On Digitally Manufacturing URBEE 2

by Jim Kor of KOR EcoLogic

Urbee 1:

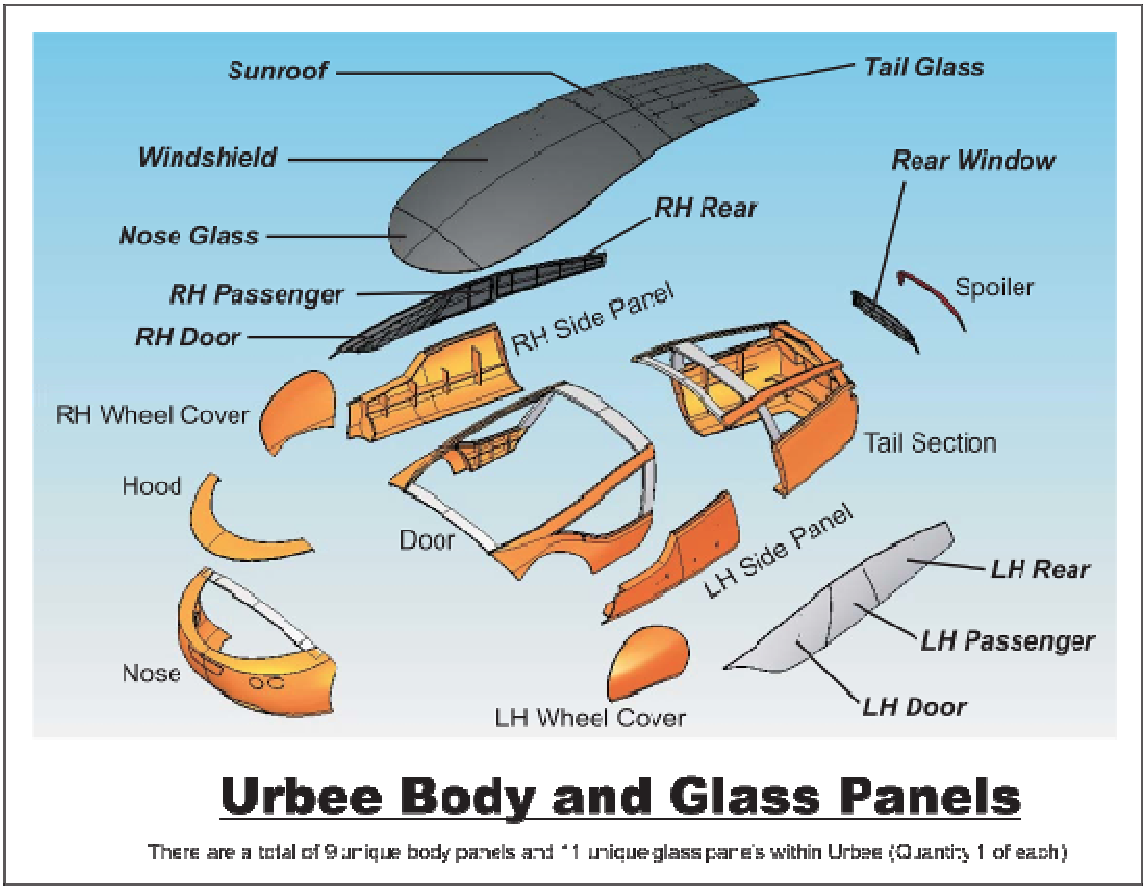
As a design engineering group, we have been working with 3D printing for several decades, since its inception. Like many designers and engineers around the world, we adopted 3D printing technology for making rapid prototypes. This revolutionized how we made models of early design concepts. Previously, models would be made by hand, in our modeling shop, using wood, foam, plastic, metal, fiberglass, and other materials. With rapid prototyping, ideas created in the computer, using CAD software, could be quickly made real (within days), and a plastic representation could be presented, in very short order, to the client for discussion and approval. Over the years, as costs of rapid prototypes came down (from $1000s down to $100s), we successfully and economically used this 3D printing technique more and more within our design and engineering process. Today, within our practice and worldwide, this is a very 'normal' way to design a product and in conducting R&D. Nowadays, rapid prototyping has become an integral part of the design process. I believe most product designers and design engineers around the world would agree with this historical perspective of 3D printing and rapid prototyping.

