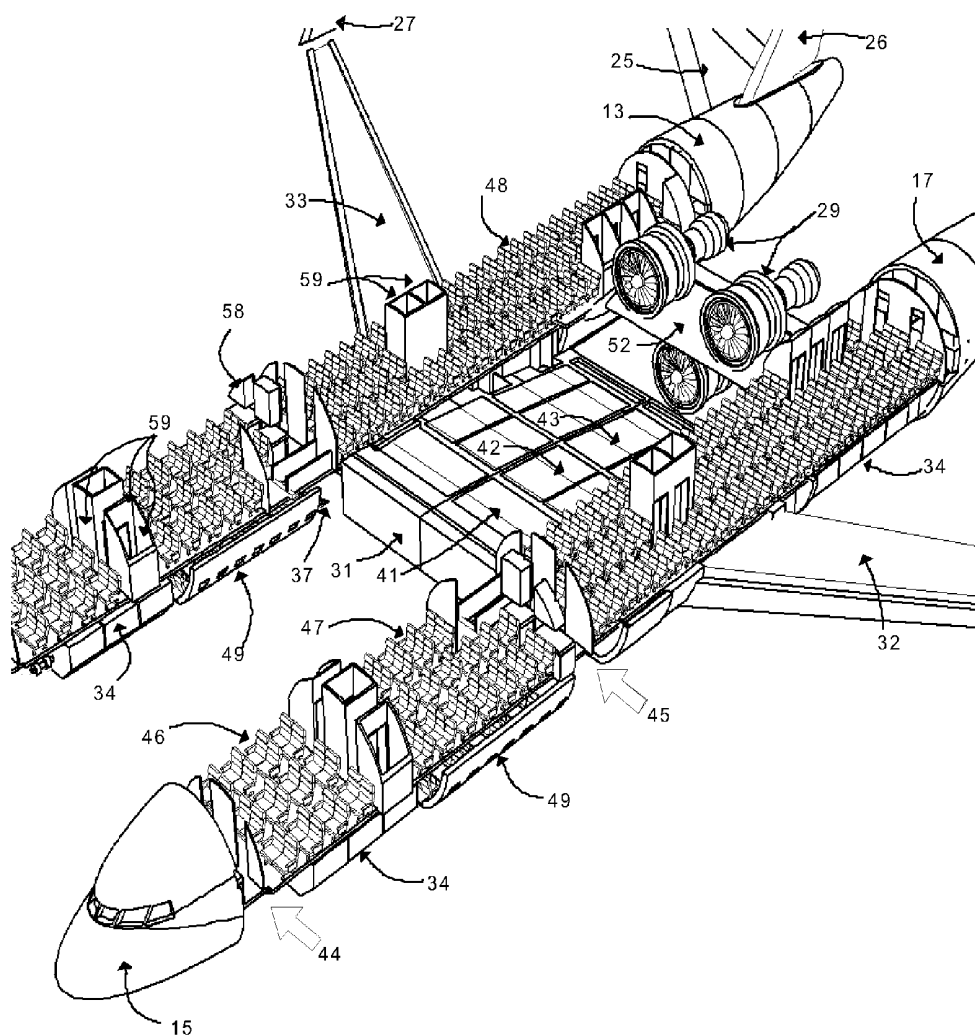


FIG. 8

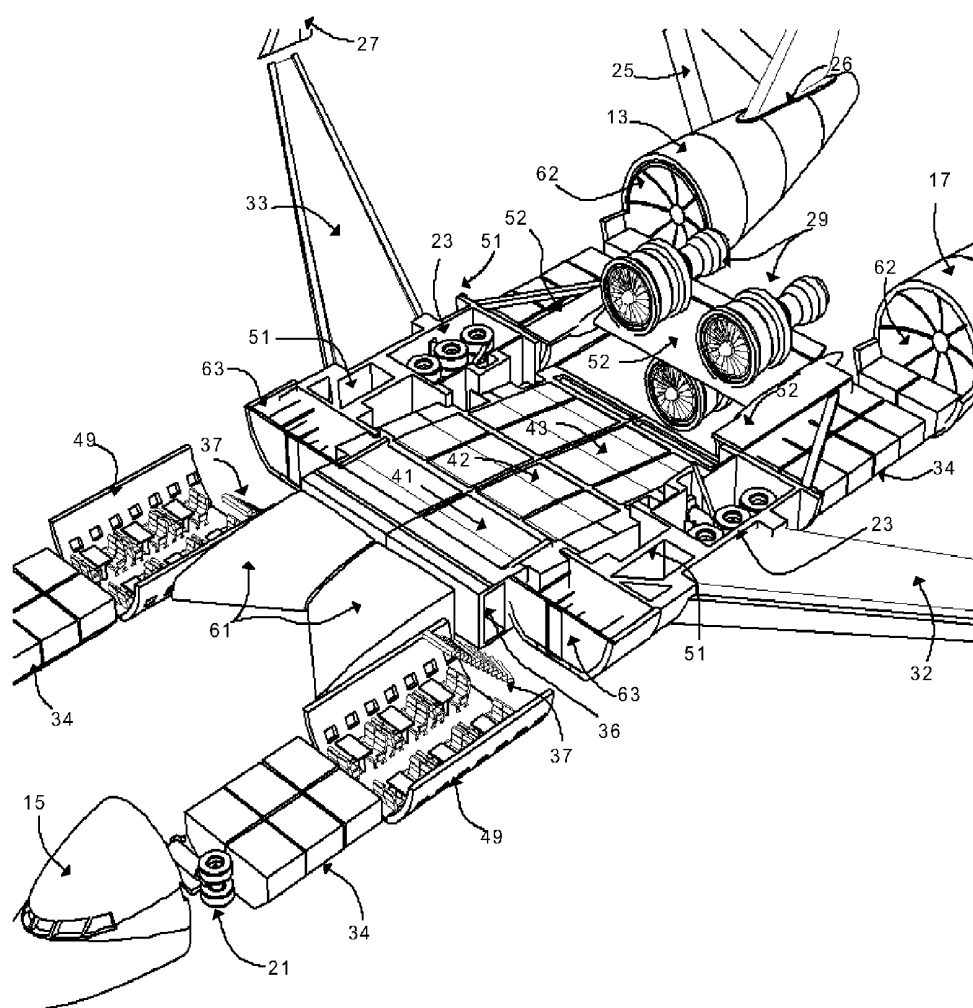


FIG. 9

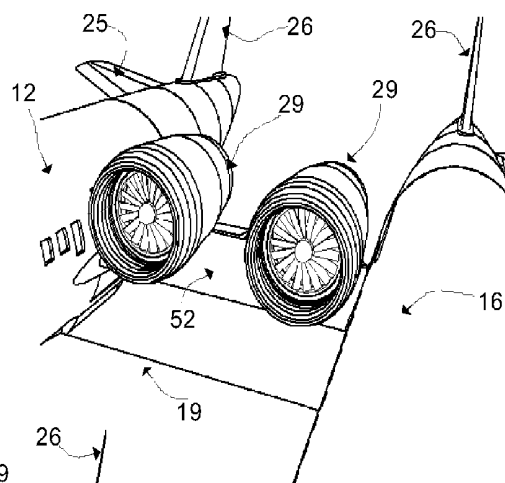


FIG. 10

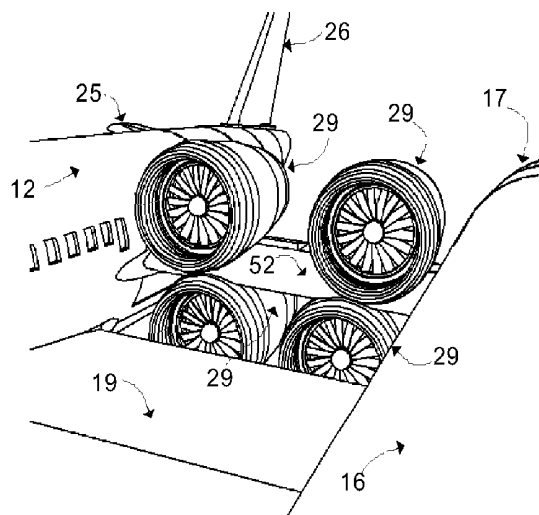
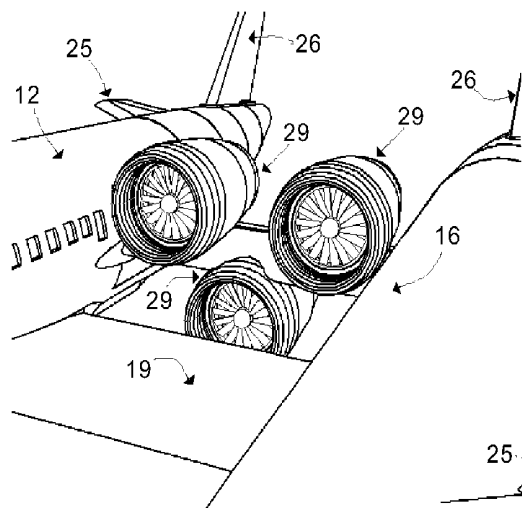


