The proposed, concept OVER Vertical Lift-off and Landing (VTOL) Aerial Vehicles (AVs) are configured with various systems and components, developed by various companies, which appear to meet the proposed ATS standards. The specific systems and components that are eventually determined to be the best choice for the final designs are TBD. Regardless, it is anticipated that the companies holding patent to those accepted systems and components (including OVER) would each enter into a licensing agreement with the multi-corporation joint venture herein referred to as the “LLC Team”. The agreement would allow the LLC Team (and any subsequent LLC Team-type manufacturer) to scale, modify, refine, improve, manufacture, operate and maintain their product(s), in exchange for a set Return on Investment (ROI), based on taxi-fare and/or lease-type profits generated by each AV in operation, which contains their product(s). It is OVER’s business approach that the LLC Team manufactured AVs (and perhaps other manufacturer’s AVs) will never be sold to any individual, company, or government agency, but rather owned, operated and maintained by the LLC Team, or any subsequent LLC Team-type manufacturer, perpetually.

4.1 Overview.

The proposed OVER AVs are designed first and foremost to provide customers with convenient, easy-to-use, speedy, affordable, cargo and passenger on-demand taxi-fare or long-term lease type services. All proposed AVs will lift-off and land vertically, be networked with GM Control and other AVs in the area, and operate with full (Level 5) autonomy. The proposed AVs have no onboard pilot or remote pilot - no “joystick” or other flight controls at all, and are therefore never susceptible to human (pilot/operator) error. They are basically “flying robots” which follow approved time-paths autonomously, flying directly from one longitude/latitude position to
another, through waypoints as required. AV’s complete time-path calculations autonomously using a standard ARC formula, and plot the “time-path” into the MAP. AVs use GPS to determine exact position throughout flight, using satellite communication (primary), cellular communication (backup), and perhaps internal altimeter to determine altitude. This data (longitude, latitude, altitude, and time) is transmitted before, during and after flight via a dedicated wireless network (e.g. ABWN) primarily, and cellular networks as a backup. Transmitted data is received by GM Control and all AVs in the area. Packet data would comply with the TCP/IP, unless a better protocol is proposed. Other common features of all AVs include system and component redundancies for safety; standard lift-off, acceleration, flight, deacceleration, and landing methods, and a standard anchoring and powering system.

In order for both AVs and Ground Vehicles (GVs) to be used to their full capacity, they must provide customers with convenience, ease-of-use, and affordability. For example, OVER’s AV and GV concepts will both provide customers a level entry/exit design, which will easily accommodate rolling stock, rolling luggage, wheelchairs, walkers, etc. Other features that provide convenience and ease-of-use in both AVs and GVs include iris scan/recognition for quick, positive identification which controls access/entry and enables payment; passenger names displayed on windows during load/unload; same size and type of doors, entryways, grab handles, seating, and windows; free Internet access, and similar ramps/platforms. Further, the strategic design of AV parking structures and GV load/unload spots, as well as placing them near each other, provides customers with easy and convenient transitions from GV to AV and from AV to GV. Other customer-focused features of the AVs and GVs include an easy-to-use application (the ATS APP) so customers can easily and quickly order autonomous travel using any Apple, Android or PC device/computer; and personalized customer profiles which store each customer’s preferences, automatic payment data, memorized destinations, etc. Further, the quantity of available AVs (CAVs/PAVs) is another key factor that will affect customer convenience, so the number must be sufficient to minimize wait times to acceptable levels. As for affordability, the cargo and passenger taxi-fare rates (cost-per-kilometer) and long-term lease rates must eventually be low enough to ensure repetitive/continued use by the masses. OVER’s financial forecast requires only $200 net income per day, per AV/GV, to make the endeavor profitable. The amount will decrease to less than $100 per day, per AV/GV within two years of production start, and to less than $50 per day, per AV/GV within 18 years. Solutions to providing convenience, ease-of-use, and affordability must be integral to all AV/GV designs, regardless of manufacturer, from the very beginning.

OVER proposes two sizes of AVs for initial production, a large model and a small model. The large CAV model (AC-4.4) has approximately 4.4 m$^3$ (~155 ft$^3$) of interior space, and the small CAV model (AC-2.7) has approximately 2.7 m$^3$ (~97 ft$^3$). The small PAV model (AP-3) accommodates up to three passengers and the large model (AP-5) accommodates up to five. It is anticipated that the large CAV/PAV models will weigh ~500kg (~1,100lb) with fuel, and be capable of carrying up to ~500kg (~1,100lb) of payload, resulting in a Gross Aerial Vehicle Weight (GAVW) of ~1,000kg (~2,200lb). The small CAV/PAV models will weigh less, but are anticipated to be capable of carrying the same amount of payload, up to ~500kg (~1,100lb). PAV models are designed to accommodate wheelchairs (although the AP-3 model may not in final design) and are equipped
with seats and windows. CAV models have no seats or windows. All models have the same size doors and door opening (5’H x 4’W).

Theoretically, all AVs should be capable of carrying payloads of approximately 500kg (~1,100lbs), because both small and large models have the same power generation systems, electric motors, and contra-rotating propellers. The small AC-2.7 and AP-3 models are structurally and mechanically identical, as are the large AC-4.4 and AP-5 models. Manufacturing and maintenance of the various models is simplified, since all use the same power generation systems, electric motors, propellers, motor/landing arms, computers, electronics, cameras, sensors, and other common parts and assemblies.

Initially, only CAVs will be authorized to fly in the new ATS. During the initial “CAV-only” operational period, it is expected that their safety record will result in the general public coming to trust the new AVs and the ATS itself, and realizing that autonomous AVs provide a very safe, secure, reliable and swift mode of transportation. After a few months/years of safe and reliable CAV operation, the general public will undoubtedly desire, if not demand, that PAVs be allowed to join the operational system.

The concept AVs are configured with proprietary “Redox” type flow batteries made by nanoFlowcell (referred to hereinafter as “power generation systems”), as well as powerful yet lightweight electric motors, optimally tuned contra-rotating propellers, and state-of-the-art communications and electronics. It is expected that the smaller AVs would travel at speeds of at least 100km/h (~62mph), with the larger AVs at speeds of at least 80km/h (~50mph), with a goal of both eventually achieving speeds of 160km/h (~100mph) or more. Regardless of speed, they will be able to fly non-stop, for at least three hours, at their maximum-allowable “cruise” speed, while carrying the maximum payload, using no more than 90% of the available fuel. This will leave 10% remaining to travel to a refueling facility. (Note: The duration of flight is actually limited only by the amount of bi-ION electrolyte “fuel” that can be carried). A compromise may have to be made between the final quantity (weight) of bi-ION fuel carried and the payload capacity (weight), while attempting to provide as many hours of continual flight as possible.

The proposed AVs will provide stable hover and flight characteristics. The characteristics of the proposed AVs will have inherent similarities to the very best quadcopter “drones” - but better. For example, the proposed AVs will lift-off, fly, hover, and land in a “smooth and steady” manner (a proposed standard), controlled with granularity and precision by the flight control SW/system. Drones on the other hand are normally controlled manually by a remote operator/pilot, unless following a GPS-based SW-controlled flight path. When controlled manually, they react to joystick movement which is often un-precise, and then make radical/jerky movements as a result, and often land harder than necessary. This is true, but to a lesser degree, even with SW-controlled drone flight and landings. However, the proposed AV’s flight control HW/SW will provide precision control of motor revolutions-per-minute (RPM) and tilt capabilities, to provide “smooth and steady” flight, from lift-off to landing. Gravitational force (G-force) on payload will be maintained at a set value (TBD), throughout acceleration and deceleration.

The proposed AVs are designed with a novel integrated pin/slot connection design (addressed in Section 4.6) with common mounting HW which will speed AV assembly, as well as enable rapid and cost-effective removal and replacement of covers and components for service/maintenance
thereafter. The concept AV’s curved exterior covers, doors and walls, as well as interior partitions and components should be constructed of strong, lightweight, honeycomb sandwich panels¹ (or similar). The tilting motor arms, and other high-stress components should be designed using “generative engineering” techniques² to maximize strength and minimize weight. Specific materials and manufacturing processes are TBD. AVs are also designed to minimize weight while ensuring reliability, durability, and longevity. AV are also designed to accommodate future upgrades or improvements such as stronger/lighter motor arm structures, improved sensors and cameras, and motor mounts that will accommodate upgraded, more powerful motors/engines.

The proposed AV designs are expected to meet or exceed the proposed standards for motor power and torque, fuel/power source capability, speeds, payload capabilities, autonomous anchoring, communications, electronics, and flight control capabilities. Although concept designs include proposed operational systems, the specific and eventual power source, fuel, motors, propellers, electronics, communications, etc. are TBD. However, any approved AV design would have to meet or exceed all proposed standards.

4.2 Safe, Secure, Reliable and Swift

The four key objectives of all AVs (CAVs and PAVs) and the ATS itself, are to provide safe, secure, reliable and swift aerial transportation for business and the general public.

4.2.1 Safe

A safe ATS demands multi-motor, VTOL type AVs to provide the inherent benefit of being able to land safely even if one or more motors fail. (Compare the proposed AVs to the inherent risk of crashing in a traditional, single-engine aircraft or helicopter, if the one, single engine fails). The concept AV designs provide multiple redundant systems to include power generation, electric motors, propellers, computers, communications, collision avoidance sensors, cameras, etc. They also provide an automatic Emergency Flotation System (EFS), which will inflate airbags mounted to each landing leg if/when a landing leg enters water. The airbags are designed to inflate rapidly like automotive airbags, but retain air pressure for at least 12 hours. A safe ATS will also require an Aerial Vehicle Autonomous Anchoring and Powering System (AVAAPS) to automatically anchor and power AVs immediately after landing on a parking pad, and to automatically un-anchor and disconnect electric power from AVs just prior to departure. These and other safety measures will significantly reduce the risk of injury or death to passengers and persons/property on the ground, as well as reduce the risk of transport damage to cargo. Over time, the ATS and the AVs/GVs themselves will prove to be “the safest form of transportation in history”.

4.2.2 Secure

In addition to being safe, AVs and the ATS must also be secure from all threats, both physical and electronic. Threats may come from inside or outside the organization. Physical threats include vandalizing or damaging an AV, attempting to access an AV’s components or systems, attempting to approach or enter an AV without authorization, or attempts to hijack or steal the entire vehicle. Electronic threats include sabotage, hacking, malware, ransomware, over-clocking, over-currenting, etc.

¹ http://www.stressebook.com/honeycomb-sandwich-panels/
² https://www.youtube.com/watch?v=vtfNIWEJxw4
reprogramming, etc. The greatest threat would be someone/something causing one or more AVs to crash to the ground. (This concern almost made me not write/publish this white paper document, because who wants to suggest something which may result in multiple deaths?). However, the U.S. has some of the most brilliant software and cyber-security engineers in the world, who will ensure, perpetually, that the ATS and all AVs/GVs are secure from these and all other threats. Electronic communication threats can be overcome by implementing high-security network communication protocols, such as 2048-bit encryption and randomly generated, multi-character passwords. If possible, the ATS should use communication protocols similar to those used by our government and military such as the Secret Internet Protocol Router Network (SIPRNET) used for “Secret” communications, or the Joint Worldwide Intelligence Communications System (JWICS) used for “Top Secret” communications. American taxpayers paid to develop these technologies and protocols, and should be able to incorporate them into the ATS, if at all possible – without revealing the underlying HW/SW technology. Additionally, OVER proposes a reward-based “Bug Bounty Program” (addressed fully in Section 6.7) to encourage sanctioned programmers/hackers to continually seek out and identify vulnerabilities in the system/SW, so they can be mitigated before being exploited. Over time, and with continual vigilance, the ATS and AVs/GVs will prove to be “the securest form of transportation in history”.

