White Dwarf and Pedal–Powered Flight

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Bryan L. Allen first learned to fly in 1974 In a foot–launched hang glider. He was the pilot of the Gossamer Condor pedal–powered airplane that won the £50,000 Kremer Prize in 1977. The Condor is now on permanent display at the National Air and Space Museum in Washington, DC. In 1979, he piloted the Gossamer Albatross across the English Channel to win the Kremer Cross–Channel Prize of œ100,000 for the group headed by Dr. Paul MacCready. in 1984, ha set a speed record at 23.5 mph when piloting the MacCready Bionic Bat, winning the fourth installment of the Kremer World speed contest for stored–energy human–powered aircraft. He still holds two Federal Aeronautique international world records: distance and duration for Class BA–1 through BA–l0 (nonrigid gas airships). All told, he has piloted eight different human powered aircraft. Bryan is employed full time by Telos Corporation, a software services company, at the Jet Propulsion laboratory In Pasadena, California. He possesses private pilot ratings for airplane single–engine land and gliders and Is looking forward to some day having an airship rating.

The White Dwarf pedal powered airship came about when Gallagher, a popular comedian, saw a model blimp in 1983 that had been built by a southern Californian named Bill Watson. He decided on the spot he needed one for his stage act. Gallagher, however, did not like the utilitarian style of Watson's demonstrator, he needed one that would make people laugh. A few weeks after their first meeting, Gallagher was on national TV guiding a Watson–built radio–controlled blimp with a bag shaped and colored like a watermelon (a Gallagher trademark), a rudder that resembled a child's kite turned sideways, and a little model Gallagher seated on an old–style bicycle mechanism vigorously pedalling away. "Whatdaya think?" he asked the audience. "Would you rather have one of these, or your car?" After mastering the art of radio–controlled flight, Gallagher would sometimes watch his blimp flying out over the heads of amazed crowds and think, "You know, that looks like fun." So he told Bill, "I want a blimp that wilt carry me." Bill did some calculations and consulted with other experts regarding this proposed blimp's structural and aerodynamic design, four months later, Gallagher was pedalling around the sky in his new toy, the White Dwarf .

The Dwarf was designed by Bill Watson who, among other accomplishments, was the chief construction engineer of the Gossamer Albatross, the pedal–powered airplane that flew across the English Channel in 1979. The airship's final design had undergone many compromises in order to make it small, maneuverable, strong, and quick to build. Gallagher had specified that he would like to fly indoors at some of his events, therefore straight line speed, although ignored, took a back seat to other goals set for this craft. This pedal–powered airship, Bill felt, had to pose the least possible hazard to spectators, specifically, the propeller location materials, and shape had to minimize the likelihood of anyone being struck. A larger, sharp–edged prop like the 13.5 ft Kevlar and carbon fiber creation on the Gossamer Albatross would have been about 10–15% more efficient than the 5.5 ft foam and spruce prop used on the Dwarf, but would not have been as safe.

During the design phase, Bill discovered that Raven Industries in South Dakota made an envelope used to carry electronic payloads aloft that could be modified for use on a pedal–blimp. Using this bag meant the blimp would have more drag and go slower than with an optimized envelope shape, but the time saved allowed the White Dwarf to be built sooner than would have otherwise been. possible.

The craft ended up having a Santos–Dumont turn–of–the–century flavor, with a gusseted and pop–riveted aluminum fuselage structure, recumbent seating position, and a large movable rudder. The rudder could move through a total arc of 15O deg and incorporated a large balance tab to capture and redirect
most of the prop wash when turning. Altitude control was accomplished by vectored thrust! the propeller being tiltable

through an arc of 100 deg (40 deg up, 60 deg down). The power train allowed pedalling in reverse, although at some loss of propeller efficiency. The propeller was geared through chains and sprockets to turn four revolutions for every one revolution of
the pedals.

Bill and Charlie created a small radio–controlled model to get a feeling for the full size blimp's control characteristics, the model suggested the Dwarf would be very maneuverable, but would be unstable in pitch. at speeds above approximately 15 mph. This instability was not corrected for. With its exposed pilot bare fuselage, and numerous external bracing cables, Bill did not expect it would be possible to fly the Dwarf faster than 10 or 11 mph.

