Science Fact

The Venus Sweet Spot: Floating Home

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Venus hosts the most human-friendly environment in the Solar System, after Earth. Once the darling of scientists and science-fiction writers alike, the *surface* of Venus has become a monumental disappointment as a vacation spot. With surface temperatures around 800 degrees F and atmospheric pressure of 90 bar, there will be no leisurely strolls along the rim of Artemis Corona in the foreseeable future.

But we could live very near there in comfort, with readily available tech today, through buoyancy. The idea of living among the clouds of Venus in floating cities has been . . . well . . . floating around since at least the early '70s, when the Russians, capitalizing on the success of their early, pioneering Venera surface probes, set forth detailed plans for great, complex habitats afloat in the so-called "sweet spot" of Venus.

The Venus atmosphere is incredibly dense, but like all planetary atmospheres, it thins out to nothing with enough altitude. At one point along this diminishing spectrum, at about thirty miles above the hellish surface, the atmosphere almost exactly matches Earth's in terms of temperature and pressure. And, what's more, due to the high concentration of CO_2, breathable air becomes a lifting gas.

Much has been made of this opportunity (by Geoffrey Landis and others), and the internet is rife with lamentations that Venus has been for too long ignored, especially after the Venera and Magellan missions gave us so much bad news about the surface. But are we too terrestrial-centric?

Venus missions compete, not often successfully, for NASA dollars, and many enthusiasts still bewail the lost opportunity that is the planet Venus. We were bolder during the '60s. NASA's Apollo Applications Program actually sported a plan for a human-piloted Apollo capsule flyby of the cloud-enshrouded planet.

Getting *to* Venus is a mere rocketry problem. Getting to that sweet spot, with much less than orbital velocity, is a bit trickier. Getting equipment and people there for the construction and population of a floating city can best be accomplished by application of buoyancy principles, the very same as those that will support the floating city itself. Alternatively, we could arrive like a meteor, capsule blunt end forward, heat shield aglow, eventually to deploy parachutes and balloons. But the payload penalty would be unacceptable, and it would be a one-way trip. Carrying along the wherewithal to be able to rocket back to your orbiting interplanetary transport ship would make for an even greater payload penalty.

However, an extremely large lighter-than-air ship could be deployed from the orbiting ship from Earth. Being well above the Venus cloud tops, the air would be as thin as that which the International Space Station glides through. The airship would bleed off orbital velocity and lose altitude by the simple expedient of tipping up its nose and letting its vast surface area slow it down, as a maple leaf drifts slowly to Earth from a high branch.

Such a craft has been in development for some forty years by John Powell of Rancho Cordova, California. It's a V-shaped, semi-rigid dirigible, or *keel ship;* the "orbital airship," as he calls it. This ship is designed as the final step in his envisioned system for lofting payloads to orbit at a fraction of the cost of rockets. John's company, JP Aerospace, a volunteer-based DIY space enterprise whose motto is "America's OTHER Space Program," has been launching scaled down versions of his concept for about twenty years. Once built, this ship, part of Powell's "Airship to Orbit (ATO)" program, will be able to take people from the stratosphere to orbit. It could also, very easily, bring people from a Venus floating city up to Venus orbit.

And back again. Yes, among the many cost and safety benefits of this approach is the fact that the ship that brought you to orbit is the very same ship that will bring you back most of the way home. It all starts with a much smaller version of the orbital airship, the Ascender, which could be called a Descender during the return trip. (This part of the system would not be needed on Venus because we're not interested in visiting its surface.) On Earth, an Ascender will bring people and goods up to a floating "dark sky station," an enormous, permanent way station, floating at about 140,000 feet. It doesn't need to be stationary with respect to the surface: the maneuverable, powered Ascender will find it and dock. In the dark sky station, astronauts and materials are transferred to the orbital airship.

The orbital airship will be mind-bogglingly big—each arm over a mile long, with a diameter of 350 feet. It cannot be brought up to the dark sky station, but must be built there. It will be designed to fly in subsonic, supersonic, and hypersonic regimes. Above Venus, the orbital airship would be deployed from the orbiting interplanetary rocket ship, and the floating Venusian city would serve as the dark sky station. People and material could be loaded onto the orbital airship to descend to the city. Eventually the ship could come back to the orbiting transport to be deflated and stowed for return to Earth.

But how can a balloon possibly slow down from orbit, or accelerate to orbit (remember, orbit requires speed, not altitude), and not be torn apart by the atmosphere? John Powel has a plan.

