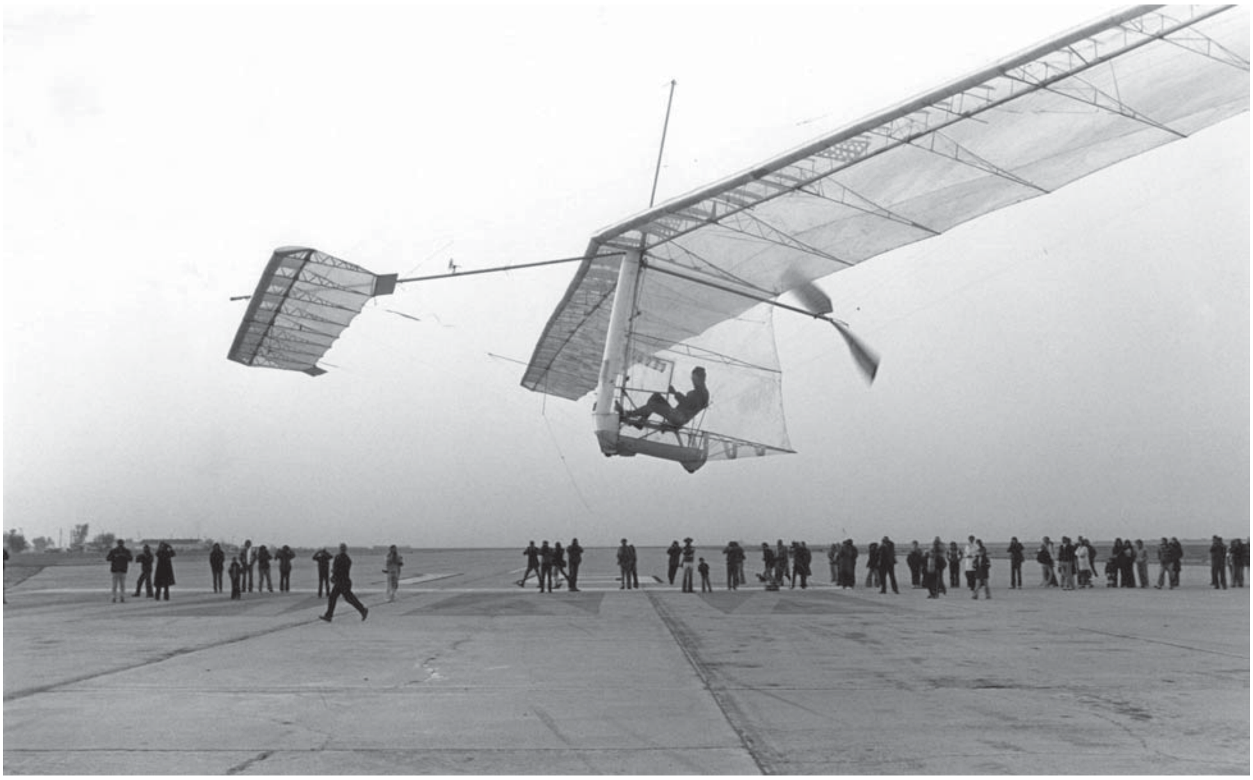


Cruising at a mere 10 mph Bryan Allen maintains head-height during the 7 1/2 minute figure of eight flight which won the $50,000 given by Henry Kremer. (Photo: Don Monroe.)

Jack Lambie

tells his story of the

Gossamer Condor

Paul MacCready's

winner of the famous Kremer prize for the first Man Powered flight around a figure eight

This is the story of a team effort which achieved the seemingly impossible under the brilliant leadership of Paul B. MacCready, Jr. It is expressed here through the eyes of one who was with the concept front the very beginning and who put together the structure which has often been. referred to as a 'man carrying indoor model'. Peter B. S. Lissanuan produced all the aerodynamic refinements; ocean sailing and fellow sailplane experts worked on the rigging; wives and sons became totally involved in this great challenge. As the design changes and location moves were made. the team expanded to embrace another ex National Champion modeller in the person of Vern Oldershaw, who plaved a great part in 'cleaning up' the detail.