4.2.3 Reliable

The design of the proposed AVs, as well as their systems, components, and materials; and the quality control of the manufacturing process all contribute to the reliability of the proposed AVs. The proposed twin electric motors powering contra-rotating propellers provide superior flight capabilities and the inherent benefits of a multi-motor system. Coupled with mature, proven systems and components, all having redundant capabilities, the AVs will prove themselves to be a very reliable form of transportation. OVER’s business approach incentivizes all Contributors, employees, and investors to provide durable, reliable, long-lasting AV components and systems, to ensure safe operations year after year, and to maximize profits. If certain systems or components prove to not be as reliable as desired/necessary, the LLC Team will rapidly redesign/modify the system/component, in-house (normally), and make the needed manufacturing changes with little delay; or replace the system/component with another product. Additionally, to ensure continuously improved AVs over time, the LLC Team will perpetually evaluate new systems and components for potential integration/upgrade to operating AVs, and/or for revisions to subsequent AV designs and manufacturing processes. Over time, the ATS and the AVs/GVs will prove to be “the most reliable form of transportation in history”.

4.2.4 Swift

Relative swift travel is a necessity to develop and maintain customer demand. It is expected that the smaller AVs would travel at speeds of at least 100km/h (~62mph), with the larger AVs at speeds of at least 80km/h (~50mph), with a goal of both eventually achieving speeds of 160km/h (~100mph) or more. Although there would be no “speed limit” when traveling horizontally within approved airspace, the cruise speed of each AV is determined by its specific capabilities and payload weight. However, speeds may be governed within vertical ascend/descend corridors to facilitate smooth steady travel, without stop or delay. Regardless of actual airspeed, the inherent elimination of bottlenecks, traffic jams, stop lights, accidents, breakdowns, and other ground-
based transportation delays, as well as the time-savings of traveling directly from point A to B, would decrease overall travel time, relative to ground transportation.

4.3 Basic AV Operation

All cargo AV operators and AV passengers will make request for their desired AV via cellular or Wi-Fi, using the ATS APP (computer or mobile device), as well as at kiosks at major vertiport locations. Cargo operators are typically employees who are authorized to order and dispatch a Cargo AV (CAV) to deliver products to customers, retail stores, or otherwise. AV passengers would be ordering a Passenger AV (PAV) to transport themselves or their party to a desired destination. Destinations would be entered as a physical address, selected on a map, or chosen from a list of previously entered destinations – hence the “customer’s profile”. As a customer uses the AVs, their profile is updated with every destination entered, and the customer can assign names to them (e.g. Work, Home, School, Store, etc.), change them or delete them.

GM Control processes the request automatically, by selecting an available AV based on type requested and arrival time, and directing it to the pick-up location. The time of arrival will appear on the customer’s mobile device or computer. Upon arrival, user identity is confirmed via iris recognition, the doors open, and the operator loads cargo, or the passenger enters the vehicle.

Once loaded, an AV uses the MAP to autonomously calculate the shortest “time-path” to destination, following the standard ARC (addressed in Section 3.12), based on maximum payload. The time-path avoids all previously approved time-paths of other AVs, and automatically calculates waypoints into the time-path as required. The purpose of the standard ARC is to distribute AVs within the authorized air space, instead of all AVs flying along the lowest, shortest route to destination. The calculated time-path, and cargo or passenger manifest, are transmitted to GM Control via the dedicated wireless network (e.g. ABWN) or cellular network as a backup. GM Control recalculates the time-path and if identical to the AV’s calculation sends approval to the AV. The AV then un-anchors from the AVAAPS and departs at the approved time.

Upon lift-off, the AV determines the actual weight of payload within seconds (based on motor RPM and speed), and re-calculates a new time-path, based on obtainable cruise speed with actual payload. While accelerating IAW the previously approved time-path, the AV transmits a new time-path request to GM Control. GM Control re-calculates the requested new time-path, and if identical to the AV’s calculation, sends approval to the AV. The AV then travels the new approved time-path while maintaining correct position-in-time (PIT) all along the route. Further, if during flight, the AV cannot maintain correct PIT due to head winds, etc., or if the passenger/operator wants to change destination, the AV re-calculates another time-path, transmits it to GM Control for approval, and then travels the new approved time-path to destination.

Throughout flight, each AV will transmit/receive data via the dedicated wireless network (primarily) or cellular networks (backup), every second or so. The data consists of the Aerial Vehicle Identification Number (AVIN), current PIT data (longitude/latitude/altitude/time), and future time-path data at key points along the route (based on the most recent, approved time-path). All AVs receive the data from other AVs in flight, but only process and plot AVs into their MAP whose PIT will come within approximately 1km (~0.62 miles) of them, anywhere and at any
time along the route. The location and time-path of these AVs are plotted to the AV’s MAP, updated each time new data is received, and tracked throughout flight.

Once the last cargo or passenger unloads from an AV, and if the AV has no further assignment, the AV will typically remain (anchored and powered by the AVAAPS) at the unload location until the next assignment. If parked at a location without the AVAAPS, the AV will use its internal Li-ion batteries to provide power to the computers, communication systems, LED lights, HD Cameras, sensors, and door window “heads up” displays, as required. If the batteries become depleted, the AV can “idle” the nanoFlowcell system to generate enough power to run all required systems as well as re-charge the batteries. Alternately, the AV may fly to a parking pad with an AVAAPS to anchor and connect to electric power.

4.4 Software for AV Operations

Software for AV operations (as well as GV operations) will be a key development hurdle as multiple systems need to be developed or revised. The companies that develop and provide license for use of the accepted SW will be compensated like Contributors, as explained in the OVER business approach. A summary of the various required SW systems was presented in Section 3.9. Virtually all SW technologies are already in existence, so no “invention” per se, is required. Similar SW systems have been developed and are in use today, and with some modification could be adapted to meet requirements. Software companies which could provide applicable SW include CA Technologies, Intel/Mobileye, Microsoft, NVIDIA, Oracle, Symantec, VMWare, and others. Specific SW requirements and solutions are TBD.

4.5 Structural Design

The structure of the “quadcopter” style OVER concept AVs is composed of a payload cabin with a 4’W x 5’H door opening, surrounded by a rounded top and rounded nose and tail cones, and two tilt-rotor motor arms which also act as landing legs, one in the front and one in the rear. The payload cabin is designed with 3-inch thick walls and ceiling, and a 4-inch thick floor containing both insulative and sound-deadening materials. (Note: The wall, ceiling and floor thicknesses could be reduced, if strength, insulation and sound reduction is sufficient). Although various design changes may eventually be made to the OVER concept AVs, the design and size of the payload cabin would remain mostly unchanged, as the current design enables level entry/exit and space for patrons using wheelchairs, walkers, etc.

Each 2’W x 5’H sliding bus-type door opens upon positive iris scan recognition. When open, each door uses an internal Li-ion battery to power a wireless communication device and the “heads up” display. When closing, a “light curtain” made of multiple photoelectric presence sensors creates multiple horizontal infrared light beams in the door opening, spaced about 2 inches apart. The beams are turned ON automatically while the doors are closing. If one or more beams are blocked/reflected, the system will stop and reverse the automatic door closing operation. As they close, the two doors come together, pins into holes, and lock upon closing with automotive type door locks. When closed, spring-loaded electrical connectors mounted in the door jambs provide 12VDC to each door, to power the display and recharge the battery.

The rounded top and nose/tail cones are attached together and to the cabin structure using an innovative pin/slot connection method, addressed below, to ease removal/replacement for
maintenance. Most of these components would be made of strong, lightweight, honeycomb sandwich panels\(^3\) (or similar), composed of carbon fiber, carbon composite, or other materials that are in ready supply and relatively inexpensive, and which can be mass produced. *(Note: If the power generation, fuel tanks and other utility components can fit inside a smaller space, the design would be revised, perhaps replacing the rounded top with a flat 3-inch thick top containing windows, and smaller more aerodynamic nose/tail cones, as illustrated in Section 4.10 below).*

The AVs tilt-rotor motor/landing arms would be constructed of very strong material/composites, as they will absorb and disperse much of the G-forces exerted during flight. Motor cowlings would also be constructed of very strong materials, as they will actually act as casings for the electric motor assemblies, which eliminates unneeded components and weight. Propellers may be made of carbon fiber or carbon composite materials. The exact materials/composites for all these structural and operational components are TBD. In all, the design provides a comfortable quiet cabin, and a safe, reliable, durable, long-lasting structure, as well as the pin/slot feature that enables rapid removal and replacement for service/maintenance.

### 4.6 Integrated Pin/Slot Connection Design

The concept AVs are designed with an innovative, integrated pin/slot connection *(see drawing below)* used to effortlessly align and connect the top, nose and tail covers to the cabin structure. This design enables quick and positive alignment and mounting of the covers. The pins/slots will speed AV assembly, as well as enable rapid and cost-effective removal and replacement of covers for service/maintenance thereafter. Further, the common mounting bolts are not completely removed when the covers are removed, but rather just unscrewed until the threaded bolt ends are backed out of the fixed frame/structure holes. This eliminates maintenance personnel from having to collect loose bolts/HW when removing the covers, and from having to reinstall loose bolts/HW. Bolt heads would contain hex, star or other inset shape to allow bolts to be rapidly unscrewed and then reinstalled and torqued, by semi-automated or fully automated systems.

\[\text{\url{http://www.stressebook.com/honeycomb-sandwich-panels/}}\]
4.7 Features and Benefits of Both CAVs and PAVs

There are two main categories of proposed AVs: Cargo Aerial Vehicles (CAVs) and Passenger Aerial Vehicles (PAVs). Both CAVs and PAVs could eventually be manufactured in various sizes and shapes, and for various purposes — but all must be compliant with accepted standards, regardless of the manufacture. All of the proposed, OVER concept CAVs/PAVs are equipped with similar power plants, fuel tanks, electric motors, propellers, communications, networking, collision avoidance and swarm technology, computers, environmental control systems, AVAAPs, and EFS. Both CAVs and PAVs will operate in a fully autonomous (Level 5) manner. The similarities between CAVs and PAVs are addressed here in Section 4.7 first, and then the unique differences thereafter in the CAV Section 4.8 and the PAV Section 4.9.

4.7.1 Customer-Focused Designs

The proposed AVs will need to be designed and operated in a manner that meets the needs of customers — from the very beginning. This customer-focused approach must be a key consideration throughout the design process. Both CAV and PAV customers will need an easy-to-use application (ATS APP) that works on both mobile and desktop devices, which allows customers to easily order and pay for CAV or PAV flights. CAV customers will need convenient landing/loading/unloading capabilities and locations, iris recognition to enable authorized access (load/unload), RFID for precise cargo manifests, level entry to accommodate rolling stock, the ability for the operator/customer to operate and track multiple CAVs at once, and a personalized customer profile to include identification, payment information, and frequent destinations. PAV customers will need convenient landing/loading/unloading capabilities and locations, iris recognition for identification and passenger manifests, level entry to accommodate patrons with luggage or wheelchairs/walkers, and a personalized customer profile as well. The profile could be maintained on the customer’s mobile device and accessed by the AV upon pick-up.

4.7.2 Aerodynamic, Strong, Durable and Long-Lasting

The initial AV designs, from the very beginning, must provide an aerodynamic shape and be constructed strong enough to travel at high speeds, perhaps 160km/h (100mph) or more, and handle future/projected higher G-force stresses (e.g. 3 Gs or more). The initial production designs should be strong enough to accommodate future motors/engines (e.g., Boeing’s blue light concept, etc.) having higher power/torque capabilities which facilitate higher speeds and/or greater payloads. The design and materials must provide durable and very long-lasting AVs.

