



Amazon's Drone Patents

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In 2013, when Amazon CEO Jeff Bezos [unveiled his idea to deliver](#) packages to customers via drone, many were quick to ask how such a bold proposition could ever really work in practice. Over three years later, the PrimeAir program remains in development, and while the company has released a number of videos describing the drone delivery system in general terms and has conducted a handful of live delivery tests, it has yet to disclose the exact details of how it plans to safely and efficiently deliver goods by drone. We know that the drones will have [a range of at least 15 miles](#) or more, that they could complete deliveries in 15 minutes or less (the first live test took 13 minutes from click to delivery, according to a tweet by Jeff Bezos), and that the aircraft [could carry items weighing up to five pounds](#). But that's about it.

However, over the period since the program was announced in 2013, the company has been filing applications for patents at what appears to be a faster rate than any other company working on drone technology today. In 2014, it [even began hiring patent lawyers to work](#) exclusively in the PrimeAir division. Based on an analysis of patent records, as of August 2017, Amazon has been awarded at least 64 patents for concepts and technologies for delivery drones, including patents for aircraft designs, safety and security systems, methods for transferring goods from the air to the ground, and hive-like fulfillment centers. Surveying a selection of the

patents that have been published so far provides a detailed sense of the company's ideas for it will turn the program from fiction to reality.

Background

The company's final delivery system will of course be contingent on a number of factors and technologies not explicitly described in these patents. For example, a drone delivery program covering a large area would likely depend on an unmanned vehicle traffic management system that could effectively and safely coordinate the operations of autonomous drones in the airspace system. Furthermore, in the U.S. and other markets, current federal regulations prohibit the use of drones beyond the operator's visual line of sight, the use of drones over people, and the use of drones to carry goods for delivery, so the drone delivery program will not be implemented until those regulations are updated, a process that could take several years (certain countries such as [China](#) and [France](#) have permitted limited drone delivery programs, though these are not yet full-scale integrated operations). Regulatory details, such as whether these drones can land on private property or must instead lower their parcels to the ground using a winch or a parachute, will have a

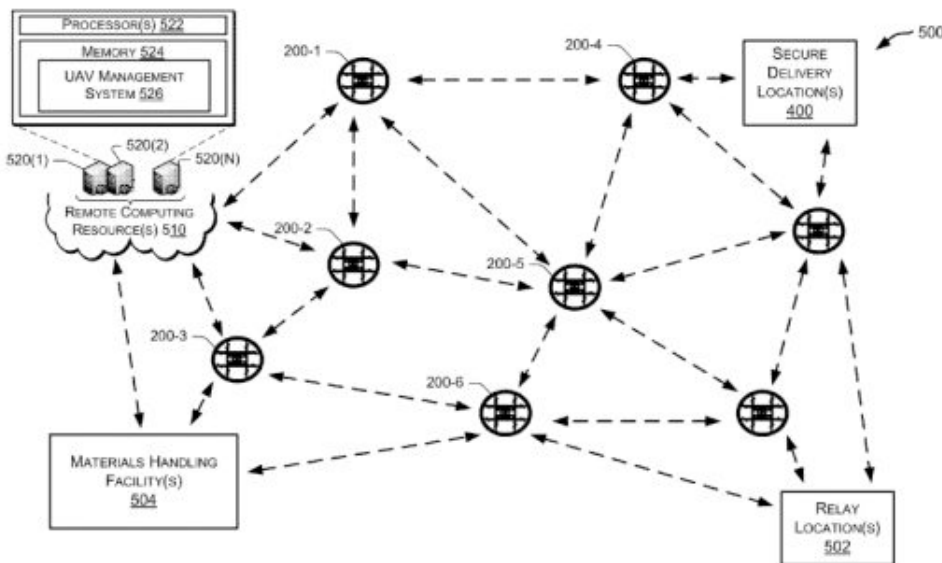
Edited by Dan Gettinger. Editorial support provided by Elizabeth Fitzgerald. Presentation by Dan Gettinger. Cover photo by Julia A./Flickr.

profound effect on what the system will actually look like when it is implemented. Amazon is not the only company planning to use drones to deliver goods; Google, Wal-Mart, and DHL, among others, are all actively working on delivery programs of their own, and these contingent factors will equally impact those companies' plans, too.

The patents reviewed here seem to reflect that Amazon is preparing for both a variety of different types of operating environments and regulatory environments.

The patents reviewed here seem to reflect that Amazon is preparing for both a variety of different types of operating environments and regulatory environments. They reflect not one single type of delivery program, but rather a range of individual elements that could be combined in many different ways. Many of the patents point to the difficult technical challenges that delivering goods by unmanned aircraft entails, such as how to get packages from the air to the ground safely, how to protect one's drones from hacking, how to ensure that the drones don't crash, and how to design fulfilment centers that will be able to handle hundreds of aircraft at once. Reviewing these patents not only provides an insight into the company's ambitious program, but also into the future of commercial drones more broadly. The technologies described here could have significant applications beyond the compa-

Ref. 1 "Unmanned aerial vehicle delivery system"



ny's delivery scheme. For example, the company's proposed safety features could be employed to make drone operations safer and more reliable in everything from infrastructure inspection to aerial photography, and the company's networked drone-to-drone communications concepts could enable swarming operations, which have a number of applications beyond parcel delivery, such as surveillance or search-and-rescue.

A full list of Amazon's drone delivery-related patents is provided on page 9.

General System Design

While many of the patents awarded to Amazon describe very specific elements of its drone delivery system, a few patents provide an overview of proposed designs for the general system as a whole. In 2015, the U.S. Patents Office published a patent filed by Amazon in 2013 (Ref. 1) that depicts the company's proposed delivery system in broad strokes. According to the patent, drones would fly directly to buyers using location data from the buyers' smartphones. Alternatively, users would be able to select a range of delivery locations, including their home, workplace, or even a boat. The patent explains that the drones would network among themselves to update each other on weather conditions. Finally, the patent describes how the drones would actively monitor their surroundings for obstacles such as animals or people. A second patent (Ref. 51), awarded to the company in 2017, describes "a plurality" of delivery drones coupled to a central management system that tasks individual drones to deliver items

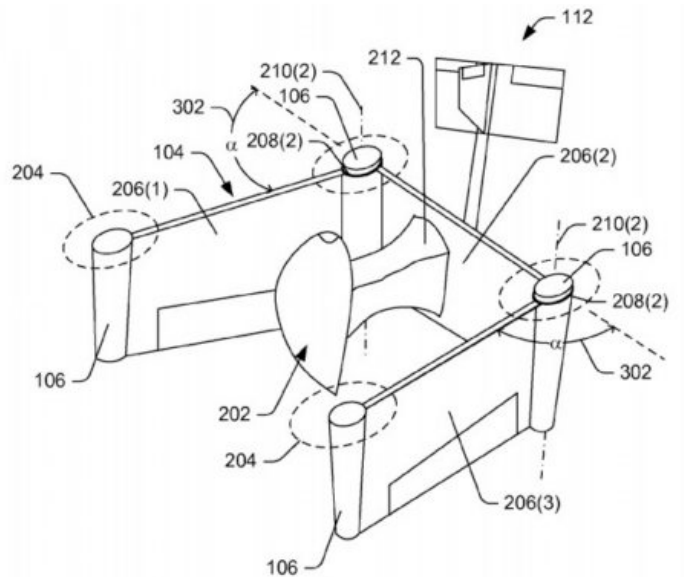
based on their location relative to the source of the package and its final destination, while another 2017 patent (Ref. 43) describes a mesh network that connects the drones to each other in order to identify each aircraft in a given area. A patent awarded to the company in August 2017 (Ref. 63), describes how one could track drones by shining a bright light at the moving aircraft, which would each be equipped with light reflectors that would bounce the light back, allowing the system to calculate the drone's location.

Data collection has always been a key piece of Amazon's business plan. Online, the company collects detailed data about our buying and browsing habits in order to generate more targeted product recommendations. It appears that the company may use its drone delivery program as yet another tool for generating data about consumers. In a [patent awarded to the company](#) in 2017 (Ref. 59), Amazon proposes a system for analyzing its drone video data of each delivery destination in order to identify characteristics at that address that could be used to generate product recommendations for future purchases. In an example offered in the patent, a drone flying over a customer's property might capture footage of some dying trees. A computer analysis system that is able to recognize the trees as being unhealthy would then generate a recommendation for a gardening product to solve the issue and the company would send that recommendation directly to the consumer.

Delivery Drone Designs

Over the course of the program's development, the company has unveiled a range of designs for its delivery drones. The original model, presented at the time the program was unveiled in 2013, was a small, boxy multirotor system. But the company's thinking appears to have evolved dramatically since then. One of the more well-known designs is the large vertical take-off and landing system featured in a [popular PrimeAir commercial](#), which transfers to horizontal flight once it reaches an appropriate altitude. Meanwhile, [in a live test delivery near](#) the program's research facility in the U.K., the company used a more traditional multirotor design.

When the delivery program is implemented, it is likely that the company won't employ one single drone design. In [an early patent that provided](#) an overview of the program (Ref. 1), the company describes how it may use a wide variety of drone designs to account for the diversity of types of packages that they will carry. The patents that Amazon has been awarded so far provide many clues as to the different forms that its drones might take. One patent (Ref. 53) [shows a foldable multirotor drone](#) that would transform itself into a compact shape for takeoff, landing, and operations through tight spaces, and then unfold itself for regular flight. The patent describes how the system's foldable arms could also be adjusted dynamically

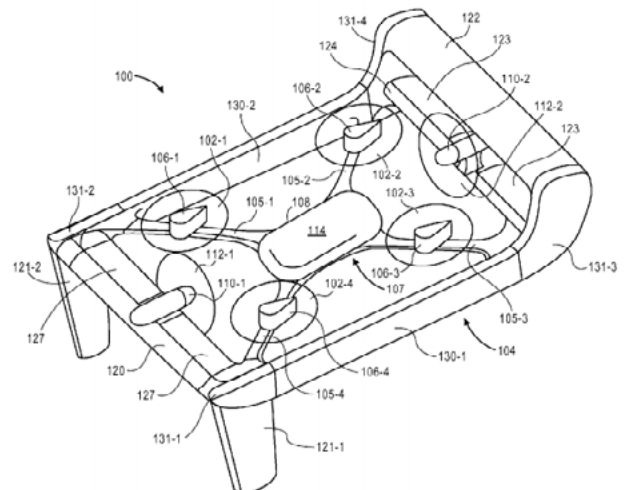


Ref. 24 "In-flight reconfigurable hybrid unmanned aerial vehicle"

in response to environmental conditions to help optimize the aircraft's efficiency in flight.