All of this was in progress a year ago at Shafier. The collective skills of the talented team were to realise the ambitions which had frustrated countless others for almost 18 years ... but we intrude on Jack Lambie's story:

IN AUGUST OF 1976 my wife Karen and I had just completed the first tandem bicycle trip around the world - a journey of over 15,800 miles - when 1 received an invitation to lunch with Paul MacCready. I had heard rumours that he was all excited about trying for the Kremer Prize and I approached the lunch with some trepidation. I didn't really think it could be won. In fact, 1 had co-founded human-powered speed contests in 1975 to provide an inexpensive and practical alternative for engineering students and others interested in human power and aerodynamics. Our streamline bikes had yet to reach 50 mph, despite exotic, fully-faired, prone-position machines. Paul and I had known one another in soaring for many years and we had also collaborated on a truck air-drag reduction project for the National Science Foundation. I had great respect for his achievements as a soaring competition pilot (once a world and three times a national champion) and as a scientist/businessman. Nevertheless, I felt his pursuit of manpowered flight and the $50,000 Kremer Prize - the largest ever offered in aviation - was chimerical.

"I've calculated the power requirements for a standard hang glider," Paul said, "and it needs three horsepower to fly. But if it were enlarged to a 90ft span and kept the same weight, it could fly on only 0.3 horsepower." "How can you make a plane that size that weighs only 50 pounds?" Paul sketched a curious design on a napkin (how many great technological advances in aeronautics had begun as sketches on paper napkins?) The drawing appeared to be a toy 'jack', the kind kids play with and bounce a ball.

"See, Jack? Every part of the structure is used to brace another part. It will use a forward stabiliser so we can make use of this forward tube."

"But Paul," I persisted, "what about the weight? How could we make a plane that large weigh so little?"

"We don't need much strength," he answered. "The Kremer rules only require a 10 ft maximum height at the start and finish of the flight. That's not far to fall if anything breaks."

He explained that the wing loading would be very light and that it would operate a lift coefficient of only .9 (compared to 1.4, or better, for previous MPAs). This meant a single-surface airfoil would have low drag.

My preconceptions crumbled. I could see for the first time that man-powered flight was an engineering feasibility.

Construction began in the huge Rose Parade float shed down in the Arroyo Seco not far from Paul's home in Pasadena. We laid out 2in. diameter, 0.035in. thick alloy tubes in 12ft sections that were joined to make an 88ft span wing. We put water bags at the corners of the seven ribs to simulate air loads and adjusted the wires to keep everything in line.

The approach was so radical compared to past MPA designs and yet so easily built that there was worry about someone picking up the idea and beating us to the prize. After all, $50,000 is a lot of money, and secrets of certain competition airplanes have always been rather well kept as long as it was important to do so. I fended off the questions of curious visitors, telling them we were making a special water bag holder, a contemporary metal sculpture for the Pasadena Museum of Modern Art, etc. We made some of our early tests at night on the lonely Rose Bowl parking lot. On 9th October 1976, ten days after my meeting with Paul, we carried the gigantic frame and its mylar covering across the street to the park. Though the lightly misting rain added a lot of weight, the craft acted more like a balloon than an airplane. We walked with it at 5 mph; it lifted easily and strained at the ropes we attached to all corners. Nothing broke. The structural idea was reasonable. Now for refinement.

An old friend of Peter Lissaman's who ran a test pilot school at Mojave Airport agreed to let us use half of his big hangar. I motor glided to the desert to check it out and, by coincidence, the 96ft span just fitted into the hangar. We soon moved our tubing there after we had chemically milled it down from 22 thousandths at the centre to 14 thousandths of an inch at the outer sections of the wing. Paul's brother-in-law, Kirk Leonard, is a skilled engineer and craftsman and he spent many hours on the new finer version while Peter worked with the computer on aerodynamics at AeroVironment Inc. The advantage of the computer is that 20 years of aerodynamic experience can be brought to bear in seconds instead of months of laborious computation. Span, area, speeds, angles of attack can be changed and efficiencies read out quickly. Propeller performance, too, could be checked out over a whole range of sizes, rpms, aspect ratios, and various angles of attack.