FIG. 11



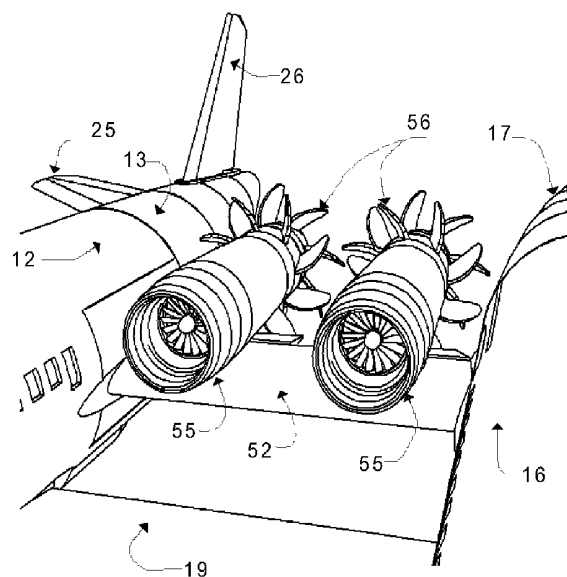


FIG. 12

FIG. 13

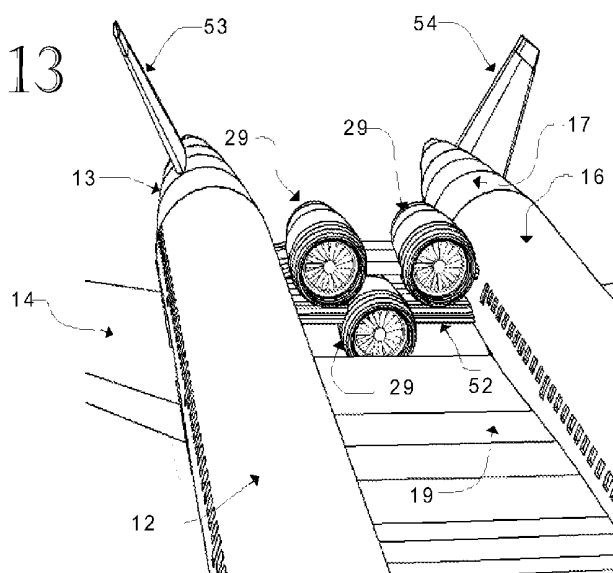


FIG. 14

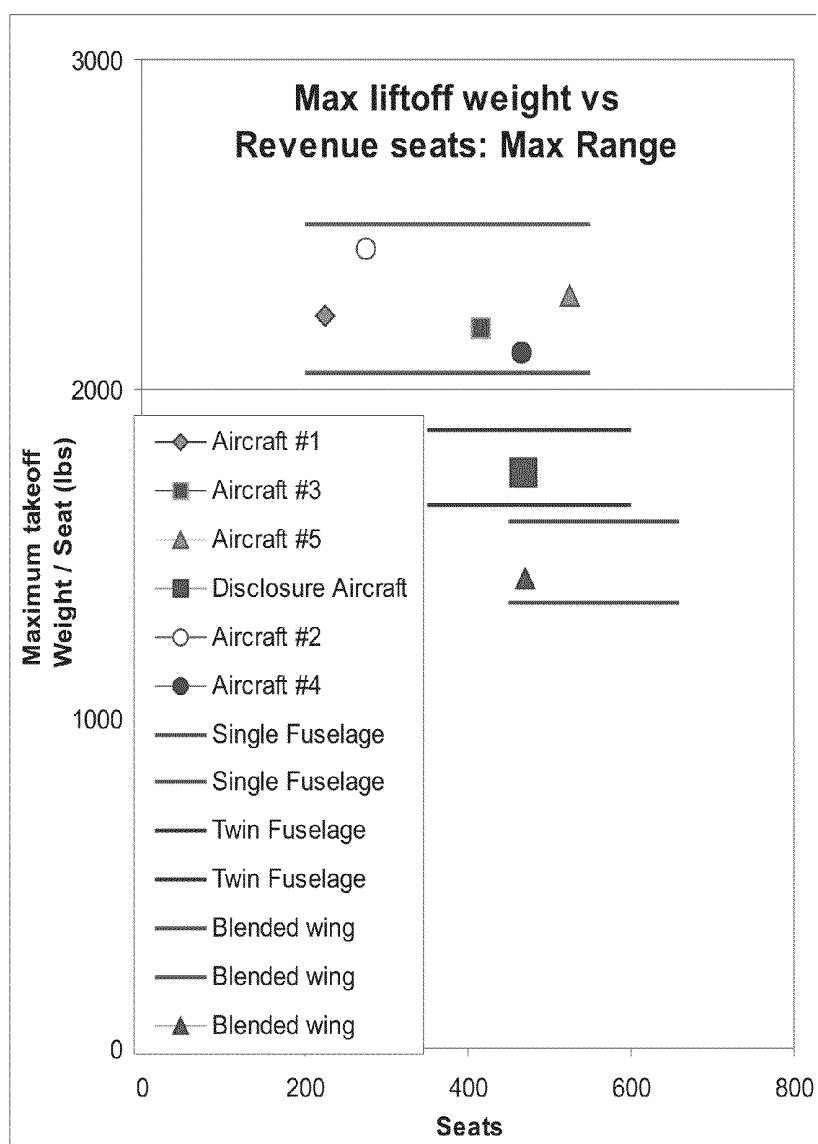


FIG. 15

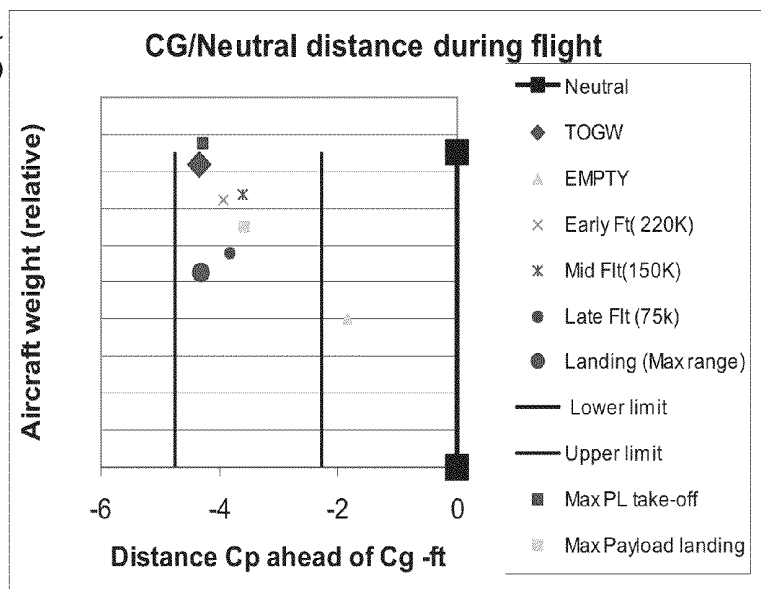


FIG. 16

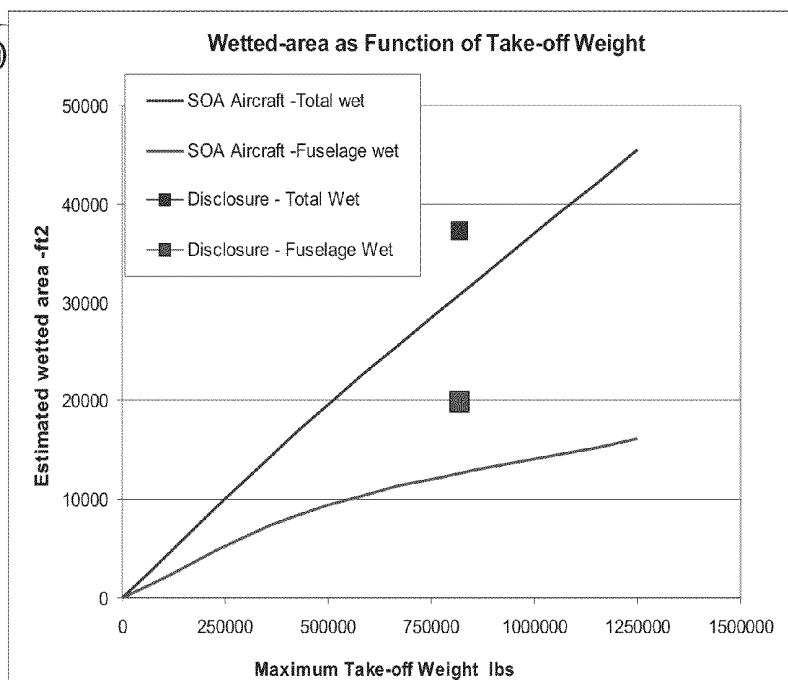


FIG. 17

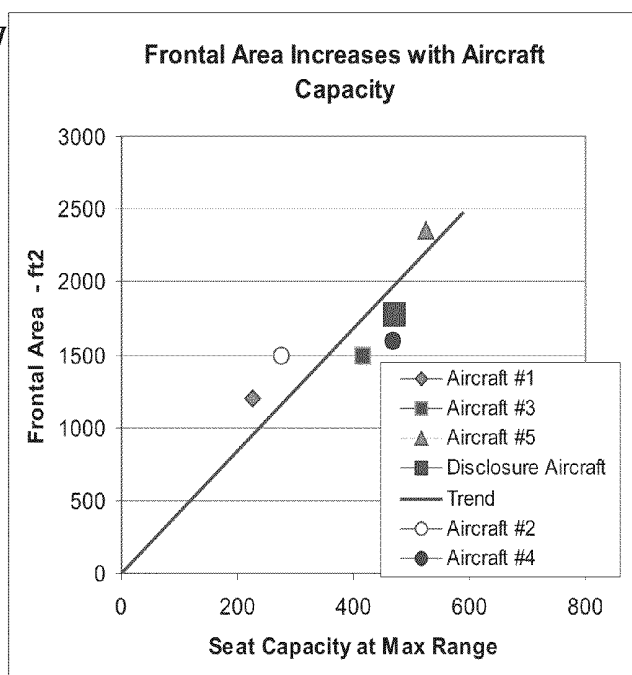


FIG. 18

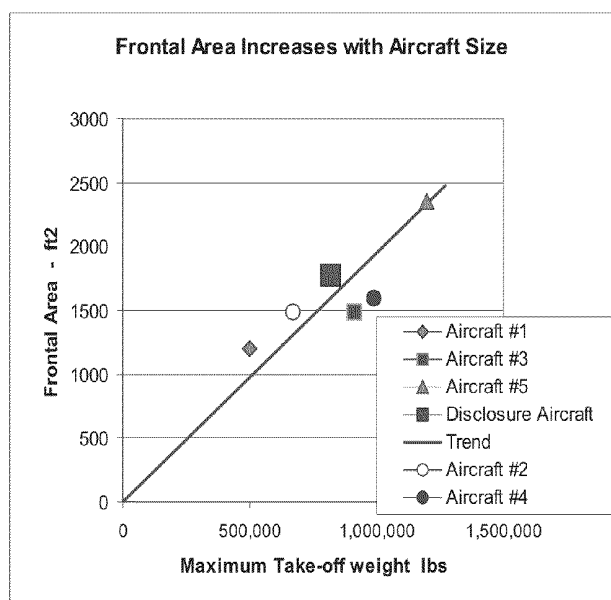


FIG. 19

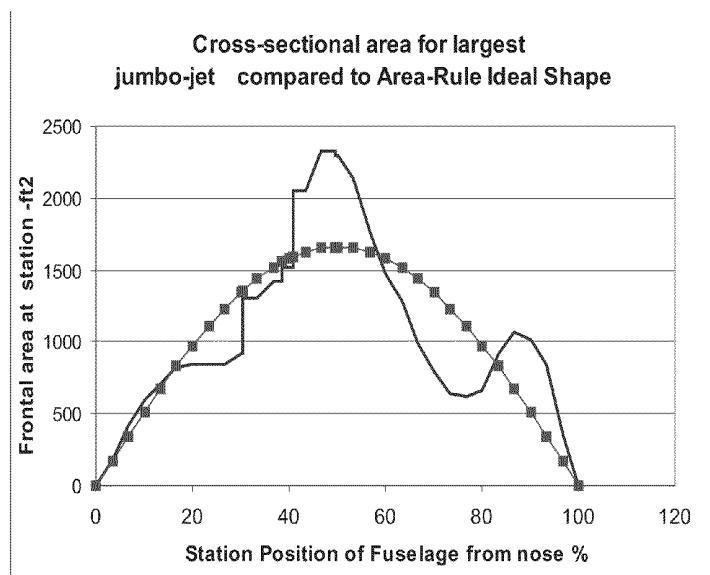


FIG. 20

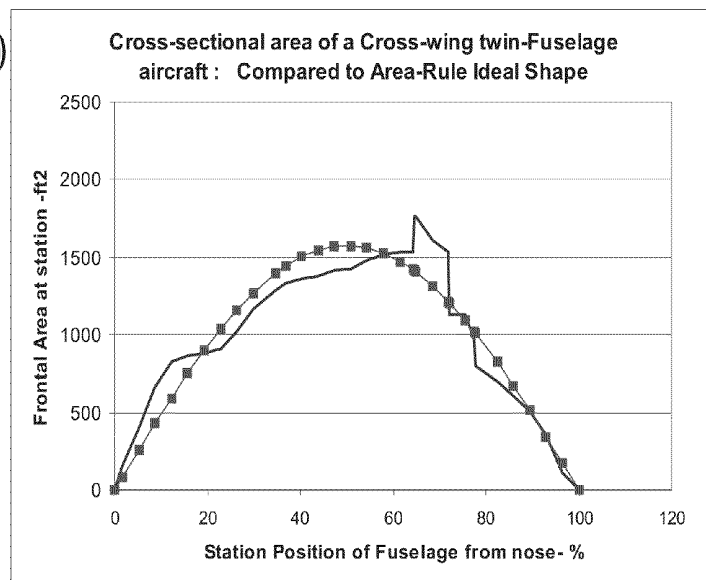
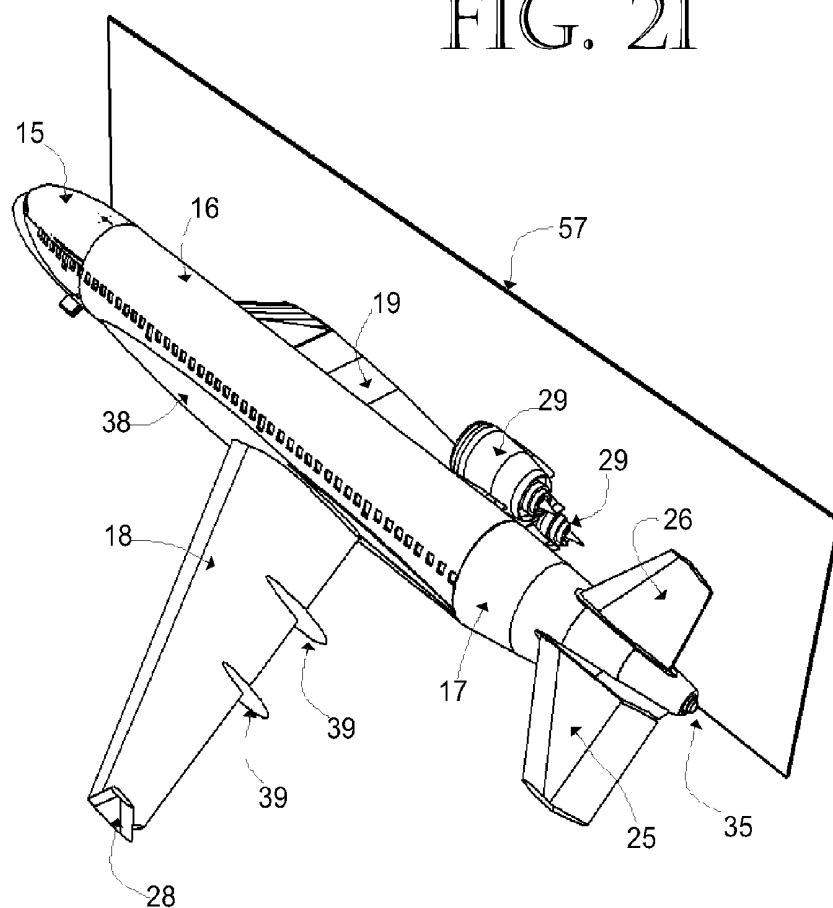


FIG. 21



CROSS-WING TWIN-FUSELAGE AIRCRAFT**CROSS-REFERENCE TO RELATED APPLICATIONS**

[0001] Do not Apply

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BACKGROUND OF THE INVENTION

[0003] Air traffic model forecasts suggest there is need for large capacity commercial aircraft to meet future air travel needs. Aircraft manufacturers already are in process of envisioning and designing new aircraft, and researching enabling technologies to meet anticipated demands. The largest of such aircraft now in service, are compromised in design by limits of ground facilities able to handle them. Such aircraft are also placing strain on the technologies of propulsion, structural design, and materials. Restrictions in place limit maximum wingspan and maximum weight for these aircraft. New blended-wing aircraft are now being researched for the eventual replacement of tube-wing aircraft design, but they present their own set of design issues, highest priority being how to solve safely cabin pressurization requirements and assure proper performance stability margins as a commercial aircraft. Blended-wing designs have efficiency advantages over traditional tube-wing designs of today, but are a further down-line solution, and may not be viable in time to meet nearer term needs.

