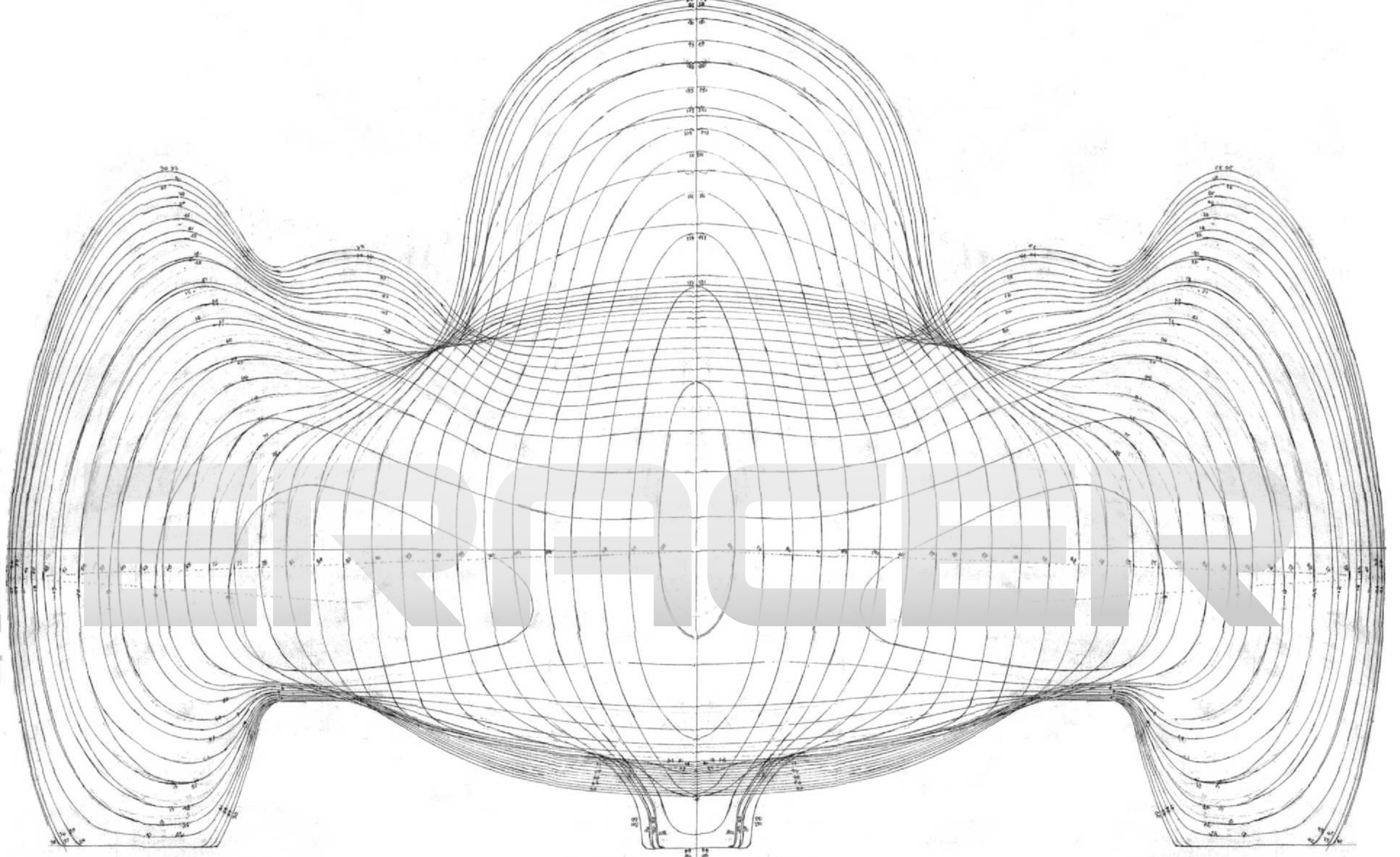
ELECTROLITE EL-IV 2003/04

Being second fastest (oval and road course) was a pretty strong incentive. We decided to build one more challenge to the speed record...the ultimate streamliner. I had noted that some vehicles, like Kirk Swaney's creations, were dramatically lower than ours, the drivers in a full recumbent, or luge position. While this presented some visibility issues, it reduced the frontal area and pushed the windshield further back, reducing the wetted surface of the cockpit. We considered going to even smaller front tires, but, with Doug Milliken's advice, concluded that the increased rolling resistance would offset the reduction in the frontal area. (I have since read claims that the 16" Primo Comet has an even lower CCr than the Moulton tires, but I still question its durability in our application). We decided the 20" rear tire was unnecessary, and used a third 17" Moulton tire...this car would not be a road racer. Doug built us a special wheel with a Ron Wood fixed gear hub, threaded on both sides, and we enclosed it with his aero covers. Fred made adapters for a chain ring on one side and later, a brake rotor for the other.

Rules require the driver to be ballasted to 180 lbs. With 64 lbs. of battery and, as it worked out, 105 lbs of car, our total would be 349lbs. That's over 116 per wheel, or about the same as a big guy on a Moulton...with luggage. But the difference here is side loading. When you turn a bicycle, it leans into the corner, which keeps the forces straight down the tire. Three wheelers don't lean, or they're not supposed to anyway. I've seen some amazing contradictions to that rule. I even saw one at Phoenix that was built to lean, but the mechanism defied description. At 120 psi the contact patch is only one square inch. We are asking a lot from a little piece of rubber. During one of our first tests in the new car, I told Fred I thought the break pads needed seating. He said to go back out and do some panic stops. Sounded like a good idea, so I got it up over 40 mph, a good speed for our local 1/3 mile oval, and slammed on the brakes- upgraded to 8" avid rotors with mechanical calipers- the result was instantaneous: POW! A well-used pair of the old Wolblers blew out at the same time. After an hour on that track the Wolblers would become what we call 'toast', and I'd keep them for just for testing. The new Bridgestones, on the other hand, will have enough life that we can turn them around and race them again. An hour at New Hampshire shows hardly any wear, so I'm thinking of taking Doug up on his offer of 17" Stelvios, a lighter tire with even better rolling resistance. After that incident I added another 8" brake to the rear wheel, actuated by a separate pedal, thinking that if I ever did a real panic stop, I could at least spread it over 3 square inches. I also had in mind that I would be going a lot faster. How much faster? Here again, I'm indebted to Doug for helping me through the math.