A key objective of the OVER business approach will be to build AVs that will provide at least 10 years of dependable, useful service. The longer each AV will last, the longer the taxi-fare and long-term lease profits will roll in. If an AV were to become unserviceable and removed from service, its potential future profits are lost. Therefore, it is in the best interest of Investors, Contributors, employees, and customers for the manufacturer to proactively design, manufacture and operate aerodynamic, strong, durable, and long-lasting AVs from the very beginning. Employees and Investors are particularly incentivized because all employee bonus and Investor ROI is generated from cargo and passenger taxi-fare and lease profits, generated by the “in-use” AVs each day. If an AV is not “in-use”, it generates no revenue and therefore no profit. The longer the AVs last, the longer the profits will roll in.
4.7.3 Lithium-ion (Li-ion) Batteries

AVs will contain a sufficient number of Li-ion batteries to provide power to the computers, communication systems, LED lights, HD Cameras, sensors, actuators, and door window “heads up” displays, when parked, as required. It’s anticipated that the AV nose cone and tail cone compartments would each contain a Li-ion battery sufficient to power the computers, communication systems, lights, cameras, sensors and actuators, and that each door would contain a Li-ion battery sufficient to power its respective window “heads up” display. (Note: The Li-ion batteries are not sufficient or intended to power the electric motor/propeller systems). The Li-ion batteries are charged by the nanoFlowcell power generation system during AV operations, and by electric grid power when connected to an AVAAPS. The charged batteries will be sized to provide the required power (voltage/amperage) for the said systems for up to eight hours of parking, at a location without electric grid power. When parked at a location without the AVAAPS, the heater and air conditioning (A/C) systems will be powered by the nanoFlowcell system running at “idle”, as required, which will also recharge the batteries. If a battery becomes depleted while parked at a location without electric grid power (e.g. only 10% remaining), the AV will either (1) fly to a parking pad equipped with the AVAAPS to connect to electric grid power, or (2) operate the nanoFlowcell system at “idle” to recharge the batteries.

4.7.4 NanoFlowcell Power Generation

Most of today's hybrid and all-electric vehicles use Li-ion batteries to provide power to the electric motors and vehicle components. Li-ion batteries have high power-to-weight ratio, high energy efficiency, good high-temperature performance, and low self-discharge. Li-ion batteries are used in many aerial vehicle applications, to include Airbus’ CityAirbus, Bell’s Nexus Air Taxi, Boeing’s CAV prototype, Electroflight’s P1e (part of Rolls-Royce’s ACCEL initiative), Jetpack’s multicopter, Kitty Hawk's Cora, and many others. The main problem with current battery power, including Li-ion, is limited flight duration. Flight duration for most electric aircraft is currently about 30 minutes, which would be unacceptable for the anticipated ATS standard which would require AVs to have the ability to fly non-stop, for at least three hours, using no more than 90% of the available fuel/charge, leaving 10% to travel to a refueling/charging facility.

As such, OVER proposes a combination of various developed technologies for power generation, electric motor, and propeller systems, which when combined into the proposed AV models, should provide sufficient power for lift and propulsion, and flight duration of at least three continual hours. The proposed systems are a nanoFlowcell\(^4\) power generation system, nanoFlowcell aluminum-mesh synchronous electric motors, and a contra-rotating propeller system (CRPS) similar to the one manufactured by Contra Electric Propulsion Ltd.\(^5\)

For the concept AVs and GVs, power is generated and provided by proprietary “Redox” type flow batteries, made by nanoFlowcell, headquartered in Kilchberg, Switzerland. NanoFlowcell’s revolutionary technology, if true, could provide scalable, eco-friendly power, sufficient to provide medium to large AVs with the required lift and flight capabilities, as well as sufficient speeds and flight duration. NanoFlowcell’s Press Kit for 2017 states: “With nanoFlowcell based on flow cell

\(^4\)https://nanoflowcell.com/
\(^5\)http://www.contraelectric.com/
technology, we have developed a proprietary energy technology that will supply energy to a new generation of electric vehicles – on land, on water and in the air – in a manner that is practical, environmentally compatible and safe.” Further they state “Our technology is mature, the time has come, nanoFlowcell is ready to help electric mobility attain its breakthrough. NanoFlowcell will be a crucial, if not downright decisive technology in shaping sustainable individual mobility.” The announcement goes on to state “The innovation centre - known internally as QUANT-City - will encompass research into a diverse range of mobile and stationary applications, a production facility for the nanoFlowcell itself, its membrane and the complementary bi-ION electrolytes. Pilot production of prototype applications is also planned”.

According to the company, nanoFlowcell is the most innovative and most powerful energy storage system currently available for mobile applications. Unlike batteries, the nanoFlowcell is “fueled” with energy in the form of positively and negatively charged liquid electrolytes, called “bi-ION”. These positively and negatively charged liquids are stored in separate tanks, and pumped through a converter (the actual cell of the nanoFlowcell system) in separate circuits. Here, the two electrolyte circuits are separated only by a permeable membrane, and as the positive and negative electrolyte solutions pass one another on either side of the converter membrane, an exchange of ions takes place. This converts the chemical energy bound within the bi-ION into electricity, which is then directly available to their proprietary low-voltage (48-volt), aluminum-mesh, synchronous electric motors, and other electrical demands. The nanoFlowcell system is environmentally friendly, producing no harmful gasses or pollutants. The system is scalable to different demands, and applicable to both mobile and static applications.

**QUANT 48VOLT.** Although primarily a research and development firm, nanoFlowcell built a prototype electric sports car, the QUANT 48VOLT⁶ (pictured on next page⁷), to demonstrate the power generation technology. Specifications for the 2017 QUANT 48VOLT vehicle were obtained from their website⁸, and are presented below.

- Body style: Coupé
- Top speed: 300km/h (186mph)
- Acceleration: 0-100km/h (0-62mph): 2.4 sec
- Transmission: Automatic
- Drive: All-wheel drive
- Number of doors: 2
- Number of seats: 2+2
- Motor Type: 4x low-voltage (48V) synchronous
- Fuel type: Electric (bi-ION)
- Maximum power: 560 kW (760 hp)
- Max torque per wheel: 2000 Nm (1475 ft lbs.)
- Battery Type: nanoFlowcell (6 cells)
- Voltage (48 V)
- Capacity: 300 kWh
- Current: Max 1,500 Amps per cell; 9,000 total
- Energy consumption: (still in testing)
- Tank volume: 2 x 250 Liters (2 x 66 gal)
- Range: >1,000 km (>621 mi)
- Harmful emissions: 0

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The proposed AVs are designed to contain two complete nanoFlowcell power generation systems for redundancy, one in the front nose cone and one in the rear, as illustrated below. (Note: This design would be revised if the power generation, fuel tanks, and other “utility” components can fit inside a smaller space, as illustrated in Section 4.10 below). The front system would power four motor/propeller systems (one on each corner), and the rear system would power the other four motor/propeller systems (one on each corner).
Each power generation system and its connected electric motor/propeller systems would be capable of independently providing sufficient power and lift to maintain hover and land safely with full payload, as well as providing sufficient power to all other components (except the heater and A/C). Therefore, if one power generation system fails or any motor/propeller system fails, the AV can still safely land without any degradation in flight control or other component functionality. (Note: The proposed AVs would autonomously land at the nearest emergency landing area, if a power generation, motor, propeller, or other key system or component fails).

4.7.5 NanoFlowcell bi-ION Electrolyte

NanoFlowcell’s proprietary bi-ION electrolyte fuel is nonflammable, nonexplosive, noncorrosive, nonhazardous, sustainable, and harmless to health and the environment. Further, it is less expensive to produce than refining fossil fuels or manufacturing Li-ion batteries. However, mass production of the bi-ION electrolytes in sufficient volume and in sufficient locations will be key to facilitating the use of the technology in VTOL AVs and GVs. According to an April 2018 announcement, Nunzio La Vecchia, CEO for nanoFlowcell Holdings Ltd, said: "We have achieved a laboratory breakthrough in our bi-ION research that has prepared the way for mass production of the electrolytes - which is a key prerequisite for the market success of our flow cell technology. Supported by Investors, we will now build a pilot facility replicating the entire value-creation cycle of our technology. It will serve as a blueprint for further innovation centers for our nanoFlowcell technology to be established worldwide."

The nanoFlowcell power generation system is quick and easy to “recharge”, by refilling the two tanks with the two charged bi-ION liquids (one positive and one negative). The proposed AVs and GVs contain two bi-ION tanks (see above illustration), made of lightweight material and designed to be refilled simultaneously at refueling stations, eventually without human assistance. Vehicles could be refueled within a few minutes, and quickly resume operations until needing to be refueled again. (NanoFlowcell is still testing the energy consumption of the QUANT 48VOLT vehicle, so required tank size and flight duration cannot be determined at this time). For now, the proposed large AVs are designed with two tanks having a capacity of approximately 190 liters (~50 U.S. gallons) each, and the smaller AVs having a capacity of approximately 136 liters (~36 U.S. gallons) each. However, initially, both sizes of AVs are expected to carry only about 38 liters (~10 U.S. gallons) in each tank, weighing about 76 kg (~167 lbs.) combined. Extending flight time can be accomplished by carrying more bi-ION electrolyte, which may be possible with more powerful motors, or with higher density bi-ION electrolytes in the future, without compromising payload capacity. The extra, built-in tank capacity will make redesign unnecessary.

The number of bi-ION production facilities will be based on demand, delivery distance, and production capabilities (TBD). Multiple bi-ION production facilities will eventually be built across the nation. It is expected that total bi-ION production will far exceed the needs of just the AVs and GVs, so to meet other mobile and stationary application needs.

The low voltage nanoFlowcell power generation and electric motor system appears to meet/exceed most criteria for use on AVs, namely, high power/torque, long flight duration before refueling, ability to manipulate RPM with granularity, scalability, low noise levels, and no pollution. In all, the low-voltage nanoFlowcell technology, their aluminum-mesh synchronous 48-
volt motors, and the ability to quickly refuel (eventually autonomously) appears to provide a workable power solution for VTOL AVs and GVs alike.

It should be said that there is some skepticism about the validity of the nanoFlowcell technology, products, and claims. To put the matter to rest, nanoFlowcell and its Founder and CEO Nunzio La Vecchia need to allow electric mobility engineers, scientists, chemists, U.S. government representatives from DOT and FAA, and other electric mobility experts to test the system and document the results. This will either prove it true or not.

An important point here is that regardless if the nanoFlowcell system works or not, eventually there will be some viable power generation or storage solution that will meet the proposed standards. This uncertainty should not delay the development and establishment of standards for a new ATS, and development of alternative or additional AV and GV solutions.

4.7.6 NanoFlowcell Electric Motors

The proposed AV designs use two complete nanoFlowcell power generation systems (one in the front nose cone and one in the rear), to power a total of eight nanoFlowcell low-voltage (48-volt) aluminum-mesh synchronous electric motors. Each AV is comprised of a total of eight motors and eight propellers, in four motor placements (four corners). Each nanoFlowcell power generation system would provide power to four motor/propeller systems (one on each corner). An illustration of one motor placement (corner) showing the two motors and two propellers is presented below. The motors in the AVs would be “scaled up” to an optimum size, to generate the required horsepower and torque.
The concept AVs are configured with four contra-rotating propeller systems, similar to the system used on the Electroflight P1e\textsuperscript{9} all-electric racing aircraft (pictured here). The P1e configuration uses a transmission shaft made by Contra Electric Propulsion Ltd. and propellers made by Hercules Propellers Ltd. Although the P1e YASA electric motors (pictured below) are capable of providing high power and thrust, they operate at high-voltage (800VDC), which is incompatible with nanoFlowcell’s low-voltage (48-volt) system. So, the proposed system for the concept AVs and GVs uses low-voltage nanoFlowcell aluminum-mesh synchronous electric motors (similar to those used in the QUANT 48VOLT), driving a contra-rotating transmission shaft (similar to the Contra Electric Propulsion Ltd. design used on the Electroflight P1e).