[0004] This disclosure aircraft represents a transition design, based on proven technologies of today's aircraft, and offers a paradigm shift to a twin-fuselage tube-wing design concept, thereby retaining traditional pressurization solutions present tube/wing designs offer. This two fuselage design doubles the seating capacity of the newest non-jumbo jet, rivals jumbo-jet capacity, with considerably more efficient dimensions, lesser wingspan, and reduced length and height. Further, growth within a family of aircraft based on the twin-fuselage configuration of this disclosure may surpass mega-transport seat capabilities.

BRIEF SUMMARY OF THE INVENTION

[0005] The disclosure aircraft (10) describes an aircraft of significant physical size designed to carry hundreds of passengers at a maximum range greater than 8000 nautical miles. It is dimensionally smaller than today's jumbo-jet designs and therefore very amenable to all world airports able to

service these largest of commercial airliners. Unique to this design is the twin-fuselage tubular-wing configuration joined by a cross-wing structure that contributes lift and provides a passage means to allow movement from one fuselage to the other.

[0006] The fuselage is envisioned to be able to accommodate 9-abreast seating in a double row coach class. Each fuselage is typically able to seat 230 to 300 passengers in multiple-class arrangements.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

[0007] The aircraft of this disclosure (10) is described by 21 figures and one table and represent the configuration basis for the claims made. The disclosure aircraft (10) is estimated to be compatible with specification presented in Table #1; all other performance assumptions