The plan is rooted in historic achievements by balloons. People have been setting records in helium balloons since the '30s. Piccard and Kipfer reached 51,775 feet in 1931. Russians Prokofiev and Gudenoff reached 72,000 feet in 1934. In the late '50s and early '60s, the air force's Man High and Excelsior projects paved the way for the Mercury astronauts by reaching the stratosphere, staying there for hours doing science, in balloons. In 1960, Captain Joe Kittenger jumped from his balloon at 102,800 feet. In 1966, Nick Pianteneda, a truck driver from New Jersey, reached 123,500 feet, a record that has stood until recently when in 2014 Alan Eustace jumped from a balloon at 135,890 feet.

All these feats of derring-do (and many others) were in "zero pressure" balloons, the kind we are all used to seeing, if only in newsreels. Acres of clear plastic rise into the air with a large bubble or bolus of Helium giving the tip of the giant balloon a slightly spherical shape. The balloon is only partially inflated, huge amounts of bag material hanging from the bolus, down to the gondola carrying people and equipment and ballast. (The missions mentioned above all involved a pressurized gondola or a pressure suit. Above 30,000 feet there is not enough oxygen or pressure to support life.)

The reason for only inflating the balloon partially is that, as it rises, the outside pressure decreases, allowing the helium to expand, which continues to provide lift as it displaces more of the ever lighter air. Once fully inflated the balloon will no longer go up. Your choices then are to stay put, cut away or pop the balloon and parachute back to terra firma, or vent helium . . . carefully. This last option is a very tricky, delicate operation: you are releasing the very stuff that keeps you up there.

But the orbital airship is not designed this way. It has more in common with blimps and dirigibles, those massive cruise ships of the air of a bygone day. The familiar fat-cigar-shaped airships come in two major varieties. Dirigibles, like the mighty Zeppelins, have a complete rigid, internal structure, giving the ship its shape. The bag of hydrogen or helium inside still allows plenty of room for catwalks and access so the crew can monitor and if necessary take maintenance or emergency action. The controls, engines, and propellers are usually mounted in or attached to the so-called "control car" situated on the Earth-facing belly of the behemoth. Dirigibles and blimps were so large that they could lift all this infrastructure, crew and crew quarters, along with passengers (more concerned with the age of the Bordeaux they ordered with dinner than with the principles of buoyancy).

Dirigibles have a long and glorious (and infamous) history—from the great Zeppelin ships of Germany that carried passengers in comfort in antebellum Europe, to those that bombed England and Poland during the First World War. Dirigibles included the Graf Zeppelin of transatlantic service and postage stamp fame, and the Hindenburg of tragic notoriety. (Yes, hydrogen is not a good idea, near the Earth anyway.) The U.S. military lofted many dirigibles, most noteworthy of them the *Macon* and the *Acron* with their stories of deep tragedy and uplifting survival. To this day, the mighty hangars that housed these marvels of the air still stand in many places; California's NASA Ames Research Center in the San Francisco Bay Area has one.

Blimps are perhaps more familiar, the Goodyear blimp being a prime example. Blimps are completely dependent on the helium inside for their shape. The controls, motors, and propellers are housed in a module below the gas bag, much like in dirigibles, but the helium bag, not any internal structure, gives the cigar its length, girth, and shape.

Midway between these is the semi-rigid dirigible, or "keel ship." This type of lighter-than-air craft has a structural member, below the bag and running the length of the ship, upon which is built, or from which hangs, all of the necessary infrastructure. This structural member, the truss, can be inside the outer envelope, or outside the ship altogether and attached to it. The keel ship also has a glorious past. Italian aviator and aeronautical engineer Umberto Nobile, after WWI, built mighty keel ships, the *Norge* and the *Italia*, and in them made amazing exploratory flights over the arctic, flying over the North Pole, the first to reach it by air.

But going hypersonic? It seems like surely this must be fantasy, but it's true. The historical roots of this concept are also deep, relatively. Precursors and proof of concept experiments abound. In 1964 a NASA Goddard experiment called Inflatable Micro Meteoroid Paraglider, or IMP, proved that an inflatable could successfully fly at 5,000 miles per hour in the atmosphere, at 300,000 feet. The success of this delta-shaped inflatable glider led to the design of FIRST (Fabrication of Inflatable Reentry Structure for Test), a means for emergency escape from the International Space Station. This inflatable life raft could, the designers were sure, bring an astronaut safely back from the ISS to Earth.

ECHO, the first communications satellites, launched in 1960 and 1964. They were little more than mammoth (one-hundred-foot-diameter), metalized Mylar balloons in high orbit. They passively bounced TV between the U.S. and Europe. At the time, it was a marvel to get live images from Europe, at least while ECHO was in the right position. Equally marvelous was inflating such a huge balloon after a rocket ride to space.

