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(54) **UNMANNED AERIAL VEHICLE WITH ELECTRICALLY POWERED, COUNTERROTATING DUCTED ROTORS**

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5,419,513 A *	5/1995	Flemming et al.	244/12.2
5,575,438 A	11/1996	McGonigle et al.	
6,070,831 A *	6/2000	Vassiliev et al.	244/120
6,270,038 B1	8/2001	Cycon et al.	
6,450,445 B1	9/2002	Moller	
6,592,071 B2	7/2003	Kinthead et al.	
6,672,538 B2	1/2004	Millea et al.	
6,691,949 B2	2/2004	Plump et al.	
6,694,228 B2	2/2004	Rios	
6,758,436 B2 *	7/2004	Rehkemper et al.	244/17.11
6,840,480 B2 *	1/2005	Carroll	244/120
2004/0129833 A1	7/2004	Perlo et al.	
2005/0061910 A1 *	3/2005	Wobben	244/17.23
2005/0082421 A1	4/2005	Perlo et al.	

OTHER PUBLICATIONS

“Handheld Spy Chopper.” Popular Science, Sep. 2008, pp. 62-63. Information on Competitors UAV’s.

* cited by examiner

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B64C 27/10 (2006.01)

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See application file for complete search history.

(57) **ABSTRACT**

An unmanned aerial vehicle having counterrotating ducted rotors that are driven by electric motors. The vehicle has a low weight and a small profile. The unmanned aerial vehicle is suitable for a number of different tasks, including control, surveillance and reconnaissance, communication, and other tasks without exposing personnel to dangerous situations. The vehicle is particularly suited for entering buildings and other enclosed structures and spaces such as caves. The unmanned aerial vehicle can also be equipped for potential offensive actions.

(56) **References Cited**

U.S. PATENT DOCUMENTS

1,541,976 A *	6/1925	Longren	244/120
3,135,481 A *	6/1964	Sudrow	244/23 C
3,722,830 A *	3/1973	Barber	244/17.23
4,955,560 A *	9/1990	Nishina et al.	244/53 R
5,150,857 A	9/1992	Moffitt et al.	
5,152,478 A *	10/1992	Cycon et al.	244/12.2
5,277,380 A	1/1994	Cycon et al.	

19 Claims, 10 Drawing Sheets

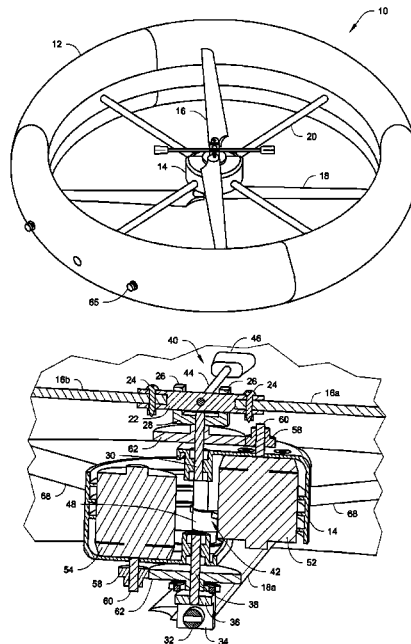
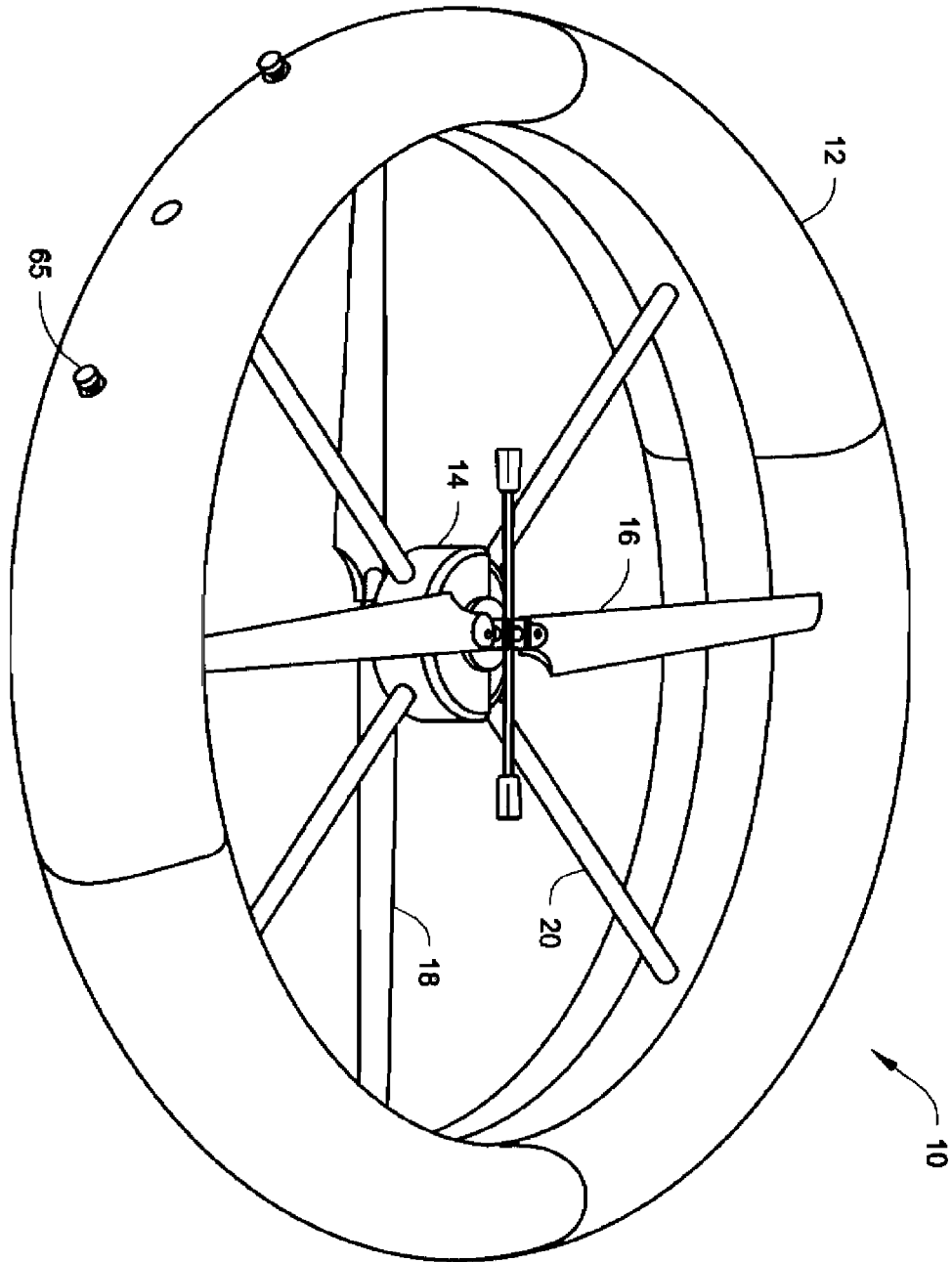