are based on this specification for the disclosure aircraft. The specifications of Table #1 are for the purpose only of giving further understanding as to the general size and weight of the disclosure aircraft, and these specifications do not represent a singular point design to which the claims presented herein only apply.

[0008] Below is a summary of the figure specifics.

[0009] FIG. 1 is an isometric view of a Cross-Wing Twin-Fuselage Aircraft (10), the name given to the disclosure aircraft, in take-off mode, the Isometric view looking from above.

[0010] FIG. 2 is an isometric view of the Cross-Wing Twin-Fuselage Aircraft (10) in take-off mode, the view looking from below.

[0011] FIG. 3 is the same aircraft (10) in an isometric view, the aircraft being in final approach as seen from below just as the aircraft has passed.

[0012] FIGS. 4, 5, and 6 show a top plan view, a side view, and a frontal view respectively for the Cross-Wing Twin-Fuselage Aircraft (10).

[0013] FIG. 7 shows typical main deck seating and service accommodations, 9-abreast seating for coach (48) and 6 to 8 abreast seating for other classes (first class (46) and business class (47)). The figure suggests a 3-class capacity of 538 passengers or more. Typical locations for lavatories (59) and galleys (58) are also shown.

[0014] FIG. 8 shows the fuselage under-belly allocations below the main deck and points out the main cross-wing structure (51), the structural tie for the engines (52), the location of fuel tanks (32,33,41,42,43), holds for cargo (34), forward (21) and main landing gear (23) stowage, buoyancy holds (61), crew rest areas (63), an on-board lounge (49), stairways to the lounges (37), the passage between the fuselages (36), and the aft fuselage bulkheads (62).