So, when we first approached RedEye On Demand and Stratasys in Minneapolis, over 3 years ago, we had the above in mind. At that time, we had the Urbee 1 body in our computers, thanks to the latest Autodesk software (Inventor Pro, Alias, and Showcase). Our clay model of the body had been successfully scanned and put into CAD, thanks to Tebis, in Detroit. We had also achieved our goal of a very low aerodynamic drag (Cd = 0.15), verified through computer simulation software, thanks to the efforts of CD-Adapco in Detroit. Before approaching RedEye, we had talked about making the Urbee 1 body out of fiberglass, because we had extensive experience with this material and process. This seemed a natural choice for us. We had designed fiberglass tractor hoods, fenders, roofs, etc. and hand fabricated the required master moulds within our shop. So, we knew fiberglass intimately, both its many advantages, but also its disadvantages. However, about a year before we approached RedEye, we had read in an article or advertisement (and I believe it was in Design News), about the advancements RedEye was making, which included 3D printing some rather large parts. So, only BECAUSE we had the CAD files of the Urbee 1 body in our computers, and BECAUSE we knew the shape was aerodynamic and correct (and would not change), we considered the possibility of rapid prototyping the Urbee 1 body. And notice I used the words 'rapid prototyping'. We just wanted one physical car body, in plastic, exactly like our CAD model, so that we could prototype Urbee 1. We were not thinking anything beyond that, at that time.

Our concern as we approached Stratasys was, "Could they rapid prototype panels large enough to do the entire Urbee body?" We were worried about getting sidetracked in a separate and potentially lengthy R&D project dealing with just the car body, and this is something we, the Urbee team, did not want to do. Mainly because the car itself, beyond the car body, needed all of our team's R&D focus. And, the other option, a fiberglass body, contained zero risk for us, just a lot of meticulous and lengthy hand-work in our shop. Lucky for us, we met Jeff Hanson at RedEye On Demand, the visionary behind the company. After several months of back and forth discussion with Jeff and others at RedEye, including mulling over the many details that needed considering, we at KOR EcoLogic partnered with RedEye and Stratasys in making the Urbee 1 body. We carefully and cautiously proceeded in this direction knowing that it would be groundbreaking, but also knowing it was doable. We chose this direction because, as product designers, we were well aware of the advantages of rapid prototyping (accuracy, speed, etc.), as compared to the disadvantages of going with a fiberglass body (tooling, lengthy hand-work, toxicity, etc.). And with the Urbee 1 car body already in our computers, with all that hard work already done, this seemed the right way to go: ... just print out one car body, and that part of the Urbee prototype would be ready to go.

The 3D printing method we decided upon is called Fused Deposition Modeling (FDM). Think of this process as a very sophisticated, computer-controlled glue gun that creates the part, layer by layer, from the bottom to the top of the part. The computer program takes its fundamental instructions from the original CAD model. In our case this would be the fender, body panel, or glass window we had designed for Urbee 1. The part starts out in the form of a continuous roll of plastic of round cross section, about the diameter of a single spaghetti noodle. This roll is fed into the 3D printer, and that noodle is what goes IN to the head of the glue gun. But the plastic string that comes OUT of the glue gun, which is building the part layer by layer, is about the diameter of a human hair. So, amazing detail can be built into the 3D printed part, along with amazing accuracy. In this way, the FDM 3D printers tirelessly make parts, without any human intervention required from start to finish.

The incredibly talented people within RedEye and Stratasys made this first-ever 3D printed car body happen. Our contacts were: Jeff Hanson, Joe Hiemenz, and Noah Zehringer, and it became a true pleasure working closely on Urbee with these people. Jeff, Joe, and Noah are masters of innovation. They successfully overcame the numerous issues that a project like this can uncover as it moves towards completion. Our strategy was to first make a 1/6th scale model, cut up exactly like the real car would be in its 20 separate panels, which included all of the body components and all of the window templates (see illustration attached).