The Dwarf took three people, each working a 40–hr week two and a half months to complete. The construction crew was Bill Watson, Charlie Sink, and myself. As with any prototype aircraft, there were many details that had to be worked Out during construction. The control system, the seat, the fittings, all these and more were designed while we made them. We even built the trailer to haul the deflated airship around, assisted by Bill's brother Skip. Many samples of proposed components were built and ripped apart with a calibrated, hydraulic press test rig we made. By following the dictum, "Keep it simple and light, with safety first," we quickly found our solutions. One factor that distinguished us from many aircraft homebuilders was that we were interested in the end result rather than the building process. "Good enough, was a phrase heard many times during the construction of the White Dwarf Yet we were careful to keep our standards high and always think or safety. We kept very much in mind the fact that the person we were constructing the blimp for earned as much in one night as any of us earned in a year and was a total novice at flying. At a total cost of under $40,000, which included the trailer, tooling, a $15,000 prebuilt envelope, and generous wages paid to the three of us, the Dwarf still turned out to be one of the lower cost prototype aircraft (that actually worked), pedal or otherwise of which I know.

As Gallagher has no pilots license or formal flight training, we intended to. operate the blimp under the FAA's Part 103 rules. These regulations specify a maximum empty weight of 254 lbs, a maximum fuel load of 5 gal, a maximum speed of 55 knots with maximum landing speed of 24 knots, and a limit of one occupant. Any aircraft meeting these simple rules can legally be flown by unlicensed operators in areas having light air traffic away from settlements. However, by calling the blimp an ultra light, we met with the hostility that some folks harbor against machines having "no license required." Many people in aviation feel all ultra light category aircraft are inherently unsafe and unsound, feeling that ultra lights and their operators threaten all other branches of aviation, Say "ultra– light" to a lot of pilots and they are repulsed immediately, their reaction is as if someone suggested to devout fundamentalists that a Hell's Angels member be appointed the new minister of their church. We wanted to stay as far away from other aircraft as possible, but we needed a tall hangar to store the blimp in if we were to be able to leave it inflated between flight trials, therefore, we spent some time looking for airports run by people who at least had an open mind about ultra lights. The White Dwarf required about 6000 ft3 of helium at a cost between $800 and $1200, it just made sense that we would want to keep the craft inflated between flying sessions.

We were able to find a hangar and airfield at Carnarillo, about 40 miles northwest of Los Angeles, that would allow us to operate on a very limited basis. The airport manager at first seemed to think we were a bunch of loonys, but ended up proposing we use a site under the base leg of the traffic pattern only yards from our hanger that was perfect for the tethered test flights we wanted to perform.

Tethered Flights

We found that operating this small airship (27–ft tall, 47–ft long, and just over 6000 ft3 in volume) was easier than we expected. Turns with a radius under 50 ft could be accomplished, something we proved decisively by doing 180–deg turns inside our hangar two days before our first outdoor flights. True "hangar flying" is possible with such a small airship, with several similar blimps inside an enclosure like the Astrodome, you probably could have races!

Response from the vectored–thrust system was better than anticipated, when outdoor flights commenced, we found that moderate pedalling would net 200 ft per min (fpm) climb rates and 300 fpm descents. Contrary to our expectations and experience with other human–powered aircraft, it took only one person (with the pilot strapped into the Dwarf's seat controlling the rudder) to ground handle the airship in winds as strong as 14 mph. And talk about easy to fly After we put a minor on the front pedal mount post so each pilot could see the rudder position, not one of the over 40 people who have since flown the blimp has had any trouble adjusting to the control system. "How hard do you have to pedal?" we answered with another question: "How fast do you want to go?" Pedal lazily and you would eventually top out at 4 or 5 mph, pedal like a bike racer sprinting for a gold medal and you would zip around (relatively speaking . . .) at 11 or 12 mph, 7–8 mph seemed to be a sustainable cruise speed.

Spreading the Fun

We let quite a few people fly the White Dwarf once we had completed our flight testing. I used to work for an ultra light manufacturer and soloed quite a few people in fixed–wing ultra lights. I never got away from suffering sweaty–palmed stomach–knotting tension when watching students make their first powered solo. However, I was never tense soloing a person in the White Dwarf, even when, in one case, the student had never been aloft in any flying machine and was only given 30 seconds of verbal instruction. When we would allow people to fly the blimp for the first time, we would dangle a "guide rope" over the side that had five 2–lb weights spaced evenly along its 25–ft length. As the guide rope contacted the ground, the weights no
longer pulled down on the blimp, giving in an excess of lift that made it rebound from the ground. We found it nearly impossible to make bad landings with this "landing gear." Training radios?

Didn't need them, we just shouted up at the students. Student going the wrong way? We would give a tug on the 200–ft Dacron–sheathed Kevlar tether and he would come back whether he
wanted to or not. This ultra light airship turned out to be an anxious ultra light flight instructor's dream come true.