Fig. 1



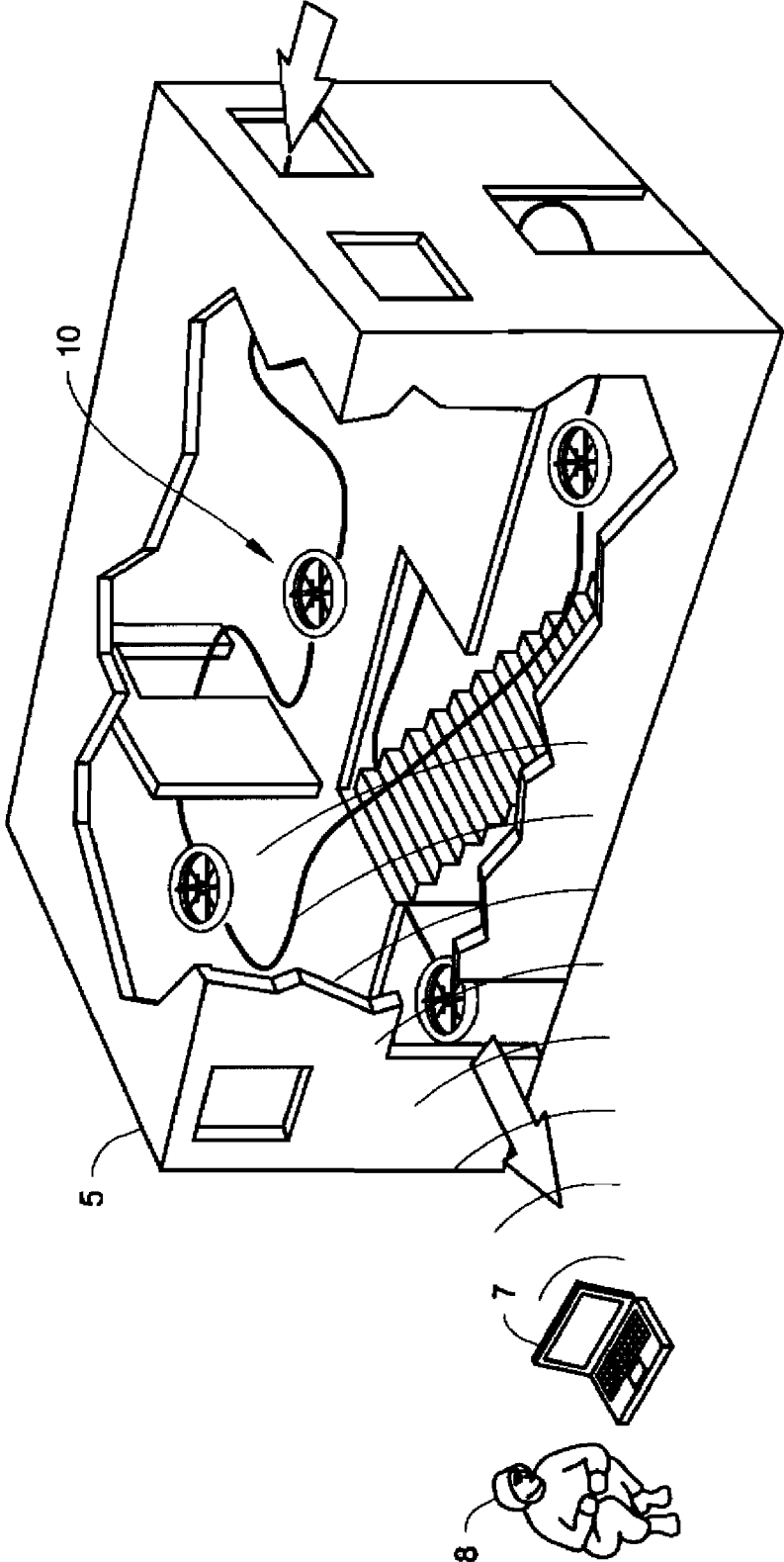


Fig. 2

Fig. 3

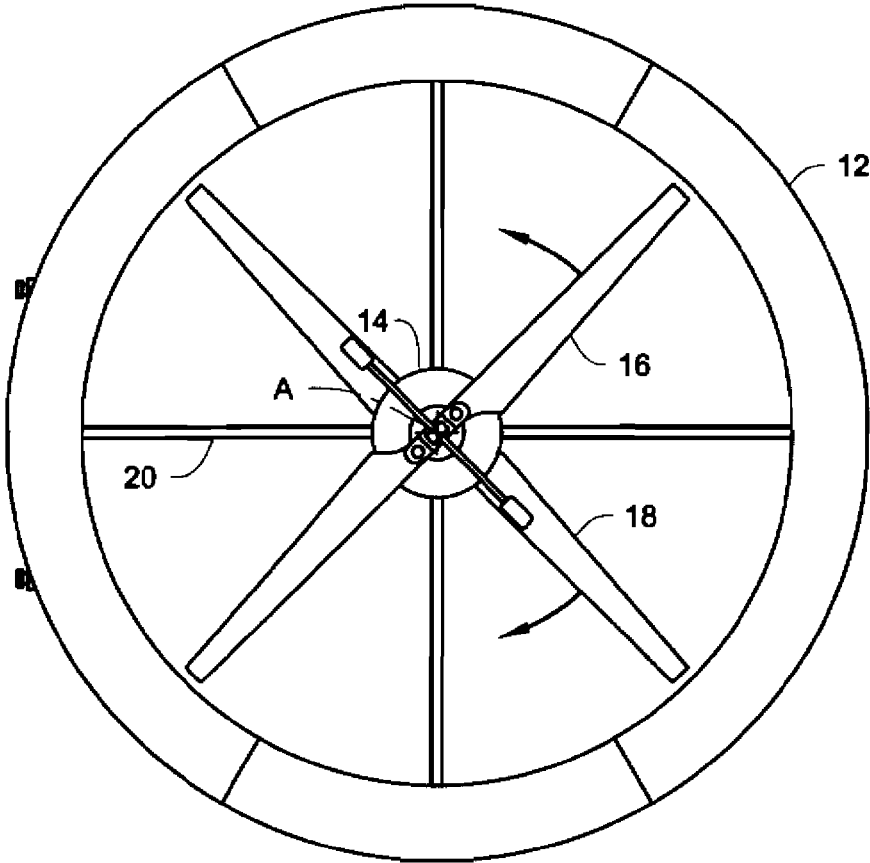
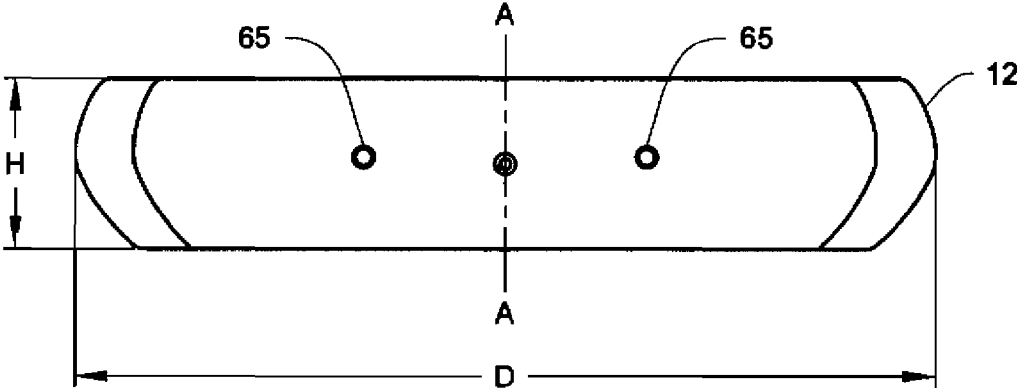