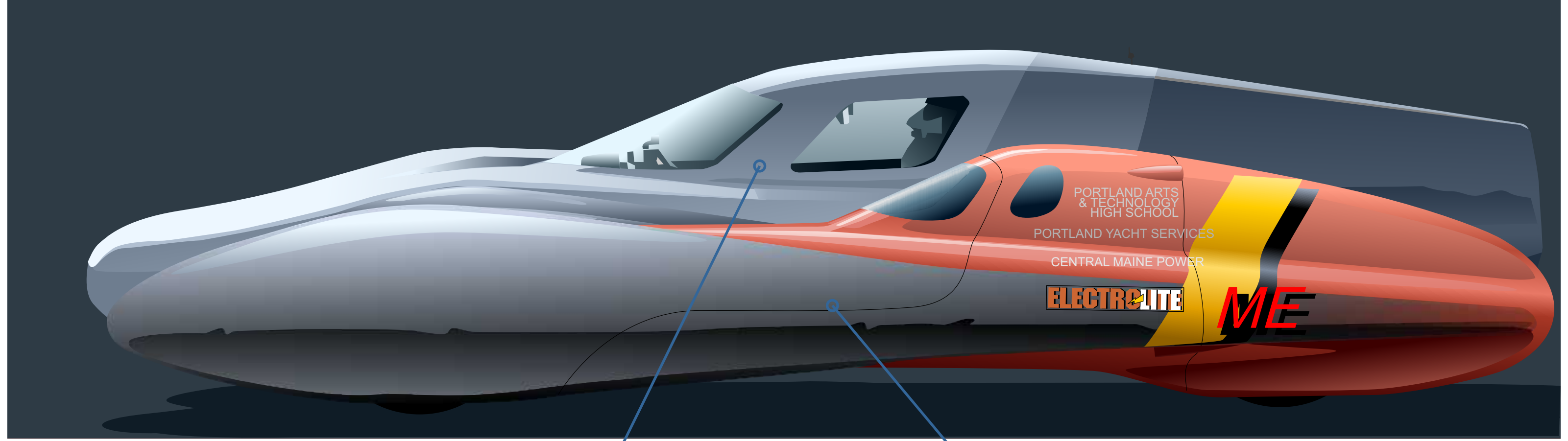
I knew that the fastest the EL-II had ever been was 55 mph on the long straight at PIR, and that I was drawing 32 amps @ 24 volts to do it. Knowing the rolling resistance and motor efficiency from published data, and taking estimated guesses at wheel bearing and chain drag, I calculated the only thing left - aero drag. The Cd worked out to be .133, which Doug says that isn't too bad for a home build. I made the assumption that our new car would be at least as sleek, hoping the changes would bring an even lower Cd. But the frontal area would measure 25% less, it would roll easier, it would be 20 lbs lighter, and it would more powerful. We had built the EL-II to fit the standard battery everyone was using, but a rule change allowed a much wider variety, literally. Our battery box was a structural mount for the front suspension; double wishbones with coil spring over hydraulic (mountain bike) shocks. Our best run in Oregon, or anywhere else, had delivered 38 amp hoursthe competition announced a new high of 46! They offered to loan us some better batteries, but they simply wouldn't fit. We eventually rebuilt it and made the one in the new car plenty wide. Space in the new design was at a premium, so the front suspension became just rubber mounts on a beam axle passing right through the box.



ARTIST'S STATEMENT PORTLAND MUSEUM OF ART JURIED BIENNIAL SUBMISSION 2 August 2004

The Electrolite ELIV is kinetic sculpture. I designed and built it in my basement, about 4 blocks from the museum. My intent was to create the fastest one horsepower electric race car in the country... and make a tangible statement on the ethic of efficiency, as in 'doing more with less is good' or 'elegance is more beautiful than power'.

The form evolved from an intuitive sense of aerodynamics- a fusion of teardrops enveloping 3 wheels, 2 batteries and my rather lanky 6'+ frame. There were no wind tunnels or computer simulations, only sandpaper caressing a styrofoam plug, feeling the path of least resistance. Without the technology to verify it, I decided that all I could do was make it look fast and it probably would be. Like a fish. But with references to those race cars from an age when speed was still romantic.



ELII

POWER INPUT watts
observed @ 55mph:
(32amp @ 24v)...............768
(2) 12v Interstate MT-51
38Amp/hr @ 24v (.912 Kw/hr)
1.22hp, 62 lbs.

ESTIMATED LOSSES

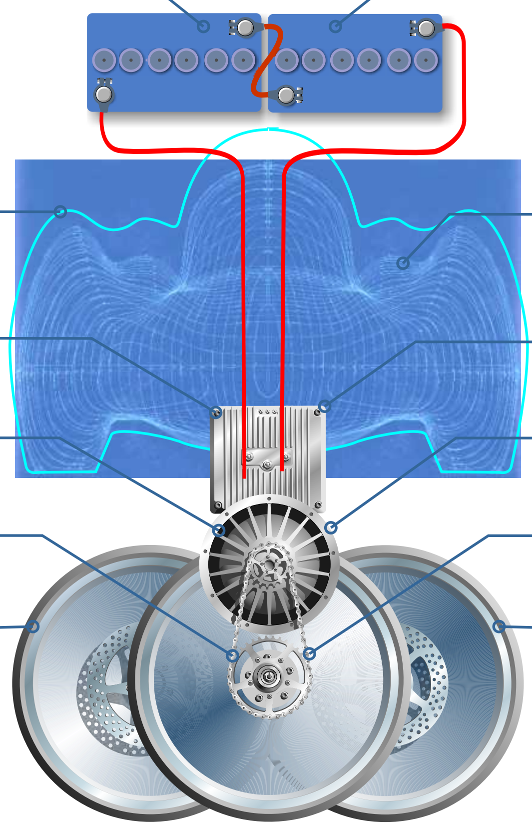
aero resistance.....(62%) 473.0
Cd = .133, frontal area
4.219sq.ft

controller............(1%) 8.0
Curtis PMC 1204-001

motor...............(15%) 115.2
Lynch LEM200 @ 1500rpm, 85%efcnt

chain, wheel bearings.(4%) 30.4
24:34 bicycle sprockets

rolling resistance..(18%) 141.4
(2) 17" Moulton tires, 120psi
(Cr.0028) 125 lb load =.700 lbf,
and (1) 20"Avocet, 100psi
(Cr.0052) 114 lb load = .593lbf,
for a combined 1.293lbf, or
(1.988x55)=141.4 Watts.



ELIV

POWER INPUT watts
projected @ 68 mph:
(40amp @ 24v)...............840
(2) 12v AGM Batteries
45Amp/hr @ 24v (1.08 Kw/hr)
1.45hp, 67lbs.

ESTIMATED LOSSES

aero resistance...(65.2%) 548.1
Cd = .133, frontal area
3.108sq.ft

controller............(.4%)3.6
Alltrax 400amp

motor................(15%) 126
Lynch LEM200 @ 1500rpm, 85%efcnt

chain, wheel bearings.(4%) 33.6
24:24 bicycle sprockets

rolling resistance(15.4%) 128.7
(3) 17" Moulton tires, 120psi
(Cr.0028)x340lb total load=
.952 lbf,x (1.988x68)=128.7w

Trying to be conservative, I assumed that 38 amps was attainable. That's only 1.3 horsepower, which as I recall, amounts to a hand pushing you along with something like 14 lbs of force. My elaborate calculations predicted that even that small amount of force would propel the EL-IV to 68.5 mph...which is, like, scary! (Someone later pointed out an arithmetic error that would put the number even higher, but I thought I'd leave it at that.