Project SHOTPUT led the way for Echo in 1959 by launching smaller balloons above the atmosphere where they'd inflate going at Mach 10, on a trajectory that brought them into the lower atmosphere where they would burst.

In 1961 a 12-foot-diameter balloon was rocketed into space and, after inflating, orbited at the equivalent of Mach 24, studying the atmosphere. It discovered Earth's so-called Helium bulge.

Buoyed by these early successes in the records of the early space program, John Powell was convinced that, with new, dedicated designs and new, better materials, the orbital airship could work.

The ship will share basics with its smaller cousin, the Ascender: V-shape, keel, and reverse ballonet.

Managing helium is a challenge. It will go up whenever and as fast as it can. It has been known to blow out the nose of blimps if they tilt up uncontrollably. To tame the flighty element, blimps and dirigibles can employ a ballonet system. Inside the large helium-filled envelope there are smaller cells filled with air. A system that can selectively add air to or vent air from these inner cells would have the effect of forcing the helium to move as desired. Inflating the ballonet, the balloon inside the balloon, makes it expand, moving the helium away, thus reducing lift in that location. Keel ships, like all blimps and dirigibles, are longer horizontally than vertically, so stability is a concern. A series of ballonets can help maintain the proper attitude by adjusting lift fore and aft, in balance. With controlled *im*balance, the nose can be raised for ascent or lowered for descent. This is crucial for the Ascender because at some height there will be no more lift. To achieve the dark sky station, the ship will have to tilt up and use propellers to gain the final feet of altitude.

Powell chose to use reverse ballonets in his design. Here the whole outer envelope is inflated with air, and the ballonets are filled with a prescribed amount of helium. Control is achieved by pumping helium, through transfer tubes, between fore and aft cells, to raise or lower buoyancy where and as required.

This design decision was arrived at based on performance. Conventional ballonet systems are limited in how high they permit the vehicle to go. A reverse ballonet system is like having a row of zero pressure balloons inside the outer envelope, and the heights such balloons can reach are demonstrated historically, and daily. With air venting and replenishment in the *outer* envelope, the craft maintains its shape at all altitudes as the helium inner cells expand (and contract on descent). Keeping a constant shape is important for maintaining the control the Ascender needs.

The orbital airship will have many features the Ascender will not. The arm cross-section will be elliptical rather than round, as in the Ascender. This is needed for successful operation in super- and hypersonic realms. The leading edges of the arms will be hardened against buffeting at the high velocities (even though the air will be a whisper away from nonexistence). The support structure will be provided by air beams—not carbon-fiber tubes and spars.

The strength of a tube inflated to a few PSI above the ambient air is strikingly demonstrated by HDT Global, Inc., who gladly suspend a car from one of their air beams, arcing rainbow-like between two anchors some thirty feet apart.

Air beams will provide strength and rigidity at a fraction of the weight of any other technology. JP Aerospace is busy designing and experimenting with their own. In fact, on meeting Powell, he will likely tell you that accomplishing his vision will require mastery of about twelve new technologies. He estimates he is somewhere between numbers four and five. But work goes forward with gusto.

The orbital airship will have a more pointed nose than the Ascender, because that geometry is more appropriate for the higher speeds. At speeds approaching orbital velocity—17,500 mph—boundary layer concerns drive the design (or drive the designer crazy). They drove the cross-sectional geometry of the arms, the nose profile, and invited aboard some unique systems tied into the ship's propulsion.

Where the Ascender, traveling more slowly in thicker air near Earth (the troposphere), will move by means of propellers, the orbital airship must rely on rocket propulsion of some sort to accelerate in the very rarified air of the stratosphere and above.

For this Powell has chosen to develop a hybrid engine with a JP twist; adding a fifth element, making it, in his words, a "symphony" engine.

A symphony engine is, at heart, a hybrid solid rocket motor. Solid fuel and a liquid oxidizer are the first two of the symphony engine's five elements. Hybrid solids are more controllable than conventional solid rockets. They can be throttled and started and stopped. Powell anticipates using paraffin as the fuel; less granular, avoiding the splintering problem and thus more stable and safe. Next, a radio frequency (RF) generator for tuning of the plasma, thus energizing the plume and increasing thrust.

MagnetoHydroDynamics (MHD) is added for the additional thrust. Handily, MHD, at lower speeds, can reclaim electrical energy from the plasma plume. Finally, the fifth element—and one of those new technologies JP Aerospace is working to master—the plasma, will be directed between two rows of strong magnets, giving a boost to the plasma much like a small linear accelerator.