According to the Contra Electric Propulsion Ltd. website, their Contra-Rotating Propeller System (CRPS) uses YASA axial flux 750 series electric motors\textsuperscript{10} (pictured here)\textsuperscript{11} which operate on high voltage (800VDC), from 0-2800 RPM. Each YASA motor is capable of providing 112.5kW (150hp) and 400Nm (295ft.lbs) of continuous torque at >75kW. The twin-motor system is rated at 225kW (302 hp) max power. Drawbacks of the YASA motors are that they operate on high voltage (800VDC) and that they require a liquid cooling system.

Benefits of the nanoFlowcell aluminum-mesh 45-phase synchronous electric motors are that they operate on low-voltage (48-volts), have greater horsepower and torque than the YASA motors, and do not require a liquid cooling system. They have a solid stator structure made of light alloy, which when combined with the aluminum-mesh design makes them lighter in weight than YASA or other comparable motors. They are also scalable, generate very low noise levels, are encased to be water resistant/proof, and produce no pollution. Further, RPM can be manipulated with granularity and precision to provide smooth and stable flight.

There are various other engines and electric motors which could possibly work in an AV application, including Duke, GoTek Energy’s DynaKinetic, Jonova, NEVIS, Orbital Power, Rad-

\textsuperscript{9} https://www.wattflight.com/electric-propeller-aircraft/electroflight-p1e/
\textsuperscript{11} https://www.aerosociety.com/media/5055/electroflight-motor-web.jpg?width=500&height=333.3333333333337
Max/Rad-Cam, Scuderi, Stirling, Tesla, and Venturi. Various fuel sources include Li-ion batteries, gasoline, diesel, jet-fuel, hydrogen gas, hydrogen fuel cell, propane, etc. However, none of these alternatives provide the many benefits of the proposed nanoFlowcell solution.

4.7.7 Contra-Rotating Transmission Shaft

The concept AVs are designed to use a contra-rotating transmission shaft similar to the one pictured here\(^{12}\), which is the one used in the Electroflight P1e. The P1e’s transmission shaft is part of the Contra-Rotating Propeller System (CRPS) made by Contra Electric Propulsion Ltd. Motor power is transmitted directly to two coaxial shafts by way of splined couplings in the motors and on the shafts, and then on to the two propellers attached to the two star-shaped flanges. The design of the CRPS shaft assembly and bearings ensure there is no single point of failure, thereby providing a high degree of reliability. Vibration damping assemblies are not required. The transmission shaft may require modification to operate with the nanoFlowcell motors, or the nanoFlowcell motors may require modification to drive the shaft, or both.

4.7.8 Contra-Rotating Propellers

The two propellers used on the Electroflight P1e (pictured here) are manufactured by Hercules Propellers Ltd\(^ {13}\). The front propeller is 178cm (70 in) diameter and the rear is 170cm (67 in) diameter, both fixed pitch. The CRPS drives the propellers over a huge RPM range, without any form of gearing. This allows the use of simple and extremely robust fixed pitch propellers. This enables thrust reversal in light aircraft while exceeding variable pitch propeller efficiency. This feature offers a unique method of rapidly reducing speed and enhancing maneuverability in flight, which may be a benefit to the AVs, but that is TBD. The specific fixed-pitch propeller geometry for the AVs will need to be engineered to the rotational and torque characteristics of the nanoFlowcell motors, as well as to provide the most efficient and effective thrust at cruise speed for each AV model. The result will be a compact lift and propulsion system that achieves powerful results with smaller diameter propellers, as compared to a single motor/engine, single propeller design. Further, the use of fixed pitch propellers provides low cost and maintenance free operation.

**Noise Cancelling Effect.** Another key advantage of a twin propeller CRPS, as compared to a single propeller system, is that a noise cancelling effect is achieved through dissimilar propeller RPM. A

\(^{12}\) [http://www.contraelectric.com/innovation/the-system-components](http://www.contraelectric.com/innovation/the-system-components)

\(^{13}\) [http://www.hercprops.com/](http://www.hercprops.com/)
small difference in RPM produces out-of-phase soundwaves (anti-phasing), which counteract each other and reduce the amplitude (volume) of noise. The result is an overall quieter system.

4.7.9 Flight Characteristics of a Twin-Motor/Contra-Rotating Propeller System

The inherent capability of a typical quad-motor drone, using four single-motor/propeller systems, is that it can safely maneuver and land with only three single-motor/propeller systems operational. With three operational single motor/propeller systems (any three), the flight control computer has full control over pitch and roll, but not yaw. This means that if a typical drone loses a single motor/propeller system, it will spin around on the vertical axis, but is still able to safely maneuver, descend and land on target. The AV spins because two propellers are turning one way (e.g. clockwise) and only one turning the other way (e.g. counterclockwise), creating a 2:1 clockwise force on the AV itself, turning/spinning it clockwise on the vertical axis, in this example.

An improved flight characteristic of the proposed twin-motors driving contra-rotating propellers, as compared to single-motor/single-propeller systems, is that if one of the eight motors or propellers were to fail, the AV would automatically and autonomously stop the opposing motor/propeller on the opposite corner, and perform an emergency landing. In this situation, the concept AVs can still hover and land safely, with full payload, while maintaining full control over pitch, roll, and yaw. This means that they will not spin around on the vertical axis because three of the six remaining operational motors and propellers are turning one way (e.g. clockwise) and the other three of six are turning the other way (e.g. counterclockwise), creating a 1:1 force on the AV. This inherent flight characteristic will provide a safer system and safer landings if such an emergency situation were to occur.

4.7.10 Scaling Up the nanoFlowcell Power Generation System and Motors for AVs

The power generation system currently used in the QUANT 48-VOLT sports car produces a total of 560kW (~751 hp), producing 2,000Nm (~1,475 ft lbs.) of torque per wheel. This size is more than sufficient for the proposed GVs, but not for the AVs. It is anticipated that the large concept AV models will weigh ~500kg (~1,100lb) with fuel, and be capable of carrying up to ~500kg (~1,100lb) of payload, resulting in a Gross Aerial Vehicle Weight (GAVW) of ~1,000kg (~2,200lb). The small concept AV models will weigh less, but are anticipated to be capable of carrying the same amount of payload, up to ~500kg (~1,100lb).

The solution for the AVs is to “scale up” the nanoFlowcell power generation system and motors to provide an estimated 1,640kW (~2,200hp) per system, which is supposedly sufficient to make an emergency landing with only one operational system. (This is only an estimation). Based on these values, the AVs will require two power generation systems, each about three times as powerful as the QUANT 48-VOLT sports car engine. The AVs will also require electric motors about three times as powerful as the wheel motors in the QUANT car. According to nanoFlowcell, the power generation system and motors are fully scalable, and larger systems are already developed. The system will also need to be designed to fit within the curved confines of the AV nose/tail cones.

Based on the above values, the concept AVs would be configured with two power generation systems, one in the nose cone and one in the tail cone, each scaled up to provide about 1,640kW (~2,200hp) of power. This amount of power will enable the AV to safely hover and land, even if
one system became inoperative. The two systems together will provide an estimated 3,280kW (4,400 hp) of power to enable swift lift and propulsion (six times the power of the QUANT car system), as well as generate heat and air conditioning. Whether the nanoFlowcell system can be scaled up to provide the needed power, and sized to fit within the AV concept designs, is TBD.

4.7.11 Electric Motor Cowlings

The proposed AVs have an innovative motor placement/mount design, where the cowlings would act as the case, holding the motor components in place, instead of being just a cover. The proposed aluminum-mesh synchronous electric motors would be built into the motor cowlings themselves, without an additional aluminum case, saving weight. The cowlings would be an easily removeable 2-part half-split design, constructed of very strong but lightweight carbon/carbon composite materials, which also provides necessary ventilation. The design allows maintenance personnel to rapidly remove and replace a motor/propeller assembly, including the integrated cowlings, and quickly get the AV back in operation. Further, the motor to arm mounts are designed to accommodate future motor or propulsion systems with minimal/no redesign or modification.

4.7.12 Tilt Rotor Function

The concept AVs use a “tilt rotor” function, where two twin-motor/contra-rotating propeller systems are mounted to the opposing ends of a round motor/landing arm. The round motor/landing arms are installed through holes in the AV’s body, perpendicular to forward flight, extending an equal distance on both sides. There are two motor/landing arms, one in the front end of the AV body (illustrated here) and one in the rear. The arms rotate to tilt the attached motor/propeller systems simultaneously. The tilt function will be controlled by two (redundant) electric motors mounted inside the front AV body, which simply turn geared rings mounted around the center of the front motor/landing arm, which tilts the front motor/propeller systems. Two additional electric motors are mounted inside the rear AV body, which turn similar geared rings mounted around the rear motor/landing arm, which provides tilt to the rear motor/propeller systems. The flight control system (HW/SW) will control the degree of tilt on each arm independently. The motor/landing arms and motor/propeller systems tilt 90 degrees forward and back, relative to the 0 degree, straight up position.

The primary objectives of the tilt rotor function are to maintain the entire AV body in a level position at cruise speed once acceleration has ceased, and to provide maximum forward propulsion while simultaneously maintaining required altitude. The motor/landing arms are an innovative, weight-saving design that support the twin-motor/contra-rotating propeller systems, the Emergency Flotation Systems (addressed in Section 4.7.19) and provides a landing leg assembly having an HD camera and LED lights for precise landings - all in a singular form. This design eliminates separate arms for motors and separate structures for landing, reducing weight.
4.7.13 Lift

The capabilities of each AV, to include lift, will be specified by the manufacturer, and verified during each airworthiness inspection. Lift, as defined herein, is a measurement of the amount of gross weight that an AV’s motor/propeller systems can raise off the ground. The ATS standards will stipulate that one of the two power production systems, which would be configured to power one-half of the total motor/propeller systems, must be able to provide enough lift to safely hover and land the entire AV, full of fuel and with maximum payload, which is the Gross Aerial Vehicle Weight (GAVW). This standard provides an additional layer of safety, to ensure that AVs will never fall from the sky due to loss of a single power generation system, or a motor/propeller system. This standard provides a total lift (using all eight motor/propeller systems) that is at least twice that required to lift the GAVW, which provides reserve power for speed and emergency maneuvers.

4.7.14 Electric Propeller Icing Control System

In order for AVs to provide service year-round, at any location, they require an electric propeller icing control system\textsuperscript{14}. Traditional systems consist of an electrical energy source, a resistance heating element, wiring, and system controls such as on-off switches, ammeters, and circuit breakers. The ammeters permit monitoring of individual circuit currents. For the concept AVs, the icing control system will be an automated, autonomous system able to detect ice buildup and provide intermittent application of power to the heating elements to remove ice after formation, but before excessive accumulation. Electrical power from the nanoFlowcell power generation system will be transferred to the propeller hubs and then to the blades by automated controls. Heating elements will be mounted in the propeller spinners and blades. A timer/cycling unit determines the sequence of which blades are being deiced, and for what length of time. The timer/cycling unit varies the current in each blade element based on light or heavy icing conditions, to balance ice removal and to avoid excessive vibration. To prevent element overheating, the icing control system is used only when the propellers are rotating and for short periods of time. The unit would energize the heating element circuits for about 15 to 30 seconds, with a complete cycle time of about 2 minutes. Proper control of heating intervals aids in preventing runback, as heat is applied just long enough to melt the ice face contacting the blade.