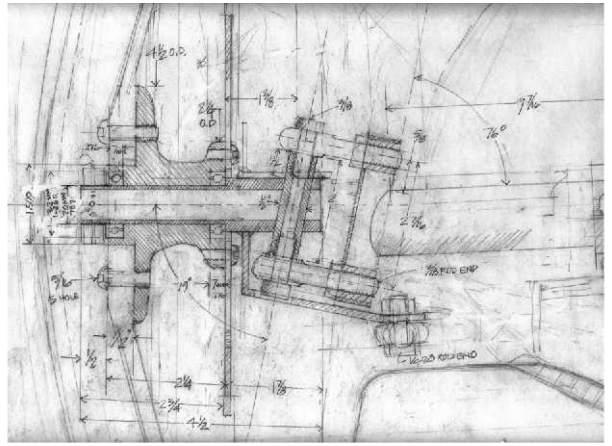
We had built the silver car (EL-II) in a frenzied 7 months. This one stretched over 18 months. We thought we were older and wiser, but it turned out we were just older. A lot more things went wrong, and we realized that, especially with the composites, we were working out of our depth and with inadequate facilities- most of the work was done in my cramped basement. While I sanded the foam plug Fred acquired more tools and did all the machining, including a beautiful pair of custom hubs. We molded the wheels again in the same material as the body-carbon/Kevlar/epoxy over 3/8" end grain balsa. I fabricated the suspension in chromoly and a neighbor welded it. The Moulton, by the way, inspired the rear swing arm in all our cars: a pair of triangles pivots on a tube (in this case supporting an 18 lb. motor) and butts to a rubber stop. It was two rubber stops in the earlier designs, but I thought we could reduce some of the flexing by using one. The triangles are nicely tapered and curved bike fork tubes. Where the last car had a fully independent front suspension, this one would have a simple straight tube front axle. The thinking was that this car would be built just to go after the Electrathon record, and that meant it would run only on the biggest ovals (road races were a lot of fun, but that's not how you set records), which were bound to be smooth enough that we wouldn't really need any suspension. Nothing is perfectly smooth, of course, and given the high pressure in the tires, we mounted the axle with small rubber doughnuts to absorb at least some of the shock. Fred made a pair of pillow blocks so we could rotate the axle to adjust our caster angle. As it turned out, it was adjusted exactly once, and never touched again. Someday I will weld little tabs to the axle and eliminate the blocks, as they rub against my calves and restrict my leg movement. Stretching out the build time meant the designers could think up even more clever details to make this the coolest Electrathon streamliner ever built. We were developing a sort of justification...even if this thing didn't shatter the record, it would look terrific, and inspire someone else to try and top it! The battery box cover, for instance, got sculpted to suggest a straight 8 valve cover....not a Buick, as commonly suggested, but a Bugatti. The rear view mirrors, though, became really complex. Rules dictated 8 square inches, and I couldn't have something that big outside disrupting the airflow. I had pulled the windshield to about 3" in front of my nose, so there was virtually no room for them inside the canopy. The solution was a pair of video cameras, 5/8" x 5/8" x ¾" fitted into little teardrops molded into the body just behind my head. A single camera would have worked, but I am reserving the top of the tail for a detachable vertical wing. Some of the extreme HPV's have sprouted them to squeeze a little extra speed from the wind...the premise being that if you are essentially circling in a light breeze, the headwind cancels out the tailwind, and the rest of the time you are sailing. Those same extremists have also eliminated the windshield and attempted to steer by watching a small video screen, but I think that may be getting just a little too scary. My own monitor, which grew to include a 20gig hard drive video recorder, was attached to the canopy just above my crotch. Rules now require a 5 point harness, but we were planning that safety feature anyway. If you are lying almost completely flat a 'seat belt' does nothing to slow your forward momentum in a frontal crash. Further developing the theatrical nature of the car, we added a third camera in the nose to document the full experience. All this meant a separate power system with its own battery, meter and charging port. The silver car is steered with a two handled joystick in your lap, but there was no room for that here, so we devised a pair of pivoting tubes at our side that link directly to the knuckle. Both have

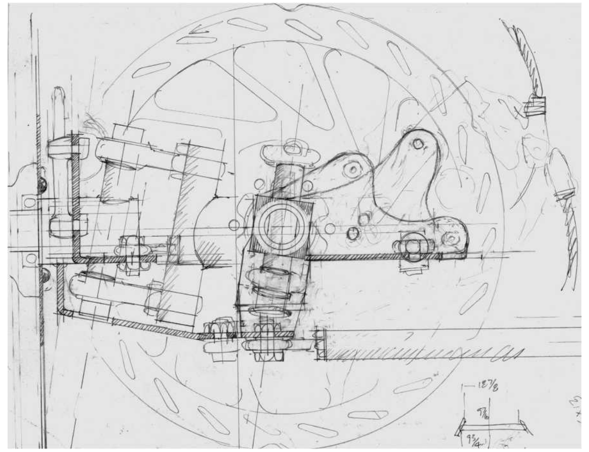
an on/off trigger for the power and one has a limiting potentiometer inside and a rotating dial on top. Just squeeze either trigger to go and tweak the knob to tell it how fast. The other tube has a rotating switch to change the channels on the TV. While I was in the process of designing the car there was a freak Electrathon accident in Iowa. A high school team was doing their annual recruitment exercise at the middle school…students would get to test drive an Electrathon car around the parking lot following an experienced driver in another car so they couldn't go too fast. With all the faculty and students watching, a 14 year old girl suddenly and inexplicably veered from the course and into a barrier. She was wearing a five point harness and a full face helmet, but the barrier was a horizontal pipe at exactly her eye level. She died instantly.

My initial reaction to the news, probably shared with everyone else in Electrathon, was total horror and disbelief, tinged with an irrational sense of guilt that we might be somehow responsible. There had been another death earlier, but it was more a case of tragic stupidity. A high school boy in Connecticut was test driving his Electrathon on a school running/walking path without permission, and while looking over his shoulder at a meter, ran down and killed an 86 year old woman on her daily walk. That one seemed easily preventable with just a little common sense, but the Iowa incident was another matter. There was a lot of anguished discussion among the board members. The Iowa group mandated full roll cages for their region, and tried very hard to make them mandatory for the rest of the country. I thought that was too extreme a reaction to a highly unique occurrence, pointing out that Michael Schumacher would have met the same fate with his F1 car in the same situation. Personally, I resolved to never again have anything to do with an Electrathon race that wasn't on a real racetrack. There are just too many hazards like that pipe rail, and its too difficult to keep people and race cars separated. The Electrathon America board barely rejected the full role cage in a vote, but it felt like just a question of time before it passed. I wasn't looking forward the fruits of my labor being outlawed, so I did my best to make it with at least a semblance of a full roll cage. The canopy opening then, had to be cut to leave a structural element in front of my nose, but I still needed a minimal side window. This left a windshield post of a couple inches which might be construed as a roll bar if it came to that. It also had to turn a right angle to clear my shoulder, which put its structural integrity into question, but I put many extra layers of carbon and Kevlar around the balsa core to stiffen it the best I could. The rest of the roof, though, was broad and heavily reinforced, I think you could drive a truck over it. The only problem remaining, and one I was totally unsure of until months later when the design became physical reality, was getting my head into place. It turned out, that yes, it could be done, but since it looks rather like the contortionist monkey and the football, I prefer not to do it for an audience. Luckily, the reverse is quite easy, if you roll your butt out of the car first, the rest of the body follows in one fluid motion. There is still the matter of undoing two seat belt latches, popping four awkwardly placed canopy latches and kicking the canopy up before you roll out, but I can do it in the 20 seconds allowed…barely… and with lots of practice beforehand. I should mention that it's gotten harder every year.

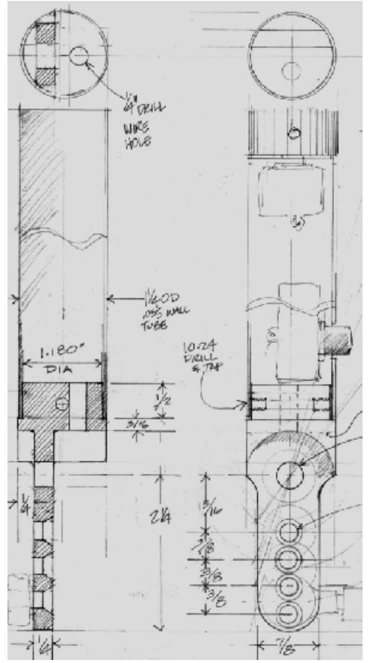
I made a mock up on my bench of all the essential parts then climbed in to measure where my knees, toes, hands, butt and eyeballs needed to be.