Off–Tether Flights

After flying the White Dwarf on tether for several months, Bill and I decided to attempt an off tether cross country flight. Both of us have experience flying radio– controlled gliders, ultra lights, hang gliders, and pedal powered airplanes such as the Gossamer Albatross. This experience sensitized us to the very small–scale weather effects we expected would bother the Dwarf. Our goal was to go three times as far and stay up three times as long as was done with the Gossamer Albatross on its 22.3–mile, 2.8–hr English Channel flight in 1979. The area we chose for off tether flight operations was along the northern edge of the Salton sea, our base being the large hangar at La Quinta flying Service In Thermal, California. Aerial scouting from a Cessna 172 led us to believe that a flight southeast from Thermal along the eastern edge of the Salton Sea looked like the best prospect for a long flight in California during the wintertime, although we knew care would have to be taken to avoid military airspace over and around the water. We felt that flying over water during midday would allow us to avoid atmospheric convection that otherwise might compromise control and safety. We drove the Dwarf in its trailer to Thermal in early February of 1985. After dropping off the trailer, we went to the local welding–supply shop where our preordered helium was waiting. Our I–ton pickup staggered to the airport under the 3500– lb load of 25 helium tanks, mute testimony to why we do not recompress the helium from the White Dwarf when it is deflated, the additional expense of transporting nearly 2 tons of tanks plus the cost of a high–capacity compressor unit Would be much more than just letting the helium go. Capturing the helium in a lower–pressure receptacle does seem feasible, we have not pursued this, but I am sure we would if we (rather than Gallagher) owned the blimp.

After inflating and rigging, we started to learn about flying off tether. One week had been set aside for testing and practice before I would attempt a record flight. The first morning Bill flew, then I did. We were both very cautious, staying within 50 ft of the ground and no more than a few hundred feet from the ground crew. We were concerned about sudden weather changes that might overpower us and waft us away. We suspected the strong thermals could lift us too high, too fast, the Dwarf, to be as small as possible, does not have a ballonet to accommodate envelope pressure changes, but only a spring loaded manually operated valve for pressure regulation. We did not know how fast the bag pressure would rise as we ascended, But only that Raven Industries, the bag's manufacturer, expected the envelope would burst when pressurized to 17 in. of water. We had a lot of questions, but there was no one we could ask who knew anything about free flying a pedal–powered airship.

Even the first tentative free flights felt different from tethered flight. Both Bill and r experienced a tangible awareness of freedom that we had not noticed previously when flying the Dwarf Any tendency to exult in this new–found freedom was tempered by the realization that we now had the "freedom" to blunder into any nearby power line, church steeple, or other obstacle.

At around 10:30 a.m., we found thermal activity would increase to the point where flying was uncomfortable. It was necessary during morning flights to vent a small amount of helium every half hour or so (due mostly to the solar heating of the bag) to keep the envelope pressure within the conservative (we hoped) maximum pressure limit of 2 in. of water on which we had decided. Because we would normally fly the blimp only 1 or 2 lbs "heavy," any increase in envelope pressure would stretch out the bag a bit and make the blimp overly buoyant. Since we had no ballonet, the only way to deal with being overly buoyant was to vent helium, land and add more ballast. This was not as easily done as said. Most pedal powered aircraft are difficult to keep up, we sometimes found it difficult to keep the White Dwarf down.

Late–afternoon flying had quite a different character. The lessening solar input worked to make the blimp heavy, which we joyfully dealt with by releasing water ballast in flight, joyfully, because water costs nothing, plus this gave the pilot myriad opportunities to rain down on unsuspecting targets.

On the following day, we got a bit more adventuresome and the air a bit more unstable. After some gentle early–morning flights by Bill, myself, and our fellow builder, Charlie Sink (who decided that 20 ft was plenty high enough, even though he had been higher on tether), the convection started to be in excess of 200 fpm. In these conditions, I decided to stay within just a few feet of the ground to hopefully avoid the strongest lift. This tactic worked for a while, then I flew into some gradual lift west of the airfield that lifted me 100 ft or so.! decided that I would try putting in a full down vector on the prop, I knew with vigorous pedalling in calm air this would yield a descent rate of up to 300 fpm. Checking the variometer, I found I was still ascending at about 100 fpm while working fairly hard. "No problem," I thought to myself, "I'll just turn 180 deg and fly out of the lift, I haven't been in it very long." I turned to the east and accelerated to about 9 mph indicated air speed, confident that I would be out of the lift in no time. After a minute, I noticed that I had made no progress over ground and was, in fact, still over the tree where I first noticed the lift. "Must be a breeze up here," I thought, "I'll turn and head downwind to the west." By now I was about 800 ft above ground level (AGL). After changing course again, I was still over the same spot! I vented helium for about 20 seconds, enough I knew to make me descend at about 400 fpm when in calm air, and turned from side to side in search of sinking air. Now I was in the middle of the airport traffic pattern, fearing a collision, my parachute back on the ground, and still ascending. Finally, I was gently buffeted by small puffs of turbulence, the variometer indicated my climb had ceased, and I noticed I was actually tracking away from that lone tree now far below. I vented helium for another 20 seconds, noting my altitude as 1200–ft AGL, and slowly started down. Although I had just set an unofficial altitude record for human–powered aircraft, r was disgusted and a bit frightened by the experience of being helplessly wafted upward. Once I was in the thermal, it