4.7.15 Fire Detection and Suppression Systems

Fire and/or smoke can present a grave risk to passengers, whether within the cabin, the front/rear nose cone compartments, or at any of the four motor placements. The risk of fire is reduced through the use of both passive and active systems\textsuperscript{15}. Passive methods include the use of noncombustible materials, separation by routing, compartmentalization (use of firewalls), isolation, proper ventilation and drainage. The active method is comprised of three smoke detectors which function as an autonomous fire detection system. They would detect smoke within the cabin, or the front or rear nose cone compartments. In case of a cabin fire, a portable, hand-held fire extinguisher would be used by a passenger to extinguish the fire. Due to the low

\textsuperscript{14} https://www.aircraftsystemstech.com/p/propeller-auxiliarsystems-ice-control.html
\textsuperscript{15} https://aviation.stackexchange.com/questions/23135/how-does-a-fire-suppression-system-work
probability of occurrence, and the ability to make an emergency landing within minutes, there
are no fire extinguishing systems for the utility compartments or for the four motor placements.

4.7.16 Motor Runaway

An AV (or GV) may experience motor runaway due to a short in the electrical system or motor
windings, or in the case of an AV, due to a no-load situation such as a broken/missing propeller.
In any of these situations, the speed of an AV/GV motor may be uncontrollable, and RPMs could
increase to or beyond maximum limits. To mitigate motor runaway, AVs (and GVs) will contain
speed/current limiting devices (e.g. resettable circuit breakers) for each of the motor circuits
eight in an AV and four in a GV). If either speed or current exceeds predetermined thresholds,
the device would autonomously “trip” OPEN, thereby deactivating that particular motor circuit.
When the voltage/current is removed from the motor winding, motor runaway will cease.

In an AV, the motor control circuitry will also autonomously cut power to the “sister” motor on
the opposite corner that turns in the opposite direction, to prevent the AV from spinning on the
vertical axis. (Note: Although power is removed, both motors will continue to spin as a result of
wind force on the propellers, since the concept vehicles contain fixed-pitch propellers with no
feathering capability). After the above actions are complete, the AV will make an emergency
landing. GVs will make an emergency stop, as per GV operational protocols.

4.7.17 Hover and Landing Capabilities in Emergency Situations

Each concept AV has two nanoFlowcell power generation systems, one in the front nose cone
and one in the rear. Each system provides power to four motor/propeller systems, one in each
corner of the AV. Each power generation system and associated motor/propeller systems would
be sized/scaled (as necessary) to independently provide sufficient power and lift to enable safe
and stable hover and landing capability with full payload, as well as providing sufficient power to
other select components (e.g. computers, sensors, cameras, lights, etc.). Therefore, in an
emergency situation where one power generation system or motor/propeller system fails, the
AV can still hover and land safely, without degradation of flight control or other component
functionality. If this controlled emergency landing had to occur over water, the EFS would deploy
to keep passengers, cargo and the AV itself floating on top of the water, for up to 12 hours.

In the concept AV design, even if an AV completely lost one of the power generation systems,
which would remove power from four motor/propeller systems (one on each corner), the AV
would be able to hover and land level and safe at full payload. If the AV lost all four
motor/propeller systems in the front, or all four in the rear, the AV would still be able to hover
and land safely at full payload, but in an end-down or nose-down position. If the AV lost all four
motor/propeller systems on the back side, or all four on the door side, or if five or more were to
fail (anywhere), the AV would not be able to hover or land safely with full payload.

This design configuration will require that each motor/propeller systems be capable of providing
at least 1/4th of the total power required to hover with full payload. This would be the
motor/propeller system’s full-power capability (100%). Therefore, when operating normally with
eight motor/propeller systems, each system will provide at least 1/8th of the total power required
to hover with full payload, requiring only 50% of its total capability. This results in at least 50%
reserve power capability which would be used to provide propulsion for swift flight, to buck headwinds, to counter downdrafts, and maintain correct PIT.

4.7.18 Emergency Landings

In most emergency situations (e.g. power generation or motor/propeller system failure) the AVs autonomously navigate to and safely land at an emergency landing area – even at full payload. The on-board computers automatically and autonomously select the closest available landing area from MAP data, calculate and transmit an emergency time-path to the selected landing area, obtain GM Control approval, and safely navigate to and land at the area. The MAP will include multiple emergency landing areas/spots, pre-identified for emergency situations. These emergency landing areas include approved/established landing areas and helipads, as well as both public and private land such as fields, parks, clear areas along roads, and other areas clear of trees, power lines, structures, etc. The manufacturer will dispatch another similar AV to the landing site to pick up affected passengers/cargo, as well as employees/investigators for recovery. Manufacturer employees will move cargo to, or assist passengers into the replacement AV, which would then proceed to the original destination. Employees/investigators would then evaluate, photograph, and document the emergency landing situation, and transport the AV back to manufacturer. Once there, root cause analysis (RCA) is performed, and appropriate actions taken to prevent reoccurrence.

4.7.19 Emergency Flotation System (EFS) (Patent pending, provisional application #62836964)

The concept AVs contain a novel Emergency Flotation System (EFS), which will detect if the AV landing legs enter water (e.g. river, lake, ocean, etc.) and then inflate eight separate, independent airbags to provide flotation. The EFS is comprised of two airbag assemblies mounted on each landing leg, for a total of eight separate, independent assemblies. Each assembly contains a water sensor, an inflator, a half-donut shaped airbag, and a pressure relief valve. The outside surface is
designed to “tear open” under the force of the bag inflating. Two optical infrared water sensors, similar to the Neptune Systems OS-1\textsuperscript{16}, are installed on the outside surface of each leg. They are protected from rain but able to detect water when it reaches 6 inches above the surface. When a water sensor detects water, it automatically closes its contacts to allow 12VDC to activate the inflator within its airbag assembly, independent of all other assemblies. The inflators are similar to those used in automotive airbag systems (e.g., Autoliv, Delphi, Takata, TRW, etc.). Once activated, the inflator allows sodium azide (NaN\textsubscript{3}) to react with potassium nitrate (KNO\textsubscript{3}) to produce hot blasts of nitrogen gas, which inflates the airbag in about 30 milliseconds. Each airbag assembly contains its own airbag, which is folded and stored within the assembly. The airbags are made of urethane materials designed to maintain air pressure once inflated, similar to aircraft evacuation slide systems (e.g., EAM Worldwide). Each airbag is protected from over inflation by a pressure relief valve. When inflated, the shape of an airbag resembles a half-donut shape, and its size will support/float at least 1/4\textsuperscript{th} of the AV weight at full payload. This larger than necessary size creates a degree of redundancy which allows an AV to float with full payload even if only four of the eight airbags inflate, for whatever reason.

4.7.20 Aerial Vehicle Autonomous Anchoring and Powering System (AVAAAPS) (Patent Pending)

The Aerial Vehicle Autonomous Anchoring and Powering System (AVAAAPS) automatically and autonomously anchors and connects electric power to VTOL AVs upon landing on a standardized, covered ATS parking pad. The AVAAAPS also automatically and autonomously un-anchors AVs and disconnects electric power upon takeoff. The AVAAAPS anchors and connects electric power to an AV throughout the time it is parked, facilitates safe loading/unloading of cargo and passengers, keeps AVs from blowing off parking pads in high winds (particularly elevated parking pads), eliminates manual systems and tasks, reduces risks of injury and death to personnel, and reduces risks of damage to other aircraft, equipment and infrastructure. It’s scalable, both larger and smaller, to anchor and power virtually any fully autonomous VTOL AV, whether manned or unmanned, existing or future. The AVAAAPS is expected to anchor AVs within seconds of landing, and keep them anchored even in very high winds. The AV Assembly drawing on the next page, shows an AV Assembly factory installed on the underside of an AV, including its “blade”, four LED Lights, and two HD Cameras. The Pad Assembly drawing shows a Pad Assembly mounted to a landing surface and illustrates the Receiver slot that will receive the AV Assembly “blade”.

**Arrival Procedure:** When an AV approaches within ~15 feet of a parking pad, the AVAAAPS automatically and autonomously establishes secure wireless communication with the AV, using the dedicated wireless network, Wi-Fi Direct, or Bluetooth (TBD). The AV Assembly provides the AV with two (redundant) video feeds, which are used by the Flight Control System (FCS) to automatically align and land the AV over the Receiver in the Pad Assembly. The AV must align to the Receiver (within a tolerance of +/- 1 inch), or hover and re-position until it’s within tolerance. As the AV Assembly descends into the Receiver, electric power is connected to the AV. After landing, the AV autonomously turns motor power OFF and its FCS transmits a wireless “ANCHOR” signal. When the Pad Assembly receives the ANCHOR signal, its Control Circuitry applies +12VDC

\textsuperscript{16} https://www.neptunesystems.com/fmm-accessories/
power to an electric motor, which turns a gear that moves a dowel pin (round gear rack) forward through a hole in the AV Assembly, to anchor the AV.

**Departure Procedure**: When an AV applies electric power to its motors, the AV automatically transmits a wireless “UN-ANCHOR” signal, to the Pad Assembly. Once received, the Control Circuitry applies -12VDC power to an electric motor, which turns a gear in reverse to move the dowel pin backwards, out of the holes in the AV Assembly, which un-anchors the AV from the ground so the AV can depart. As the AV departs, the electric power pin and socket connectors pull apart and grid power is removed from the AV.

In order to accommodate the AVAAPS, AVs must have an unobstructed bottom surface that is 6 inches above the landing surface. An AV Assembly configured for 1-phase AC power (3 conductors), as illustrated here, is expected to measure only 8¾” long X 1½” wide and extend down 3” from the bottom of the AV. A 3-phase 4-conductor AC version would be about 1” longer, and a 2-conductor DC version would be about 1” shorter. The entire AV Assembly and the Pad Assembly dowel pin will be made of a very strong, durable material such as titanium. The combination of small size, high strength-to-weight ratio, and aerodynamic-shaped blade provides a very strong, unobtrusive anchoring device that produces minimal drag and minimal effect on flight performance. Other than the dowel pin, the balance of the Pad Assembly will be made of high-strength steel.

The AVAAPS will be essential to providing safe and reliable fully autonomous VTOL AV operations, within a future, national, standardized, networked Autonomous Transportation System (ATS). It is a multi-use product, suitable for military, commercial, and private applications. The “market” for the AVAAPS includes existing AV owners, AV manufacturers, and facilities with covered parking pads and AVs. Potential customers include military, law enforcement, other government agencies, corporations, and private citizens. The AV Assembly portion of the technology can be
sold, individually, to existing AV owners for retrofit, but will primarily be sold to AV manufacturers for factory installation in new AVs. Alternately, AV manufacturers can obtain license to manufacture the AV Assembly themselves. The Pad Assembly portion of the technology can be sold to customers with facilities, individually, to be installed in covered ground-level and elevated parking pads, in future multi-level VTOL AV garage-style parking towers, and indoors in enclosed hangers. Both portions of the technology can be sold to customers who own both an AV and a covered parking pad. As an added value, insurance costs may go down for AVs that have the AV Assembly installed, and for facilities that have the Pad Assembly installed. The projected far-future market sales for the AVAAPS are in the millions, to equip millions of fully autonomous VTOL AVs and parking pads with autonomous anchoring and powering capabilities, to facilitate an efficient future Autonomous Transportation System (ATS).

OVER is promoting the AVAAPS technology as a U.S. and international standard, and is seeking to obtain U.S. government approval and industry acceptance/endorsements. OVER is seeking Investors and industry partners to manufacture and provide the AVAAPS technology to VTOL manufacturers and other customers. OVER is also seeking to license the AV Assembly portion of the AVAAPS to multiple VTOL AV manufactures, to be manufactured by them, and installed by them, in their specific VTOL AVs.