Years later I got my first computer and tried building a model in SketchUp… not entirely successful.



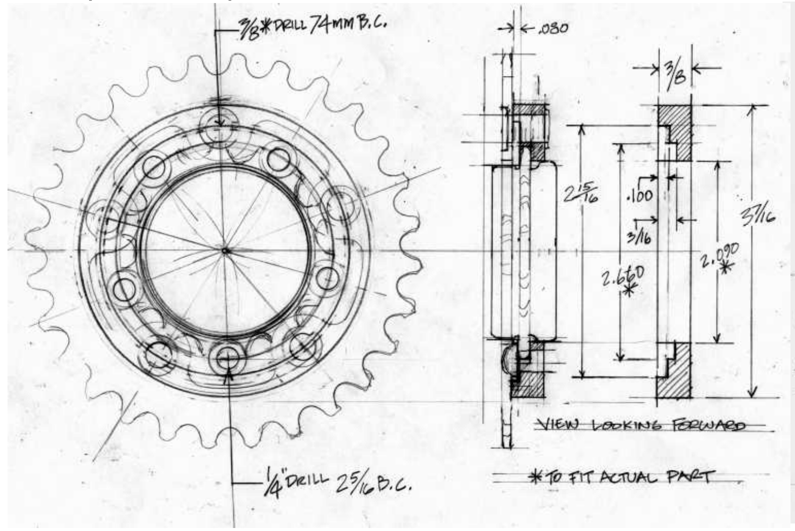


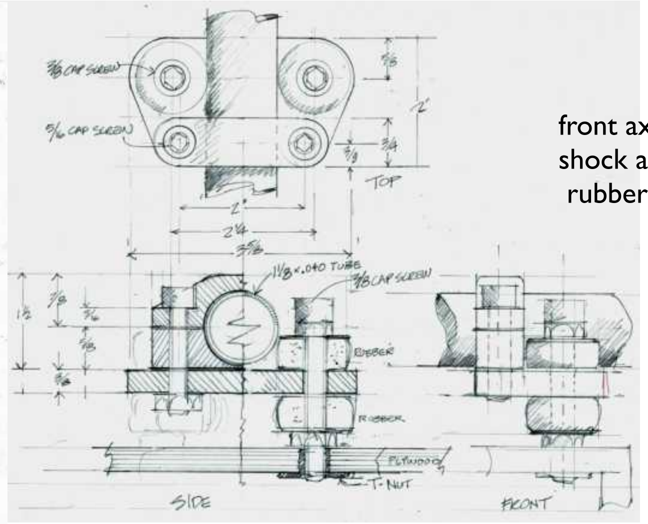
Spindle, hub, brake and knuckle front view side view



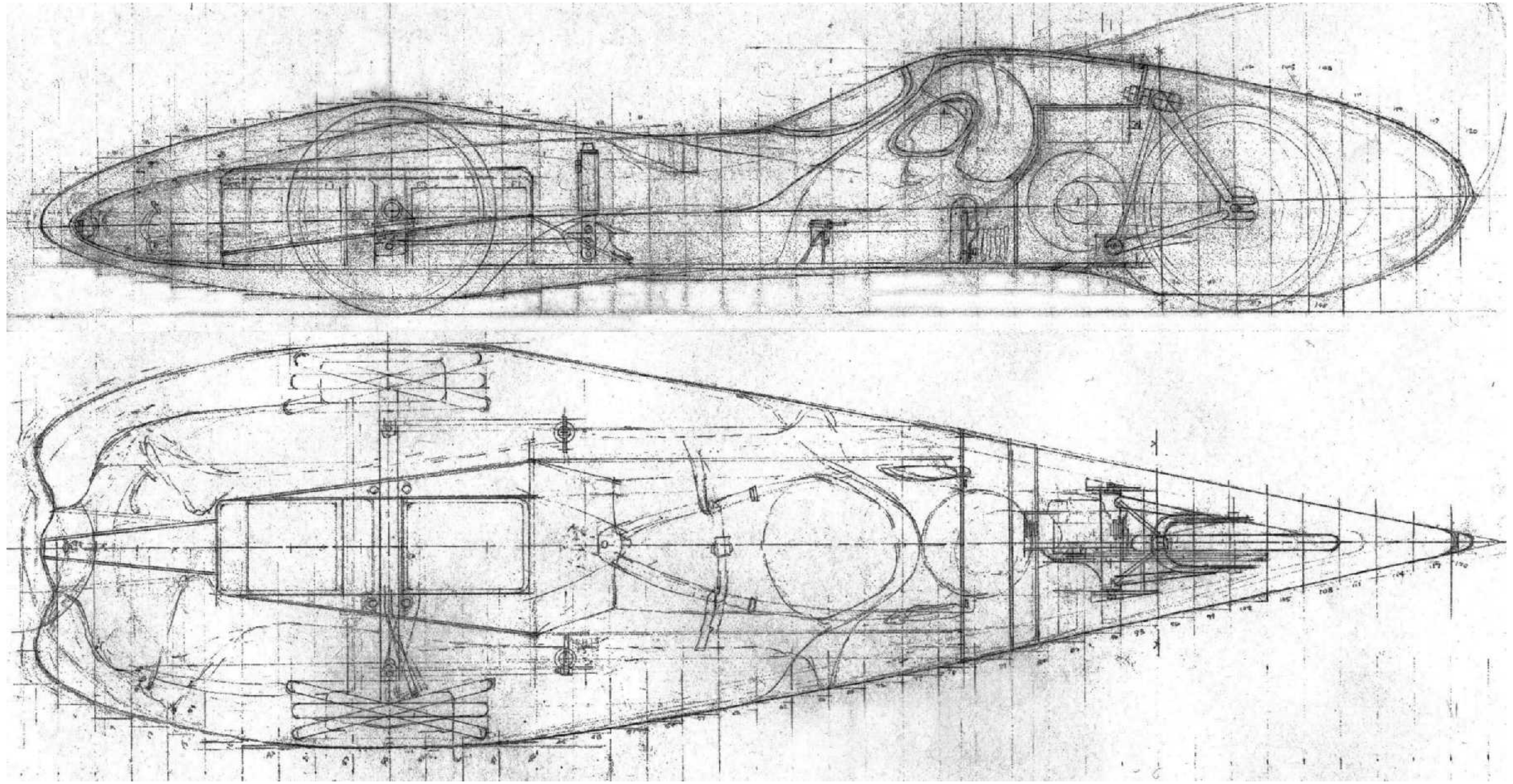
steering handle and speed control potentiometer