[0015] FIGS. 9, 10, and 11, show examples of turbo-fan jet engine installations (29) located just rear of the central cross-wing section as it connects the twin fuselages together.

[0016] FIG. 12 shows that the disclosure aircraft (10) is compatible with other propulsion techniques, that shown is with prop-prop engines (55) and contra-rotating propellers (56).

[0017] FIG. 13 shows a design variant using a v-tail (53-54) configuration.

[0018] FIG. 14 shows capabilities for three different aircraft design approaches, comparing today's aircraft (aircraft #1-#5), with the disclosure aircraft design, and blended wing expectation, design capability bands, plotted in terms of the

overarching efficiency factor (Maximum take-off weight including payload and fuel/revenue seat).

[0019] FIG. 15 shows the center-of-gravity movement referenced to the center-of-lift for several flight and payload conditions as function of the disclosure aircraft weight.

[0020] FIG. 16 shows state-of-the-art fuselage and total aircraft wetted areas, a factor affecting drag, and the point design wetted areas for the disclosure aircraft, plotted as a function of maximum take-off weight.

[0021] FIG. 17 shows typical commercial aircraft frontal area and how it increases with aircraft seating capacity, showing also the frontal area of this disclosure aircraft (10) to be within a reasonable design scatter band.

[0022] FIG. 18 shows the similar frontal areas but referenced to aircraft weight at liftoff.

[0023] FIG. 19 shows the cross-sectional area presented to the atmospheric ether of a typical jumbo-jet of current design, at nose-to-tail stations, compared to the smooth ideal suggested by the area-rule for least wave drag.

[0024] FIG. 20 shows the same information as FIG. 19, but for the cross-wing twin-fuselage aircraft of this disclosure (10).

[0025] FIG. 21 shows the disclosure aircraft (10) plane of symmetry (57) and that mature design can effectively take advantage of a lowered drag coefficient as is the case for catamaran design, by self-canceling a portion of the wave drag.

[0026] Each figure shows identification number callouts of the disclosure aircraft assembly or feature, and are here summarized for reference:

[0027] ID #: Cross-wing Twin-Fuselage aircraft of this disclosure (10); Right-Fuselage (nose-section with pilot deck) (11); Right-fuselage (main central section) (12); Right-fuselage (Rear-section) (13); Right-Main wing (14); Left-Fuselage (nose-section) (15); Left-fuselage (main central section) (16); Left-fuselage (Rear-section) (17); Left-Main wing (18); Central Cross-wing (19); Unassigned (20).

[0028] ID #: Forward-Landing-Gear dual-wheel [Steered] (2) (21); Forward-Landing-Gear Cowling bubble (one/fuselage) (22); Main-Landing-Gear triple bogey-wheel (2) (23); Main-Landing-Gear Cowling bubble (one/fuselage) (24); Split-Stabilizer (2) one/fuselage (25); Split-Vertical-tail (2) one/fuselage (26); Right vortex-control Winglet (27); Left vortex-control Winglet (28); Turbo-fan engine with Nacelle (3) (29); Unassigned (30).

[0029] ID #: Central Wing-box structure containing personnel passage (31); Right wing fuel tank (32); Left wing fuel tank (33); Cargo containers (14 per Fuselage) (34); APU (35); Personnel passage tunnel in cross-wing box (36); Stairways (37); Fuselage cowling for reduced drag [helps approach area rule] (38); Anti-shock pods (not to scale) and for cross-sectional smoothing and housing of flap mechanicals (39); Unassigned (40).

[0030] ID #: Forward cross-wing fuel tank (41); Middle cross-wing fuel tank (42); Aft cross-wing fuel tank (43); Forward main-deck access door (44); Middle main-deck access door (45); First-class seating section (46); Business-class seating section (47); Coach-class seating section (48); On-board lounge (49); Unassigned (50).

[0031] ID #: Wing-box structural reinforcement housing main-landing-gear, (51); Aft tie-structure for engine (52); Right-fuselage V-tail (53); Left-fuselage V-tail (54); Turbo-

prop engine (55); Contra-rotating propeller pair (56); and Longitudinal Plane-of-Symmetry (57); Galleys (58); Lavatories (59); Unassigned (60).

[0032] ID #: Buoyancy holds (61); Aft-fuselage pressurization bulkhead (62); Crew rest area (63).

DETAILED DESCRIPTION OF THE INVENTION

[0033] The aircraft (10) of this disclosure is presented with isometric views FIGS. 1-3, plan-views FIGS. 4-6, and cut-away detail views FIGS. 7-8.

[0034] Fuselage

[0035] The description of the fuselage concept is to show how very similar it is to the fuselage designs of the commercial airlines of today.

[0036] The fuselage of the disclosure aircraft (10) is just over 200 ft in length. The main deck provides seating accommodations for passengers and services FIG. 7. It is anticipated that passenger loading can be accommodated through two forward entrances (44,45) for each fuselage.

[0037] One of the twin fuselages, left or right, in the nose section (11 or 15) will contain the pilot cockpit cabin, equipped as other commercial aircraft, but with additional displays for scene visibility masked by the fuselage twin nose section, so viewing from the chosen cockpit need not be compromised. The other fuselage nose section is available to provide passenger amenities, as airlines would so choose.

[0038] The forward under-belly section FIG. 8 of each fuselage (12,16) provides for container/palletized cargo (34). Just in front of this cargo hold is stowage volume for the forward steering landing gear (21) and avionics. A cargo door opening to the cargo hold would be positioned just aft of the forward landing gear. Moving further aft in the fuselage belly are passenger lounges (49) stairs (39), passage tunnel entrance (36) for connection and passage between the twin fuselages, then crew rest areas (63)—servicing also as medical centers. The wing box (51) follows. Aft of the wing box (51) are the main landing gear (23) stowage volumes, the main landing gear (23) being a triplet-paired wheel bogey, simply hinged inward and down for landing. Behind the main landing gear is the engine tie structure (52) a reinforcement bridging structure for support of the fuselage-mounted engines (29), then additional cargo holds. As shown in the figures, each twin-fuselage is a near-mirror image of its twin. The fuselage is to be designed and manufactured in accordance with accepted practice of today.

[0039] There are no tricks for cabin pressurization. All but the tail section of each fuselage is pressurized forward of a rear bulkhead (62) at the aft end of the passenger cabin. Exceptions to this pressurized section description are the under-belly sections containing the landing gear. In the under-belly section surrounding the main landing gear (23), additional structure (52) supplements the generically designed fuselage sections (12,16) for landing gear support transitions, and for structure necessary to support the engines (29). Pressurization safety margins in these holds can and will be achieved without difficulty.

[0040] Behind the main fuselage rear bulkhead (62) are tapered fuselage transitions (13,17) supporting vertical tail (26) and stabilizer (25) interfaces. At the most aft station of one fuselage is location for an auxiliary power unit [APU] (35) as is presently accepted practice. The fuselage rear transitions (13,17) are biased high allowing for takeoff angles-of-attack and may include cowling to reduce drag, i.e. to improve area-rule cross-sectional smoothness.

[0041] Along the inner side of the under belly, localized bulging of the outer-skin is used to provide necessary envelope for housing stowed landing gear. Further, transitional flaring cowed volumes (38) are added at and before the outer-wing (14,18) root interface to smooth the increasing area presented to the atmospheric ether. It is not by design that the fuselage will act to provide any lifting force at a zero angle-of-attack. The fuselage will add lift for positive angles-of-attack.