4.7.21 Cabin Environmental Control

A revised design for cabin environmental control scraps the separate heater and air conditioner systems and duct (illustrated at the end of Section 4.7.4), and replaces it all with two heat pump type units positioned behind the seats, one in the front utility area and one in the rear. The integrated duct work would only be required behind the seats, not over the top of the cabin as illustrated in Section 4.7.4. These small duct spaces would route return air from the top of the wall, behind the occupant’s head, down across a condenser. The conditioned air is then blown by quiet, internal fans down and out the wall, below the seats. An evaporator would be positioned in a small air-scoop area, in the lower external section of the AV, below each heat pump unit. Each thermostat-controlled heat pump will simultaneously and independently provide heating or cooling to the cabin space, as required. Such a heat pump will need to be designed/engineered specifically for the AVs, but the same/similar unit would be used on all AVs and GVs. Manufacturers of traditional aircraft heater and air conditioning systems include Air Comm, Cool Air, DC Thermal, Hornet, and ThermaCool.

4.7.22 Sling Net

The OVER concept AVs contain a “sling net” which can be attached to the AV and used to rescue people, animals and property from flooded, cut-off or isolated locations. Constructed of durable polyester or poly/silk web material, the sling net is contained in a small bag attached to the AV interior (e.g., under a seat) with Velcro. The “net” would be approximately 3m X 3m (~10ft X 10ft) square, and have four heavy-duty straps connected to each corner, about 4m (~13ft) long. Each strap would have a heavy-duty carabiner attached to the end, so they can be looped over a motor arm and secured. Once attached, an empty AV could descend over an affected area, hover approximately 4m (~13ft) off the ground while people, animals or property are placed in the net, and then ascend and carry the payload to a safe location. The procedure could be repeated as
required. After use, the sling net would be inspected, and if in good condition refolded and returned to the bag, and replaced in the AV for future use. If damaged, it would be replaced.

4.7.23 Sensors

Both CAVs and PAVs will have various sensors, to perform a variety of functions. Common sensor functions include iris recognition, door obstruction, collision avoidance, water detection, smoke detection, hazardous gas detection, explosives detection, radiation detection, power generation voltage and current, and electric motor temperature and RPM.

The *iris recognition sensor* would be a COTS product, modified as necessary for the AVs. The HW/SW in the AVs will communicate iris recognition data with GM Control to positively identify the individual prior to AV access/entry. The iris recognition sensor data would provide occupant data used to generate passenger manifests prior to departure. The iris recognition data would also be used to access customer profile, payment data, memorized destinations, etc. Potential companies that provide iris recognition systems that could be adapted to the AVs include BI² Technologies, EyeLock LLC, and Iris ID.

The *door obstruction sensor* would be a COTS product, modified as necessary for the AVs. The preferred embodiment is a “light curtain” made of multiple photoelectric presence sensors which create multiple horizontal infrared light beams in the door opening, spaced about 2 inches apart. The beams are turned ON automatically while the doors are closing. If one or more beams are blocked/reflected, the system will stop and reverse the automatic door closing operation. Potential companies that provide light curtain sensors that could be adapted to the AVs include Guardshield, HTM Sensors, and Telco Sensors.

The *collision avoidance sensors* would be part of an airborne collision avoidance system, similar to the Airborne Collision Avoidance System X (ACAS X), currently in development to reduce the risk of mid-air or near mid-air collisions between traditional fixed-wing aircraft. If the risk of collision is imminent, the AV’s Flight Control System (FCS) will use swarm technology to initiate maneuvers that will significantly reduce the risk of collision. Other automotive-type collision avoidance sensor/system manufacturers include GM’s Cruise Automation, Intel’s Mobileye,

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17 http://www.bi2technologies.com/
18 https://www.eyelock.com/
19 http://www.irisid.com/
20 https://ab.rockwellautomation.com/Sensors-Switches/Operator-Safety/Light-Curtain
22 https://www.telcosensors.com/products/light-curtains
23 https://www.skybrary.aero/index.php/ACAS_X
Safe Drive Systems (SDS)\(^2^5\), and WAYMO\(^2^6\). Examples of automotive manufacturer’s branded collision avoidance systems\(^2^7\) which may be adaptable for AV or GV use include the following.

- Pre Sense Front Plus, Avoidance Assistant, and Multicollision Brake Assist (Audi)
- Driving Assistant Plus (BMW)
- Active City Stop and Forward Alert (Ford)
- Collision Alert System (General Motors)
- Collision Mitigation Brake System (Honda)
- Smart City Brake Support (Mazda)
- PRE-SAFE\(^\text{®}\) Brake and Collision Prevention Assist (Mercedes-Benz)
- Forward Collision Mitigation (Mitsubishi)
- Intelligent Brake Assist with Forward Emergency Braking (Nissan)
- Crew Protect Assist, Front Assistant, Lane Assistant, and Multi Collision Brake (Skoda)
- EyeSight (Subaru)
- Safety Sense 2.0 (Toyota)
- City Emergency Braking (Volkswagen)
- IntelliSafe and City Safety (Volvo)

The modified or new collision avoidance system, in combination with swarm technologies and the FCS, would maintain the AVs proper distance from animate objects (other AVs, traditional aircraft, birds/duck/geese, weather balloons, rogue flying vehicles, falling objects/space debris, etc.) as well as inanimate objects (terrain, buildings, communication towers, power lines, trees, etc.). If the system identifies an animate object, that based on the calculated trajectory will come within the safety sphere of the AV, the AV’s computers autonomously make appropriate flight adjustments (e.g. tilt rotor and/or motor RPM) as required, to avoid collision. The AV will ensure that it does not encroach on another AV’s safety sphere, and that no object encroaches on its own safety sphere. For example, if the AV were going to fly into an inanimate object (crane, tower, building, etc.) the systems would detect the object and autonomously maneuver the AV accordingly. If flight adjustment is made, then the AV returns to its original time-path after passing the inanimate object (or after an animate object passes), to get back on-course and on-time. Further, the collision avoidance and FCS compare AVs, structures or other objects with those contained in the MAP; plot any vehicles, structures or other objects detected into the MAP (which are not in the MAP); and transmit their location to GM Control and other AVs in the area. AVs will have at least six collision avoidance sensors installed around the outside of the AV, for each system, on the top, bottom, front end, rear end, door side and back side. The AV’s two (redundant) collision avoidance systems and their 12 sensors total create a 360-degree monitored safety sphere around each AV.

In addition to the common sensors above, CAVs have two redundant Radio Frequency Identification (RFID) sensors inside the cargo compartment, used to digitally identify all cargo and

\(^{25}\) https://www.safedrivesystems.com/
\(^{26}\) https://waymo.com/
\(^{27}\) https://en.wikipedia.org/wiki/Collision_avoidance_system#Automobile_manufacturers
generate cargo manifests prior to departure. RFID system manufacturers include A2B Tracking\textsuperscript{28}, RFID Sensor Systems\textsuperscript{29}, and Sensor Integration\textsuperscript{30} to name a few. PAVs have two iris recognition sensors inside the passenger compartment instead of RFID, as well as a built-in microphone and speaker.

4.7.24 High-Definition (HD) Cameras and LED Lights

Both CAVs and PAVs have various HD cameras and LED lights, to perform a variety of functions including landing, loading/unloading, security, and cargo/passenger cabin illumination and video. Major manufacturers of small HD cameras include Aptina, Omnivision, Sharp, ST Micro, and Toshiba. The exact make/model of HD cameras and LED lights is TBD.

- **Landing:** The concept AVs have HD cameras and LED lights for landing placed in the middle of the bottom surface, near the AVAAPS AV Assembly, and in each of the four landing legs/feet. The video outputs are fed into the AV’s FCS and used to maneuver and align the AV to the AVAAPS Pad Assembly, and/or the X-shape landing target decal adhered to every parking pad and landing area. During a landing approach, the cameras near the AV Assembly, on the bottom of the AV, are used to align the AV Assembly over the Pad Assembly, and the camera within each landing foot is used to align each leg over the lines of the X-shape decal, which ensures that the AV doors face the proper angular position (attitude). The position of the AV cameras relative to the Pad Assembly or the X-shape landing target decal is used by the FCS to control the tilt and RPM of the electric motor/propeller systems to safely and accurately align and land the AV.

- **Security:** All AVs will contain at least four cameras and LED lights positioned around the outside of the AVs for security. These cameras will always be ON, with video feeds going to the AV’s computers, and possibly to the passenger’s mobile devices as well. When parked, if the cameras detect motion, the camera’s video feed will be automatically routed to GM Control for evaluation. If the movement if from an unauthorized intruder, the AV may be directed to lift-off and travel to another parking pad. Further, GM Control could notify local law enforcement if the intruder appears to be malicious, or notify maintenance if a benign object is detected in a landing/parking area and just needs to be removed (e.g. cardboard box, trash, toy, animal, etc.).

\textsuperscript{28} \url{https://www.a2btracking.com/commercial-asset-tracking/}
\textsuperscript{29} \url{http://www.rfidsensorsystems.com/default.htm}
\textsuperscript{30} \url{https://www.sensorsintegration.com/products-rfid}
• **Cargo/Passenger Cabin Video:** All AVs will contain cameras positioned in the upper corners of the cargo/passenger cabins, which will record video of cargo and passengers from the time of loading/entry to the time of unloading/exit. The video will be saved to both AV computers (redundancy) and retained in the AV’s computers for approximately 30 days. Live-feed video could be viewed by GM Control in response to a passenger pressing the “Emergency” button; or a component, system or sensor failure/alarm. Recorded video could be viewed within the 30-day period by the customer, the manufacture, or by law enforcement (with appropriate warrant) to investigate vandalism, damage, theft, or other crimes.

• **Running/Emergency LED Lights:** All AVs will contain bright LED “running lights” around the AV structure: Blue in the front, White in the center, and Red in the rear. Further, on the outside surface of the motor cowlings are additional lights to provide Blue/White/Red rapid flashing lights if the AV has to make an emergency landing. Although running lights are not necessary for the AVs or ATS to function properly, they are included in the design so traditional aircraft pilots can see the AVs at night.

4.7.25 **Communications**

Both CAVs and PAVs will have the same communications functionality. Communication functions include dedicated wireless network, satellite and cellular. It is anticipated that all communication circuitry will be integrated into each computer motherboard, instead of within independent stand-alone devices.

• **Dedicated Wireless Network:** The dedicated wireless network would be the primary form of communication for AVs. The HW/SW could be a COTS product, modified as necessary for the AVs. The HW/SW would provide the primary means to transmit/receive time-path data and other data to/from GM Control and other AVs. AVs may also use the dedicated wireless network to communicate ANCHOR and UNANCHOR signaling to the AVAAPS and ramp/platform/bridgeplate structures, but the exact HW/SW is TBD. One company that may be able to provide dedicated wireless network HW/SW is Airborne Wireless Network 31 (ABWN).

• **Satellite:** The satellite communication HW/SW could be a COTS product, modified for the AVs, and would provide primary GPS positioning/navigation data. Companies that provide satellite communication HW/SW which could be adapted to the AVs and used for GPS positioning/navigation include Garmin 32, Magellan 33, and TomTom 34.

• **Cellular:** The cellular network would be a backup form of communication for AVs. Cellular communication HW/SW could be a COTS product, able to transmit/receive data on any current cellular network (e.g. GSM/GSMC, CDMA, iDEN), eventually using 5G technology. The dedicated airborne wireless network and cellular networks will provide multiple communication paths to virtually eliminate any single point of failure. The cellular HW/SW would provide backup (redundant) transmit/receive capabilities to/from ground-based cellular towers for GPS positioning/navigation data, time-path data, and data to/from GM Control and other AVs. The make/model of cellular HW/SW is TBD.