drive sprocket adapter



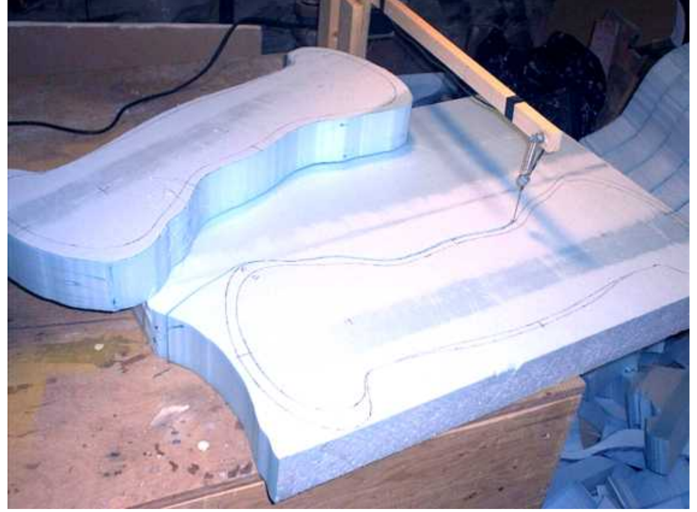


front axle mount and shock absorbing rubber doughnuts

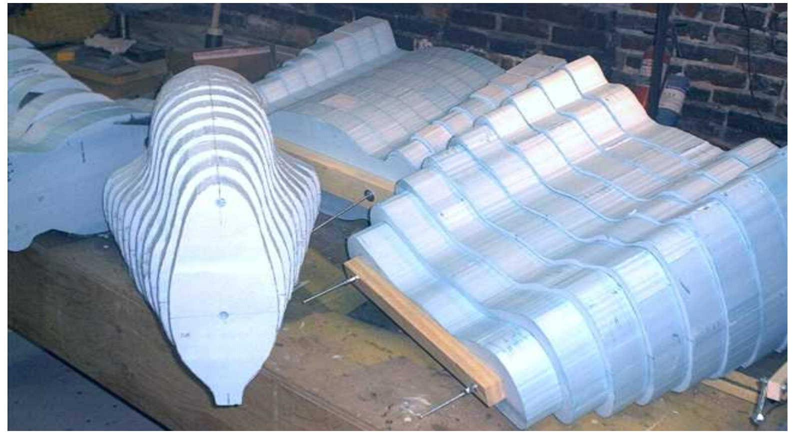
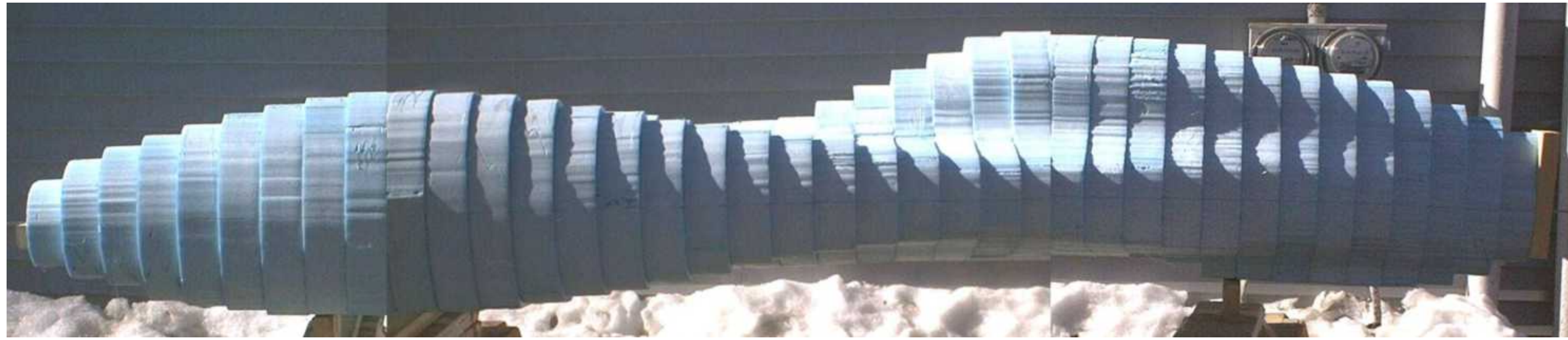


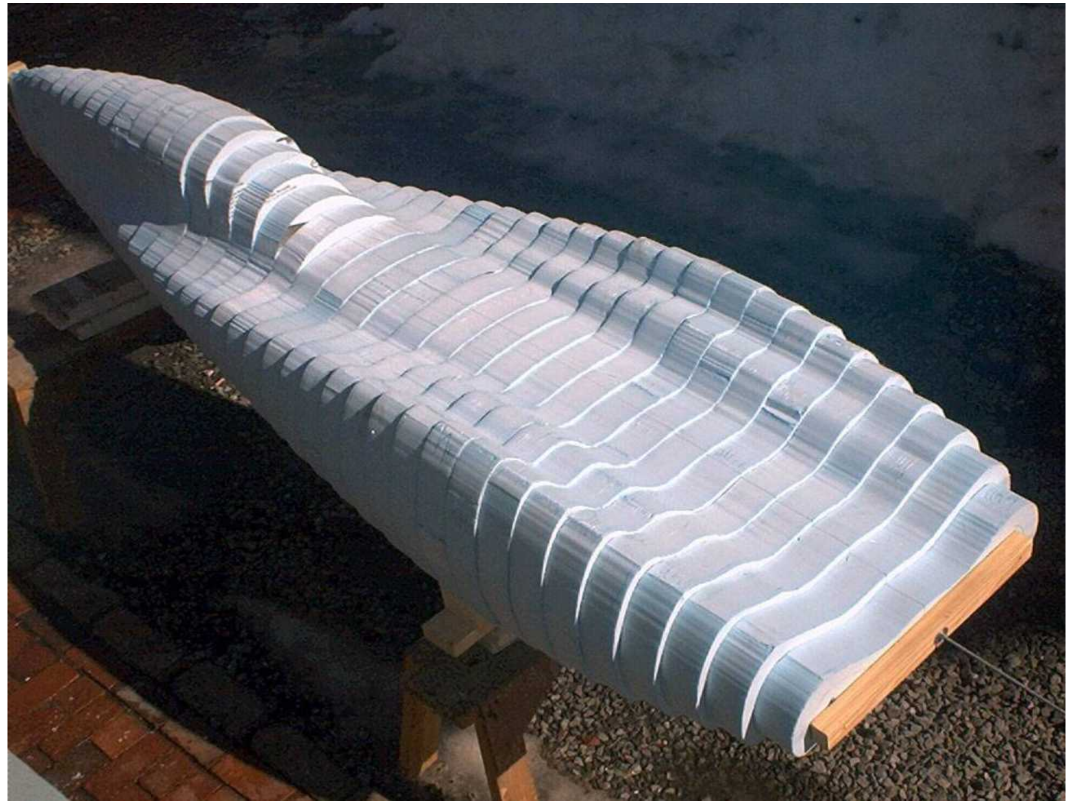
side and top views

The vertical lines indicate the 3" foam blocks, and were measured to construct the front view (p.1) contour drawing, or lofting diagram
I've been a professional draftsman since I was 16, and this is probably the technical drawing I am most proud of.