[0042] Preliminary analyses of the complete aircraft indicate that localized flared cowling volumes (38) at the fuselage—outer wing aerodynamic transition act to minimize overall near-sonic drag, the localized bulging effecting a smoother transition of the increasing and decreasing station equivalent frontal areas, criteria's suggested by area cross-sectional rules for minimum drag. Typical fuselage bulging (38) are as shown and act also to provide cowling at the fuselage wing and central cross-wing interfaces, and aid in providing additional stowage volume for the main landing gear. The bulging (38) shown is typical of what may be beneficial, though to exactly define the optimum of outer-wing fuselage transition, wind tunnel data is necessary.

[0043] Aft Engine Mounting

[0044] The aft mounted engines (29) make the aircraft a pusher design, i.e. the thrust vector is behind and in this case above the aircraft center-of-gravity. The engine thrust vector develops a nose-down moment about this center-of-gravity, fully compensated by tail stabilizer design (25). The moment helps in overall aircraft stability allowing the center-of-lift [CL] to be near to the center-of-gravity [CG] without stability margin issues. The engine complement (29) mounts aft on the fuselage, thus eliminating outer-wing hanging appendages that effect overall wing lifting capability, thus providing a greater outer-wing lift coefficient due to elimination of usual wing-engine pylon and exhaust-flap issues. This means less drag, particularly in the critical take-off climb phase, less asymmetric yaw in event of engine-failure since engines are near to the aircraft centerline, and allows shorter landing gear, air-stair, and exit-slide lengths. The engines mount together on a single bridging structure (51), without need for pylons, this structure (51), attaches to each fuselage just under the main decks, meaning a close structural connection to fuselage reinforced structure required for the main landing gear and the central wing box connection. This arrangement means efficient weight design, opportunity for engine-noise isolation, and reduced cabin vibration than for pylon mounted fuselage engines commonly seen in today's in-service aircraft.

[0045] More benefits of this engine configuration for the disclosure aircraft (10), are listed below:

- 1) Engine thrust torque allows for full stability even if the lift center-of-pressure were to move slightly forward of aircraft center-of-gravity;
- 2) Throttle back-off will cause the nose to rise in the opposite direction afforded by wing flap extension, thereby achieving lower approach and landing speed;
- 3) For takeoff and landing, angle-of-attacks can be lower;
- 4) Engines work to reduce stall tendency;
- 5) Engine services concentrated within local engine area, not wing-to-wing for reduced weight.
- 6) Aft fuselage-engine-mounts are safer in event of a ditch scenario in that the engines (29) and outer wings (14,18) are not susceptible to tear-off.

[0046] Engine Nesting

[0047] Turbo-fan engine configurations (29) for the cross-wing twin-fuselage aircraft (10) are numerous. For each configuration, engines mounted high and aft of the central wing means engine noise radiates up and away from the ground while in flight (Under wing designs reflect noise off the wing bottom and toward the ground). Three concepts are shown in this disclosure, 2, 3 and 4 engine layouts.

1) A two-engine design FIG. 10, each engine mounted high on the single bridging structure (52), just aft of the cross-wing, engine thrust determined by the aircraft requirements.

2) A three-engine configuration FIG. 11, [shown in most of the figures], the third engine mounted on the under side of the single bridging structure (52), the third engine centrally located on that structure. Aerodynamic trim can also be incorporated on this connecting member.

3) A four-engine compliment FIG. 12, a fourth engine mounting along side the under-side mounted engine of the three-engine configuration, thereby sharing that same bridging lower-fuselage connecting structure (52).

[0048] In each of the engine arrangements, the collective engine thrust force applies a nose down moment about the aircraft center-of-gravity [CG] in an additive fashion, as does the center-of-gravity of the aircraft, relative to the wing lift center-of-pressure [CP]. This means that the correcting stabilizer moment may be larger than with aircraft designs that mount the engines below the wings. Further, ample stability margins in pitch control are achieved with lesser CG/CP separation due to the moment direction provided by the high thrust position. All engines can be angled slightly up or down as determined by wind tunnel test results.

[0049] Central Cross-Wing

[0050] The central cross-wing structure (19) is designed to provide structural connection, bridging between the twin fuselages (11-13,15-17). This wing structure (19) provides about 25% of the total lift, its airfoil not designed for a maximum lift, as are the outer-main lifting wings (14,18). Its position and lift contribution relative to the main outer-wings is tailored for the fuselage design-length chosen. Further, enhanced ground effects will be present due to the central cross-wing section contributing to lower take-off and landing speeds; this lift also tailored to assist takeoff and landing stabilities. This wing section (19) is not pressurized, as are the fuselages (11-12,15-16), except for a tubular passage connection (36) that allows personnel movement between the fuselages. Aerodynamic functionalities could include laminar over-surface flow control, lift abatement capability, but is not expected to include flap or other active aerodynamic control surfaces. Wing-to-fuselage cowling (38) will be designed to minimize drag.

[0051] This wing section (19) also provides fuel tank volume for about half of the loaded fuel, that tankage being in the mid-to-rear portions of this wing section airfoil. Depending on specification of the user, forward portions of this wing section can house buoyancy holds to enhance floatability of the aircraft.

[0052] It is expected that the placement of an airfoil just in front of the engine compliment will have beneficial effects, for example, negative pressures caused by the engine intakes just behind the wing may increase laminar flow over the airfoil adding lifting efficiency for this wing section, and/or may help lower in-going air temperature seen by the engines,

enhancing engine efficiencies at cruise. These are possibilities that the design suggests, but require test and detailed simulation to quantify.

[0053] Main Lifting Wings

[0054] Each of the main outer wings (14,18) is swept at about 35 degrees and carries the other half of the fuel load. The wing root is from the lower mid-section of the fuselage (12,16) and attaches to the main cross-wing box (51) connecting each wing (14,18) to each other. The mean chord of the main wings have a contour that provides a lift coefficient of >0.5 , and a stall angle-of-attack characteristic of >15 degrees when combined with the central cross-wing structure (19). Vortex winglets (27,28) enhance the wing area lift effectiveness and manage wing vortex generation.

[0055] The wing root (38) is shaped to minimize fuselage/wing drag interactions. Wing softness (compliance) is integral to the outer wing design and is expected to eliminate cabin flight roughness. Leading edge design is of traditionally accepted standards. Wing flaps are utilized for landing, while wing ailerons and trim surfaces work to provide roll stability and pitch force trim. Note the disclosure aircraft roll moment-of-inertia is greater than comparable tube-wing aircraft of today. Ailerons sizing will be larger, but the disclosure aircraft will not be as susceptible to forces effecting roll.

[0056] Each of the main lifting outer-wings (14,18) may include anti-shock pods (39) (two per wing shown; not-to-scale) to improve the flow over the upper outer-wing surface, facilitate a smoother area profile presented to the slip-stream, and act as cover for flap extension mechanicals.

[0057] Stabilizer

[0058] The rear stabilizer (25) is of a split design, one-half attached to each fuselage rear cone section (13,17). The stabilizer is an airfoil designed to produce a negative lift force. The design is to be such that at altitude and cruise speed, overall aircraft drag will be lowest and in-flight control stability and margins are maintained. The stabilizer provides pitch control for take-off and counters wing-flap effects during approach and landing. There is nothing new or revolutionary as to the way the stabilizer is designed, or the way the disclosure aircraft will handle, except that no state-of-the-art fuel tank volume would be incorporated into the stabilizer.