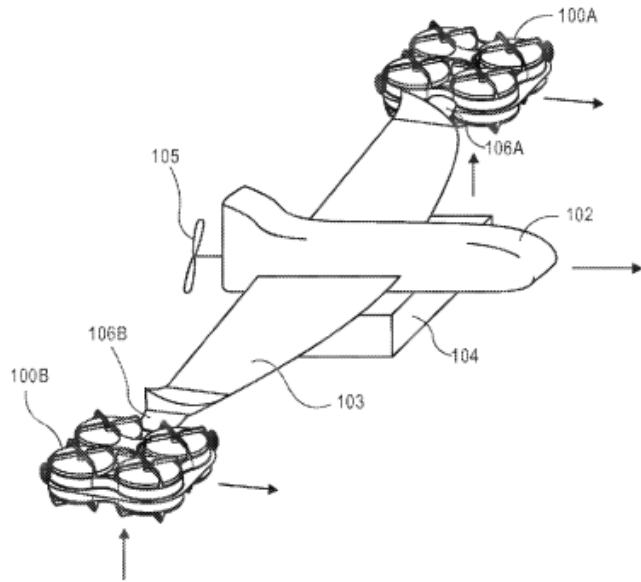
Another patent, [filed by the company in 2014](#) (Ref. 24), describes a foldable fixed-wing drone that can take off and land vertically. During take-off and landing, the drone's wings and tail would fold so as to provide additional points on which the system can sit. At cruising altitude, the system would unfold and transition to horizontal flight. (The benefit of such a system is that it can fly more quickly than traditional rotor drones but doesn't require a landing strip like traditional fixed-wing drones.) Another patented drone design [features an unusual tri-wing configuration](#) (Ref. 21).

The company also appears to be experimenting with alternate means of combining the versatility of



Ref. 21 "Unmanned Aerial Vehicle with a Tri-Wing Configuration"

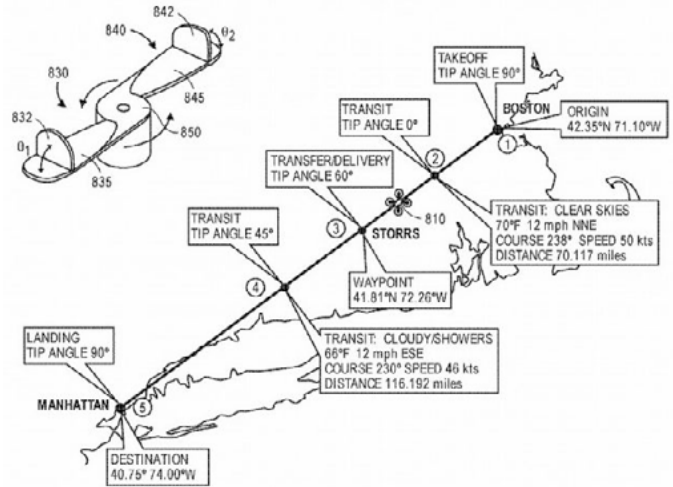
rotor drones with the speed and efficiency of fixed-wing systems. In 2017, the company was awarded a patent (Ref. 41) for a system by which small multirotor [drones would vertically lift a fixed-wing drone](#) off the ground to an altitude where it can begin flying on its own. Once the fixed-wing drone has been dispatched, the rotor drone would then return to base to launch the next system. (Boeing Insitu, a U.S firm that primarily makes drones for military operations, has demonstrated a similar system).



Ref. 41 "Using multirotor lifters to deploy fixed wing aircraft"

The company is also looking into the idea of [modular drones](#) that can be built to-order for each flight by a robotic system. A patent awarded (Ref. 6) to the company in 2016 shows how a robot would select components, including the vehicle's airframe and its sensor type, based on the characteristics of the package, the weather conditions, the length of the route, and other factors.

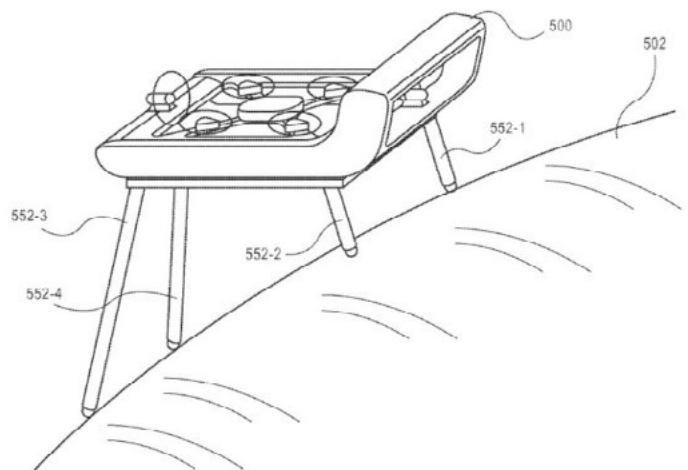
Further patents awarded to the company in 2016 and 2017 [offer additional details about](#) possible designs and features for Amazon's delivery drones. [One patent](#) (Ref. 36) describes a drone equipped with a variable landing gear that senses the contours of the landing surface and adjusts the length of each of its legs so that the drone is horizontal when it settles on the ground. Once they have landed, these drones might deploy a barbed spike that affixes to the ground for further stability. This design is intended to help protect fragile goods when the drone lands on uneven surfaces. Another



Ref. 31 "Geometrically reconfigurable propellers" This image shows the design for an adjustable propeller as well as how such a system would adjust for varying conditions along a flight route.

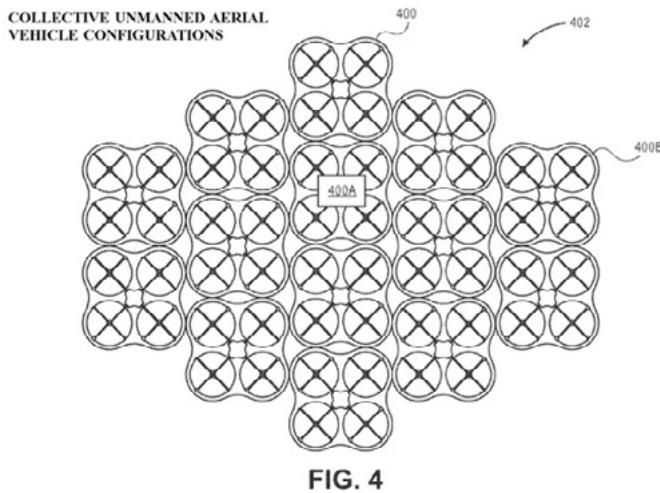
[patent](#) (Ref. 31) describes a design for drone propellers with adjustable tips that can fold up or down to reduce drag depending on environmental conditions, which the drone would sense automatically.

Another design patent, awarded to the company in June 2017 (Ref. 56), describes how the company's drone propellers would [feature a serrated leading edge](#) to cut down on the noise created by the systems while in flight. (The company has been awarded at least three other patents for noise abatement: [a drone that would generate](#) supplementary noises to counter the undesirable acoustics produced by its rotors (Ref. 16), a [second noise masking](#) system (Ref. 41), and [a randomized motor speed design](#) that would reduce tonal noise (Ref. 11).) Another patent (Ref. 17) describes a drone that can be controlled [by humans with hand gestures](#).



Ref. 36 "Unmanned Aerial Vehicle Descent"

Another challenge that the company is looking to address is payload capacity and endurance. Individual drones are significantly limited in their ability to carry heavy payloads for extended periods. According to the company, its drones will generally only carry packages weighing less than five pounds for under 30 minutes. In order to be able to transport a greater volume of goods and yet also fly for longer periods, the company has patented a “Collective Unmanned Aerial Vehicles” system (Ref. 20) by which many small delivery drones can be attached to each other to form a single large flying aircraft with greatly increased range and payload.



Ref. 20 “Collective Unmanned Aerial Vehicle Configurations”

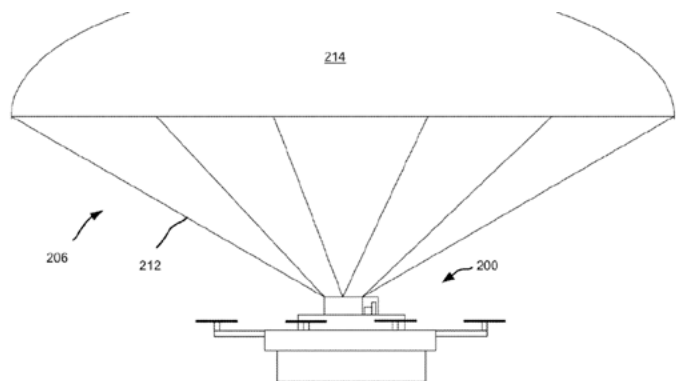
Safety and Security Features

Safety has been a primary concern among policymakers evaluating the feasibility of Amazon and other companies’ proposed drone delivery programs. In order to be permitted to conduct autonomous drone operations over populated areas, Amazon will need to demonstrate that its system will not pose a potential threat to public safety, even when a drone suffers a catastrophic failure. To address these concerns and ensure that potential hazards arising from widespread drone delivery are minimized, Amazon has patented (Ref. 39) a collision system for drones based on the system it uses for its Blue Origin rockets. According to the patent, when the drone’s sensors detect a system failure or an imminent collision, it will deploy parachutes or airbags, or some combination thereof. The patent also describes how a drone might feature emergency gas-based propulsion systems that would orient the drone so that its rotors are facing

upward, thereby minimizing the risk of injury to people below. An additional patent outlines a safety system (Ref. 29) that shuts off the aircraft’s rotors if it detects an imminent collision, while a patent issued to the company in June 2017 (Ref. 58) describes drones that would be equipped with secondary motors that would kick in when a primary motor fails.