Fig. 4



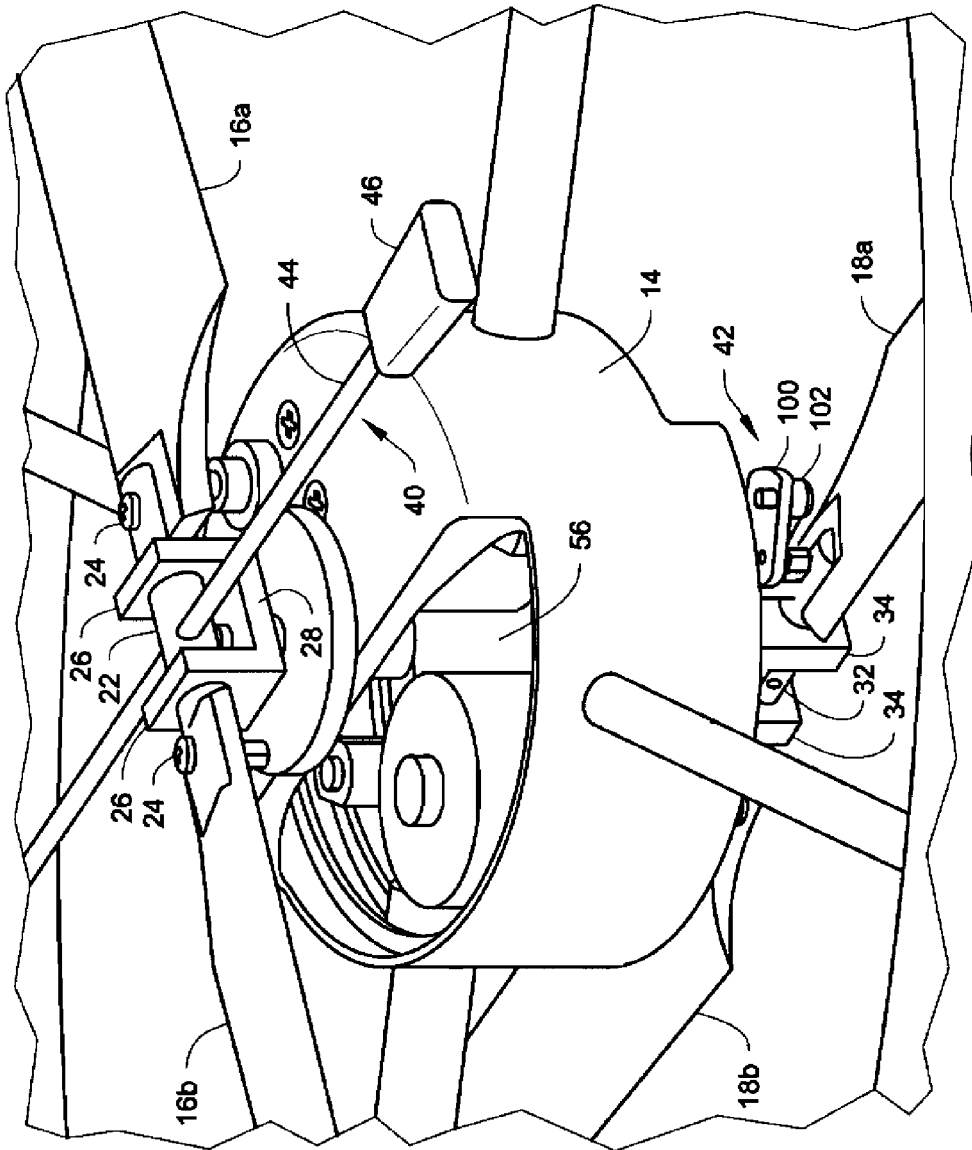
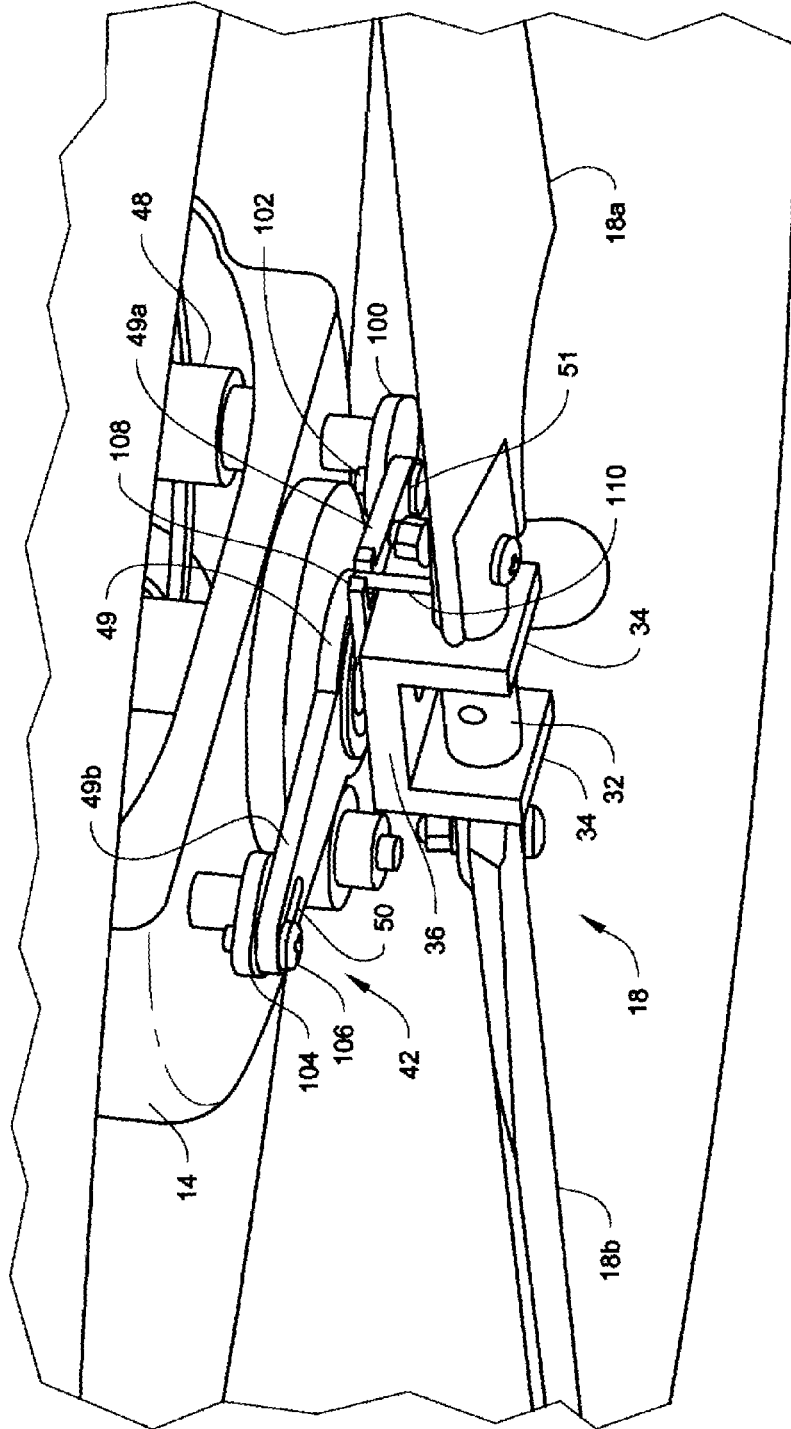