[0059] Vertical Tail

[0060] A vertical tail (26) rises above each of the aft twin fuselages (13,17) as shown by the figures. Aircraft yaw control is the vertical tail function, just as with other aircraft. Benefits of this configuration are that the forces needed of the vertical tail are lower than for conventional aircraft of size. Crosswinds and engine out situations usually size the vertical tail area requirement. This configuration reduces fuselage cross-section exposure to crosswinds due to protections the wind-facing fuselage offers the leeward fuselage. Engine-out yaw moments are of much less magnitude due to the central location of the engines. Each vertical tail is expected to be less in area than the usual single tube/wing aircraft tail size, meaning the combined vertical tail surface area will be about half.

Comparisons with State-Of-The-Art

[0061] Necessary to the viability of any proposed large aircraft is an assessment of design, state-of-the-art comparison, and analyses of factors affecting performance and range. It is shown that a twin-fuselage aircraft, like that of this disclosure (10) offers airlines and manufacturers a transition design option, even as they research ways to develop more efficient aircraft for the future. Measured in the promise of

lowered aircraft weight per passenger revenue seat, much of today's technology centers on solving problems that will make a blended-wing aircraft feasible. Blended-wing design offers promise for much lower operational costs as shown in FIG. 14. The weight at takeoff per revenue seat is an excellent direct measure of operational cost per seat, the blended wing representing a solution approaching half the operating costs of today's aircraft. Blended-wing technology, however, is a way into the future. Needs today for greater capacity are pushing design to second deck transition solutions to add seat capacity, ground-facilities limiting aircraft footprint size increases. State-of-the-art double deck solutions seem necessary, a lighter weight two-fuselage approach just not being in view. However, the two-fuselage design offers a compelling alternative, equivalent capacity, lower weight, and less airport footprint at lower cost. The twin-fuselage approach incorporates and builds on now-available material and state-of-the-art engineering technologies for fuselage and wing design, taking full advantage of lightweight composite materials. It would seem that a twin-fuselage aircraft is an overlooked alternative until now.

[0062] FIG. 14 shows this directly. The overarching efficiency factor (Maximum take-off weight/revenue seat) compares today's aircraft (aircraft #1-#5) with the disclosure aircraft (10), and a blended wing design band of expectation. It is easily seen the disclosure aircraft occupies a transition efficiency space between aircraft of today and tomorrow's aircraft. The disclosure aircraft (10) offers a transition "half-way step", a step that technology of today can support. FIG. 14 shows bands-of-design capabilities for the tube-wing aircraft designs of today, expected blended-wing aircraft design, and the gap band filled by the disclosure aircraft (10). As is seen, the disclosure aircraft (10) offers between 20% and 30% improvement in overall capability, based on the ratio parameter, take-off-weight/revenue seat. The comparison shown is for aircraft with a similar maximum range. None of this should be a surprise, except in the effectiveness of this transitional solution. It is in effect a paradigm shift that should and must be considered, for the needs of commercial aviation are here now, particularity needs for capacity increase at long range.

[0063] The cross-wing twin-fuselage is not a strange looking aircraft (10); rather it offers a pleasing profile, very much like an aircraft should look. It is not a radical departure from the aircraft of today. Two, three and four engine configurations are tradable options. Military transport configuration options abound. Development costs are expected to be reasonable for the potential gains offered by this configuration. Much of the design can be borrowed from today's aircraft. Fuselage cabin dimensions can be borrowed as well as engines and wing-compliant technologies.

[0064] This disclosure aircraft (10) should well be considered as evolutionary design, not revolutionary design, but its impact for increasing seat capacity within or lesser dimensions of today's jumbo jets is revolutionary, with much lowered seat costs/mile performance.

[0065] Here are a few more reasons why airlines and passengers should like this aircraft.

- 1) Passenger surroundings will feel familiar, not over crowded, and safe.
- 2) Usual percentage of window-isle seating retained.
- 3) Opportunity for creative use of "cockpit" space.
- 4) Seat capacity rivals the largest of jets with operating costs reduced by 20% to 25%.

- 5) Capable of nearly doubling seat revenue within today's accepted overall aircraft dimensions.
- 6) Serviceable from existing airport gates.
- 7) Passenger loading from up to four entrances.
- 8) Rear engine location makes for quiet cabins.
- 9) Will be noise-friendly near airports.

Other Factors

[0066] The viability of large aircraft in this niche is pretty much determined by overall weight as discussed in the State-of-the-art comparisons paragraph above. Other factors of design related to the cross-wing twin-fuselage disclosure aircraft uniqueness are addressed below. Data results shown are from preliminary design assessments and comparative analyses of the disclosure aircraft with today's state-of-the-art commercial jumbo-jets, and was used to validate overall flight stability, drag estimates, and the expected benefit of the disclosure aircraft.

[0067] Control and Stability Characteristics

[0068] Stability safety margins for the disclosure aircraft are comparable with those of today's commercial aircraft. An analysis of center-of-gravity positions over a flight profile from takeoff through landing has been estimated to validate that controllability and stability are safely achieved. Results of the disclosure aircraft center-of-gravity movements are shown in FIG. 15, at varying flight conditions as a function of aircraft weight. For all cases examined, maximum takeoff gross weight (TOGW), three mid-flight weights, and for two landing weights, (maximum payload, and maximum range payload), the center-of-gravity always remains ahead of the lift center-of-pressure, within bounded limits equivalent to less 10% of the outer-wing average wing cord-length, well within accepted practice for controllability, stability, and safety, the analyses based on fuel tank loading and depletion management schedules.

[0069] The center-of-lift can and will also be controllable, within limits, in manners used by today's aircraft, including, but not limited to leading edge and flap extensions, spoilers, boundary-layer laminar-flow enhancement techniques, and angle-of-attack changes. Suffice to say, the aircraft of this disclosure will not be a difficult aircraft to fly.

[0070] Drag Factors and Characteristics.

[0071] Drag issues are discussed and compared with the current state-of-the-art aircraft. Parasitic drag factors are discussed in terms of the wetted, frontal area, and wave-drag.

[0072] Wetted Area

[0073] A two-fuselage solution at first seems to be an unnatural design. After all, two fuselages will lead to a greater fuselage wetted-surface area parasitic drag for an equivalent cross-sectional area single fuselage. The same logic applies for frontal area comparisons. So how can the disclosure aircraft compete with the single large equivalent cross-section fuselage approach? The answer is in the numbers, the design, and that induced drag is of near equal importance to parasitic drag magnitudes.

[0074] 1) For equivalent seat capacity, the twin fuselage aircraft will always be substantially lighter in total weight than a single fuselage aircraft. (See FIG. 14). This means that the induced drag-component will also always be less.

[0075] 2) Frontal fuselage cross-sectional areas of single and twin fuselage aircraft need not be the same for equivalent payload floor areas and/or seating capacities.

[0076] 3) Wetted areas for an aircraft are more than just the fuselages. Wetted area must include the whole of the aircraft,

wings and all. A larger parasitic drag-component does not disqualify an aircraft design in terms of overall efficiency.

