

# Building a Next Generation Airship

## Part Two



### *In Pursuit of the Perfect Personal Aircraft*

*story by Dan Nachbar*

**W**

e are certainly not the first to build a hot air blimp. Others have been building them since the 1970's. The earliest

attempts were essentially elongated hot air balloons with some fin shaped appendages. Unlike the typical Helium blimp, early hot air ships had little or no pressurization. In other words, the shape of the envelope was supported mostly by the "static head pressure" of the hot air. These early aircraft earned the mildly derisive label of "saggy baggies." They didn't go very fast and the floppy rudders on their fins didn't do a very good job of steering.

In order to get more rigidity, designers soon switched to pressurized envelopes. A fan was added to sustain the pressure as well as supply fresh air to the burners. These pressurized non-rigid designs have been the mainstay of hot air blimp design for decades. They have gradually improved and now provide greater air-speed and better turning, but they are still very difficult to handle at low airspeeds or on the ground in anything greater than a very mild breeze. I wanted to be able handle our blimp on the ground in at least a modest breeze without needing the entire population of a mid-sized town as ground crew.

The size of the ground crew can be greatly reduced through the use of a mooring mast to secure the aircraft on the ground. These masts work much like a mooring buoy for a boat. In fact, most of the blimps in the world, which are helium-based, use them.

However, using a mooring mast isn't the whole story. In particular, masts work best when the aircraft can drive itself up to the mast the way most boats drive themselves up to a buoy. But most blimps, including helium-based blimps, can't do this. The reason is that most blimps use rudders for steering. Rudders don't work very well at low airspeeds. Thus, blimps, even the ones that use masts, usually land in the middle of a field and employ a substantial, if not appallingly large, ground crew (between 12 and 20 people) to shepherd the aircraft over to its mast.

There is one exception to this big-ground-crew approach and that is the modern-day Zeppelin-NT airship which uses vectored thrust steering -- a tail-mounted propeller that can point sideways and steer the aircraft by pushing the tail around. This is essentially the same

way that a small motor boat steers. This approach works much better than a rudder at the low airspeeds needed for mooring and allows the Zeppelin-NT to drive itself right up to its mooring. As a result, the NT, which is 250 feet long and nearly 290,000 cubic feet in volume, reportedly operates with a truck-mounted mast and only three ground crew members in surface winds from zero to 30 knots.

In addition to providing improved control on the ground, and thus vastly reduce the size of the ground crew, vectored thrust steering provides other advantages. Of greatest importance is the ability to precisely maneuver to a particular point and then point the blimp into the wind and hold that location for extended periods of time. Helicopters can do this but only with a great deal of fuss and downblast. There are also fun things to do such as spinning the blimp around like a top. This can make the pilot a bit dizzy after a while. Trust me, I know.

The key requirement for vectored thrust steering is having a propeller (and something to turn it) mounted on the tail of the blimp. Unfortunately, the tail of hot air blimps with fabric-only envelopes, unless pressurized

to wildly high levels, can't possibly support the weight of an engine and propeller. Thus, I saw a need for a different envelope design.

### **The Ribbed Envelope**

As I mentioned in Part 1, one day I posed the general structural challenge presented by hot air blimps to my friend and neighbor John Fabel. The very next day, John came up with a tension membrane design to fit the bill.

There are lots of tension membrane structures in the world. They are the preferred way to create a shaped fabric volume that can be readily folded or disassembled. The most common examples are umbrellas and modern camping tents.

For our blimp, John envisioned taking a fabric envelope of the desired shape and size (say 132 feet long and 70 feet in diameter) and adding a half dozen or so 132-foot long sleeves that run from the nose of the ship to the tail. Into these sleeves insert hollow 132-foot long, 2.5 inch diameter "tent poles". The poles are composed of 12-foot segments that are coupled together. They can be taken apart for transport. The "tent poles" are very similar to, if much larger than, the ribs



*The concept of a tension membrane structure, as used in the style of tent pictured above, underlies the airship Alberto's unique envelope design.*



*With its truck mounted mooring mast the Zeppelin NT can operate with a minimal crew of three. ©ZLT*

that run inside the fabric of an umbrella.

To inflate the envelope (i.e. to open the umbrella) the ends of the poles at the nose are gathered together and secured to a nosecone. Likewise, the ends of the poles at the tail are gathered together and hooked to a tailcone. A cable is run on the inside of the envelope from the nosecone to a winch mounted on the tailcone. We fire up the winch and start reeling in the cable. As the cable gets shorter, the nose and tail are pulled together forcing the ribs to bow outward. Eventually, the fabric is pulled taut. The end result is a stable, self-supporting, tension membrane structure.