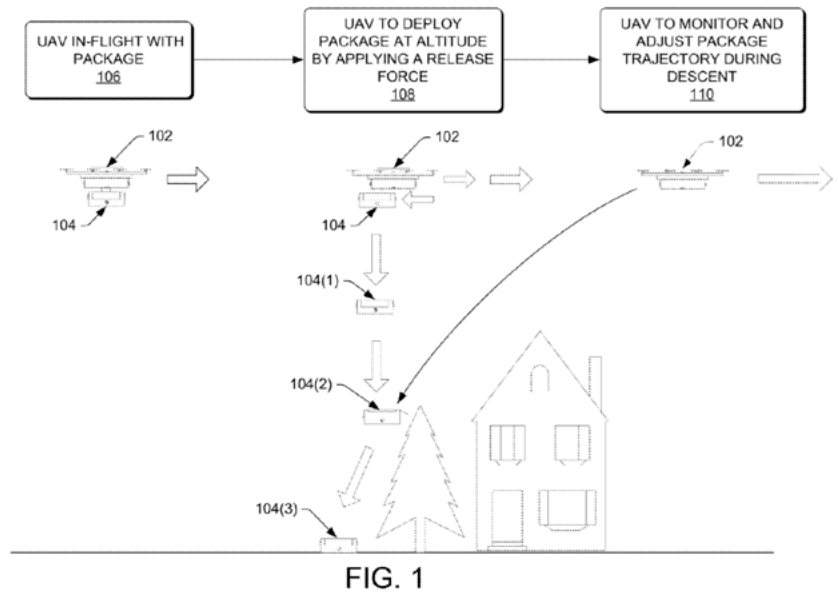
Another requisite for wide-scale autonomous drone operations is that the aircraft be capable of automatically avoiding collisions with other aircraft in the airspace without direct human control. Without the ability to detect and avoid other objects, especially other aircraft, Amazon’s PrimeAir system is unlikely to be approved by the Federal Aviation Administration or other countries’ aviation authorities. One of Amazon’s earliest delivery drone patents, published in 2015 (Ref. 2), describes how the delivery drones’ collision avoidance system might rely on a variety of sensors, including sonar and laser rangefinders that can determine the precise distance between the drone and an obstacle. In June 2017, the company was awarded a patent for one possible sense-and-avoid system design (Ref. 54) based on acoustic sensors that could alert the drone to the presence of nearby aircraft. Obstacles near the landing zone for package deliveries could also pose a threat; to ensure that all landings are safe, Amazon has patented a system by which the drones analyze images of the landing area as they descend in order to determine that it is clear and safe (Ref. 36). That being said, even the safest systems might still fail, and so Amazon has patented a protective cover design (Ref. 9) to shield persons or property from the drone’s fast-spinning rotors in a collision.

Others have voiced concerns that Amazon’s drones could be susceptible to hacking. In order



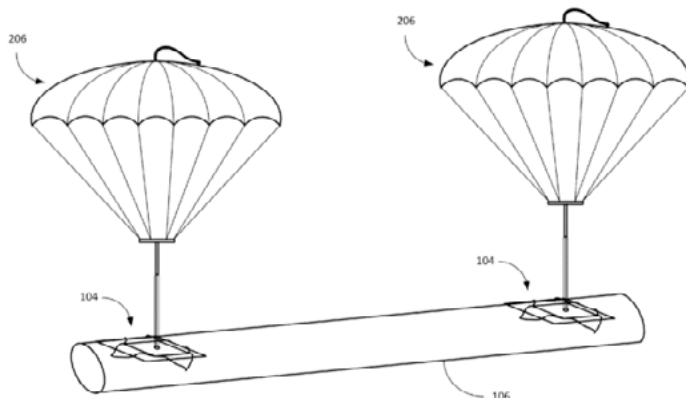
Ref. 39 “Damage avoidance system for unmanned aerial vehicle”

to address these concerns, [Amazon filed a patent](#) (Ref. 18) for a system to protect its delivery drones from hacking and spoofing. According to the patent, which was awarded in 2016, the system would employ a heavily encrypted mesh network established among its drones that could evaluate whether any single drone within the network has been compromised. If the system detects that a drone has been hacked, it will direct the aircraft to land or hand control over to another airborne drone in the network. In [another patent awarded in August](#) 2017 (Ref. 61), the company proposes a technique for determining whether data received by a delivery drone can be trusted (if the drone determines that it cannot be trusted, it will ignore the data).



Air-to-Ground Delivery Mechanisms

Many have wondered how exactly the PrimeAir drones will physically get their packages from the air to the ground safely and reliably without the item breaking or causing harm to persons or property below. In its commercial demonstration of the concept for the delivery program, as well as in its first live delivery test, the drone physically landed on a designated landing pad in the customer's backyard. But landing a drone isn't necessarily safe or feasible in every scenario, so the company has also secured patents for a variety of methods for putting packages on the ground without having to physically land the drone itself. In one patent, filed in 2015 (Ref. 52), the company proposes using a [lightweight winch](#) to slowly lower goods to the ground from a low altitude. The design features a counterbalance system to keep the goods from swaying as they descend.



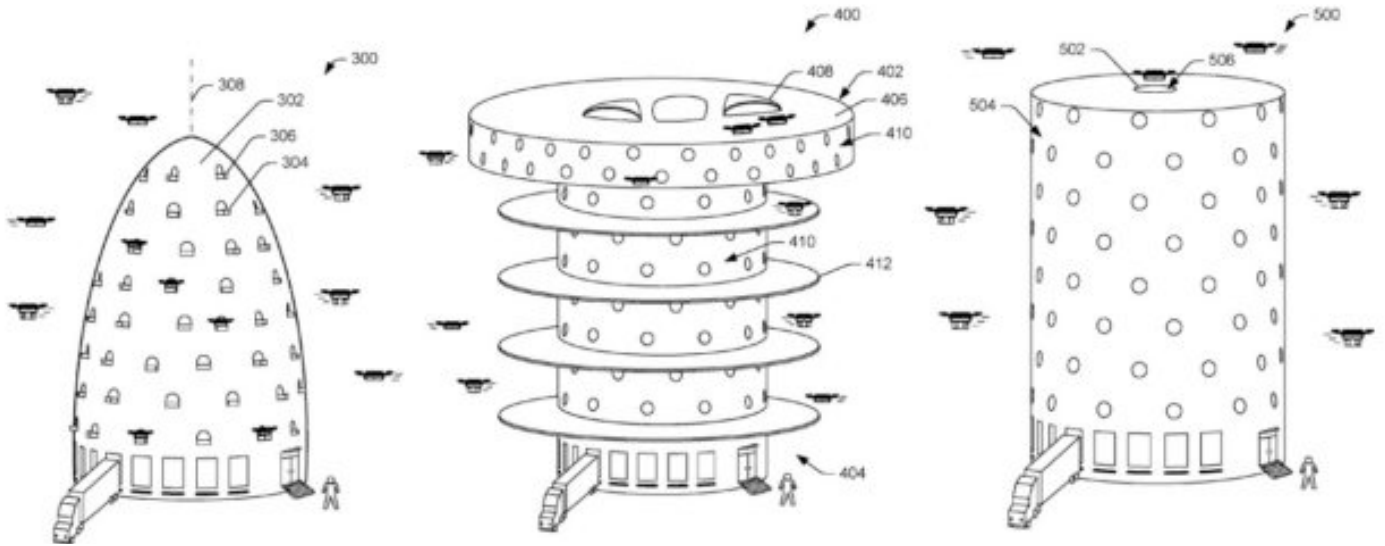
Ref. 48 "Aerial package Delivery System"

Ref. 27 "Maneuvering a package following in-flight release from an unmanned aerial vehicle"

A [second winch system](#) patent (Ref. 58) describes how the drone may jettison a part of the tether along with the package, depending on the altitude at which it is flying.

The company is also looking to potentially lower goods to the ground using parachute systems. In 2017, the company was awarded patents for three separate parachute-based systems. In the [design described by one](#) of the patents (Ref. 27), the drone would eject the package while hovering over the target destination, using pneumatic actuators, spring coils, and electromagnets to ensure that the goods fall in the right direction. A second patent [describes a low-cost parachute](#) system (Ref. 48) built into a package's shipping labels. Some packages may not even require parachutes. An alternate idea patented by the company in early 2017 (Ref. 22) would encase [packages in protective foam](#), allowing the drone to simply drop the goods onto the delivery area without a parachute.

In certain circumstances, such as in cluttered environments or windy conditions, a parachute, a winch, or a simple air drop might not be effective or safe. In a patent awarded in August 2017 that addresses this concern (Ref. 62), the company describes a [retractable chute system](#) attached to the underside of a drone that can be used to funnel goods to the ground (as well as dampen the sound of the drone, according to the patent).



Ref. 55 "Multi-level fulfillment center for unmanned aerial vehicles"

delivery drones could land and recharge, wait for inclement weather conditions to pass, or pick up and deliver packages. A central control system would help direct individual drones to their docking stations, calculating the best route based on factors such as prevailing wind conditions. (The company was awarded a second [patent for a similar system](#) (Ref. 19) six months later.)