There is another use for the plasma. Research has shown that injecting a bit of plasma to disrupt that pesky boundary layer can reduce drag. For a huge balloon going supersonic and beyond, drag is, both literally and figuratively, a big drag. Some approaches to reducing drag include installing magnetrons on the leading edge of the wing to generate microwave radiation to create plasma. At subsonic speeds it can be accomplished by putting small fins along the leading edges of the wings, which we see on commercial aircraft. But at the greater speeds and at altitudes around 200,000 feet, something more is needed. Magnetrons are a weight and energy liability, not to mention the wiring and control headaches. The JP solution? Tap into the plasma that the symphony engines are already creating. Experiments are ongoing.

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To date, practical trial inflations and flights have been done only with scaled down versions of the Ascender. Much of this experience will inform final designs and systems for the orbital airship. A ninety-foot-long Ascender had its maiden flight in September 2018 and more test flights of this and previous, smaller iterations are planned. Data is being accumulated as JP Aerospace continues to tread that fine line between science and technology.

Of course, for a do-it-yourself space program that has adopted a volunteer business model, funding becomes an ever-larger challenge as the airships grow in size. As JP and his merry band of volunteers chip away at that list of technologies to master, JP himself chips away at his wish list of things needed to achieve his dreams of flight. He's designing a life support system. (Yes; eventually a person will ride to the stratosphere in one of his creations.) He needs a large hangar to protect his ships during construction, against the capricious winds of the Nevada desert.

How has JP Aerospace stayed afloat all these years? By crowd funding efforts, corporate sponsorships, DOD contracts and grants, its web-based "JPA store," and being hired to loft items for TV commercials and documentaries.

His 42-acre site outside of Lovelock, Nevada, lovingly called "Area 42," has seen the launch of the ninety-foot Ascender, as well as various commercial launches. There's nothing quite like having your product (be it, among other things, a rubber chicken, a bottle of margarita mix, a chair, or some flowers) photographed against the curvature of the planet and the black of space. Those and the so-called Pong Sat flights are a story unto themselves. Check the website.

It all goes toward the realization of John Powell's vision for a more genteel route to orbit.

Just imagine it: You and your fellow astronauts board a huge Ascender, along with supplies bound for the International Space Station. Silently your yacht to space lifts from the ground. In two hours or so, you are docked to an incomprehensibly large floating city, the dark sky station. The sky is indeed a barely perceptible purple blending to black. You are at the top of the stratosphere, at about 140,000 feet. You and your buddies transfer to the orbital airship, and again in silence you begin your trip to the ISS, this time arriving in a day, or in up to three days, the leisurely pace set by the laws of buoyancy and motion. You sail the heavens in as grand a fashion as the passengers of yesteryear sailed the oceans blue. You have added almost nothing to the pollution of the Earth's atmosphere, and have arrived refreshed, experiencing no more than a fraction of a *g* above normal.

That's John Powell's vision. He is quick to point out that anyone looking to transport a hundred tons of goods and people from England to New York would be crazy to try blasting it into the air to arc over the Atlantic and crash land in the big apple. We have used the medium of the ocean for centuries to move the stuff of civilizations. Why not use the ocean of air blanketing our planet to get stuff the mere 120 miles into and above the air?

Now imagine you're in orbit around the planet Venus. You regard the cloud-tops with respect. There's sulfuric acid and who knows what in those thick gray bands circling the planet, not to mention what's underneath all that dense atmosphere. But your destination is a sweet spot, about thirty miles above the hell hidden below you. You enter an orbital airship, christened for this mission profile as the "Scender" (because it will first *de*scend to deliver you to the floating city you are visiting, then *a*scend to bring people back for the return trip to Earth). The trip begins in silence as the huge ship departs the Earth transport ship that brought you this far. In comfort you watch as the airship tilts up relative to the planet's surface. You start to feel some freedom from weightlessness as the ship decelerates. In a day or two you are floating in the sweet spot, Venus gravity now fully in force. There is sound as the super-rotating Venus atmosphere begins pushing you along. Once your ship has achieved the same speed as the raging storm, you can chase the floating city because you are almost motionless relative to it now. The ship docks and you enter through various air locks. You are now inside, in shirtsleeves and breathing the air unaided. In fact, you are breathing the very air that keeps the city afloat. CO_2 scrubbing and the occasional supplement of oxygen keep things pleasant. Welcome to *Powell City*.

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John J. Vester has worked in printing, graphic arts and as an analyst for California's State Architect. Now retired, he spends more time hiking in the Sierras, and woodworking. A space buff since childhood, John was present at a last Shuttle launch and Spacex's first launch from Vandenberg Air Force Base. John lives in Rancho Cordova and volunteers for JP Aerospace. After making a minor splash in Analog *a long time ago, his Muse has come back from vacation and, to his own surprise, John now has a book looking for a home.*