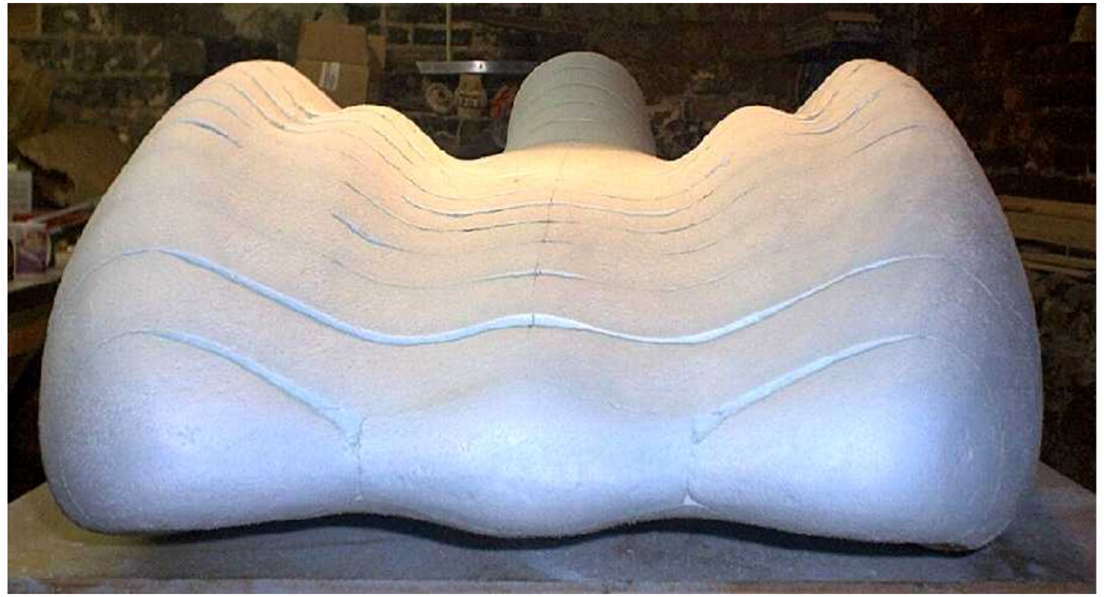
We made the plug in my basement this time. Not an ideal workspace by any stretch of the imagination, but I'd poured a new floor and built a workbench, so it was at least tolerable, if a little cramped. Most important I could work at home and at least be close to the family. I built a little hot wire setup that made cutting out the contours a lot more accurate, and discovered that by moving at just the right speed, it would melt just enough to cut without producing what I figured was a pretty toxic smoke. The 3" thick foam was all bellied in the middle, so I was careful to run a belt sander over each section to flatten them. They seemed to fit together well and the shape looked pretty nice. I was trying to be more accurate this time, as everything had to fit very tightly and there was even less room for error. I had been sanding for weeks when my careful measurements seemed to be adding up wrong. For the first time I measured the overall length, which should have been 120", given the 40 three inch sections. It was 2 ½ too long, meaning each section was, despite my efforts to correct it, more than 3" thick. The result was that the distance between my nose and my toes was greater than it should be, and my calves intersected with the front axle just enough to make it pretty uncomfortable at the end of an hour. Another lesson learned…the hard way.

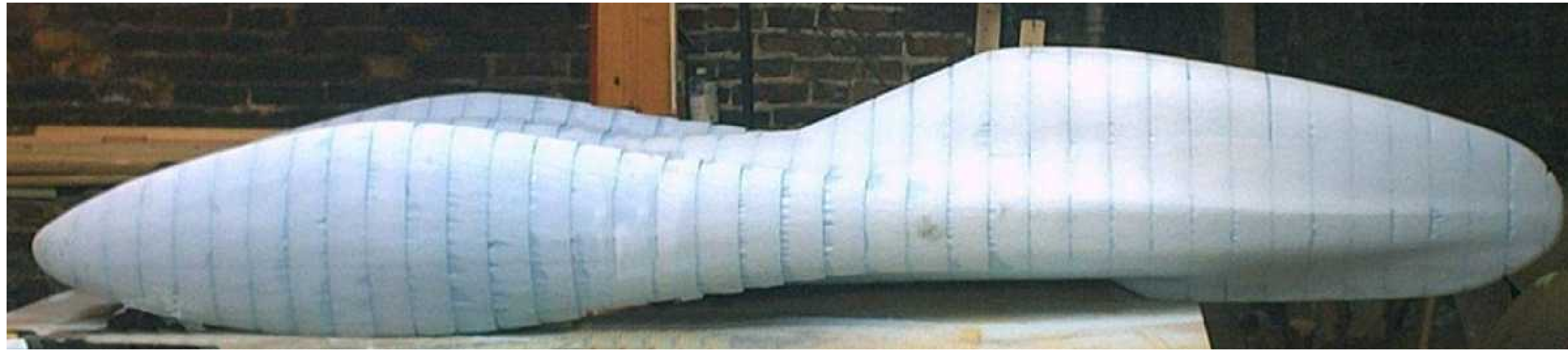




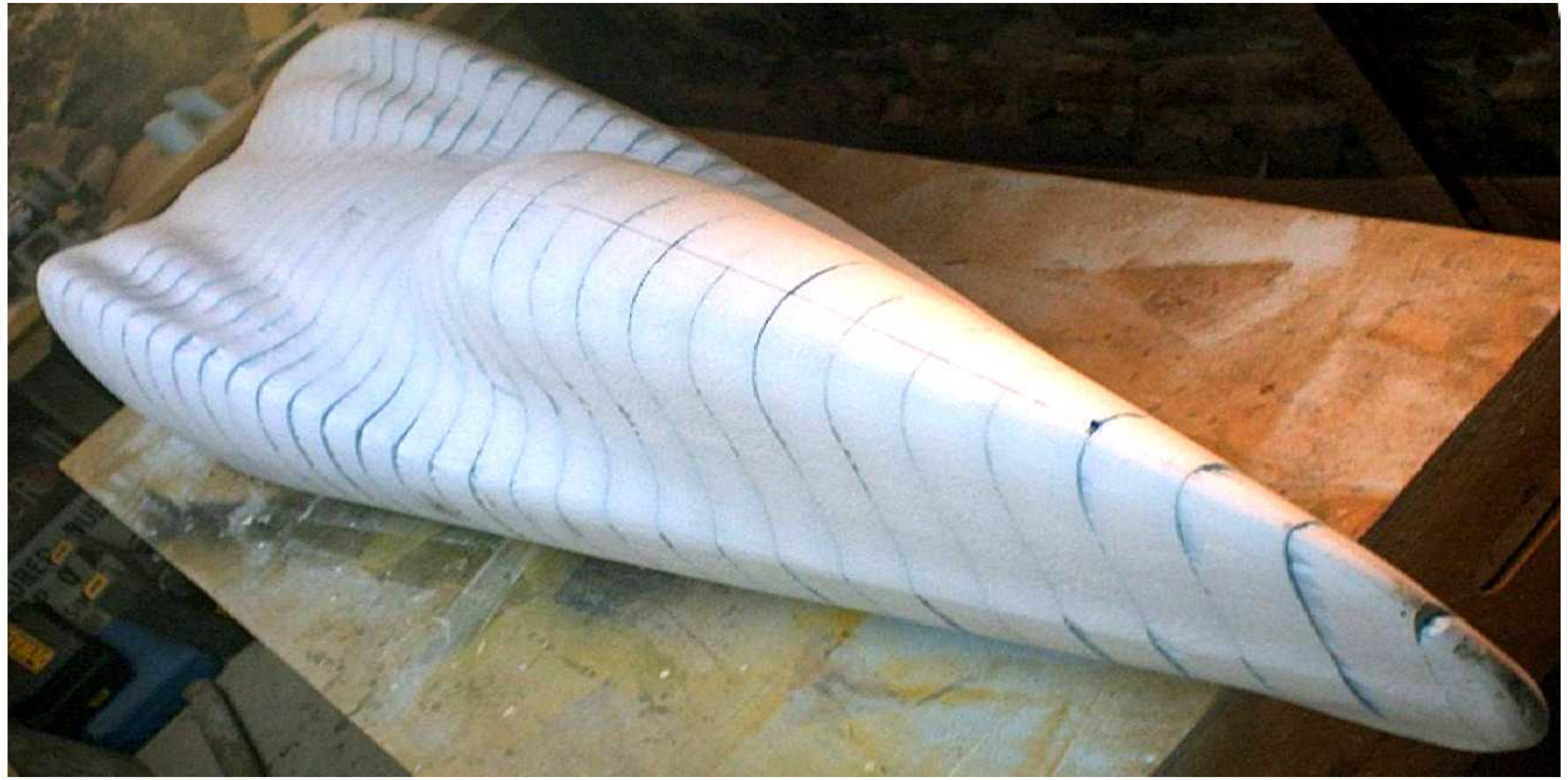


The foam sanded pretty smooth.
I knew that when I'd sanded down to the edge of each section it was time to stop.