Fig. 5A

Fig. 5B



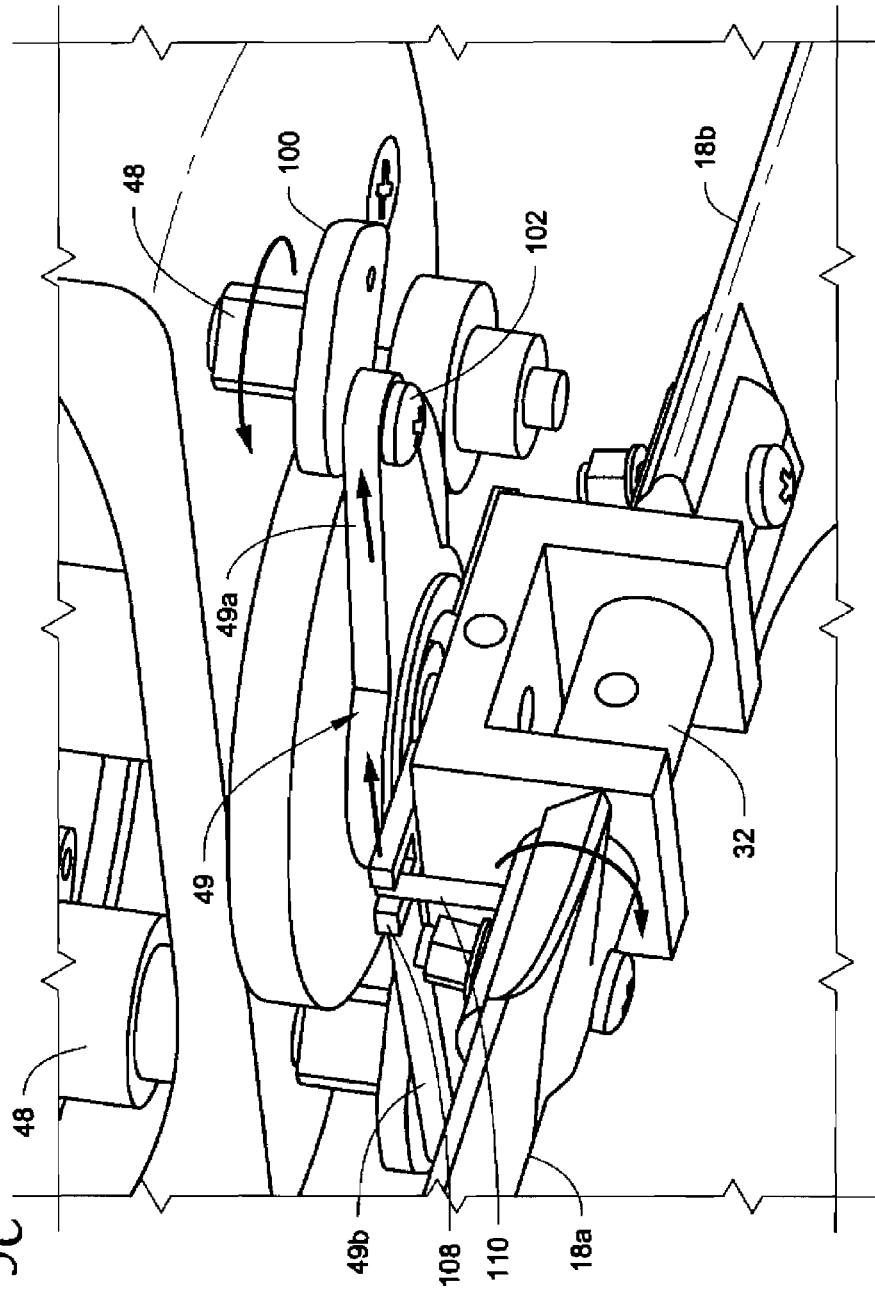


Fig. 5C

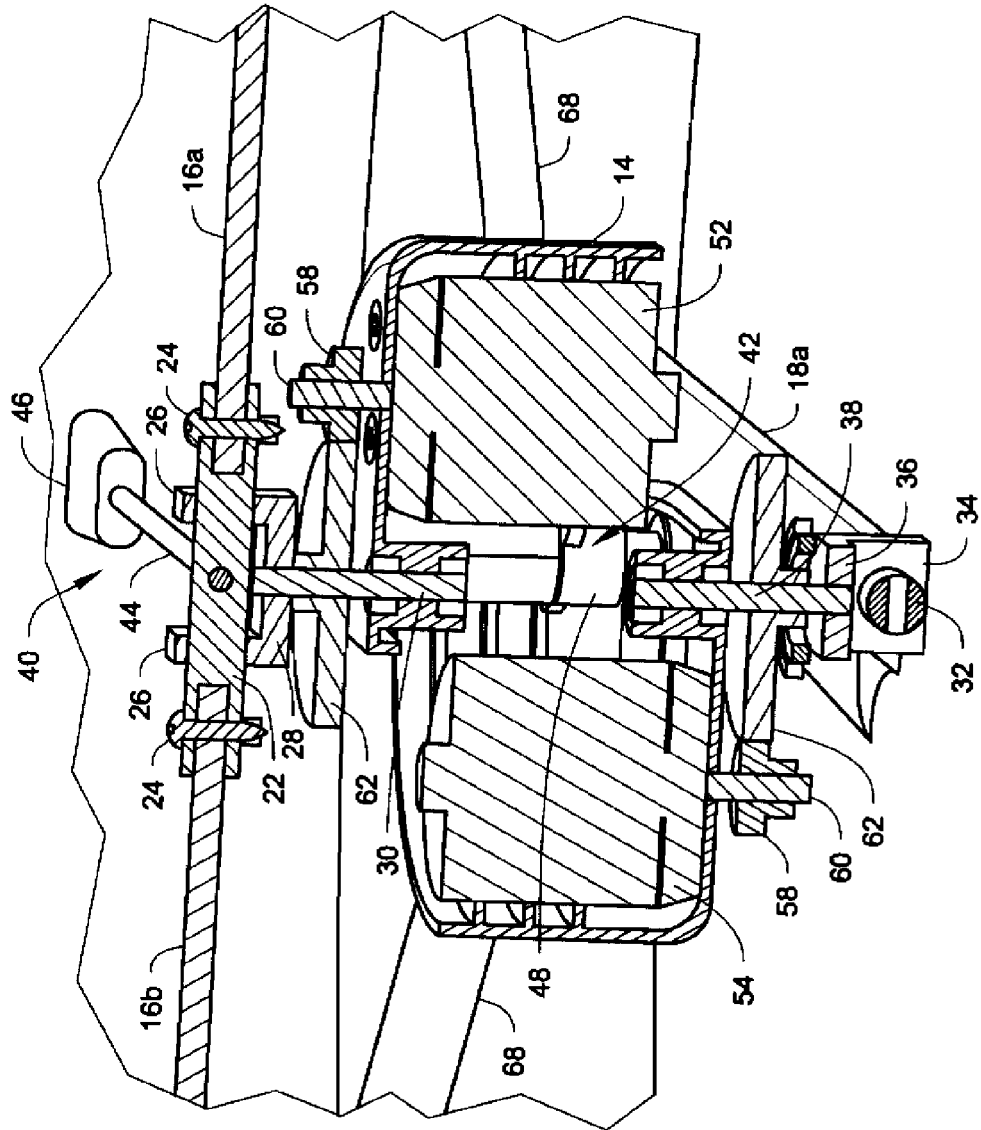


Fig. 6

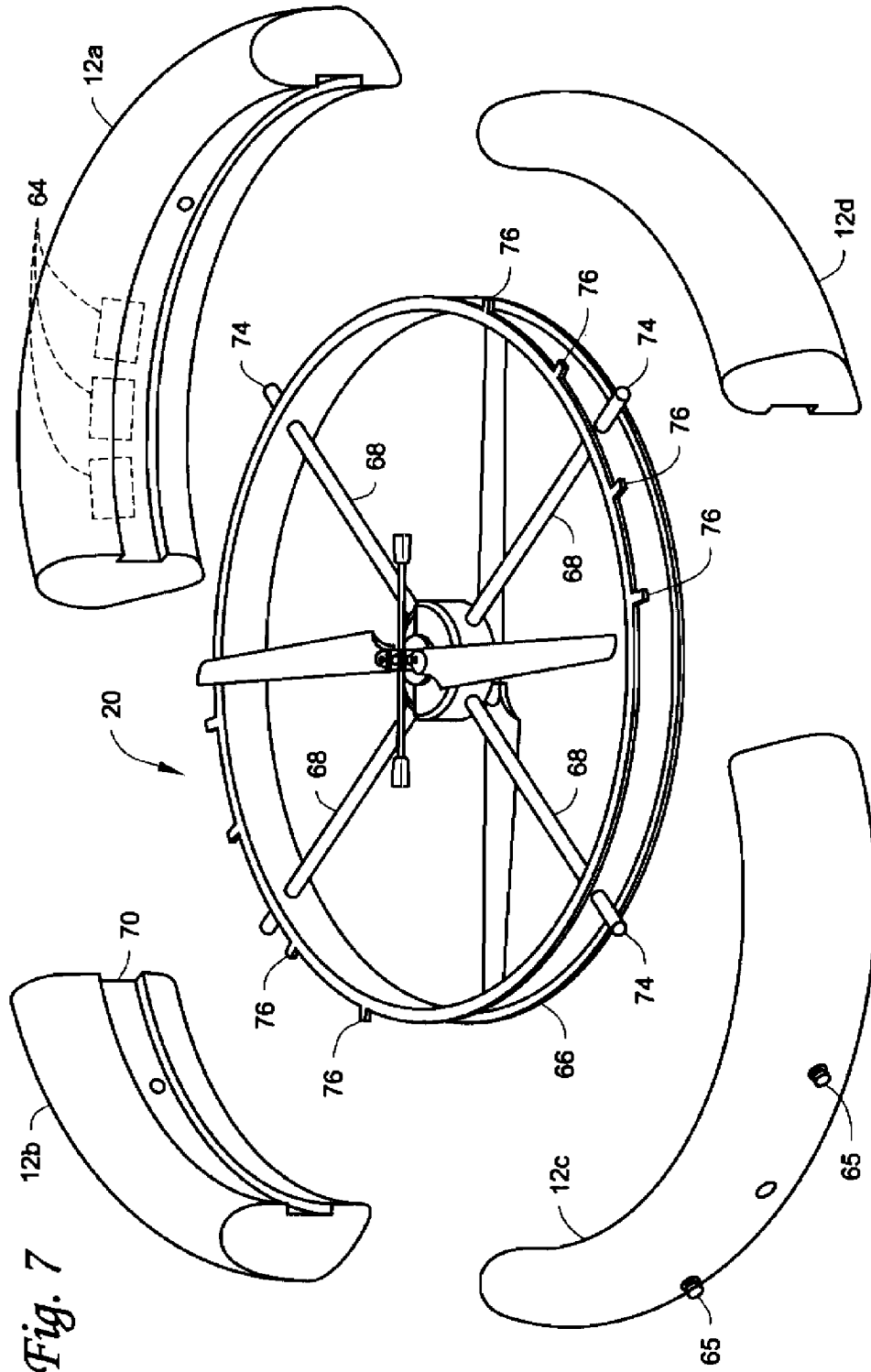


Fig. 7

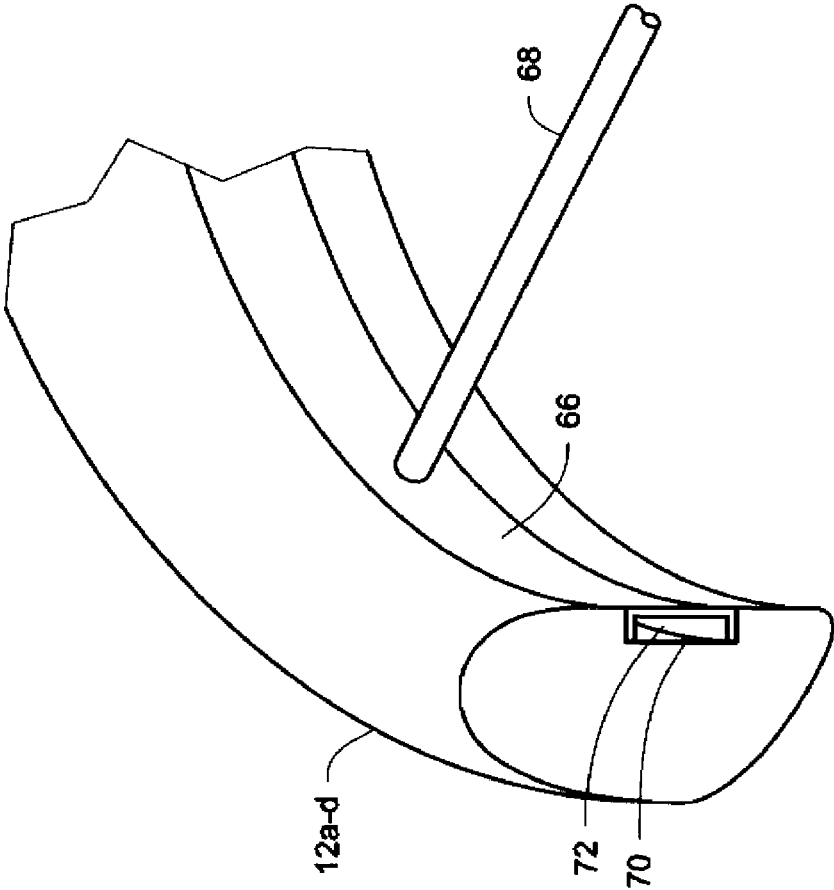


Fig. 8

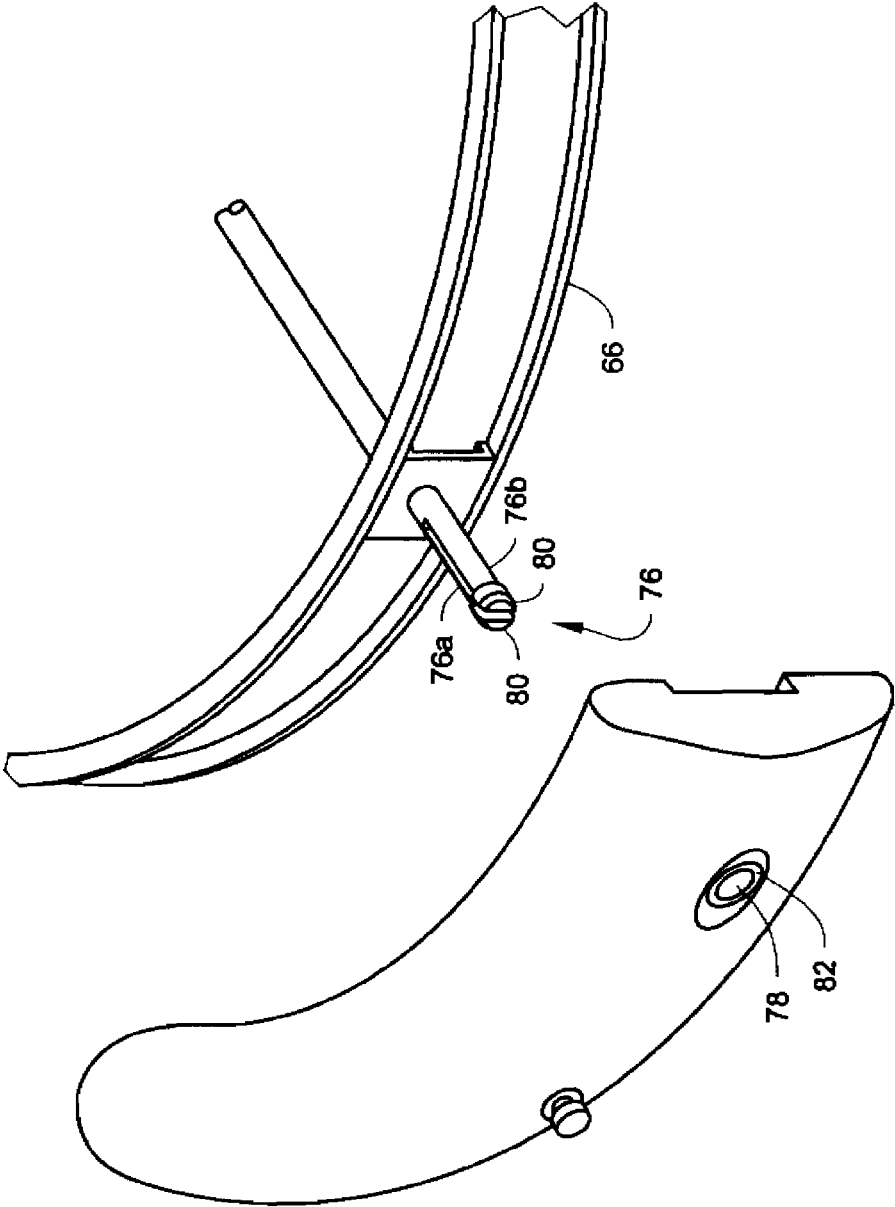


Fig. 9

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**UNMANNED AERIAL VEHICLE WITH
ELECTRICALLY POWERED,
COUNTERROTATING DUCTED ROTORS**

FIELD

The disclosure relates to an unmanned aerial vehicle, in particular an aerial vehicle having counterrotating ducted rotors that are driven by electric motors and which has a low weight and a small profile.

BACKGROUND

In many military and law enforcement situations, it is desirable to perform control, surveillance and reconnaissance, communication, and other tasks without exposing personnel to dangerous situations.

For example, it is often necessary for military and law enforcement personnel to enter buildings and other enclosed structures and spaces. Entry into structures is done for various reasons, including searching the interiors of the structures, surveillance and reconnaissance, and apprehending individuals within the structures.