To deflate the envelope (i.e. to close the umbrella) simply release the tension on the cable and let the air out.

The metaphor between the ribbed envelope design and an umbrella is quite close. To be a bit more precise, the ribbed envelope is very similar to having Siamese-twin umbrellas. The top of the two umbrellas point in opposite directions, their ribs run continuously, and their central pole and handles are replaced by the

cable running through the center of the envelope. In fact, if we ever get tired of flying Alberto (never!) we can chop the structure in half and easily get either half listed in the Guinness Book as the world's largest umbrella.

Aside from setting oddball records, there are two very valuable attributes of this design. First, we are provided with natural "hard points" on the nose and tail -- well supported locations that have structural rigidity and can carry large loads. The rigidity on the nose will serve us well when the blimp is hitched to a mooring mast. The rigidity on the tail is just what we need to mount an engine and propeller for steering.

Second, we can easily attach fins to the envelope. A hub can be located in the center of the ship and poles can radiate outward in a manner very much analogous to the struts on the inside of an umbrella. However, unlike an umbrella, our struts don't stop when they reach the ribs. They continue outward for another 20 feet or so to extend beyond the exterior surface of the envelope. A web of fabric over



*Inflation begins with the ribs gathered at a tail cone (left) and nose cone (right). The nose cone is elevated on a small A-frame which allows a duct to direct cold air from an inflation fan into the envelope. The picture below shows the envelope just prior to the start of hot inflation.*



the top of each strut forms the fins. When the envelope opens and closes, these fins open and close right along with it.

### **Other Components**

Alberto's cabin is quite different than the bottom end of a typical balloon. One big difference is that there are no walls on the cabin. Rather than standing, the occupants sit in two seats from an old Toyota Corolla with 4-point harnesses to avoid any unfortunate flopping about. Between the seats is the control panel that can be reached by either pilot or passenger. Forward and slightly above head level is another panel with gauges and other indicators. The weight of the cabin is sup-

ported by six suspension lines that lead from the top of the cabin to a pair of "catenary curtains" that run along the ribs on the top of the envelope. As a safety measure, the cabin is also attached to the envelope fabric and directly to the bottom-most rib.

The burners were salvaged from a type-certified balloon and have factory-installed electric blast valves. They are normally operated by a pushbutton held in the pilot's left hand. However, the pilot can also use a lanyard to mechanically fire the burners in case of electrical failure. Each burner is fed by its own 20-gallon horizontal tank.

A tailcone ties the ribs together, holds the winch that controls the cable run-

ning through the center of the envelope, and supports the engine and propeller. The blimp is steered by swiveling the engine and propeller from side to side. The steering is an electrically powered fly-by-wire system. Switches in the cabin operate an electric motor that is geared way down. The steering motor started out its life as an off-the-shelf winch. We reworked it to meet our needs. The tailcone assembly with all the components in place weighs about 300 pounds.

Finally, the nosecone is structurally similar to the tailcone, but it supports much less equipment. The only significant items are a winch and A-frame assembly (one of the many ingenious design elements created my

co-builder Mike Kuehlmuß) for lifting the nose while on the ground.

### **A Typical Flight**

When we arrive at the field for a flight, the blimp is already assembled. It is protected from the elements by a tent above and a tarp below. At 140 feet long and 20 feet wide, the tent was itself a significant sewing project.

When deflated, the envelope lays on both sides and on top of the cabin. After removing the tent (one of many unglamorous tasks that fall to our crew chief Wayne Crouch), we use the winch and A-frame assembly on the nose cone to lift the nose of the ship to allow us access to the cabin. We load fuel tanks, get the cabin ready for flight,



Standard hot air balloon burners (left) are located inside the envelope which allows for a tighter fit between the cabin and envelope. The photo on the right shows co-builder Mike Kuehlmuss observing the burners from the cabin during a tethered flight test. Note the horizontal 'lay down' tanks mounted behind the seats.

and attach handling lines to the nose and tail to keep the ship aligned and to each side of the blimp to prevent the envelope from rolling during inflation. With the side lines attached, the envelope can readily be kept upright. Without them, until the blimp is fully inflated and the weight of the cabin is carried by the suspension lines, the slightest crosswind will cause it to roll quicker than a hound dog looking for a belly scratch. Finally, a tie-down line runs from the cabin frame to a ground anchor.

We then connect a fabric airduct (50 feet long and 4 feet in diameter) from the inflation fan to the envelope (via the cabin) and start with a cold inflation. During cold inflation we walk into the envelope for that portion of our pre-flight inspection. Most folks rightly avoid walking on envelope fabric. However, unlike in a balloon, the fabric we walk on is always going to be on the very bottom of the envelope. We are abusing fabric that is under very little strain. Tears or structural failure on this portion of the envelope do not present a risk to flight safety.