[0077] FIG. 16 shows wetted area comparisons of aircraft in service today and the wetted areas for the disclosure aircraft, fuselage only and total. Fuselage wetted areas as shown are relatively large for the twin fuselage design, but the figure also shows wetted areas for the complete aircraft, inclusive of wings, stabilizer and vertical tail, wing-fuselage transitions, engine pylons, and nacelles; the total aircraft wetted area differences not being pronounced as they are when comparing fuselage-wetted areas only. In the end, what is first thought to be an overarching factor in determining overall drag is not, nor does it accurately predict drag effect considerations at the bottom line.

[0078] Frontal Area

[0079] Frontal areas of large aircraft are large indeed. Frontal area is a component of aircraft parasitic-drag; it affects thrust requirements and cruise speed. Frontal area is best presented as a parameter associated with aircraft seating capacity and/or overall aircraft weight. FIGS. 17 and 18 show these comparisons. The disclosure aircraft is within point design scatter of existing aircraft, and shows best when referenced to seat capacity. Twin fuselage frontal area falls well within acceptable ranges, particularly if based on seat capacity at max range FIG. 17. It is to be remembered that frontal area consideration is only one of several design parameters affecting parasitic drag. Aircraft can achieve lower total drag by addressing other factors as well, (lowered gross weight, adherence to area-rule shapes, and higher wing-aspect ratios), frontal area impacts thereby lessened.

[0080] The Wave-Drag Effects

[0081] The smoothness of the cross-sectional area change along an aircraft body length, nose-to-tail, helps to determine wave-drag magnitudes (a factor in determining the overall parasitic drag component) at cruise speeds, and surprisingly is largely independent of actual shape. Aircraft designs that approximate what is called the transonic area-rule, (an aerodynamic shape should change in cross-sectional area as smoothly as possible) approach the ideal shape for lowest parasitic drag at transonic speeds, particularly above Mach 0.75, this being a most important operating speed range for commercial aircraft. A "perfect" aerodynamic shape would roughly look like a fat cigar, pointed at both ends. FIG. 19 compares this ideal with the typical jumbo-jet used today and FIG. 20 is the same cross-sectional presentation for the cross-wing twin-fuselage aircraft of this disclosure. The figures show that though the average cross-sectional area presented to the atmospheric ether volume (frontal average areas are roughly similar), the disclosure aircraft more nearly approximates the ideal. This then should allow the disclosure aircraft to be characterized by a lower-than-expected overall drag coefficient, meaning higher cruise speed.

[0082] For the typical jumbo-jet presented in FIG. 19, the cross-section grows quickly, levels off, then grows rapidly as the wing-nacelle cross-sections present themselves, after that, then quickly fall to again quickly rise once more over the tail and stabilizer cross-sections. Transitions can be made somewhat smooth, but cannot be a good approximation of the also shown ideal shape profile.

[0083] In contrast, the profile for the disclosure aircraft much better approximates the shape ideal until such point that the engine nacelle cross-sections are accounted for, FIG. 20. The engine nacelle cross-sections represent the sudden rise, then fall-off just past mid-station. The much closer adherence

to the area-rule achieved by the disclosure aircraft is expected to equate to a lowered coefficient-of-drag, meaning a lowered parasitic drag, and therefore an at least equivalent or higher overall cruise speed at the minimum drag point.

[0084] Catamaran Effects

[0085] There is another design consideration that the disclosure aircraft will benefit from, that being a “catamaran effect”, where facing fuselages develop wave-drag profiles that partially cancel, cancellation due to the opposing fuselage wave-drag fronts. FIG. 21 shows the longitudinal plane-of-symmetry where drag-waves will interact. These wave-drag interactions reduce left and right-directed drag wave propagations, by the right and left fuselages respectively, thereby effecting overall drag. Though not shown, each fuselage could be contour tailored, nose-to-tail, as would be seen in a top plan form view, shaped such that induced wave-drag of the inside left and right fuselages interact with greater wave-drag cancellation, the outward facing fuselage surfaces being less curved to the atmospheric ether, thereby reducing the outboard fuselage surface net contribution to the coefficient-of-drag.

Detail Description Summary

[0086] The overall performance and operational benefits of this disclosure aircraft are clear. It is established that lowered seat operational costs are a fallout of this twin fuselage design. The disclosure aircraft provides significantly lower weight per seat-mile at maximum range, and though exhibiting a higher coefficient-of-drag, still promises 20 to 30% greater affordability than capabilities of today’s single-fuselage aircraft. All technologies are here now, meaning acceptable risk and development cost. The disclosure aircraft fits into a niche airlines need, passengers will appreciate, and if developed will help to reduce overall energy expenditures by aircraft.

1. What I claim as my invention is a dimensionally efficient large long-range aircraft design being of a cross-wing twin-fuselage configuration, unique in that propelling engines (two, three, or four engine arrangements) are centrally mounted aft of a central cross-wing section, such section being both partial wing, fuel tanks, and structural connection for twin-fuselage attachments, inclusive with means-of-passage between fuselages, the outer main wings being free from hanging appendages, thereby enabling of efficient aerodynamic-lift wing design, such configuration utilizing both a split stabilizer and a split vertical tail, the full flight center-of-gravity profile adequately forward of wing lift-center, that lift-center, along with engine thrust, both contributing a nose down center-of-gravity moment, which is countered by a

reverse lift airfoil stabilizer providing ample nose-up moment, thereby achieving flight safety margins with low drag for both normal and engine-out operations, said engine locations biased high and aft, so that the central cross-wing and outer wings provide ground noise abatement, passenger cabin noise minimized by aft engine installations.

2. What I claim as my invention is a dimensionally efficient large long-range aircraft of claim 1, but for a configuration with turbo-prop engines used to propel the aircraft in place of turbo-fan engines, turbo-prop engines turning contra-rotating propeller pairs, one or two such pairs acting along co-aligned longitudinal axes, the propeller pairs being of type and design to achieve high overall efficiency and speed.

3. What I claim as my invention is a dimensionally efficient large long-range aircraft of claim 1, inclusive of the wing-fuselage arrangement of cross-sectional frontal area increase and decrease, achieving a smoothed and tailored shape, specifically designed to closely approximate the transonic area-rule minimum-drag ideal, that shaping accomplished by the staggering of the central cross-wing forward and the outer-wings aft, bulging of the fuselage transition from fuselage to the outer wing forward root, and localized bulging in aft sections of the fuselages, the effect of such tailored and smooth cross-sectional area transitional shaping, nose-to-tail, achieving a lowered overall coefficient-of-drag, that lowered drag coefficient affecting a higher optimal speed achieved at the point of minimum required thrust.

4. What I claim as my invention is a dimensionally efficient large long-range aircraft of claim 1, the fuselage contour, nose-to-tail, in a top plan form view shaped such that induced wave-drag of the left and right facing fuselages interact to cancel a portion of developed wave drag, a so-called “catamaran effect”, the outward facing fuselage surface being less curved to the atmosphere ether, thereby effecting the net drag inducing cross-sectional area equivalent.

5. What I claim as my invention is a dimensionally efficient large long-range aircraft of claim 1, with dual and fully redundant cockpits, such aircraft being capable of being flown from either fuselage, or with two pilot cabins being at the most forward location of the twin fuselages respectively, typically, pilot in left fuselage, copilot in right fuselage, with virtual camera functionality in each cabin respectively of opposite cabin visibility.

6. What I claim as my invention is a dimensionally efficient large long-range aircraft of claim 1, with consideration of growth opportunities, and for a configuration using a combined v-tail and a larger wing plan, with stability control similar to that of blended-wing configurations.

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