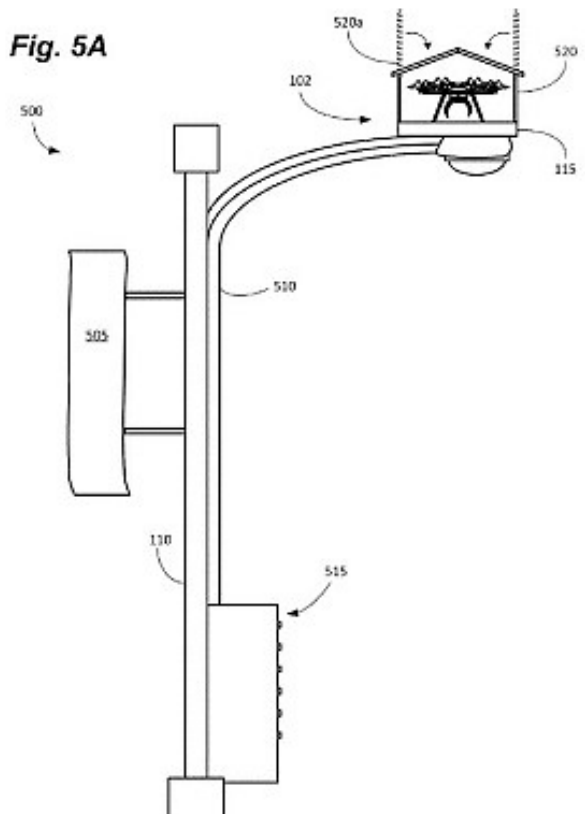
Today, Amazon's massive ground-based delivery networks are built around large warehouses called fulfillment centers, usually located on the outskirts of cities. But these centers would be too remote for drones to reach the company's urban customers. To work around the issue, the company has patented a concept for high-rise drone delivery fulfillment centers (Ref. 55) that would be located within cities and other densely populated areas. These towers, which may be staffed primarily by robotic systems, would feature multiple take-off and landing ports to allow increased drone traffic, and may be large enough for the drones to fly around inside.

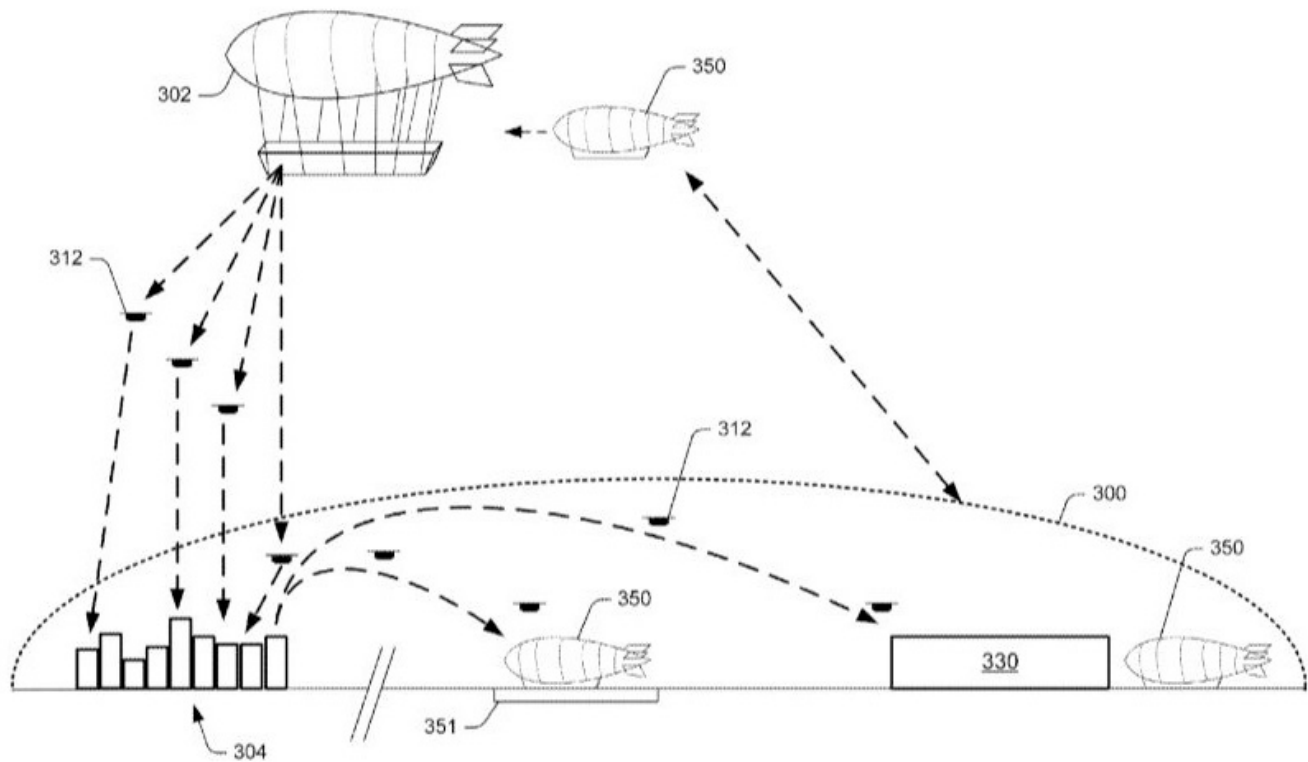
Eventually, Amazon delivery drones might not even take off and land from fixed sites. Even ground-based Amazon delivery drones might not necessarily take off and land from fixed sites. In September 2016, the company was awarded a patent for technologies (Ref. 15) that would enable drones [to land on moving vehicles](#). Under the proposed system, Amazon would enter into agreements with a number of shipping companies for permission to land their drones on transportation vehicles such as trucks or vans in cases where those vehicles are travelling to an area that is close to the drone's

Docking Stations and Fulfillment Centers

The battery life of small commercial drones has proven to be a major limiting factor for the technology. A drone delivery program, which would require aircraft to operate for extended periods over long distances, might be hampered by the battery life of each individual drone. In July 2016, Amazon was awarded a [patent for drone docking stations](#) (Ref. 8) that would be mounted on tall structures such as lamp posts, cell phone towers, and churches where

Ref. 8 "Multi-use UAV docking station systems and methods"





Ref. 4 “Airborne fulfillment center utilizing unmanned aerial vehicles for item delivery”

destination, effectively allowing the drone to hitch a ride and conserve its battery power. The patent notes that the drones could also use these vehicles as landing points in emergency situations, such as loss of power or mechanical issues.

An even loftier concept is the company’s “[airborne fulfillment center](#)” (Ref. 4), which Amazon patented in 2016. These systems would be giant fulfillment airships that orbit an area at 45,000 feet, serving as a mobile hub for networks of delivery drones. The patent notes that the major benefit of such a design would be that the drones can effectively glide from the fulfillment center to the delivery location without using any power. Smaller airships would supply the airborne fulfillment centers with fuel, new goods for delivery, and human operators. In August, 2017, Wal-Mart, which is developing a delivery drone program of its own, [patented a design for a similar floating warehouse](#) concept. Amazon has also proposed using high-altitude airships to monitor its delivery drones—in a patent (Ref. 64) awarded in August 2017, the company outlines the design for an airship that loiters at 45,000 feet, monitoring every delivery drone in a large coverage area.

In a [patent](#) from August 2017 (Ref. 60) that builds on this idea, the company proposes mobile main-

tenance facilities that could be mounted on trains, container ships, or trucks. These facilities, which would be equipped with automated systems for retrieving the drones, replacing their batteries, and loading them with new products for delivery, could be deployed to areas where demand is expected to be particularly high. These facilities could also be equipped to carry out repairs on damaged drones, sparing the company the hassle of having to send its aircraft back to large facilities that may be further away from the delivery area.

➤ Amazon's Other Drone Patents

Though the majority of Amazon’s drone-related patents appear to be geared toward its proposed delivery program, the company has also filed a number of patents involving drones that are not intended specifically for delivery. In 2016, the company was granted a patent for a miniature [voice-controlled drone assistant](#), potentially for law enforcement applications. Additional patents describe how the company may use drones to [manage inventory](#) and even [transport canvas tote](#) bags for employees within fulfillment facilities. The company has also patented a design [for an RFID reader drone](#) that can operate within inventory facilities.