For military and law enforcements personnel, entry into structures can be extremely dangerous. Often, the personnel may not know whether there are potentially dangerous or potentially friendly occupants within a structure, how many occupants there are, or where the occupants are located within the structure. In addition, the personnel may not know the interior configuration of the structure or the location of potentially dangerous obstacles. As a result of these unknowns, the personnel may need to make spur of the moment decisions during and after entry, which can lead to dangerous, and potentially fatal, errors in judgment. Further, to enter a structure, the personnel often leave the safe confines of a location, for example an armored vehicle, thereby exposing themselves to potential danger prior to entry.

The use of unmanned vehicles for performing control, surveillance, reconnaissance, communications, and other tasks is known. These include ground based remote-controlled wheeled or tracked vehicles, and aerial vehicles including the Honeywell Micro Air Vehicle, the Honeywell Kestrel, and the Allied Aerospace iSTAR.

Many prior unmanned vehicles are powered by combustion engines, making the vehicles noisy even with sounds mufflers in place. In addition, the use of an engine(s) and the need to carry the requisite fuel supply increases the weight of the vehicle, thereby decreasing the portability of the vehicle, especially by humans.

SUMMARY

An unmanned aerial vehicle having counterrotating ducted rotors that are driven by electric motors. The vehicle has a low weight and a small profile. The unmanned aerial vehicle is suitable for a number of different tasks, including control, surveillance and reconnaissance, communication, and other tasks without exposing personnel to dangerous situations. The vehicle is particularly suited for entering buildings and other enclosed structures and spaces such as caves. The unmanned aerial vehicle can also be equipped for potential offensive actions.

The vehicle is controlled remotely by an operator using a suitable controller, such as a lap top computer or a personal data device. In addition, the vehicle can send information back to the controller relating to the task being performed.

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The vehicle is configured as a modular system, which enhances portability by humans and allows repair and refit of the vehicle tailored for a particular application. The size and weight of the vehicle are such as to further increase portability. In addition, the vehicle is configured to perform in environments where magnetometers, GPS and digital compasses are degraded.

In one embodiment, the unmanned aerial vehicle includes a shroud that is concentric about an axis, with the shroud having an interior space. A hub is disposed on the axis, with a first bladed rotor being rotatably mounted on the hub within the shroud for rotation in a first direction about an axis of rotation concentric with the axis of the shroud, and a second bladed rotor being rotatably mounted on the hub within the shroud for rotation in a second direction about an axis of rotation concentric with the axis of the shroud, where the second rotation direction being opposite the first rotation direction. A first electric motor is disposed in the hub and in driving engagement with the first bladed rotor for rotating the first bladed rotor in the first rotation direction, and a second electric motor is disposed in the hub and in driving engagement with the second bladed rotor for rotating the second bladed rotor in the second rotation direction. Further, at least one battery is disposed in the interior space of the shroud providing electrical power to the first and second electric motors.

In another embodiment, the unmanned aerial vehicle includes a shroud that is concentric about an axis, with the shroud including a plurality of shroud sections each of which is separately detachable from the vehicle. A hub is disposed on the axis, with a first bladed rotor being rotatably mounted on the hub within the shroud for rotation in a first direction about an axis of rotation concentric with the axis of the shroud, and a second bladed rotor being rotatably mounted on the hub within the shroud for rotation in a second direction about an axis of rotation concentric with the axis of the shroud, where the second rotation direction being opposite the first rotation direction. A first electric motor is disposed in the hub and in driving engagement with the first bladed rotor for rotating the first bladed rotor in the first rotation direction, and a second electric motor is disposed in the hub and in driving engagement with the second bladed rotor for rotating the second bladed rotor in the second rotation direction. Further, the vehicle includes at least one battery providing electrical power to the first and second electric motors.

DRAWINGS

FIG. 1 is a perspective view of the unmanned aerial vehicle.

FIG. 2 is a depiction of an exemplary use of the unmanned aerial vehicle.

FIG. 3 is a top plan view of the unmanned aerial vehicle.

FIG. 4 is a side view of the unmanned aerial vehicle.

FIG. 5A is a close-up view of the hub of the unmanned aerial vehicle illustrating details of the passive control system for the upper bladed rotor.

FIG. 5B is a close-up view of the hub illustrating details of the active control system of the lower bladed rotor.

FIG. 5C illustrates control of the blade angle of the lower bladed rotor.

FIG. 6 is a cross-sectional view through the hub to illustrate details of the drive mechanisms for rotating the bladed rotors.

FIG. 7 illustrates the shroud sections forming the shroud of the unmanned aerial vehicle.

FIG. 8 is a close-up view of a portion of a shroud section connected to a ring.

FIG. 9 details the non-destructive, detachable connection between the shroud sections and the ring.

DETAILED DESCRIPTION

An unmanned aerial vehicle **10** having counterrotating ducted rotors that are driven by electric motors, with the vehicle having a low weight and a small profile. The unmanned aerial vehicle **10** is suitable for a number of different tasks, including control, surveillance and reconnaissance, communication, and other tasks without exposing personnel to dangerous situations. The vehicle **10** is particularly suited for entering buildings and other enclosed structures and spaces such as caves. The unmanned aerial vehicle can also be equipped for potential offensive actions.

The vehicle **10** will be further described as being used in a military setting to enter a building **5** and perform reconnaissance therein, as shown in FIG. 2. However, it is to be realized that the vehicle **10** can be used in settings other than military, for example law enforcement. In addition, the vehicle can be used enter other man-made and naturally occurring structures, for example caves, and can be used in a manner that does not require entry into a building or other structure, for example open air surveillance and reconnaissance. Further, the vehicle **10** can be used to perform tasks other than reconnaissance, including passive tasks such as control and communications, and aggressive tasks such as offensive action against a building occupant(s).

Turning now to FIG. 1, the unmanned aerial vehicle **10** includes a non-rotating shroud **12** that is concentric about an axis A (see FIGS. 3 and 4), a non-rotating hub **14** that is disposed on the axis A, first and second bladed rotors **16**, **18**, and a non-rotating frame **20** that connects the shroud **12** to the hub **14**.

With reference to FIGS. 3 and 4, the vehicle **10** is generally circular in configuration, having a relatively small profile with a maximum height H and maximum diameter D chosen to facilitate maneuverability within the building **5**. For example, the vehicle **10** can have a maximum height of about 5.0 inches and a maximum diameter of about 22.0 inches. In addition, the vehicle **10** has a low weight to increase portability of the vehicle **10**, particularly by humans. For example, the vehicle **10** preferably has a weight of less than about 5 pounds, more preferably a weight of about 3 pounds or less.

With reference to FIGS. 3, 5A, 5B and 6, the first and second rotors **16**, **18** counterrotate within and relative to the shroud **12** so that the rotation direction of the first rotor **16** is opposite to the rotation direction of the second rotor **18**. The first rotor **16** is mounted at the top of the hub **14** and the second rotor **18** is mounted at the bottom of the hub **14** so that the first rotor **16** is the upper or top rotor while the second rotor **18** is the lower or bottom rotor. In the illustrated embodiment, the distance between the rotors **16**, **18** is about 25% of the radius of the first or second rotors **16**, **18**, with both rotors being surrounded by the shroud **12**.

The first rotor **16** includes first and second blades **16a**, **16b** connected by a rod **22**. As shown in FIGS. 5A and 6, each end of the rod **22** is in the shape of a clevis, with the root ends of the blades **16a**, **16b** being received in the respective clevis and secured to the rod **22** by bolts **24**. The rod **22** is rotatably mounted on a pair of flanges **26** that are integral with a base plate **28**, to allow rotation of the rod **22** and thus change in the blade angle of the blades **16a**, **16b**. The base plate **28** is fixed to a drive shaft **30** that is in driving engagement with a drive mechanism for rotatably driving the first bladed rotor **16**. The drive shaft **30** is rotatably supported on the hub **14** by bearings.