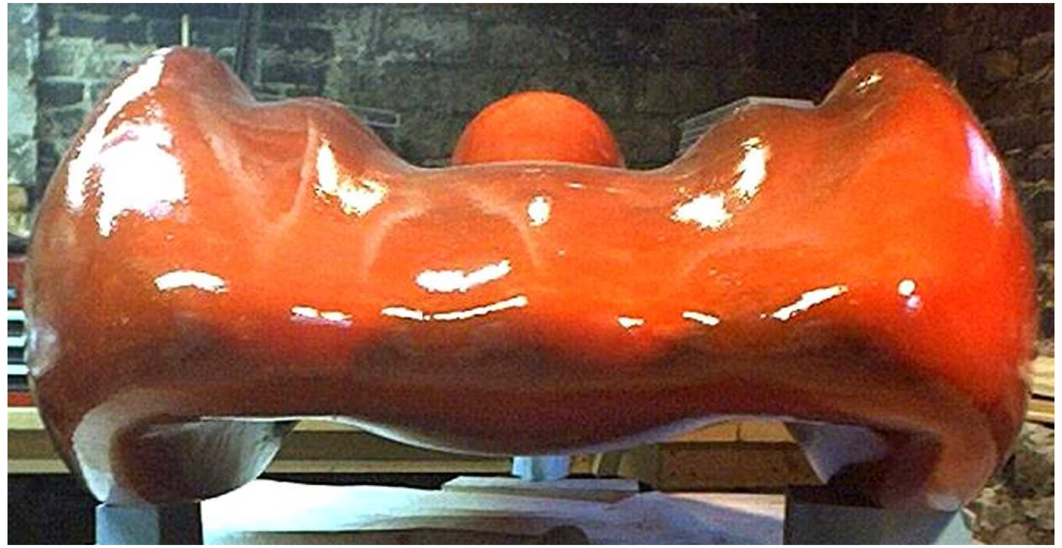
I have to say this was the most rewarding and enjoyable part of the whole process, to watch and feel the shape come alive. As I sanded I would imagine I was the wind caressing a smoothly voluptuous body.

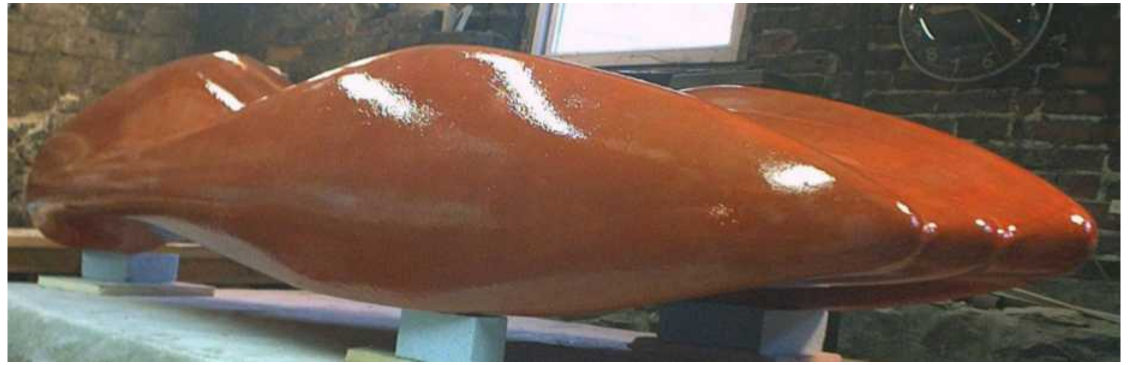


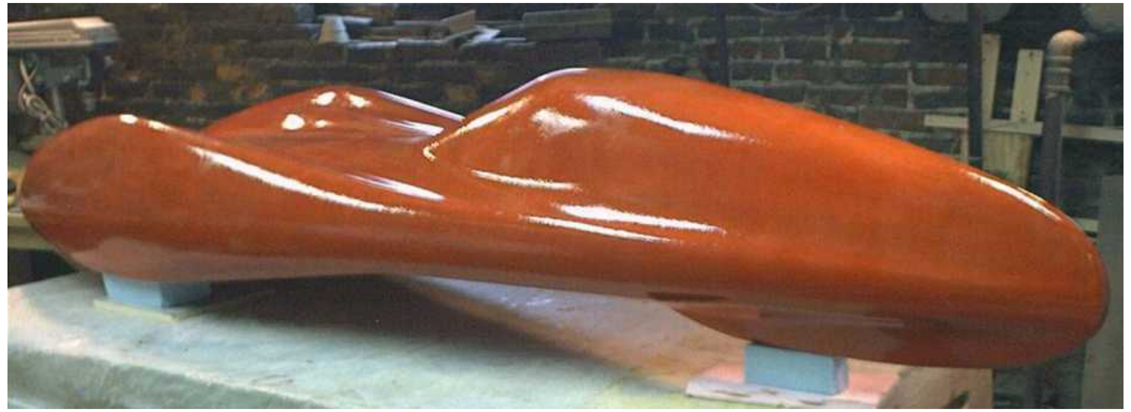




Then we wrapped it in fiberglass and epoxy, and sanded...and sanded...and sanded....and coated it with more epoxy and sanded it some more

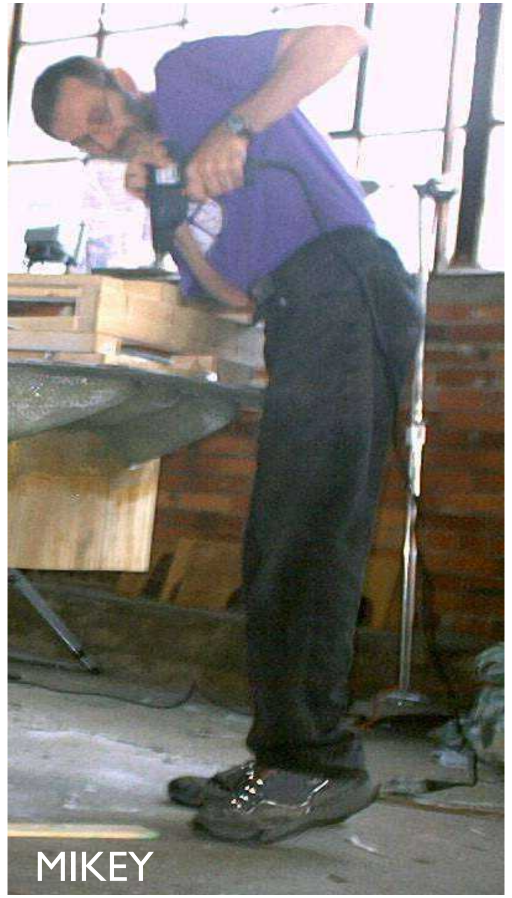






Then we sprayed it with Duracoat, sanded it with really fine sandpaper and rubbed in a million (never enough) coats of wax.

We cut a flange out of formica covered masonite, sprayed it with a release agent, then a thick gel coat, and smeared the whole thing with tons of gooey, smelly polyester resin and fistfuls of chopped strand fiberglass mat. The plywood bulkheads were to stiffen and support the mold when we flipped it over and repeated the process for the bottom half.



Et voila!
A nifty two part mold.

Well not quite.

Pulling the molds off the plug was excruciating. We pried and pounded wedges, then finally poured water into the gap to let capillary action 'float' the plug out of the molds.
There was some serious orange peel texture because the magic didn't quite work. Blame the amateur craftsmen. We had done this a couple times before, but still didn't really know what we were doing.