Table of Patents

Ref #	Patent #	Award Date	Patent Title	Abstract	Link
1	20150120094	4/30/2015	Unmanned Aerial Vehicle Delivery System	This disclosure describes an unmanned aerial vehicle ("UAV") configured to autonomously deliver items of inventory to various destinations. The UAV may receive inventory information and a destination location and autonomously retrieve the inventory from a location within a materials handling facility, compute a route from the materials handling facility to a destination and travel to the destination to deliver the inventory.	Source
2	US20150277440A1	10/1/2015	Sense and avoid for automated mobile vehicles	This disclosure describes an automated mobile vehicle that includes one or more distance determining elements configured to detect the presence of objects and to cause the automated mobile vehicle to alter its path to avoid the object. For example, a distance determining element may be incorporated into one or more of the motors of the automated mobile vehicle and configured to determine a distance to an object. Based on the determined distance, a path of the automated mobile vehicle may be altered.	Source
3	20150379876	12/31/2015	Object Avoidance for Automated Aerial Vehicles	This disclosure describes an automated aerial vehicle that includes one or more object detection elements configured to detect the presence of objects and an avoidance determining element configured to cause the automated aerial vehicle to automatically determine and execute an avoidance maneuver to avoid the objects. For example, an object may be detected and an avoidance maneuver determined based on a position of the object and an object vector representative of a direction and a magnitude of velocity of the object.	Source
4	9,305,280	5/5/2016	Airborne fulfillment center utilizing unmanned aerial vehicles for item delivery	Described is an airborne fulfillment center ("AFC") and the use of unmanned aerial vehicles ("UAV") to deliver items from the AFC to users. For example, the AFC may be an airship that remains at a high altitude (e.g., 45,000 feet) and UAVs with ordered items may be deployed from the AFC to deliver ordered items to user designated delivery locations. As the UAVs descend, they can navigate horizontally toward a user specified delivery location using little to no power, other than to stabilize the UAV and/or guide the direction of descent. Shuttles (smaller airships) may be used to replenish the AFC with inventory, UAVs, supplies, fuel, etc. Likewise, the shuttles may be utilized to transport workers to and from the AFC.	Source
5	2016077391	5/19/2016	Unmanned aerial vehicle configuration for extended flight	This disclosure describes a configuration of an unmanned aerial vehicle (UAV) that will facilitate extended flight duration. The UAV may have any number of lifting motors. For example, the UAV may include four lifting motors (also known as a quad-copter), eight lifting motors (octo-copter), etc. Likewise, to improve the efficiency of horizontal flight, the UAV also includes a pushing motor and propeller assembly that is oriented at approximately ninety degrees to one or more of the lifting motors. When the UAV is moving horizontally, the pushing motor may be engaged and the pushing propeller will aid in the horizontal propulsion of the UAV.	Source
6	9,348,333	5/24/2016	Modular air delivery	Aspects of modular airborne delivery are described. When a shipping container is provided to an airborne carrier for delivery, the airborne carrier may assess weather across a route for airborne delivery of the shipping container, evaluate an approach to drop the shipping container at a delivery zone, and calculate a remaining amount of time until a target delivery time, for example. The airborne carrier may then select components to assemble a modular unmanned aerial vehicle (UAV) based on those or other factors, and assemble the UAV using the selected components. The modular UAV may then be directed to deliver the shipping container according to instructions from the airborne carrier. According to the concepts described herein, flexibility and other advantages may be achieved using modular UAVs for airborne delivery.	Source

Ref #	Patent #	Award Date	Patent Title	Abstract	Link
7	9,376,208	6/28/2016	On-board redundant power system for unmanned aerial vehicles	An unmanned aerial vehicle ("UAV") is configured with a redundant power generation system on-board the UAV. A redundant power system on-board the UAV can selectively utilize an auxiliary power source during operation and/or flight of the UAV. The power system on-board the UAV may include a battery and at least one auxiliary power source comprising a combustion engine. The combustion engine on-board the UAV may be selectively operated to charge the battery when a charge level of the battery is below a full charge level, and/or to power one or more propeller motors of the UAV.	Source
8	9,387,928	7/12/2016	Multi-use UAV docking station systems and methods	Systems and methods for providing a series of multiuse UAV docking stations are disclosed. The docking stations can be networked with a central control and a plurality of UAVs. The docking stations can include a number of services to facilitate both UAV guidance and maintenance and community acceptance and benefits. The docking stations can include package handling facilities and can act as a final destination or as a delivery hub. The docking stations can extend the range of UAVs by providing recharging/refueling stations for the UAVs. The docking stations can also include navigational aid to guide the UAVs to the docking stations and to provide routing information from the central control. The docking stations can be incorporated into existing structures such as cell towers, light and power poles, and buildings. The docking stations can also comprise standalone structures to provide additional services to underserved areas.	Source
9	20160229530	8/11/2016	Unmanned Aerial Vehicle Protective Frame Configuration	This disclosure describes a configuration of an unmanned aerial vehicle (UAV) that includes a frame that provides both structural support for the UAV and protection for foreign objects that may come into contact with the UAV. The UAV may have any number of lifting motors. For example, the UAV may include four lifting motors (also known as a quad-copter), eight lifting motors (octo-copter), etc. Likewise, to improve the efficiency of horizontal flight, the UAV may also include one or more pushing motor and propeller assemblies that are oriented at approximately ninety degrees to one or more of the lifting motors. When the UAV is moving horizontally, the pushing motor(s) may be engaged and the pushing propeller(s) will aid in the horizontal propulsion of the UAV.	Source
10	9,415,869	8/16/2016	Mobile Antenna Array	A plurality of UAVs may be operated in a fleet, each of the UAVs in the fleet being configured to work collectively to achieve one or more functions, such as to create a display or implement an antenna array. The fleet of UAVs may operate individually and/or may be coupled to one another to operate as a collective unit. In some embodiments, one or more UAVs in the fleet may operate individually, while two or more UAVs in the fleet may be connected to one another. In such embodiments, the individual UAVs and the connected UAVs may together comprise the fleet.	Source
11	9,422,055	8/23/2016	Unmanned aerial vehicle motor driving randomization for noise abatement	This disclosure is directed to varying a speed of one or more motors in an unmanned aerial vehicle (UAV) to reduce unwanted sound (i.e., noise) of the UAV. A UAV may include motors coupled with propellers to provide lift and propulsion to the UAV in various stages of flight, such as while ascending, descending, hovering, or transiting. The motors and propellers may generate noise, which may include a number of noise components such as tonal noise (e.g., a whining noise such as a whistle of a kettle at full boil) and broadband noise (e.g., a complex mixture of sounds of different frequencies, such as the sound of ocean surf). By varying the controls to the motors, such as by varying the speed or revolutions per minute (RPM) of a motor during operation by providing random or pseudo-random RPM variations, the UAV may generate a noise signature with reduced tonal noise.	Source

Ref #	Patent #	Award Date	Patent Title	Abstract	Link
12	9,421,869	8/23/2016	Deployment and adjustment of airborne unmanned aerial vehicles	This disclosure describes a power unmanned aerial vehicle (UAV) that may generate a current from a magnetic field of an overhead power line. In various implementations, while the power UAV is flying, the power UAV may receive another UAV at a platform. A control element of the power UAV may generate signals to cause the power UAV to fly to a location of a conductor of the power line. The control element may also determine a position of the secondary coil with respect to the power line and generate control signals to adjust the position of the secondary coil based on the determined position of the secondary coil, a determined safety distance, and/or a determined threshold distance for efficient current generation. A shielding substrate may also be provided to shield electronics of the power UAV or other UAVs from magnetic fields.	Source
13	9,454,154	9/2/2016	Incident light sensor on autonomous vehicle	An incident light meter on an autonomous vehicle receives ambient light and outputs an incident light measurement in response the ambient light. One or more image sensors of the autonomous vehicle image the environment of the autonomous vehicle. An exposure setting is generated at least in part on the incident light measurement. The one or more image sensors capture a digital image at the exposure setting.	Source
14	9,409,642	9/9/2016	Collapsible lift propellers	Aerial vehicles may be equipped with collapsible lift propellers and thrust propellers. The collapsible lift propellers may include retractable tips that may pivot or rotate from a first orientation substantially co-aligned with a main body of the collapsible lift propellers during ordinary operations and a second orientation substantially transverse to the main body of the collapsible lift propellers when rotation of the collapsible lift propellers is stopped. The collapsible lift propellers may further include biasing elements, e.g., springs for biasing the retractable tips into the second orientation, and mechanical stops for inhibiting the pivoting or rotation of the retractable tips beyond the first orientation.	Source
15	20160257401	9/9/2016	Landing of unmanned aerial vehicles on moving transportation vehicles for transport	Unmanned aerial vehicles ("UAVs") (400) which fly to destinations (e.g., for delivering items) may land on transportation vehicles (e.g., delivery trucks, etc.) (201) for temporary transport. An agreement with the owner of the transportation vehicles (e.g., a shipping carrier) may be made for obtaining consent and determining compensation for landings, and the associated transportation vehicles that are available for landings may be identified by markers on the roof or other identification techniques. The routes of the transportation vehicles (201) may be known and utilized to determine locations where UAVs (400) will land on and take off from the transportation vehicles (201), and in cases of emergencies (e.g., due to low batteries, mechanical issues, etc.) the UAVs (400) may land on the transportation vehicles (201) for later retrieval.	Source
16	9,442,496	9/13/2016	Active airborne noise abatement	Noises that are to be emitted by an aerial vehicle during operations may be predicted using one or more machine learning systems, algorithms or techniques. Anti-noises having equal or similar intensities and equal but out-of-phase frequencies may be identified and generated based on the predicted noises, thereby reducing or eliminating the net effect of the noises. The machine learning systems, algorithms or techniques used to predict such noises may be trained using emitted sound pressure levels observed during prior operations of aerial vehicles, as well as environmental conditions, operational characteristics of the aerial vehicles or locations of the aerial vehicles during such prior operations. Anti-noises may be identified and generated based on an overall sound profile of the aerial vehicle, or on individual sounds emitted by the aerial vehicle by discrete sources.	Source