Likewise, as shown in FIGS. 5B and 6, the second rotor **18** includes first and second blades **18a**, **18b**. The blade **18a** is connected to the blade **18b** by a rod **32** that extends through flanges **34** that are integral with a base plate **36**. The rod **32** is rotatably supported by the flanges **34** to allow rotation of the blades **18a**, **18b** to change the blade angle of the blades **18a**, **18b**. The base plate **36** is fixed to a drive shaft **38** that is in driving engagement with a drive mechanism for rotatably driving the first bladed rotor **16**. The drive shaft **38** is rotatably supported on the hub **14** by bearings.

A passive control system **40** is connected to the first rotor **16** for controlling the plane of rotation of the first bladed rotor by changing the blade angles of the blades **16a**, **16b**. With reference to FIGS. 5A and 6, the passive control system **40** includes a weighted fly bar that includes a shaft **44** that is fixed to and extends through the rod **22**, and weights **46**, each having the same weight, at each end of the shaft **44**.

In addition, an active control system **42** is connected to the second rotor **18** for controlling the plane of rotation of the second bladed rotor by changing the blade angles of the blades **18a**, **18b**. With reference to FIGS. 5B, 5C and 6, the active control system **42** includes a pair of servos **48** (only one servo is shown in FIG. 6) disposed within the hub **14**. A plate **49** having a pair of arms **49a**, **49b** is mounted under the housing of the hub **14** so as to be slideable in a direction perpendicular to the rotation axis of the rotor **18** as shown by the arrow in FIG. 5C. A slot **50** is formed in the end of the arm **49b**, while a hole **51** is formed in the arm **49a**. One servo **48** is linked to the arm **49a** by a link **100** having an offset pin **102** disposed in the hole **51**. The other servo **48** is linked to the arm **49b** by a link **104** having an offset pin **106** disposed in the slot **50**. A clevis **108** is connected to the plate **49** and at a generally right angle thereto so as to move with the plate. A pin **110** extends upwardly from the rod **32**, with the end of the pin **110** disposed between the arms of the clevis **108**.

As shown in FIG. 5C, rotation of either servo **48** causes rotation of the respective link **100**, **104**, thereby actuating the offset pin **102**, **106**. Since the pins **102**, **106** are offset from the axis of rotation of the servos **48**, the plate **49** will be forced to move in a direction perpendicular to the rotation axis of the rotor **18**. This causes the clevis **108** to move in the same direction, which actuates the pin **110** causing the rod **32** to rotate thereby changing the angle of the blades **18a**, **18b**.

In view of the symmetrical rotors **16**, **18**, active control of only one rotor is required for translational flight along any axis. The servos **48** and plate **49** allow active control of the blade angles of the blades **18a**, **18b** to achieve translational flight of the vehicle **10**. In contrast, the weighted fly bar is directly connected to the blades **16a**, **16b** for automatically and equally changing the blade angles of the blades **16a**, **16b**. As a result of the direct connection between the weighted fly bar and the rotor **16**, under normal operating conditions, the weighted fly bar tends to return the vehicle **10** to a steady state hovering condition.

The hub **14** rotatably supports the rotors **16**, **18**, and has a generally hollow interior in which electric motors **52**, **54** for driving the rotors **16**, **18** are disposed. The hub **14** can be made of a material providing good tensile strength and low weight, for example, carbon fiber polyamide composite. The electric motors **52**, **54** are, for example, 65 W motors.

As shown in FIG. 5A, the hub **14** includes an opening **56** at the top thereof to provide access for installation and maintenance, and to provide an airflow path to allow cooling of the motors **52**, **54**. If necessary, a filter (not shown) can be installed over the opening **56** to filter out sand and dust from the air.

The motors **52**, **54** are in driving engagement with the rotors **16**, **18** through respective suitable drive mechanisms. In the illustrated embodiment, each drive mechanism includes a drive gear **58** connected to the output shaft **60** of the motor **52**, **54**, and a driven gear **62** that is connected to the respective drive shaft **30**, **38**. However, other drive mechanisms could be used to connect the motors **52**, **54** to the rotors **16**, **18**, for example a belt drive mechanism.

Turning now to FIG. 7, the shroud **12** is formed of a plurality of shroud sections **12a**, **12b**, **12c**, **12d** that are detachably connected to the vehicle **10**. In the illustrated embodiment, four shroud sections are used. However, a larger or smaller number of shroud sections can be used. In addition, the shroud sections **12a-d** in the illustrated embodiment are not of the same circumferential size as a result of the different functions of each section. The shroud sections could be made to have the same circumferential size if desired. Regardless of whether the shroud sections are of the same circumferential size or not, the shroud sections should combine to form a 360 degree circle.

Each shroud section **12a-d** forms a module that contains elements used in the operation of the vehicle **10**. For example, section **12a** can house one or more batteries **64**, for example lithium-based batteries, such as lithium sulphur batteries, or other comparable power supply, for providing power to the motors **52**, **54**. Section **12b** can house control equipment, for example various processors and electronics, used to control vehicle **10** flight and operations, including control of other shroud modules. Section **12c** can house a suitable payload specific to the intended use or application of the vehicle **10**. For example, the section **12c** can house passive equipment such as one or more cameras **65**, an infrared illuminator, a microphone, and sensors, or offensive equipment such as weapons. Section **12d** can house communications equipment for enabling communications with a suitable controller **7**, such as a lap top computer or a personal data device (see FIG. 2).

Preferably, the shroud **12** contains one or more optic flow sensors. The optic flow sensors are used along with an inertial measurement unit for navigation of the vehicle **10** and to help the vehicle **10** avoid collisions with objects within the building. In an exemplary embodiment, there is at least one optic flow sensor in each of the shroud sections **12b**, **12c**, **12d**. The use of optical flow sensors allows the vehicle to operate without using guidance systems such as GPS. As a result, the vehicle can be used in environments that are not suitable for GPS and other sensors or where the performance of GPS and other guidance systems are degraded, such as in caves.

Each shroud section **12a-d** is made from durable, lightweight materials. For example, each shroud section **12a-d** can be made from ARCEL® foam, a carbon fiber composite or combinations thereof. When made of ARCEL® foam, each shroud section **12a-d** can have a weight of about 53 grams before the addition of additional components. The total weight of the shroud sections **12a-d** with additional internal components can be, for example, approximately 2 pounds.

The shroud sections **12a-d** are designed to be non-destructively detachably connected to the frame **20** to allow disassembly of the vehicle to increase portability, and to allow individual sections **12a-d** to be removed and replaced with other sections or for repair. Since the shroud sections **12a-d** are replaceable, the vehicle **10** can be tailored to differing uses and applications by replacing the shroud sections with sections suitable for the intended use of the vehicle. The detachable connection between the shroud sections and the frame **20** is preferably achieved using a non-destructive mechanical

and electrical connection that permits removal of the sections without destroying or damaging the shroud sections or the frame.

The frame **20** is used to connect the shroud **12** to the hub **14**. The frame **20** is designed to be stiff, have a low weight, and minimize the effect on the airflow through the vehicle **10**. In the illustrated embodiment, the frame **20** includes a ring **66** that is concentric to the axis A, and rods **68** that are integral with the ring **66** and connect to the hub **14**, as shown in FIGS. **1**, **3** and **7**. The ring **66** and rods **68** can be made of, for example, a composite material, such as a carbon fiber composite. In addition, the rods **68** are preferably hollow tubes to reduce weight and act as conduits for wires passing from the shroud sections **12a-d** to the hub **14**. The rods **68** are preferably integrally formed with the ring **66** and the hub **14**. However, the rods **68** could be detachably connected to both the ring **66** and the hub **14** to allow replacement of the rods in the event of damage to the rods.

As shown in FIG. **8**, the ring **66** is generally C-shaped in cross-section with the "C" facing outward. In addition, each shroud section **12a-d** includes a channel **70** defined on the inner face thereof that receives the ring **66** therein. When the ring **66** is received within the channel **70** of a respective shroud section, the inner surface of the ring is flush with the inner face of the shroud section, and a gap **72** is formed between the base of the "C" of the ring and the shroud section (see FIG. **8**). The gap **72** provides space for routing wiring and the like.