31 [https://www.airbornewirelessnetwork.com/index.asp](https://www.airbornewirelessnetwork.com/index.asp)
33 [https://www.magellangps.com/](https://www.magellangps.com/)
4.7.26 Plugs, Sockets and Cabling

To facilitate mass-production, and especially service and maintenance thereafter, most if not all sensors, cameras, lights, and communication antennas will be manufactured to fit within a uniquely sized and configured “plug” which will plug into its matching “socket” (and only its matching socket) permanently mounted in the AV. Each plug and socket type/size have a unique alignment keyway and notch, to prevent the wrong type of plug from being inserted into a given socket. When the correct type/size plug is inserted into its matching socket, and the plug’s keyway aligns with the notch in the socket, the plug will slide all the way into the matching socket. Most if not all plugs (containing a sensor, camera, light, antenna, etc.) will be powered via copper, and will communicate with the computers via CAT-6/7 certified copper twisted-pair cable, fiber optic cable, or the preferred embodiment - wireless. The novel plug/socket design, illustrated with copper wiring below, is used to easily mount or remove sensors, cameras, lights, or communication antennas to/from the AV. The plug/socket design meets the following objectives:

- Ability to remove and replace each sensor plug from its socket quickly, easily, and independently, without having to remove an AV cover
- Ability to remove and replace AV covers without having to remove any sensor separately
- Inability to insert the wrong type/size sensor plug into a given socket, due to keyway
- Common captive bolt mounting HW, all having the same size bolt head (e.g. 8mm).

The proposed location of each socket, type and contents of each plug (sensor, camera, light, and communication antenna) and the quantity to be installed in the CAVs and PAVs is provided below.

<table>
<thead>
<tr>
<th>Location of Socket</th>
<th>Type of Sensor/Device</th>
<th>CAV</th>
<th>PAV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outside, Front End</td>
<td>Collision Avoidance Sensors (System #1 and #2)</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>HD Camera</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Blue LED Running Light</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Outside, Rear End</td>
<td>Collision Avoidance Sensors (System #1 and #2)</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>HD Camera</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Red LED Running Light</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Outside, Door Side</td>
<td>Collision Avoidance Sensors (System #1 and #2)</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>(mounted above doors)</td>
<td>HD Camera</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>IRIS Camera</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Location of Socket</td>
<td>Type of Sensor/Device</td>
<td>CAV</td>
<td>PAV</td>
</tr>
<tr>
<td>-------------------------</td>
<td>-----------------------------------------------------------</td>
<td>-----</td>
<td>-----</td>
</tr>
<tr>
<td></td>
<td>White LED Running Light</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>White LED Load/Unload Lights, projecting downward</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Outside, Back Side</td>
<td>Collision Avoidance Sensors (System #1 and #2)</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>HD Camera</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>White LED Running Light</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Outside, Bottom</td>
<td>Collision Avoidance Sensors (System #1 and #2)</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>HD Cameras for Docking (part of AVAAPS)</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>White LED Lights for Docking (part of AVAAPS)</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>White LED Running Light</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Loudspeaker, flush-mount, water resistant</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Collision Avoidance Sensors (System #1 and #2)</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>HD Camera</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Wireless Network Communications Antenna</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Satellite Communications Antenna</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Cellular Communications Antenna</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>White LED Running Light</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Outside, Top</td>
<td>Motor Temp Sensor (Inside cowling)</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Motor RPM Sensor (inside cowling)</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Blue LED Running/Emergency Light (outside cowling)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Outside, Left Front</td>
<td>White LED Emergency Light (outside cowling)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Motor Cowling</td>
<td>Red LED Emergency Light (outside cowling)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Outside, Right Front</td>
<td>Motor Temp Sensor (Inside cowling)</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Motor Cowling</td>
<td>Motor RPM Sensor (inside cowling)</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Blue LED Running/Emergency Light (outside cowling)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Outside, Right Front</td>
<td>White LED Emergency Light (outside cowling)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Motor Cowling</td>
<td>Red LED Emergency Light (outside cowling)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Outside, Left Rear</td>
<td>Motor Temp Sensor (Inside cowling)</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Motor Cowling</td>
<td>Motor RPM Sensor (inside cowling)</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Blue LED Emergency Light (outside cowling)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Outside, Left Rear</td>
<td>White LED Emergency Light (outside cowling)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Motor Cowling</td>
<td>Red LED Running/Emergency Light (outside cowling)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Outside, Right Rear</td>
<td>Motor Temp Sensor (Inside cowling)</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Motor Cowling</td>
<td>Motor RPM Sensor (inside cowling)</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Blue LED Emergency Light (outside cowling)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Outside, Right Rear</td>
<td>White LED Emergency Light (outside cowling)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Motor Cowling</td>
<td>Red LED Running/Emergency Light (outside cowling)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Outside, Left Front</td>
<td>White LED Lights, for Landing</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Landing Foot</td>
<td>HD Camera, for Landing</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Outside, Right Front</td>
<td>White LED Lights, for Landing</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Landing Foot</td>
<td>HD Camera, for Landing</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Outside, Right Rear</td>
<td>White LED Lights, for Landing</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Location of Socket</td>
<td>Type of Sensor/Device</td>
<td>CAV</td>
<td>PAV</td>
</tr>
<tr>
<td>---------------------------------------</td>
<td>-----------------------------------------------</td>
<td>-----</td>
<td>-----</td>
</tr>
<tr>
<td>Outside, Left Rear Landing Foot</td>
<td>HD Camera, for Landing</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Outside, Right Rear Landing Foot</td>
<td>White LED Lights, for Landing</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>HD Camera, for Landing</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Inside, Front Nose Cone</td>
<td>Smoke Detector</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Inside, Rear Nose Cone</td>
<td>Smoke Detector</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Inside Cabin, on Wall</td>
<td>Emergency Button, for Passengers</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Inside Cabin, Four Upper Corners</td>
<td>HD Cameras</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>IRIS Camera</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>RFID Sensors</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Inside Cabin, Ceiling</td>
<td>White LED Lights, for loading/unloading/reading</td>
<td>3/6</td>
<td>3/6</td>
</tr>
<tr>
<td></td>
<td>Smoke Detector</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Hazardous Gas Detector</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Explosives Detector</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Radiation Detector</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Microphone</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Speaker</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Wi-Fi Router providing Free Internet access</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

Note: 3/6 denotes 3 in the small AVs and 6 in the large AVs.

4.7.27 Alarms

An expected standard is that all sensors, HD cameras, LED Lights and communication antennas must be fully operational before an AV can provide service to customers. AVs must be in GREEN (fully functional operational condition) for GM Control to authorize/approve a normal time-path. If an AV detects that a system or component is not working properly (e.g. motor temp, collision avoidance, HD camera, etc.) it automatically transmits the alarm to GM Control. Alarms will be either AMBER (diminished operational condition) or RED (critical/non-functional operational condition). Either alarm condition must be resolved before the AV can provide service to customers. Examples of different types of alarms are presented below.

<table>
<thead>
<tr>
<th>System</th>
<th>Problem</th>
<th>Type of Alarm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emergency Button</td>
<td>Glass broken and button depressed</td>
<td>RED</td>
</tr>
<tr>
<td>Power Generation</td>
<td>Any problem with either system</td>
<td>RED</td>
</tr>
<tr>
<td>Motor</td>
<td>Any problem with any motor</td>
<td>RED</td>
</tr>
<tr>
<td>Propeller</td>
<td>Any problem with any propeller</td>
<td>RED</td>
</tr>
<tr>
<td>Computer</td>
<td>Any problem with either computer</td>
<td>RED</td>
</tr>
<tr>
<td>Communications</td>
<td>Any problem with any function</td>
<td>RED</td>
</tr>
<tr>
<td>Sensor, HD Camera, or LED Light</td>
<td>Any problem with two or more devices</td>
<td>RED</td>
</tr>
<tr>
<td>Fuel (bi-ION)</td>
<td>Leak, clog, inoperative pump</td>
<td>RED</td>
</tr>
<tr>
<td>Low Fuel (bi-ION)</td>
<td>Detected in either tank</td>
<td>RED</td>
</tr>
<tr>
<td>Sensor, HD Camera, LED Light</td>
<td>Any problem with one device</td>
<td>AMBER</td>
</tr>
<tr>
<td>AVAAPS</td>
<td>Any problem</td>
<td>AMBER</td>
</tr>
</tbody>
</table>
When an AV senses an alarm, whether airborne or on the ground, it autonomously takes the appropriate action, monitored by GM Control. The table below specifies the appropriate actions, depending on location (Airborne or On the Ground) and alarm type (RED or AMBER).

<table>
<thead>
<tr>
<th>Location</th>
<th>Alarm</th>
<th>Flight Status and Appropriate Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airborne</td>
<td>RED</td>
<td><strong>The AV must land immediately.</strong> If a Service Center is within its immediate area, the AV will autonomously calculate and file an emergency time-path to that Service Center, and then proceed to land immediately. If no Service Center is within its immediate area, the AV will autonomously calculate and file an emergency time-path to any standard, available <strong>landing area</strong> within the immediate area, and then proceed to land immediately. If no landing area is available within the immediate area, then the AV will autonomously calculate and file an emergency time-path to the nearest <strong>emergency landing area</strong>, and then proceed to land. GM Control will dispatch another similar fully operational (GREEN) AV to the landing area, where cargo or passengers will be moved to the new AV and continue to their destination. Once landed, the AV is “Out-of-Service” and cannot carry payload until the problem is resolved. The AV will not lift-off/fly in RED alarm condition, and if it lands away from a Service Center, it will require mobile service or transport.</td>
</tr>
<tr>
<td>On the Ground</td>
<td>RED</td>
<td><strong>The AV is “Out-of-Service” and cannot carry payload until the problem is resolved.</strong> The AV will not lift-off/fly in RED alarm condition, and will require mobile service or transport, if not already at a Service Center.</td>
</tr>
<tr>
<td>Airborne</td>
<td>AMBER</td>
<td>If carrying payload, the AV will proceed to destination IAW the approved time-path. If empty (no payload), the AV will autonomously calculate and file a time-path to the nearest Service Center. If it proceeds to the destination to deliver the payload, it will then be classified as “Out-of-Service” and cannot carry payload again until the problem is resolved. The AV would then be in an “On the Ground – AMBER” condition. The AV will autonomously calculate and file a time-path to the nearest Service Center that can resolve the problem, and may lift-off and fly, <strong>with no payload</strong>, to the nearest Service Center. Alternately, the customer or GM Control may request mobile service or transport, so the AV doesn’t have to lift off at all.</td>
</tr>
<tr>
<td>On the Ground</td>
<td>AMBER</td>
<td><strong>The AV is “Out-of-Service” and cannot carry payload until the problem is resolved.</strong> The AV will autonomously calculate and file a time-path to the nearest Service Center that can resolve the problem. The AV may lift-off and fly, <strong>with no payload</strong>, to the nearest Service Center. Alternately, the customer or GM Control may request mobile service or transport, so the AV doesn’t have to lift off at all.</td>
</tr>
</tbody>
</table>
4.7.28 Refueling

The refueling concept provides a quick and easy way to refuel AVs (and GVs) with electrolyte liquids called bi-ION®. The bi-ION electrolyte liquids facilitate the use of the proposed nanoFlowcell® power generation technique. AV units (CAVs and PAVs) will fly to local refueling stations, provided by LLC Team and other manufacturers, IAW an automated scheduled or as assigned by GM Control. Each AV contains two tanks for the charged bi-ION electrolyte liquids, one for the positively charged liquid (RED) and one for the negatively charged liquid (BLUE).

**Capless Fillers.** AVs will have two capless fillers, one for the RED (positive) bi-ION electrolyte liquid, and one for the BLUE (negative). These capless fillers would be similar to the “Easy Fuel”™ cap pictured here, but with no external flap cover. They only need to be of a simple design (e.g. spring-loaded flap which makes an external water-resistant seal) to keep rainwater from getting in and the charged bi-ION electrolyte liquids from splashing out. The capless fillers may be positioned side-by-side to receive a twin-fluid, twin-spout filler nozzle such as nanoFlowcell’s design pictured below, or positioned separately and use separate, standard single-spout nozzles.