Ref #	Patent #	Award Date	Patent Title	Abstract	Link
17	9,459,620	10/4/2016	Human interaction with unmanned aerial vehicles	The unmanned aerial vehicle may include a propulsion device, a sensor device, and a management system. In some examples, the management system may be configured to receive human gestures via the sensor device and, in response, instruct the propulsion device to affect an adjustment to the behavior of the unmanned aerial vehicle. Human gestures may include visible gestures, audible gestures, and other gestures capable of recognition by the unmanned vehicle.	Source
18	9,524,648	12/20/2016	Countermeasures for threats to an uncrewed autonomous vehicle	Uncrewed autonomous vehicles ("UAVs") may navigate from one location to another location. Described herein are systems, devices, and methods providing countermeasures for threats that may compromise the UAVs. A plurality of UAVs may establish a mesh network to distribute information to one another. A first UAV may receive external data from a second UAV using the mesh network. The external data may be used to confirm or cross-check data such as location, heading, altitude, and so forth. Disagreement between data generated by the first UAV with external data from the second UAV may result in the determination that the first UAV is compromised. Remedial actions may be taken, such as the first UAV may be directed to a safe location to land or park, may receive commands from another UAV, and so forth.	Source
19	9,527,605	12/27/2016	Multi-use unmanned aerial vehicle docking station	Systems and methods for providing a series of multiuse UAV docking stations. The docking stations can be networked with a central control and a plurality of UAVs. The docking stations can include a number of services to facilitate both UAV guidance and maintenance and community acceptance and benefits. The docking stations can include package handling facilities and can act as a final destination or as a delivery hub. The docking stations can extend the range of UAVs by providing recharging/refueling stations for the UAVs. The docking stations can also include navigational aid to guide the UAVs to the docking stations and to provide routing information from the central control. The docking stations can be incorporated into existing structures such as cell towers, light and power poles, and buildings. The docking stations can also comprise standalone structures to provide additional services to underserved areas.	Source
20	20160378108	12/29/2016	Collective Unmanned Aerial Vehicle Configurations	This disclosure describes a collective UAV in which multiple UAVs may be coupled together to form the collective UAV. A collective UAV may be used to aerially transport virtually any size, weight or quantity of items, travel longer distances, etc. For example, rather than using one large UAV to carry a larger or heavier item, multiple smaller UAVs may couple together to form a collective UAV that is used to carry the larger or heavier item.	Source
21	20160375997	12/29/2016	Unmanned Aerial Vehicle with a Tri-Wing Configuration	This disclosure describes a configuration of an unmanned aerial vehicle (UAV) that includes a substantially polygonal perimeter frame and a central frame. The perimeter frame includes a front wing, a lower rear wing, and an upper rear wing. The wings provide lift to the UAV when the UAV is moving in a direction that includes a horizontal component. The UAV may have any number of lifting motors. For example, the UAV may include four lifting motors (also known as a quad-copter), eight lifting motors (octo-copter), etc. Likewise, to improve the efficiency of horizontal flight, the UAV may also include one or more thrusting motors and corresponding thrusting propellers. When the UAV is moving horizontally, the thrusting motor(s) may be engaged and the thrusting propeller(s) will aid in the horizontal propulsion of the UAV.	Source

Ref #	Patent #	Award Date	Patent Title	Abstract	Link
22	9,536,216	1/3/2017	Delivery of packages by unmanned aerial vehicles	A package delivery apparatus uses an unmanned aerial vehicle (UAV) to deliver a package containing a product to a delivery destination area. The UAV uses GPS signals to guide it to the delivery destination area and an altimeter to determine its height above the delivery destination area. The UAV then adjusts its height to a preferred drop or release height for that package and product and releases the package. An optional camera allows a human operator to view the delivery destination area. An expandable foam package surrounds the product to protect the product from impact and moisture. The package may be streamlined to reduce air resistance and increase the range of the UAV. The package characteristics, such as its thickness, are determined based one or more of the weight and fragile nature of the product, and the drop height.	Source
23	9,550,577	1/24/2017	Electricity generation in automated aerial vehicles	This disclosure describes a system and method for operating an automated aerial vehicle wherein the battery life may be extended by performing one or more electricity generation procedures on the way to a destination (e.g., a delivery location for an item). In various implementations, the electricity generation procedure may include utilizing an airflow to rotate one or more of the propellers of the automated aerial vehicle so that the associated propeller motors will generate electricity (e.g., which can be utilized to recharge the battery, power one or more sensors of the automated aerial vehicle, etc.). In various implementations, the airflow may consist of a wind, or may be created by the kinetic energy of the automated aerial vehicle as it moves through the air (e.g., as part of a normal flight path and/or as part of an aerial maneuver).	Source
24	9,550,567	1/24/2017	In-flight re-configurable hybrid unmanned aerial vehicle	This disclosure is directed to an unmanned aerial vehicle ("UAV") that transitions in-flight between vertical flight configuration and horizontal flight configuration by changing an orientation of the UAV by approximately ninety degrees. The UAV may include propulsion units that are coupled to a wing. The wing may include wing segments rotatably coupled together by pivots that rotate to position the propulsion units around a center of mass of the UAV when the fuselage is oriented perpendicular with the horizon. In this vertical flight configuration, the UAV may perform vertical flight or hover. During the vertical flight, the UAV may cause the wing to extend outward via the pivots such that the wing segments become positioned substantially parallel to one another and the wing resembles a conventional fixed wing. With the wing extended, the UAV assumes a horizontal flight configuration that provides upward lift generated from the wing.	Source
25	US 9550561 B1	1/24/2017	Determining center of gravity of an automated aerial vehicle and a payload	This disclosure describes a system and method for determining the center of gravity of a payload engaged by an automated aerial vehicle and adjusting components of the automated aerial vehicle and/or the engagement location with the payload so that the center of gravity of the payload is within a defined position with respect to the center of gravity of the automated aerial vehicle. Adjusting the center of gravity to be within a defined position improves the efficiency, maneuverability and safety of the automated aerial vehicle. In some implementations, the stability of the payload may also be determined to ensure that the center of gravity does not change or shift during transport due to movement of an item of the payload.	Source

Ref #	Patent #	Award Date	Patent Title	Abstract	Link
26	9,555,883	1/31/2017	Unmanned aerial vehicle sensor synchronization	Described are methods and apparatuses for synchronizing two or more sensors of an UAV. In the implementations described, a synchronization event is performed such that identifiable signals of the synchronization event can be collected by each sensor of the UAV. The synchronization event may be generated by a synchronization event component that generates multiple output signals (e.g., audio, visual, and physical) at approximately the same time so that different sensors can each collect and store at least one of the output signals. The collected signals are then compared and the sensors are adjusted to align the signals.	Source
27	9,567,081	2/7/2017	Maneuvering a package following in-flight release from an unmanned aerial vehicle (UAV)	A package delivery system can be implemented to forcefully propel a package from an unmanned aerial vehicle (UAV), while the UAV is in motion. The UAV can apply a force onto the package that alters its descent trajectory from a parabolic path to a vertical descent path. The package delivery system can apply the force onto the package in a number of different ways. For example, pneumatic actuators, electromagnets, spring coils, and parachutes can generate the force that establishes the vertical descent path of the package. Further, the package delivery system can also monitor the package during its vertical descent. The package can be equipped with one or more control surfaces. Instructions can be transmitted from the UAV via an RF module that cause the one or more controls surfaces to alter the vertical descent path of the package to avoid obstructions or to regain a stable orientation.	Source
28	9,561,849	2/7/2017	Vehicle configuration with motors that rotate between a lifting position and a thrusting position	This disclosure describes a configuration of an unmanned aerial vehicle ("UAV") that will facilitate extended flight duration. The UAV may have any number of lifting motors. For example, the UAV may include four lifting motors (also known as a quad-copter), eight lifting motors (also known as an octo-copter), etc. Likewise, to improve the efficiency of horizontal flight, the UAV also includes a pivot assembly that may rotate about an axis from a lifting position to a thrusting position. The pivot assembly may include two or more offset motors that generate a differential force that will cause the pivot assembly to rotate between the lifting position and the thrusting position without the need for any additional motors or gears.	Source
29	US 20170160750	2/16/2017	Virtual safety shrouds for aerial vehicles	An aerial vehicle and system for automatically detecting an object (e.g., human, pet, or other animal) approaching the aerial vehicle is described. When an approaching object is detected by an object detection component, a safety profile may be executed to reduce or avoid any potential harm to the object and/or the aerial vehicle. For example, if the object is detected entering a safety perimeter of the aerial vehicle, the rotation of a propeller closest to the object may be stopped to avoid harming the object and rotations of remaining propellers may be modified to maintain control and flight of the aerial vehicle.	Source
30	9,573,684	2/21/2017	Unmanned aerial vehicle delivery system	This disclosure describes an unmanned aerial vehicle ("UAV") configured to autonomously deliver items of inventory to various destinations. The UAV may receive inventory information and a destination location and autonomously retrieve the inventory from a location within a materials handling facility, compute a route from the materials handling facility to a destination and travel to the destination to deliver the inventory.	Source
31	9,573,674	2/21/2017	Collapsible lift propellers	Aerial vehicles may be equipped with collapsible lift propellers and thrust propellers. The collapsible lift propellers may include retractable tips that may pivot or rotate from a first orientation substantially co-aligned with a main body of the collapsible lift propellers during ordinary operations and a second orientation substantially transverse to the main body of the collapsible lift propellers when rotation of the collapsible lift propellers is stopped. The collapsible lift propellers may further include biasing elements, e.g., springs for biasing the retractable tips into the second orientation, and mechanical stops for inhibiting the pivoting or rotation of the retractable tips beyond the first orientation.	Source