Returning to FIG. **7**, the ends **74** of the rods **68** extend past the ring **66**. In addition, a plurality of tabs **76** extend from the ring **66**. In the illustrated embodiment, there are two tabs **76** between each projecting end **74** so that two tabs **76** and a projecting end **74** are associated with each shroud section **12a-d**. The projecting end **74** and the tabs **76** engage with suitable apertures **78** formed in the shroud sections.

Details of the connection between the shroud sections and the ring **66** are shown in FIG. **9**. The end of the tab **76** is bifurcated into two arms **76a**, **76b** that can flex toward each other. The tip of each arm **76a**, **76b** is provided with an enlarged shoulder **80**. When the tab **76** is pushed into the aperture **78**, the arms **76a**, **76b** flex toward each other slightly, until the shoulders **80** project from the aperture **78** at which point the shoulders **80** snap in place to lock on to the surface **82** surrounding the aperture **78**. The projecting ends **74** are configured and function in the identical manner. This "snap-fit" connection between the ring **66** and the shroud section permits disconnection of the shroud section by squeezing the arms **76a**, **76b** toward each other to disengage the shoulders **80** from the surface **82** and thereby permitting removal of the shroud section.

With reference to FIG. **2**, the vehicle **10** is operated remotely by an operator **8**, for example a soldier, using the controller **7**. To enter the building **5** and perform reconnaissance therein, the vehicle **10** is flown by the operator **8** through a suitable access point, such as through an open door or an open window. The cameras **65** on the vehicle **10** send back a video of the interior of the building **5** to the operator **8**. The operator **8** can fly the vehicle **10** throughout accessible portions of the interior of the building to allow the entire building to be scouted. As a result, the operator **8** can determine whether the building is occupied, how many occupants there are, and where in the building the occupants are located. In addition, the operator **8** can search for weapons, explosive devices, and other potential dangers prior to entering the building **5**.

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Other configurations and uses of the unmanned aerial vehicle are possible utilizing the above described concepts.

The invention claimed is:

1. An unmanned aerial vehicle, comprising:

a shroud that is concentric about an axis, the shroud having
an interior space;

a hub disposed on the axis;

a first bladed rotor rotatably mounted on the hub within the
shroud for rotation in a first direction about an axis of
rotation concentric with the axis of the shroud;

a second bladed rotor rotatably mounted on the hub within
the shroud for rotation in a second direction about an
axis of rotation concentric with the axis of the shroud,
the second rotation direction being opposite the first
rotation direction;

a first electric motor disposed in the hub and in driving
engagement with the first bladed rotor for rotating the
first bladed rotor in the first rotation direction;

a second electric motor disposed in the hub and in driving
engagement with the second bladed rotor for rotating the
second bladed rotor in the second rotation direction;

the first electric motor and the second electric motor are
disposed between the first bladed rotor and the second
bladed rotor, the first and second electric motors are
arranged relative to each other such that in side view the
first and second electric motors overlap each other in the
vertical direction, and the first and second electric
motors are disposed on opposite sides of the shroud axis;
and

at least one battery disposed in the interior space of the
shroud providing electrical power to the first and second
electric motors.

2. The unmanned aerial vehicle according to claim **1**,
wherein the shroud has a diameter of approximately 22 inches
or less, a height of about 5 inches, and a vehicle weight of less
than about 5 pounds.

3. The unmanned aerial vehicle according to claim **1**,
wherein the shroud includes a plurality of shroud sections
each of which is separately and non-destructively detachable
from the vehicle.

4. The unmanned aerial vehicle according to claim **3**,
wherein a first said shroud sections contains the at least one
battery, a second said shroud section contains control equip-
ment, a third shroud section contains communications equip-
ment, and a fourth said shroud section contains payload
equipment.

5. The unmanned aerial vehicle according to claim **3**, fur-
ther comprising a ring attached to the shroud sections with an
inner surface of the ring flush with inner faces of the shroud
sections, the ring is concentric to the axis of the shroud, and
further comprising rods extending from the ring to the hub.

6. The unmanned aerial vehicle according to claim **1**, fur-
ther comprising a passive control system connected to the first
bladed rotor that controls the plane of rotation of the first
bladed rotor, and an active control system connected to the
second bladed rotor that controls the plane of rotation of the
second bladed rotor.

7. The unmanned aerial vehicle according to claim **6**,
wherein the first bladed rotor comprises first and second
blades connected by a rod, and the passive control system
comprises a weighted fly bar that extends through the rod
transversely to the axis of the rod.

8. The unmanned aerial vehicle according to claim **6**,
wherein the second bladed rotor comprises first and second
blades, and the active control system comprises a first servo
motor connected to the first blade and a second servo motor
connected to the second blade.

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9. The unmanned aerial vehicle according to claim **1**, com-
prising a distance of no more than about 25% of the radius of
the bladed rotors between the first and second bladed rotors.

10. The unmanned aerial vehicle according to claim **1**,
wherein the first and second electric motors each include an
output shaft that is parallel to the axis of the shroud, the output
shaft of the first electric motor extending toward the first
bladed rotor and the output shaft of the second electric motor
extending toward the second bladed rotor.

11. An unmanned aerial vehicle, comprising:

a shroud that is concentric about an axis, the shroud
includes a plurality of shroud sections each of which is
separately detachable from the vehicle;

a hub disposed on the axis;

a first bladed rotor rotatably mounted on the hub within the
shroud for rotation in a first direction about an axis of
rotation concentric with the axis of the shroud;

a second bladed rotor rotatably mounted on the hub within
the shroud for rotation in a second direction about an
axis of rotation concentric with the axis of the shroud,
the second rotation direction being opposite the first
rotation direction;

a first electric motor disposed in the hub and in driving
engagement with the first bladed rotor for rotating the
first bladed rotor in the first rotation direction;

a second electric motor disposed in the hub and in driving
engagement with the second bladed rotor for rotating the
second bladed rotor in the second rotation direction;

the first electric motor and the second electric motor are
disposed between the first bladed rotor and the second
bladed rotor, the first and second electric motors are
arranged relative to each other such that in side view the
first and second electric motors overlap each other in the
vertical direction, and the first and second electric
motors are disposed on opposite sides of the shroud axis;
and

at least one battery providing electrical power to the first
and second electric motors.

12. The unmanned aerial vehicle according to claim **11**,
wherein the shroud has a diameter of approximately 22 inches
or less, a height of about 5 inches, and a vehicle weight of less
than about 5 pounds.

13. The unmanned aerial vehicle according to claim **11**,
wherein a first said shroud section contains control equip-
ment, a second said shroud section contains communications
equipment, and a third said shroud section contains payload
equipment.

14. The unmanned aerial vehicle according to claim **11**,
further comprising a passive control system connected to the
first bladed rotor that controls the plane of rotation of the first
bladed rotor, and an active control system connected to the
second bladed rotor that controls the plane of rotation of the
second bladed rotor.

15. The unmanned aerial vehicle according to claim **14**,
wherein the first bladed rotor comprises first and second
blades connected by a rod, and the passive control system
comprises a weighted fly bar that extends through the rod
transversely to the axis of the rod.

16. The unmanned aerial vehicle according to claim **14**,
wherein the second bladed rotor comprises first and second
blades connected by a rod, and the active control system
comprises a first servo motor connected to the first blade and
a second servo motor connected to the second blade.

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17. The unmanned aerial vehicle according to claim 11, comprising a distance of no more than about 25% of the radius of the bladed rotors between the first and second bladed rotors.

18. The unmanned aerial vehicle according to claim 11, further comprising a ring attached to the shroud sections with an inner surface of the ring flush with inner faces of the shroud sections, the ring is concentric to the axis of the shroud, and further comprising rods extending from the ring to the hub.

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19. The unmanned aerial vehicle according to claim 11, wherein the first and second electric motors each include an output shaft that is parallel to the axis of the shroud, the output shaft of the first electric motor extending toward the first bladed rotor and the output shaft of the second electric motor extending toward the second bladed rotor.

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