I finished the partially-completed first propeller in a couple of days, built a pilot seat frame, and got pedals, cranks, and chainwheels from my bicycle collection. One of the pleasant surprises was the ease with which the drive system went together. The plastic 'cable-chain' I ordered from New York was a little radical, but careful alignment and a judiciously located idle sprocket resulted in trouble-free performance.

First flights with Paul's son Tyler (a hang glider pilot) on board were promising. The machine seemed to float into the air at walking speed instead of 'taking off'. It hung as if suspended while Tyler pedalled rather easily making 45 second flights with a push start. Greg Miller, a new rider of racing cyclist championship quality, yet only 20 pounds heavier than Tyler, was added to the team. Greg could take off on his own and, after a good deal of flying practice, made a tremendously encouraging flight of two-and-a-half minutes while covering over a thousand foot distance. We went home that weekend sure that we were quickly going to capture the Kremer Prize.

The next time, MacCready measured and marked the one-mile figure-eight course, practised taking off and flying over the 10 ft barrier, and called out the officials. After several trials, Paul realised we were still a long way from achieving our goal. It would take at least nine minutes to do the course at the first Condor's speed, and Greg's best flight was 2 minutes and 30 seconds. It had to stay up three times longer, and the matter of control was

Specially commissioned bronze sculpture from the Royal College of Art was presented to Paul MacCready by HRH The Prince of Wales on behalf of the Royal Aeronautical Society as a memento of the achievement - the cheque is less permanent!

even more critical - a full turn had yet to be made. Paul had thought the machine could somehow be wrestled around the course using spoilers on each tip, but the plane slid to the ground shortly after one or the other flat plates was actuated. And then there was the problem of movement within the air mass. Winds of 2 to 4 mph and the slightest gustiness would limit flights to only 30 or 40 seconds. Thin, single-surface airfoils have low drag at only one angle of attack. For the Condor, a low-drag spike occurred at about 8.2 mph. Above or below that speed, the drag rose impossibly high. Finding the exact cause of the drag problem took weeks. Old gliding buddies Bill Bueby, John Lake, and I made a thicker leading edge to allow a wider speed range. It seemed to be the right move, but there were other problems: Twice the shaft-prop attachment broke. New wider blades seemed promising at first, but, like most everything so far, showed no particular gain over the old one. Peter Lissaman tried many propeller angles between 15 and 20 degrees. And the problem of turning was still with us. We tried a sail on top to provide dihedral effect, various spoilers, and tip rudders. It was frustrating. We had a plane that flew and flew, but no way would it make it around the Kremer course.

Peter spent many hours during winter working out the stability situation on the computer. The results were surprising and ominous: it appeared that it was impossible to control the Condor in bank by conventional means. It weighed about 220 pounds with the pilot on board, but the airmass deflected in its passage was around 600 lbs. This 'apparent' mass had to be rolled to bank the plane and, at the extremely low speeds we were flying, there was simply not enough force to move the huge wings and the 'fellow travelling' air up and down with any wing mounted aerodynamic device. The spoilers worked, but their coarse way of stopping a wing from flying could not be tolerated in a machine that relies on pitifully weak human energy. What about other Kremer competitors? How did they attempt to make turns?

A new design went together at Shafter, a new base in Central Valley. I would call it number two because it represented a major change in some ways. Paul kept the basic wire-braced tube-structure concept, but aspect ratio was increased from 8.3 to 12.8 and the wing loading raised from 0.22 to 0.261bs/ft'. A thick, double surface airfoil was computer-designed by Lissaman and only a single tube along the centre of pressure was used for the spar. By eliminating the rear spar, enough weight was saved to permit use of more closely-spaced ribs and a cardboard leading edge. The pilot's seat and chainwheels were enclosed by a streamlined plastic envelope.

The result was that Greg and Tyler almost immediately doubled their duration times. One evening, in the quiet air just after sunset, Greg flew for over five minutes - but making a turn and control of the new machine in bank had yet to be accomplished.