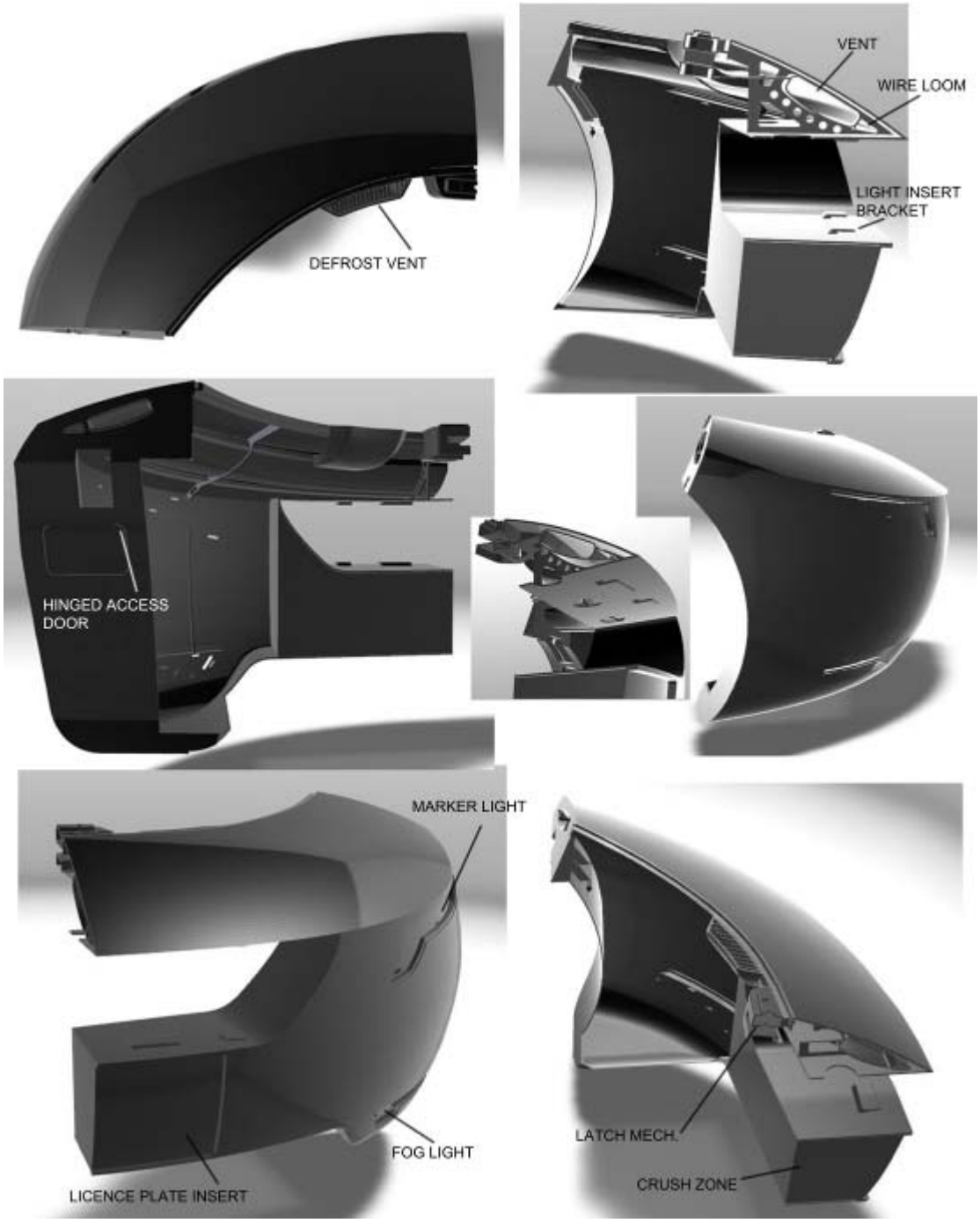
Once the 1/6th scale model was 3D printed and everything fit perfectly, we were assured that the 20 separate computer files were correct. Making the 1/6th scale model was routine rapid-prototyping, commonly done, with nothing special about the process, or the size of the parts. Then these exact same computer files that made the 1/6th scale model were scaled up. Only then did we attempt the large, full-size pieces for the Urbee body, using the same files that made the scale model. In this way, we knew that all of the large panels would fit perfectly, first time out of the printers. This is a very important consideration, because of how long it takes to print large parts (days instead of hours), and the need to avoid mistakes within these very large parts.