Ref #	Patent #	Award Date	Patent Title	Abstract	Link
32	9,590,298	3/7/2017	Orientation of directional antennas	Systems, methods, and apparatus are provided for enabling orientation of directional antennas even when one or more of the directional antennas are moving. Position information for each directional antenna is transmitted using an omnidirectional antenna transmitting at a low bandwidth and a low power. The position information of the directional antennas is used to orient the directional antennas so that a high bandwidth, low power wireless connection can be enabled and/or maintained between the directional antennas. The position information is periodically transmitted and the orientation of the directional antennas is updated as one or more of the directional antennas move so that the wireless connection between the directional antennas is maintained.	Source
33	9,586,683	3/7/2017	Transitioning an unmanned aerial vehicle to horizontal flight	This disclosure describes a configuration of an unmanned aerial vehicle (UAV) that will facilitate extended flight duration. The UAV may have any number of lifting motors. For example, the UAV may include four lifting motors (also known as a quad-copter), eight lifting motors (octo-copter), etc. Likewise, to improve the efficiency of horizontal flight, the UAV also includes a thrusting motor and propeller assembly that is oriented at approximately ninety degrees to one or more of the lifting motors. When the UAV is moving horizontally, it may be determined if the horizontal airspeed of the UAV exceeds an airspeed threshold. If the horizontal airspeed exceeds the airspeed threshold, the thrusting motor may be engaged and the thrusting propeller will aid in the horizontal propulsion of the UAV.	Source
34	9,592,910	3/14/2017	Geometrically reconfigurable propellers	An aerial vehicle may be equipped with propellers having reconfigurable geometries. Such propellers may have blade tips or other features that may be adjusted or reconfigured while the aerial vehicle is operating, on any basis. Propellers having reconfigurable blade tips joined to blade roots may cause the blade tips to be aligned with the blade roots, or substantially perpendicular to the blade roots, e.g., in order to counter adverse effects of tip vortices, or at any intervening angle. The propellers may be reconfigured at predetermined times during operation of an aerial vehicle, or upon sensing one or more operational characteristics or environmental conditions, as may be desired or required.	Source
35	9,592,908	3/14/2017	Adjustable landing gear assembly for unmanned aerial vehicles	This disclosure describes a configuration of an unmanned aerial vehicle (UAV) landing gear assembly that includes adjustable landing gear extension that may be extended or contracted so that the body of the UAV is contained in a horizontal plane when the UAV is landed, even on sloping surfaces. For example, when a UAV is landing, the slope of the surface may be determined and the landing gear extensions adjusted based on the slope so that the body of the UAV remains approximately horizontal when the UAV lands and is supported by the landing gear extensions.	Source
36	20170090271	3/30/2017	Unmanned Aerial Vehicle Descent	Described are systems and methods for surveying a destination as an unmanned aerial vehicle ("UAV") descends toward the destination. To confirm that the destination is clear of objects and includes a safe landing or delivery location, such as a substantially planar surface, the UAV may capture and process images at different altitudes during the descent. Feature points of a first image captured at a first altitude may be paired with feature points of a second image captured at a second, different altitude. A homography may be computed to confirm that the paired feature points lie in the same plane and then the two images may be registered based on the paired feature points. The registered images may then be processed to determine depth information and determine if descent of the UAV is to continue or be aborted.	Source

Ref #	Patent #	Award Date	Patent Title	Abstract	Link
37	US20170090271	3/30/2017	Method to determine a planar surface for unmanned aerial vehicle descent	Described are systems and methods for surveying a destination as an unmanned aerial vehicle ("UAV") descends toward the destination. To confirm that the destination is clear of objects and includes a safe landing or delivery location, such as a substantially planar surface, the UAV may capture and process images at different altitudes during the descent. Feature points of a first image captured at a first altitude may be paired with feature points of a second image captured at a second, different altitude. A homography may be computed to confirm that the paired feature points lie in the same plane and then the two images may be registered based on the paired feature points. The registered images may then be processed to determine depth information and determine if descent of the UAV is to continue or be aborted.	Source
38	US20170088280 A1	3/30/2017	Floating motor mount for unmanned aerial vehicles	A motor mount assembly is provided for coupling a propeller motor to a body of an unmanned aerial vehicle (UAV). The motor mount assembly includes a floating portion and acts to attenuate frequencies of vibration from the propeller motor during operation, which modifies the corresponding noise that is produced and reduces stresses on the various components. The floating portion is surrounded on all sides by isolation portions (e.g., made of elastomers or other materials) that are held within a casing that attaches to the body of the UAV. In one implementation, the motor mount assembly is modular such that one or more of the isolation portions may be replaced with different isolation portions (e.g., having different attenuation properties), depending on the direction and nature of the vibrations from the propeller motor that are to be attenuated for a particular application.	Source
39	9,613,539	4/4/2017	Damage avoidance system for unmanned aerial vehicle	This disclosure describes an unmanned aerial vehicle ("UAV") and system that may perform one or more techniques for protecting objects from damage resulting from an unintended or uncontrolled impact by a UAV. As described herein, various implementations utilize a damage avoidance system that detects a risk of damage to an object caused by an impact from a UAV that has lost control and takes steps to reduce or eliminate that risk. For example, the damage avoidance system may detect that the UAV has lost power and/or is falling at a rapid rate of descent such that, upon impact, there is a risk of damage to an object with which the UAV may collide. Upon detecting the risk of damage and prior to impact, the damage avoidance system activates a damage avoidance system having one or more protection elements that work in concert to reduce or prevent damage to the object upon impact by the UAV.	Source
40	US 20170110017 A1	4/20/2017	Aerial vehicle delivery of items available through an e-commerce shopping site	This disclosure describes an unmanned aerial vehicle ("UAV") configured to autonomously deliver items of inventory to various destinations. The UAV may receive inventory information and a destination location and autonomously retrieve the inventory from a location within a materials handling facility, compute a route from the materials handling facility to a destination and travel to the destination to deliver the inventory.	Source
41	9,630,712	4/25/2017	Using multi-rotor lifters to deploy fixed wing aircraft	This disclosure describes systems and processes using multirotor lifter to deploy and/or engage fixed wing aircraft. For example, one or more unmanned multirotor lifters may engage an unmanned fixed wing aircraft, aurally navigate the fixed wing aircraft vertically to a desired altitude, and then release the fixed wing aircraft so that the fixed wing aircraft can initiate a flight plan. In some implementations, multirotor lifter may also be configured to engage fixed wing aircraft while both the multirotor lifters and the fixed wing aircraft are in flight.	Source

Ref #	Patent #	Award Date	Patent Title	Abstract	Link
42	9,646,597	5/9/2017	Delivery sound masking and sound emission	An unmanned aerial vehicle (UAV) may emit masking sounds during operation of the UAV to mask other sounds generated by the UAV during operation. The UAV may be used to deliver items to a residence or other location associated with a customer. The UAV may emit sounds that mask the conventional sounds generated by the propellers and/or motors to cause the UAV to emit sounds that are pleasing to bystanders or do not annoy the bystanders. The UAV may emit sounds using speakers or other sound generating devices, such as fins, reeds, whistles, or other devices which may cause sound to be emitted from the UAV. Noise canceling algorithms may be used to cancel at least some of the conventional noise generated by operation of the UAV using inverted sounds, while additional sound may be emitted by the UAV, which may not be subject to noise cancelation.	Source
43	9,646,502	5/9/2017	Universal unmanned aerial vehicle identification system	This disclosure is directed to an automated unmanned aerial vehicle ("UAV") self-identification system, devices, and techniques pertaining to the automated identification of individual UAVs operating within an airspace via a mesh communication network, individual UAVs and a central authority representing nodes of the mesh network. The system may detect nearby UAVs present within a UAV's airspace. Nearby UAVs may self-identify or be identified via correlation with one or more features detected by the UAV. The UAV may validate identifying information using a dynamic validation policy. Data collected by the UAV may be stored in a local mesh database and distributed to individual nodes of the mesh network and merged into a common central mesh database for distribution to individual nodes of the mesh network. UAVs on the mesh network utilize local and central mesh database information for self-identification and to maintain a dynamic flight plan.	Source
44	9,643,718	5/9/2017	Simulated ground effect for aerial vehicles	Ground effect acting on an aerial vehicle, such as an unmanned aerial vehicle, may be simulated by discharging a gas around propeller blades of the aerial vehicle while the propeller blades are rotating. For example, a gas, such as air, may be discharged at or near the tip of the propeller blades with enough velocity to disrupt the airflow around the blade tips, thereby altering the sound generated by rotation of the propeller blade.	Source
45	9,650,136	5/16/2017	Unmanned aerial vehicle payload delivery	Techniques for using an unmanned aerial vehicle (UAV) to deliver a payload may be provided. For example, upon arrival to a delivery location, the UAV may release the payload and lower a tether coupling the payload to the UAV. Based on a distance associated with the lowering of the payload, the UAV may release the cable. This release may decouple the payload and at a least a portion of the cable from the UAV, thereby delivering the payload at the delivery location.	Source
46	9,656,749	5/23/2017	Unmanned aerial vehicle physical metrics acquisition	A weight distribution associated with an unmanned aerial vehicle (UAV) may be determined prior to dispatch of the UAV and/or after the UAV returns from operation (e.g., a flight). In some embodiments, one or more UAVs may be placed on or proximate to a physical metrics acquisition (PMA) device. The PMA device may include a grid or array of load cells may be used to determine a distribution of weight of the UAV at three or more points associated with the UAV. The distribution of weight may be used generate analytics, which may include a total weight of a vehicle, a center of mass of the vehicle (in two or more dimensions), power requirements of the UAV for a given flight task (e.g., how much battery power the UAV requires, etc.), and/or other analytics. In various embodiments, the PMA device may perform moment of inertia tests for the UAV.	Source

Ref #	Patent #	Award Date	Patent Title	Abstract	Link
47	9,663,236	5/30/2017	Selectively thrusting propulsion units for aerial vehicles	Aerial vehicles may include propulsion units having motors with drive shafts that may be aligned at a variety of orientations, propellers with variable pitch blades, and common operators for aligning the drive shafts at one or more orientations and for varying the pitch angles of the blades. The common operators may include plate elements to which a propeller hub is rotatably joined, and which may be supported by one or more linear actuators that may extend or retract to vary both the orientations of the drive shafts and the pitch angles of the blades. Operating the motors and propellers at varying speeds, gimbals angles or pitch angles enables the motors to generate forces in any number of directions and at any magnitudes. Attributes of the propulsion units may be selected in order to shape or control the noise generated thereby.	Source
48	9,663,234	5/30/2017	Aerial package Delivery System	Systems and methods for delivering packages via aerial vehicles are disclosed. The system can comprise a label that includes a parachute to enable the packages to be dropped from the aerial vehicle, yet land at the package's destination without damage. The system can include a self-adhesive backing, a plurality of parachute cords, a parachute, and a breakaway cover. The parachute cords can include a shock absorber to reduce the shock on the package of the parachute opening. The parachute and/or the breakaway cover can include graphics to provide address, velocity, or spin information for the package. The parachute cords can include a harness to separate the cords and reduce tangling of the cords and spinning of the parachute canopy with respect to the package.	Source
49	9,663,226	5/30/2017	Influencing acceptance of messages in unmanned vehicles	An unmanned vehicle receives a message from another unmanned vehicle. The recipient unmanned vehicle uses information included with the message to determine whether a quorum of other unmanned vehicles have vetted information in the message. If a quorum of unmanned vehicles have vetted the message, the unmanned vehicle uses the information in the message to determine how to perform one or more operations.	Source
50	9,671,791	6/6/2017	Managing unmanned aerial vehicles	Techniques for managing a flow of an unmanned vehicle within a space may be described. In particular, the unmanned vehicle may be determined as being location within the space. The space may be associated with metric that may be based on a plurality of other unmanned vehicles also located within the space. Pairs of location and time data may be computed for the unmanned vehicle. The pairs may represent a path for the unmanned vehicle to use within the space. The pairs of location data and time data computed based on data associated with the unmanned vehicle, data associated with at least one of the other unmanned vehicles, and the metric associated with the space. Once computed, the pairs may be provided to the unmanned vehicle.	Source
51	9671791	6/6/2017	Managing unmanned vehicles	Techniques for managing a flow of an unmanned vehicle within a space may be described. In particular, the unmanned vehicle may be determined as being location within the space. The space may be associated with metric that may be based on a plurality of other unmanned vehicles also located within the space. Pairs of location and time data may be computed for the unmanned vehicle. The pairs may represent a path for the unmanned vehicle to use within the space. The pairs of location data and time data computed based on data associated with the unmanned vehicle, data associated with at least one of the other unmanned vehicles, and the metric associated with the space. Once computed, the pairs may be provided to the unmanned vehicle.	Source