was as if every direction was upwind. It took me another 30 minutes of searching for sinking air before I got close enough to the ground crew so that they could grab the 200–ft long landing line I tossed overboard. That evening, several of us talked over my flight and concluded that we had never fully understood the true structure of thermals. We felt that there must be far more air being pulled into the sides of the thermals than textbook explanations indicated. We later concluded that the effect is most likely an aerodynamic one, similar to what occurs when a beach bail is suspended by a fast moving column of air above a blower. We could see only two remedies for dealing with thermals: one, fly faster (not really possible with the Dwarf), or two, avoid thermals.

A subsequent morning was overcast and windless. Both Bill and I took turns roaming far and wide in the blimp, chasing hawks, skimming over palm orchards, waving at passers–by. The convection that day never seemed to develop. Bill cavorted about a water tower and delighted in the powerful but dreamlike feeling, when climbing under power, of walking up an invisible staircase into the sky. I flew a triangular course north of the airfield that was 8–10 miles in length, getting a feeling for steady–state pedalling. During this flight, I startled a farmhand working 5O ft up in a palm tree when I flew 10 ft over his head and rang the bicycle bell the Dwarf carried. From the look on his face, he must have thought I was a hostile visitor from another planet.

The Record Attempt

We assembled a small group of volunteers and our appointed National Aeronautical Association (NAA) observer, Dan Glick, at Thermal airport on the morning of February 12th. Bill and I carefully checked the blimp. Its installed instruments were an airspeed indicator, electronic sailplane variometer, bag pressure gauge, ambient air thermometer, altimeter, and, on my wrist, a calculator watch. I had rigged a drinking tube from the forward ballast tank (which held about 30 lb of water) to provide me with liquid and also strapped to the fuselage two bicycle water bottles. For "fuel," we attached a container that held several sandwiches and pieces of fruit.

Takeoff was at 7:23 a.m. Initially, there was light tailwind that whisked me south toward the town of Mecca. I kept in touch with the Flight Service Station at Thermal using a small hand–held aviation transceiver taped to one of the fuselage tubes. I could talk to my chase crew (plus passing truckers and vacationers) with the CB radio we had affixed to the Dwarf With all this gear, the cockpit ambience was far removed from the Spartan feel of the Gossamer Albatross that I flew across the English Channel in 1979. That craft carried only 2 liters of water, no food, one very stripped down transceiver, a quarter–ounce bimetallic thermometer, and two ultra light custom–built flight instruments (airspeed and altitude) that had just enough batteries to function for a 2–hr flight.

As I approached the northern edge of the Salton Sea, a headwind sprang up. Two hundred ft below me, a jogger kept pace, even though I had the advantage of being able to cut diagonally across the field and orchards. My ground speed dwindled to 3 mph, things did not look good. After an hour of very slow progress, I broke through to a southerly flow of air that, with my steady pedalling, allowed me to "clip" along at 14 mph ground speed. Flying along the sea's eastern edge, I found I had to maintain 200–300 ft in elevation and closely parallel to the shore in order to keep from being either swept west over the water or east over land. It was a delicate balance, with contrary air currents just above and below me. I occasionally valved helium to stay in equilibrium, while pedalling and eating.