Now for the next ... Paul MacCready and his pilot, Bryan Allen, with Henry Kremer and Ron Moulton discussing the channel challenge. Paul has already announced he'll have a new design ready by April '78 and is first going to set a duration record of 3 1/2 hours.

In many years of model building and experimenting with a canard stabiliser, I had never been able to get one to fly as well as a conventional tail-in-the-back airplane. Paul had remained committed to the canard surface in front, but, with the better low drag and wider speed range of the new Condor, he yielded to suggestions and let us try a following tail. John Lake made a cardboard-and-foam, mylar-covered appendage and mounted it at the end of the ubiquitous aluminium tubing we used for just about everything on the ship. It seemed to work at first, but again, further testing showed the plane would still slide to the runway if held beyond a quarter turn. The drag was too high. Paul pulled the following tail off and laid it in the corner with a half dozen other ailerons, stabilisers, tip rudders, old ribs, etc.

Paul was the mastermind of the Gossamer Condor project and was supporting the project on his money. He could not let emotions cloud what he thought should be done to improve the machine. We became accustomed to having a part we had worked on for days turn up in the corner in pieces because Paul thought it wasn't light enough or that it wouldn't work. Even such skilled and experienced craftsmen as Vern Oldershaw did and re-did parts at Paul's direction to save weight here or make a better airfoil there.

The trouble with working with a true genius like Paul MacCready is that you never know when he's wrong, because much of the time he's right when your instincts are telling you the opposite. Case in point: The Condor has a lift/drag ratio of about 10:1. All the previous analyses of manpowered airplanes state a minimum of 30:1 is necessary. A little thought, however, and it's obvious that as long as sink speed is low enough, it doesn't matter what the L/D is (as Peter pointed out in his 1962 paper, 'Le Minimum'). Again, other projects (such as the Puffin II) attempt to get a lift coefficient over 1:14 from their airfoils. This requires very smooth wings with many closely-spaced ribs as well as stiff covering - and up goes the weight.

Another departure in the Condor from

other MPA designs was the ignoring of ground effect at the advice of Peter Lissaman. He had done his doctoral thesis on ground effect, and wrote that the phenomenon is not really understood and that sometimes the ground effect cushion just isn't there when you're counting on it.

MacCready's flying, banking, forward stabiliser was working exactly as he said it would, towing and yawing the plane in whatever direction we wanted - if only the Condor didn't slide to the runway once it got into a turn. Thinking about the problem one day, I mentioned some observations of my own.

"You know, Paul, I've watched Volmer Jensen slope-soar his VJ-23 ultralight a lot, and I notice that as soon as a turn is started, he pushes opposite aileron and continues and completes the turn with full down aileron on the inside wing. And when my brother Mark and I put ailerons on Hang Loose we found control reversal at low speeds. Maybe this is even more true with the Condor?"

MacCready seldom accedes to a suggestion when it is made. He picks everyone's brains, sifts through them, and it isn't until the change is made that you know he's decided to give a new idea a trial. Wonderful miracles and all that! - the opposite action wing warp was one of the final keys to success! The drag of the inner wing (due to its increased angle of attack) swings that wing back, but also adds just enough lift to keep it from dropping. The result - a perfect turn. I made a little detent by Bryan's seat. He just clicks the lever into the notch and the wings are held in a twist for a turn with no other action necessary until the ship is straightened. Then he lifts the lever into neutral and goes his way. The Condor can turn about in only 180 feet.

One last trial of a thicker airfoil was made. Peter figured the ship would fly a little slower with the higher lift wing, thus reducing the drag of wires and fuselage enough to overcome the higher drag of more thickness. Unfortunately the new wing flew at about the same speed and the drag of the deep airfoil reduced performance slightly. Vern and Bill took the wing off and hung it on the back wall of the hangar. We took the old thin wing, completely rebuilt it, covered it, and put it on. All of this in two weeks! The prize was getting closer ... I could feel it in my bones ...

Typical Flight

It's 4.45 am. I open my eyes at the sound of a car. I sit up, pull on my clothes, and stuff the bag.