Ref #	Patent #	Award Date	Patent Title	Abstract	Link
52	9,676,481	6/13/2017	Tether compensated air-borne delivery	A tether compensated unmanned aerial vehicle (UAV) is described. In one embodiment, the UAV includes a winch with a tether to lower an item from the UAV for delivery, a flight controller to control a flight path of the UAV, a tether compensation mechanism through which the tether extends, at least one sensor to identify movement in the tether, and a tether response controller. Based on movement identified in the tether, the tether response controller may determine a complementary response and direct the tether compensation mechanism to brace the tether against the movement. Thus, the tether compensation mechanism may stabilize sway or movement in the tether by moving against the sway or movement, which may help prevent the tether from undesirable swinging when lowering the item from the UAV for delivery, for example, or at other times.	Source
53	9,676,477	6/13/2017	Adjustable unmanned aerial vehicles	This disclosure describes an unmanned aerial vehicle that may be configured during flight to optimize for agility or efficiency.	Source
54	9,685,089	6/20/2017	Commercial and general aircraft avoidance using acoustic pattern recognition	This disclosure is directed to a detection and avoidance apparatus for an unmanned aerial vehicle ("UAV") and systems, devices, and techniques pertaining to automated object detection and avoidance during UAV flight. The system may detect objects within the UAV's airspace through acoustic, visual, infrared, multispectral, hyperspectral, or object detectable signal emitted or reflected from an object. The system may identify the source of the object detectable signal by comparing features of the received signal with known sources signals in a database. The features may include, for example, an acoustic signature emitted or reflected by the object. Furthermore, a trajectory envelope for the object may be determined based on characteristic performance parameters for the object such as cursing speed, maneuverability, etc. The UAV may determine an optimized flight plan based on the trajectory envelopes of detected objects within the UAV's air-space.	Source
55	20170175413	6/22/2017	Multi-level Fulfillment Center for Unmanned Aerial Vehicles	A multi-level (ML) fulfillment center is designed to accommodate landing and takeoff of unmanned aerial vehicles (UAVs), possibly in an urban setting, such as in a densely populated area. Unlike traditional fulfillment centers, the ML fulfillment centers may include many levels (i.e., stories, floors, etc.) as permitted under zoning regulations for respective areas. The fulfillment center may have one or more landing locations and one or more deployment locations to accommodate UAVs, which may delivery at least some of the items from the fulfillment center to locations associated with customers.	Source
56	US20170174319A1	6/22/2017	Propeller blade leading edge serrations for improved sound control	Sounds are generated by an aerial vehicle during operation. For example, the motors and propellers of an aerial vehicle generate sounds during operation. Disclosed are systems, methods, and apparatus for actively adjusting the position of one or more propeller blade treatments of a propeller blade of an aerial vehicle during operation of the aerial vehicle. For example, the propeller blade may have one or more propeller blade treatments that may be adjusted between two or more positions. Based on the position of the propeller blade treatments, the airflow over the propeller is altered, thereby altering the sound generated by the propeller when rotating. By altering the propeller blade treatments on multiple propeller blades of the aerial vehicle, the different sounds generated by the different propeller blades may effectively cancel, reduce, and/or otherwise alter the total sound generated by the aerial vehicle.	Source

Ref #	Patent #	Award Date	Patent Title	Abstract	Link
57	US 9688404 B1	6/27/2017	Stabilized airborne drop delivery	Stabilized airborne drop delivery using an Unmanned Aerial Vehicle (UAV) is described. In one embodiment, the UAV includes a flight controller configured to control a flight path of the UAV, a winch mechanism secured to an underside of the UAV, a platform tethered to and extendable from the winch mechanism, and a ballast system configured to stabilize the platform. The winch mechanism may be relied upon to drop an item for delivery without landing the UAV. Because the use of the winch mechanism may give rise to certain design and operating considerations, various active and passive flight and/or ballast control systems are described. These systems are configured to maintain an orientation of the UAV, the platform, and/or the item during one or more stages of airborne drop delivery.	Source
58	20170174337	6/22/2017	Redundant Aircraft Propulsion System Using Multiple Motors Per Drive Shaft	Multiple motors may drive (rotate) a single shaft coupled to a propeller. The motors may be selected such that a first motor is capable of rotating the drive shaft in an event of a failure of a second motor coupled to the drive shaft. A one-way clutch bearing, or similar device, may interface between a motor and the drive shaft to enable free rotation of the drive shaft in an event of the motor becoming inoperable, such as the motor freezing or locking in a position due to failure caused by overheating or caused by other conditions or events. Use of the second motor may secure a position of the drive shaft which may support the propeller in radial eccentric loading.	Source
59	9,714,089	7/25/2017	Trigger agents in video streams from drones	Techniques are provided for analyzing data obtained while delivering items with unmanned aerial vehicles. For example, instructions may be provided to an unmanned aerial vehicle to deliver an item. The unmanned aerial vehicle may be configured to record data while delivering the item. In embodiments, the captured data may be received by a computer system and properties about a destination for the delivery may be identified by analyzing the data. A recommendation may be generated based at least in part on the identified properties.	Source
60	9,718,564	8/1/2017	Ground-based mobile maintenance facilities for unmanned aerial vehicles	Intermodal vehicles may be loaded with items and an aerial vehicle, and directed to travel to areas where demand for the items is known or anticipated. The intermodal vehicles may be coupled to locomotives, container ships, road tractors or other vehicles, and equipped with systems for loading one or more items onto the aerial vehicle, and for launching or retrieving the aerial vehicle while the intermodal vehicles are in motion. The areas where the demand is known or anticipated may be identified on any basis, including but not limited to past histories of purchases or deliveries to such areas, or events that are scheduled to occur in such areas. Additionally, intermodal vehicles may be loaded with replacement parts and/or inspection equipment, and configured to conduct repairs, servicing operations or inspections on aerial vehicles within the intermodal vehicles, while the intermodal vehicles are in motion.	Source
61	9,725,171	8/8/2017	Analyzing navigation data to detect navigation data spoofing	Techniques for determining whether data associated with an autonomous operation of an unmanned vehicle may be trusted. For example, the data may be analyzed in light of a capability of the unmanned vehicle. The analysis may indicate an operation of the unmanned vehicle. If the operation is unsupported by the capability, the data may be determined to be untrusted. Accordingly, the autonomous navigation may be directed independently of the untrusted data.	Source
62	9,725,171	8/8/2017	Analyzing navigation data to detect navigation data spoofing	Techniques for determining whether data associated with an autonomous operation of an unmanned vehicle may be trusted. For example, the data may be analyzed in light of a capability of the unmanned vehicle. The analysis may indicate an operation of the unmanned vehicle. If the operation is unsupported by the capability, the data may be determined to be untrusted. Accordingly, the autonomous navigation may be directed independently of the untrusted data.	

Ref #	Patent #	Award Date	Patent Title	Abstract	Link
63	9,731,839	8/15/2017	Aerial vehicle delivery shroud	Described is an aerial vehicle, such as an unmanned aerial vehicle ("UAV") that includes a delivery shroud. The delivery shroud may be maintained in a retracted position while the aerial vehicle is in transit. The delivery shroud reduces the transmission of sound from the aerial vehicle to the delivery area. Likewise, the delivery shroud may also be used to facilitate delivery of a payload from the aerial vehicle to a delivery location within the delivery area.	
64	9,739,870	8/22/2017	Tracking unmanned aerial vehicles using reflected light	This disclosure describes systems and methods for visually tracking a position of an unmanned aerial vehicle ("UAV") using reflected light. A light source at an origin location, such as the location of an operator of the UAV, is aligned and emitted toward the position of the UAV. The emitted light source reflects off a reflector coupled to the UAV toward a location of the operator or a visual observer working with the operator. The reflected light increases the visibility of the UAV, thereby extending the distance from an operator at which the UAV can be operated while maintaining visible contact between the operator and/or a visual observer working with the operator and the UAV.	
65	9,741,255	8/22/2017	Airborne unmanned aerial vehicle monitoring station	Described is an airborne monitoring station ("AMS") for use in monitoring a coverage area and/or unmanned aerial vehicles ("UAVs") positioned within a coverage area of the AMS. For example, the AMS may be an airship that remains at a high altitude (e.g., 45,000 feet) that monitors a coverage area that is within a line-of-sight of the AMS. As UAVs enter, navigate within and exit the coverage area, the AMS may wirelessly communicate with the UAVs, facilitate communication between the UAVs and one or more remote computing resources, and/or monitor a position of the UAVs.	

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