Once the envelope is about one-third full, what we call the "beached whale" stage of inflation, we light the burners and begin the

hot inflation. The weight of the ribs and other structural components makes inflation slower and more complicated than for a typical balloon. The envelope doesn't simply lift off the ground. Our inflation proceeds in stages with the air in the envelope heated to near redline in order to lift more fabric off the ground. This allows yet more cold air to enter, which is then heated to near redline, and so on.

With the weight of the

engine and propeller on the tail, the nose of the blimp lifts off the ground first. Using sandbags on the the nose control line we hold the nose from going too high in order to lift the tail and complete the inflation.

Once fully inflated, the various handling lines are released except for the tie-down. (We haven't yet designed and built our mooring mast.) The pilot and passenger buckle up. The tie-down is released. We go for a ride.

Our typical flight lasts for one to two hours. We are lucky to fly from a fairly large field (100+ acres) which allows us to exercise the aircraft without really leaving "home". Most of our time in the air is spent experimenting with various maneuvers such as flying to and loitering about the top of a particular tree (a.k.a. training for key-grabs), making precision landings, and spinning over a particular point on the ground. We usually wander



The instrument cluster includes this panel sitting between the pilots and passenger and a 'heads up' display (see photo of cabin above.)

back to the launch point every 20 to 30 minutes to swap in a fresh fuel tank or fresh pilot.

At the end of the flight, we fly the blimp right up to the ground anchor and reattach the tie-down. We then position the tarp underneath the blimp. Next we release the tension on the nose/tail line and open one or both of the top vents. (The vents are a pair of triangularly shaped Velcro style vents.) The envelope deflates and settles on top of the tarp and cabin. The tail settles first and then the nose supported again by the winch and A-frame assembly. With a bit of wrestling after deflation (the ribs settle a bit wider than we would prefer) we get all of the envelope onto the tarp, lower the nose A-frame to the ground, pitch the tent over the whole shebang, and go out for breakfast.

### *Where to From Here*

As mentioned earlier, Alberto is a development platform for trying out new technologies. Some of these technologies will be the application to our aircraft of other people's ideas. Others will be genuinely novel. Our overall goal will be to increase the performance-to-annoyance ratio.

Our first job will be to increase the airspeed. The biggest step in this direction will be increasing the size of the engine. Alberto is currently flying with a tiny 24 horsepower industrial-style (a.k.a. lawn tractor) engine. The current engine weighs about as much as an 80 hp aircraft engine but costs only 10% as much. We chose that engine just in case we goofed up somehow and dropped or otherwise clobbered the engine during our early testing. We figured that we would only be 10% as unhappy as if we had destroyed the more

expensive alternative. Now that we're confident that the structure can handle the weight of the engine, we will switch to the 80 horsepower aircraft engine.

In addition to increasing the airspeed, we'll be working on ways to increase the ground winds we can safely handle. Developing a mooring mast and its associated "docking" and "undocking" techniques is at the core of this work.

Another vein of work will focus on reducing fuel consumption. Now we burn about 30 gallons of propane per hour. We'll try a double-walled envelope design like those used successfully on record-setting balloon flights. In addition, we'll try adding some spun polyester "fluff" insulation. Unlike a balloon, we don't retrieve our envelope after each flight and truck it home. The increase in volume that such insulation entails is not an overwhelming problem for us.

We will also be working to make the ship quieter. This will involve building "cruise" burners that use lower fuel pressures and run continuously in order to greatly reduce the noise they produce. These burners will be much larger than conventional balloon burners. Again, of little concern to us because we don't routinely recover the ship from difficult to access landing sites.

Another important contribution to making the ship quieter will be the addition of electric motors for cruising. We don't expect to remove the gasoline engine. We'll opt for the added comfort of redundant propulsion. Also, the electric motors will likely be much less powerful than the gasoline engine. We'll use the gas engine to move around in a

hurry and the electric motors when we're doing our Mary Poppins thing among the treetops.

Alberto is definitely NOT a finished product. It was, is, and forever shall be a tool for exploring technologies and system design options. We enjoy flying Alberto, but we are constantly changing and improving its systems.

We are unapologetic adherents of the "build a little, fly a little, build a little more" school of technology development. In polite society this design approach is called "iterative design." In less polite company it is called "messing around until you figure out what works." We expect to continue to do this for some time to come.

it should be clear that our work is just getting started. That said, we hope to bring Alberto to at least a few balloon festivals this year. At the very least, we'll be flying at the XLTA meet that I'll be hosting in June at our base in Amherst, MA.



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### *The Immediate Future*

Given the "To Do List" in the previous section,