**Twin-Fluid, Twin-Spout Filler Nozzle.** The filler nozzle pictured here was designed by nanoFlowcell, and is used to refill their concept electric automobiles with both positive (RED) and negative (BLUE) bi-ION electrolyte liquids, simultaneously. Similar filler nozzles may be adapted to refill the concept AVs/GVs, or separate filler nozzles may be required (TBD). The refueling process would initially be performed manually by employees, but it is expected that it would eventually be a fully autonomous process for both AVs and GVs.

**Refueling Operation.** AVs will fly into an assigned bay in a refueling station which will contain the AVAAPS. The AV lands over the AVAAPS Pad Assembly, and gets anchored and powered by the AVAAPS, as described in Section 4.7.20. Once an AV lands and anchors into place, a refueling employee (or future robotic arms) inserts the filler nozzles into the capless fillers on the AV. Once inserted, the charged RED and BLUE bi-ION liquids flow through their respective nozzles into their respective tanks, until filled to the appropriate level. Once refueling is complete, the filler nozzles are removed, which allows the spring-loaded flaps in the capless fillers to close. The AV is then cleaned by employees, inside and out, as required. The AV then departs to the next assignment or to an available parking space. (Note: The total amount of bi-ION electrolyte liquids in each AV will be based on total load-lift capability for each model). It is estimated that the entire refueling process can be completed in less than 10 minutes, for the largest concept AV.

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4.8 Features and Benefits Specific to Cargo Aerial Vehicles (CAVs)

Standard CAVs are designed to transport cargo only - no human passengers. The standard CAV would accommodate multiple types of cargo, to include raw materials, component parts, machinery, appliances, furniture, groceries, other food products, medicines and medical items, emergency water/food, and many other items. It’s anticipated that the bulk of CAVs will be used by businesses to speed deliveries and/or provide a higher/premium level of service to customers. However, they can also be use by the general public for transporting (moving) personal household goods, professional goods, and other items. Standard CAVs will be insulated and environmentally controlled (A/C and heat). Standard CAVs have no seats or windows, and the interior floor and walls will be made of a tough, durable, scratch-resistant material.

4.8.1 CAV Models

OVER proposes two CAV models, the small AC-2.7 and large AC-4.4, both being enclosed, container-type units that would be used to transport general cargo. Each could carry approximately 500kgs (~1,100lbs), because they both have the same size twin-motor/contra-rotating propeller systems. The small CAV model (AC-2.7) has approximately 2.7 m³ (~97 ft³) of interior space, and the large CAV model (AC-4.4) has approximately 4.4 m³ (~155 ft³) of interior space. The two CAV models would be the same size as the two PAV units, respectively, simplifying the manufacturing assembly line design, manufacturing logistics, as well as follow-on logistics and maintenance. Having these capabilities, CAVs will provide a robust aerial cargo transportation system from day one, that will reduce the number of small vehicle/truck deliveries, and the risks, expense, congestion, delays, noise and pollution generated by this sector of the ground-based cargo delivery system. Some examples of how the standard CAV models could be used include the following:
• Transporting merchandise from distribution facilities to retail stores (maximizing Just-In-Time [JIT] processes to minimize inventory and costs)
• Transporting merchandise from distribution facilities or retail stores directly to customers
• Transporting fresh foods and other perishables directly to market or restaurants
• Transporting groceries and other food products directly to customers
• Transporting cooked/catered food directly to customers
• Transporting packages, documents, medicines and many other items between entities or directly to customers
• Rescuing persons, animals or property from flooded or isolated areas, using the “sling net”.

4.8.2 Specialized/Future CAV Models

Specialized CAVs may be developed in the future with special features to meet unique customer needs. Examples include:

• **AC-1** model, providing only one cubic meter (1m³) of cargo space
• **Combo** models to transport both cargo and human passengers. Combo models could be used by maintenance-type personnel to transport tools, parts, materials, etc. to a work site/location. They could contain a limited number of jump seats and windows.
• **Rigging** models for unique-sized cargo (e.g. lumber, PVC pipe, tinhorn, etc.). Rigging models could work in swarms to transport even larger items.
• **Refer** models to transport products that require refrigeration and/or freezing
• **Tanker** models to transport refrigerated milk or other liquids
• **Hazmat** models designed to safely transport solid and/or liquid hazardous materials.

Initially, CAVs will transport only non-hazardous cargo, however, after some months/years of safe and reliable service, DOT and FAA rules may be revised to allow hazmat to be transported on CAVs. Transporting hazmat in CAVs will prove to be a significantly lower risk to the public of accident, spill or otherwise, as compared to conventional ground transportation.

Other applications for specialized/modified CAVs may include search and rescue, emergency deliveries, aerial patrol/monitoring, firefighting support, and military/law enforcement support to name a few. The uses and applications of large, safe CAVs may be endless, and innovators will certainly continue to develop other designs to carry other types of cargo in the future. However, all such vehicles would need to operate IAW the final/approved ATS standards (e.g., communications, time-paths, collision avoidance, etc.).

4.8.3 CAV Loading and Unloading

When a CAV arrives at a pick-up location, and an authorized operator is verified via iris scan, the bus-type doors will open. The operator may load cargo using a dolly, rolling stock cages, rolling stock tubs, special pallets sized to fit either the small or large model, and/or by placing items directly on the floor by hand. As cargo is placed in the CAV, the RFID sensors record each item and the data is used to generate a cargo manifest. When loading is complete, the operator enters the destination into the ATS APP (mobile device or computer). The CAV calculates and transmits its time-path to GM Control along with a cargo manifest, obtains authorization from GM Control, and then departs at the appropriate time.
Features and Benefits Specific to Passenger Aerial Vehicles (PAVs)

PAVs are designed to transport human passengers, and a limited amount of personal/professional cargo (e.g. luggage, etc.). PAVs would be used extensively by persons commuting to/from work, home, and school, and also for general transportation for shopping, pleasure/sightseeing, tourism, and many other uses. All PAVs will be insulated, constructed with sound-absorbing/blocking material, provide free Wi-Fi-based Internet connectivity, and be environmentally controlled.

A key feature inherent with all autonomous PAVs is that anyone can ride in them, alone, at any time, including individuals with disabilities (wheelchairs, blind, deaf, etc.), children (with parental permission), elderly or other individuals who can’t drive, and even inebriated individuals who would otherwise present a danger to themselves and others, if driving a car. All occupants will sit during operation, and should use the provided lap belts. When considering these key features, readers should realize that PAVs will provide far greater and safer travel capabilities, for more individuals, than any other form of transportation in history.

4.9.1 PAV Models

OVER proposes two PAV models, similar to the two CAV models. The smaller (AP-3) would transport up to three passengers, and the larger (AP-5) would transport up to five. Each could carry approximately 500kgs (~1,100lbs), because they both have the same size/type power, motor and propeller systems. The capabilities of each model to accommodate walk-in passengers and wheelchairs is as follows.

- **AP-3**. The AP-3 model is designed to transport up to three walk-in passengers. The forward-looking seat is static (non-folding), but the rear-looking seat and jump seat are folding. With both folding seats up, the AP-3 can accommodate one walk-in passenger and one passenger in a
wheelchair. The AP-3 may be used by a single passenger (solo) for a higher fare. Note: A solo passenger in an AP-3 may also transport a bicycle.

- **AP-5.** The AP-5 model is designed to transport up to five walk-in passengers. None of the seats in the AP-5 fold up, except for the jump seat mounted to the back-side wall. When folded up, the AP-5 can accommodate four walk-in passengers and one passenger in a wheelchair.

### 4.9.2 Jump Seat

Both PAV models contain a folding “jump seat” attached to the back-side wall. One of the thinnest designs is the SurfaceGlide wall chair manufactured by Series Seating,

Both PAV models contain a folding “jump seat” attached to the back-side wall. One of the thinnest designs is the SurfaceGlide wall chair manufactured by Series Seating,

Each 20-inch wide seat has a thin profile design that measures only 4½ inches thick when folded to the wall – a key concern to ensure that wheelchair entry and exit is not obstructed. Their patented Back Glide system allows passengers to sit in comfort at a 17-degree angle, and the self-closing system automatically returns it to its upright, vertical position when not in use. The SurfaceGlide seat supports up to 600 lbs. on the front edge of the seat and up to 1,700 lbs. across the middle. Removable slipcover upholstery allows for quick change should fabric get soiled, torn, or otherwise. Other potential jump seat options include the Clam Wall Mounted Fold Up Chair by Quality Pacific Manufacturing, Inc., and the 15-inch wide Flip Mounted Folding Seat by Locomotive Seats Australia.

### 4.9.3 Windows

All windows in the concept PAVs are electronically-controlled dimmable windows, such as the “electrochromic” windows employed in Boeing’s 787 Dreamliner, called Suspended Particle Device ( SPD)-Smart Electronically Dimmable Windows (EDWs). These dimmable windows allow passengers to instantly and precisely control the amount of daylight and glare coming through their window, at the touch of a button, or with their personal mobile device. Although the picture illustrates four levels of dimness, the windows allow a continuously variable amount of dimness anywhere between clear and very dark. Passengers can continue to enjoy views on sunny days by tinting them to control the amount of light to a comfortable level, rather than blocking their view completely with a pull-down manual shade. Further, standard aircraft windows are a primary path for heat and noise to enter the cabin, but the SPD-Smart EDW systems provide thermal and acoustic insulation which results in a cooler, quieter cabin, as well as almost 100% UV protection. “SPD-Smart” is a trademark of Research Frontiers Inc. Other dimmable window solutions may include Smart Tint, nanocomposite materials (nanocrystals) developed by Heliotrope, and perovskite. The proposed

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37 http://www.pacificmarine.net/marine-deck/marine-seATS/wall-mounted-fold-up-chair.htm
38 http://locosATSoz.com/Flip-Mounted-Folding-Seat.htm
39 http://www.smartglass.com/
PAV’s would contain eight SPD-Smart EDWs, four on the back-side wall and four on the door-side wall, including one in each door. All wall and door windows on all AVs and GVs are the same type and size, which simplifies logistics, manufacturing, assembly, and maintenance. If the concept PAV/CAV designs are eventually changed to a more aerodynamic shape, as illustrated in Section 4.10, then four additional, larger SPD-Smart EDW windows could be installed in the roof.

4.9.4 PAV Loading and Unloading

When a PAV arrives at the pick-up location, and the waiting passenger is verified via iris scan, the PAV door opens and the passenger boards. When loading at a public location, the PAV will wait up to one minute per vacant seat to be occupied, unless riding “solo” in an AP-3 which has a premium fare. If loading at a private location (e.g. passenger’s driveway, etc.), the PAV will not wait for vacant seats to be occupied. Once the PAV is full, or the wait time has expired, the PAV calculates its time-path, transmits it to GM Control (for the first destination) along with a passenger manifest, obtains authorization from GM Control, and then departs at the authorized time. Upon landing, the iris detection system identifies passengers who unload, and those passengers are removed from the passenger manifest for the next flight/destination.

4.10 Other AV Designs

The current AV designs maximize the utility/mechanical space around the cabin, within the rounded top, nose cone and tail cone covers. This space is for the nanoFlowcell power generation systems, bi-ION fuel tanks, computers and electronics. If the fuel tanks and power generation systems do not require this much space, then the design can be more aerodynamic and lighter, and hence more efficient, as illustrated below. This design still provides the same passenger/cargo cabin space and level entry/exit, but adds SPD-Smart EDW glass panels (similar to the windows) in the roof, for greater visibility, which can be lightened or darkened to control the amount of light to a comfortable level. Further, this design incorporates “wings” for some degree of lift. Additionally, standard 1- and 2-passenger models, and smaller cargo models such as a 1 cubic meter model, may be designed, manufactured and offered, based on customer need/demand. Operational capabilities would still meet or exceed the recommended standards (e.g. flight time, speeds, etc.).