As we received full-size body panels from RedEye, we mounted these onto the Urbee prototype chassis. We also used the solid plastic 3D printed window panels as templates in making the glass and plastic windows that ended up in the prototype car. We used white ABS plastic for the exterior 3D printed body of Urbee 1. During the printing process, some parts required the water-soluble grey plastic used to support certain overhanging areas of white plastic. Our initial goal with Urbee 1 was just to see if we could actually make (3D print) and handle these large panels, and turn them into a car body. Worried they might be weak, we made the full-size parts rather thick, about 0.25 inches. We added simple egg-crate stiffening structures on the inside. Nothing fancy, just some bracing. The parts were a bit heavy, but not excessively so, and they ended up being very

strong. I've attached a photo of one of these big parts, just as it was finished being printed and joined together (see below).

URBEE 2:

For URBEE 2, parts will be designed more carefully as 3D parts that include exterior skin, interior skin, and lots of components integrated in between. I have attached some photos of our preliminary front bumper. Exact material choice has not been made at this time, but it will be some form of recyclable plastic. Although not essential, we are considering weaving two materials together into a mesh designed to handle the forces the part must withstand over time. One material would be very strong yet brittle, combined with another material that is less strong yet elastic. This is similar to how bones in animals are constructed, or should I say 'grown'. In animal skeletons, this combination provides very strong yet durable structures. Bone strength approaches many of the best man-made materials, while utilizing basic life-elements. Stratasys 3D printers can print two different materials at the same time, so require no modification to do this interwoven structure. We just need to design for it in CAD, and understand the forces enough that we can follow these within the part.



We are at a very early stage with these considerations. But, we are hopeful that we will make significant progress, especially working hand-in-hand with RedEye On Demand / Stratasys, as we plan to in the coming years ahead. With the right people involved, we believe we will eventually accomplish incredibly strong, amazingly durable, and 100% recyclable parts. These will be parts that are of amazing complexity, but will be much fewer parts than normal, as we integrate numerous functions within each single part.

The Promise of Digital Manufacturing

For Urbee 1 we were only thinking of rapid prototyping the body - just one body for one prototype car.

For URBEE 2, we have made a mental leap. We are now designing the car so that the major body and interior parts (about 40 to 50 parts in total) MUST be made by the 3D printing process. No other process will be able to make parts as complicated as we plan to design. This is quite different than rapid prototyping a few parts. This designing exclusively for 3D printers has been termed Digital Manufacturing. We expect to manufacture these parts in a 'factory of the future' that houses many 3D printers, all mass producing production parts.

Many production parts are already being Digitally Manufactured NOW, especially within the military aircraft industry. Also, car corporations are selling Digitally Manufactured parts NOW within some of their more specialized vehicles, where low volumes don't warrant the higher cost of tooling up for the part. So, Digital Manufacturing is here now, and will only broaden in scope, as costs continue to come down.

Our reason for embracing Digital Manufacturing is that, once you are able to build ANYTHING, then, as a designer, you can start to think of ALL POSSIBLE Solutions. This is incredibly liberating, and will allow for better and better overall designs to emerge into production. There are four technological fields of significance that will allow further exploration into finding ALL POSSIBLE solutions. These are:
1. Digital Manufacturing (3D printing used for production manufacturing)
2. Simulation Software (using the computer to mimic and understand the real world)
3. High Performance Computing (using massive computer power to derive all possible solutions, even the ones 'never thought of', similar to how evolution progresses)
4. Biomimicry (learning from Nature and employing what is learned within our emerging sustainable technologies).

These, in combination, hold the key to properly making things on Earth, or what could be called 'designing for sustainability'.

And this is what excites us about the future.

Digital Manufacturing has opened the door to the potential of economically and cleanly building almost ANYTHING.

And the ability to economically build almost ANYTHING allows thinking of almost EVERYTHING (every possibility).

And this will allow for BETTER and BETTER designs -- ones that can successfully co-exist within the natural landscape, without inflicting damage.

To us, this seems like the right way forward, and the right thing to do. Alongside RedEye On Demand and Stratasys, we've started on this journey. We're committed and we're doing it. Just watch us now.

"URBEE 2,
San Francisco to New York,
two people and a dog,
10 Gallons of fuel,
just by hitting Print."
- quote by Laura Betker, Simply Science, KARE 11, Minneapolis, USA

URBEE's trip across America is planned to occur in about 2 years (Spring, 2015)

Jim Kor, P.Eng.
President
KOR EcoLogic Inc.
Winnipeg, Manitoba
Canada

jimkor@mts.net

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