Jim Burke is rolling the doors open just as Vern Oldershaw arrives in his motorhome. Minutes later I lift the machine with one hand onto a little tow dolly. We roll it into the dawn-streaked' sky. Bryan Allen, our 24 year old rider, or pilot, arrives and helps us walk the ship a hundred feet to the end of the half mile runway. Paul MacCready, the motivating force behind this incredible adventure, pulls in with his son Tyler, who is our backup pilot. Bryan slips into the gondola cockpit, straps his feet to the pedals, and begins spinning aluminium cranks that are bolted to a 62-tooth chainwheel which pulls a cable-chain to a 52-tooth wheel eight feet above him. The drive-shaft whirls the 12ft propeller as he warms up for the effort of flight. The translucent blades flash, flash, flash in the predawn glow. I restrain the machine. It wants to go.

"Ready, Bryan?"

"Okay, I'm ready now whenever you are."

We mount bicycles. Vern steadies the wing. I ride ahead with the 'starter pole' - a 10ft barrier over which the Condor must climb at the beginning and end of the Kremer circuit. The official observer, who is also Kern County's airport chief, holds his camera and stopwatch.

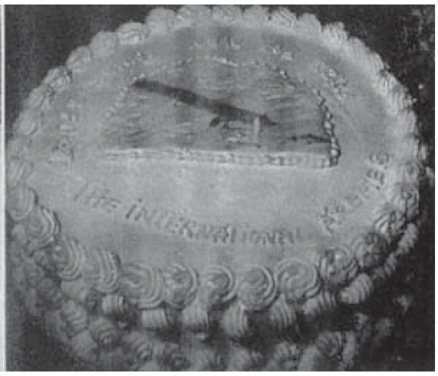
"Let's go !"

Bryan pumps a steady 110 rpm cadence. The Condor stirs on its tiny plastic wheels. . .five feet ... ten feet . it behaves more like a dirigible than a heavier-than-aircraft (indeed, its mass/size ratio is similar) and it is difficult to pinpoint the moment of lift-off. But it's off the ground and climbing with unbelievable ease in response to the horizontal canard surface. Bryan floats effortlessly over my marker.

"Good start, Bryan . . . Beautiful, - beautiful ... keep it going . . . "

The first rays of the sun strike the airplane. Its mylar covering polarises the light, creating brilliant flashes of rainbow colours which ripple and play over its surface.

We pedal easily along and behind as it moves over the runway toward the first turn a quarter mile away, our heartbeats synchronised with the faint 110 rpm whooshes of the prop. When he is almost alongside the turn marker, Bryan gently rotates the control wheel to the left. Now the canard surface's aileron tabs move it from the normal horizontal position to a bank that tows the machine around to the left. The pilot moves a lever under his seat into a notch detent which twists the left wing to a higher-but almost invisible-angle of attack than the right. This is exactly the opposite of regular airplane practice, of course. (Because of its 96ft span and 10 mph flying speed, the Condor needs only a three-degree bank to make a 150ft radius turn. The outer wing is going so much faster than the inside wing



Professor Hidemasa Kimura, Vern Oldershaw and Sam Durand tap out data on the Prof's sub-miniature calculator to compare Condor and Stork statistics. In London for the prizegiving, their meeting emphasised modelling technique influence. Special cake had full colour painting on icing, a craftsman's tribute greatly appreciated.

that the difference in lift is three times greater. Lift must be added to the inner tip - thus the reverse twist.)
Slowly, slowly the Condor wafts around the turn and starts back over the apron alongside the runway. Ipedal beside, urging Bryan on.
"Keep it up. It looks great. Keep her going."
The rider's mouth is open. He breathes deeply. An airtube in the gondola blows a faint breeze on his face as he methodically pedals along five feet above the ground. I time his cadence by counting ten strokes of his foot. He's turning 98 rpm - the steady 0.35 lip needed to stay aloft in level flight and move the airplane. Clouds of birds rise from nearby fields, as oblivious to the drama taking place as is a crop-dusting pilot who mushes in over the far end of the course on his way to land and refill the Ag-Cat's insecticide tanks.