By noon, I was over the small town of Bombay Beach. Here, the shore bent almost due east. I decided, after checking my banana supply, to cut southeast across the bay and shorten by flight path a bit. As my chase crew had no boat, this meant I was completely on my own. I kept a steady pace, watching my shadow on the water below to estimate my progress. As the afternoon went by, thermals bumped me around some, even over the water, and headwinds again slowed my progress to walking speed. By 2 p.m., I was back over land, the headwinds were decreasing, and the thermals were lessening in strength. A few agricultural planes flew alongside to check me out, thankfully not getting too close. I pedalled onward, starting to tire a bit. By 3:30, the town of Brawley was just ahead. We decided to terminate the flight at Brawley airport, I floated about lazily for 45 minutes while we waited for the local TV station to show up and film the landing. After 8.8 hr I landed, we deflated the blimp, answered questions from the spectators, went into town to eat dinner, and then drove back the 70 plus miles to Thermal. The official straight–line distance between the takeoff and landing points was just over 58 miles. The NAA and Federation Aeronautique Internationale (FAI) officially recognized my flight as establishing two new world records in the Gas–Airship category (Class BA–l–10).

I was a bit sore the next day. noticing that it was more comfortable to walk up stairs one by one rather than my normal two at once, but suffered no other ill effects. For a comparison, after the cross–channel flight of the Albatross, I had sporadic leg cramps and spells of dizziness as long as two weeks afterward.

Why have blimps not been used in all previous human–powered flight attempts? I believe this happened because all prizes for pedal flight specifically disallowed the use of any lifting gases. These rules had as their result many years of frustration, followed by the eventual technical triumphs of the

Gossamer Condor. Gossamer Albatross, and most recently, Daedalus 88. Coincidentally, the British group that wrote the rules for the Kremer Prizes that spurred on pedal–plane designers worldwide is named the "Man–Powered Aircraft Committee" (my emphasis). Maybe, it is time for a "Human–Powered Flight Committee" to come to the fore. The journey from Thermal to Brawley
in the White Dwarf was more challenging to my navigational and flight–judgment skills than my cross–channel flight in the Albatross, which mostly taxed my powers of concentration and athletic skills. Navigating through the air is always a challenge, no matter what type of machine you choose to employ. The White Dwarf allowed me (and would allow any other reasonably fit person) to set human powered flight distance and duration records equal or superior to those possible with Daedalus 88, plus it is more fun to fly and took less than 10% as much time (and, probably, money) to build (see Table I). The Dwarf is also much stronger, with a 5–g ultimate Load capability, which makes flying hundreds or thousands of feet above the ground feasible. All cross–country capable pedal airplanes have been extremely fragile. To prove this point, the Albatross suffered a broken wing moments after a perfect landing on French Soil and the Daedalus 88 broke up just before landing on Santorini. Pedal blimps can carry more load and be far sturdier than pedal–powered airplanes without suffering major performance penalties. Pedal blimps have a future because they offer performance, cost, and safety advantages over pedal planes.

Should Your Student Group Build an Airship?

Student groups can build, and have built, successful pedal powered aircraft. These groups have proven their skills in many field: structures, aerodynamics, stability and control, and project management, to name just a few. A project that facilitates such practical learning experiences is looked on with flavor by students, faculty, and administration alike. Building a human–powered aircraft can be an appropriately sized task for a student group. The return on investment of time and funds can be very good if the goal chosen is easily defined and achievable.

Various groups have shown that pedal flight is feasible, the challenge now is to expand our horizons. I feel that there are two reasonable paths to take when a student group becomes interested in building a pedal aircraft: build an aircraft using technology equivalent to that used for the Gossamer Albatross or build a blimp. The Daedalus 88 is a magnificent aircraft, but it is too labor intensive and costly for a student group to consider duplicating. Even if you built a copy, so what? Allowing everyone who worked on the plane to fly it would most likely result in turning your project into a repair course, An Albatross–like aircraft can be an excellent project, but your flight goals have to be modest (forget about setting records or flying at halftime during homecoming if you choose this type of project). Does your group want to build a craft that could set records, but everyone involved could safely pilot? You can build a blimp. You will have to master all the fields necessary to build a pedal–powered airplane plus become experts in aerostatics. The payoff may be the creation of a craft that performs better than Daedalus 88 and is stronger, affected far less by turbulence, has a lower pilot workload, takes less skill to fly, and is truly three dimensional in its capabilities rather than being a ground–skimmer. What's more you can even consider flying a blimp at home–coming.

Speculations

Pedal–powered flight stands at a crossroads. Will it continue to take the path of greater and greater structural complexity embodied by Daedalus 88, or will its emphasis become more oriented to the actual experience of flight? I have flown the Michelob Light Eagle (sister ship to Daedalus 88), and it was quite an impressive machine. However, for the satisfaction of moving through the air in three dimensions under your own power, no other machine I have flown comes close what the White Dwarf offers. Just imagine what you could accomplish if you took a low–drag fuselage like that on Daedalus 88 and grafted it onto an airship hull? Hmm ...