The repair required a special molding gel coat filler, which sanded like wrought iron, made even worse by the concave shape... much, much harder than sanding convex surfaces.

Back in my basement, we coated the mold with epoxy, layed in carbon fiber, kevlar, balsa core, and more carbon, then wrapped the whole thing with a plastic bag.

Somehow Freddy had scored an old vacuum pump retired from a hospital operating room which sucked for hours to squeeze the sandwich together and suck out the excess resin.

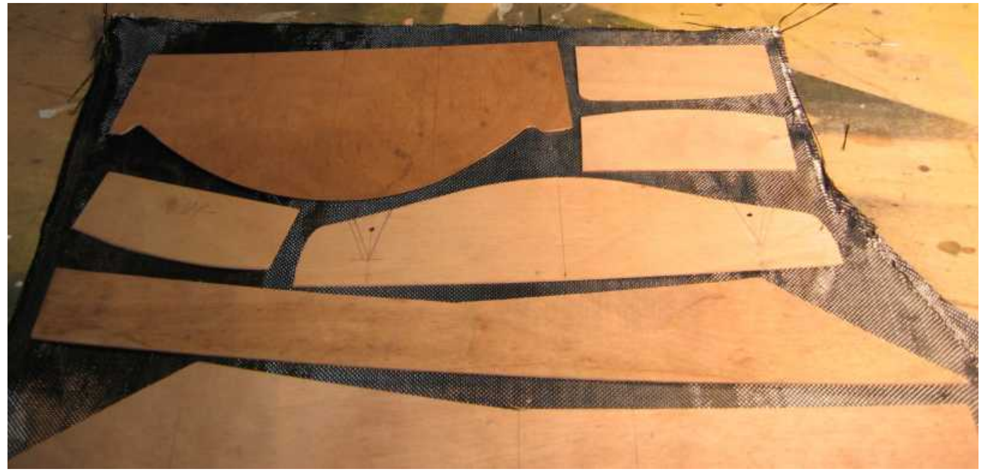
After pulling the parts out of the mold, we cut off the flange, glued the top and bottom together, cut off the tail and cut out the canopy.

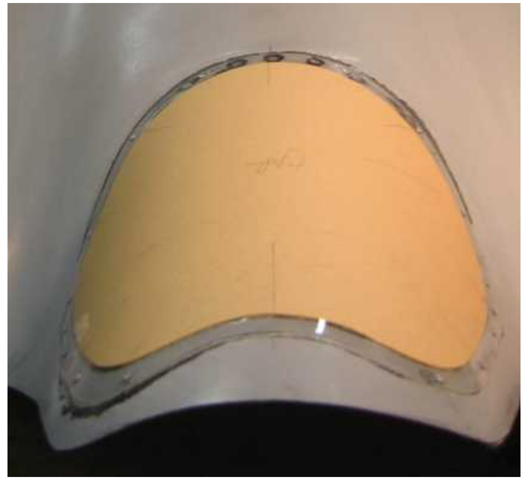
We had cleverly riveted duplicate polycarbonate windows inside the mold, so when we cut the openings we were left with a recessed flange to attach the actual windows.

I carved a battery cover in foam to resemble a straight 8 valve cover and wrapped it in carbon.

"Aha," said somebody, "it's a Buick!". "No... it's a Bugatti", I sneared.

The bulkheads and battery box were 1/8" marine plywood, clothed and glued in place.

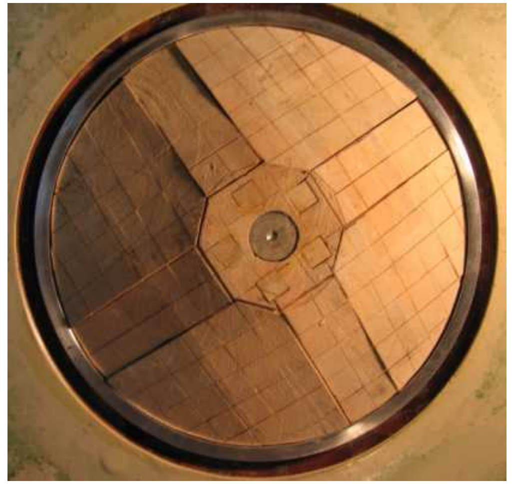


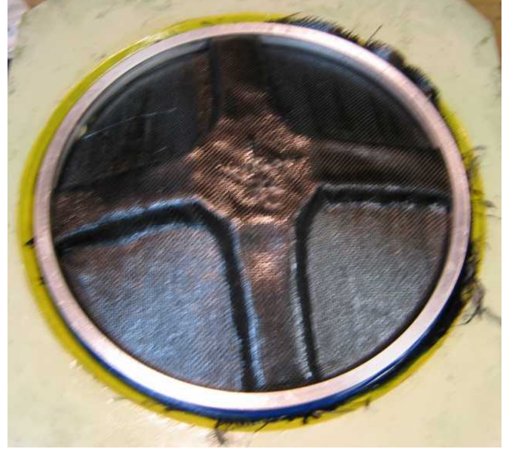
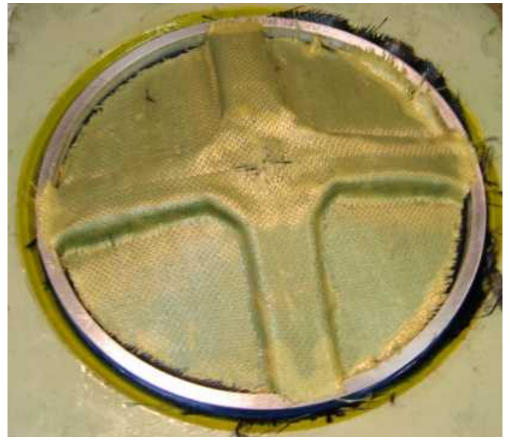
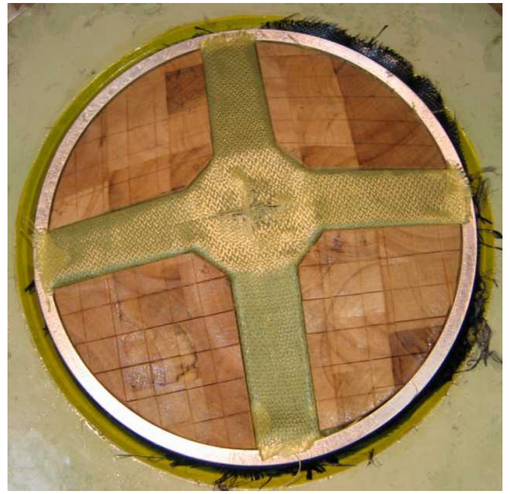


Flanges were added to attach the tail and canopy, then the windows riveted in place.

I cut and shaped the rear triangle from some bike forks, built a jig to support them while a friend welded them together.

The body was painted at the Portland Arts and Technology High School by a very generous Professor Mark Law and his gifted students. For once we were able to stand outside and watch competent professionals work their magic.

To mold the front wheels, we glued up blocks of end grain mahogany like a butchers block and Freddy turned it on his lathe. Then we went through the same process as the body, coating it with resin and carbon fiber, inserting a 17" aluminum rim, balsa centerpiece and four spokes. The removable stainless steel cylinder in the center assured a precision fit on the spindle and the layer of Kevlar added toughness. Carbon alone is strong but brittle. Then we added the rest of the balsa and more carbon. This way the cloth went from one side to the other and formed an internal web.

Once more our (barely) trusty pump squeezed it all together.