Four minutes go by. This is turning into a good flight. Will this be it? Will the Kremer Prize be won ? Have the months of building, testing, discarding, trying again and again finally taken this long-unconquered frontier of flight? The official observer is watching more intently now. Our excitement mounts as Bryan approaches the critical second turn. He's in good shape and not slowing ...
Bryan continues pumping away toward the second turn. After he makes that, all that's left will be to climb over the 10ft finish marker. The basic idea of the Condor has been correct. Working out the details took ten tunes longer than anticipated. But it's been done. We look at one another as we pedal or jog alongside. We're afraid to say it, but our half smiles make it clear we all feel our rider is about to complete the coarse.
Bryan is entering the final turn. Suddenly the wings tremble unexpectedly. Turbulence? The spar snaps and the wing folds back Bryan noses down for a quick smooth landing as we rush under to support the slowly dropping wings. It's easy to assess the damage through the transparent covering A crimped spar and some torn plastic. They can be fixed in a few hours - but flying for the day is ended. But why the sudden break? After all, the wing is stressed for 1.5 g's.

Vortices! The coughing roar of another Ag-Cat charging off with its load of insecticide provided the answer. The earlier crop duster had come in for its landing above this part of the course shedding invisible whirling dervishes from its wingtips. These airy tentacles were still active four or five minutes later and reached near enough to the ground to ensnare our bird. (There is a touch of irony here. AeroVironment, MacCready and Lissaman's company, had done the definitive research on this phenomenon under contract to the US government. But attention focused on the massive wakes of large airliners and transport aircraft.)
As we trundle the Condor back to the hangar, I ask myself, "Why are we doing this?" I know it's not the prize money; most of us aren't benefiting much from that. Perhaps it's the ful f ullment of an ancient dream, the simple human goal that hasn't been realised even at this advanced stage of aviation. Perhaps now and in the next decade there will be a new Golden Age of Flying like 'regular' planes had in the twenties and thirties. But this time for ultralights. The technical and muscular effort for a human being to lift himself into the air, climb, turn, and truly fly has been a wonderful achievement.

Repairs are easy. Gossamer Condor wing folds have become acceptable as part of the operational hazards. This time, however, the rebuild was to be the last before the ultimate fulfilment of the team's great aim - the Kremer prize.
On 23rd August, in ideal conditions with a windspeed of less than 2 knots, Bryan Allen made one of his typical 30ft take-off runs toward the north pylon on Shafter Airport runway. After a 500ft cruise it was all systems 'go' as Bryan cleared the Tee bar on the start line and observer Bill Richardson, a long experienced aviator who was appointed to authorise any claim, clicked his stopwatch. Bryan was soon into the first, right turn after 250 more feet and he made a 425ft diameter 180 degree sweep around the marker to head for the south pylon, 2,640ft away. It was a smooth cruise of almost three minutes, then another sweeping left turn to retrace his course back northwards. As he neared the original take-off point, eager followers yelled encouragement and with one last effort Bryan took the Condor over the Tee bar to finish at precisely 6:22.5. He had traced an almost perfect figure eight, the flightpaths were a mere 9ft 7in. apart on the start/finish line and met all the conditions of the famous contest. The rest is now history - or is it? The Channel is the next challenge.

Jack Lambie
Aeromodeller March 1978

On 31st December, Gossamer Condor was aired for the last time before moving across the USA to be hung in the Smithsonian Institute at Washington DC. Rough weather over Christmas almost prevented this 'last fling' but fate decreed a dead calm end to the momentous year. After the sandstorm coating of desert dust had been blown and shaken from the wings, Condor made 10 flights, among them one by Professor Geoffrey Lilley, Head of the Department of Aeronautics and Astronautics at Southampton University. Prof Lilley is a long standing member of the RAeS MPA Committee, and chaired the last Symposium in London but it was still a pleasant surprise for him to be (a) invited and (b) capable of actually flying the Condor. Apart from coordination of controlling, maintaining speed and pedalling, Geoffrey says he could have flown a long way but was quite happy with 200 yards of Human Powered Flight - and who wouldn't?