

Red Rabbit – Applied Digital Fabrication

The 56-foot Red Rabbit presented unique construction challenges that were solved through computation, programming, and a variety of fabrication techniques. Large-scale sculpture offers opportunities to employ state-of-the-art fabrication methods not easily applied to projects that involve multiple participants with varying levels of skill. Fabrication of the Red Rabbit took considerable advantage of these new methods and techniques. Indeed, its successful execution may not have been possible without them. Computation and programming also helped link the designer and fabricator throughout the construction process, enabling them to influence, inform, and respond to each other in a close, sustained collaboration.

Many of the fabrication tools used to make the Rabbit – scripting languages, nesting software, CNC machines, etc. – are increasingly becoming a recommended part of architectural studies. Although learning about these tools in an academic or laboratory setting is essential to assessing their capabilities and limitations, the Rabbit illustrates the importance of understanding the entire fabrication process, including material properties, fabrication techniques (such as welding vs. riveting), tolerances, construction document coordination, and engineering and installation constraints.

Description

The Rabbit is constructed almost entirely out of 1/8" and 3/16" thick aluminum sheets. The design is a closed, triangular mesh composed of 1466 triangles. It is suspended inside an atrium (Figure 1) by seven cables attached to the building's structural frame. The cables connect through the skin to an internal steel armature which is designed to distribute suspension loads.

The Rabbit's skin consists of two layers – an inner and an outer (Figure 2). The inner skin is matte black. It is internally reinforced with 4"-wide aluminum rings, or bulkheads, one foot on center (Figure 3). The inner skin and bulkheads are welded together to form a rigid, monocoque structure which is fastened to the internal steel frame.

The outer skin is the primary visible surface of the Rabbit. The facets of the outer skin have a 1" gap between them and "hover" 1-1/2 inches above, revealing the inner skin underneath. A custom finish of red paint and crushed red glass decorate the outer panels.

Fabrication

The guiding principal behind fabrication was to minimize the physical effort required to assemble the Rabbit. This influenced the ability to meet budget and schedule requirements. Much of the assembly planning took place in the earliest stages of digital design before any physical work was done in the shop. This resulted in a very detailed 3D model which was used to feed fabrication data to CNC machines, and also served as the project's "construction document" (Figure 4). The digital techniques and craftsmanship employed to build the model were essential to the project's successful execution in the shop.

Writing scripts was central to the construction of the model. Seventy custom scripts with a total of 3000 lines of code were written specifically for this project. A typical script generated the shape of the bulkheads and offset them 4"; another collection of scripts creates labels for each of the 3,652 pieces of aluminum.

Scripts also deconstructed the model into a format that is appropriate for import into 2D nesting software and CNC machining of each of the individual panels (Figure 5).

The CNC machine used to cut out the 2D shapes in aluminum played an important role in fabrication. This machine has a secondary head with a 400-watt YAG laser which acts as a “printer” for etching text and graphics into the surface of the aluminum quickly and accurately. This capability was used not only to create a detailed label on every panel, but also to create a three dimensional grid that is projected onto every panel (Figure 6). Technically any CNC router or waterjet cutter would be capable of creating labels and graphics such as this; however quite often it takes more time to etch the labels than to cut the part itself. For this project laser etching had an important advantage in terms of speed and cost.

The various sections of the Rabbit are assembled on a table with a matching grid. Organizing and precisely aligning the thousands of aluminum parts is as straightforward as aligning the grid and connecting the dots (Figure 7). The sculpture is divided into 14 sections to be shipped to the site individually. There they get bolted together - The outer skin panels are then fastened with hook-and-loop pads, and the whole sculpture is lifted into the atrium with winches.

Mesh Offset Limitations

Offsetting the Rabbit's outer skin to create the inner skin was an important step in developing the fabrication model. Surprisingly, scripts and existing CAD operations failed to accomplish this in any automatic way. Offsetting geometry is a common command built into nearly any commercially available CAD program, however a nuance about the way these programs perform offsets made the command ineffective for this particular project.

Common mesh offset algorithms use an offset direction aligned with the normal of each vertex. By definition, the faces of the resulting mesh are not coplanar with the faces of the original, and are separated by a *maximum* of the nominal offset distance (Figure 8). It seems likely there is a computational solution, however preliminary investigation indicates that it is not simple. This is an opportunity for improvement to existing CAD software. For the Rabbit, the offset skins were created manually.

Conclusion

Although this is an art project, the scale has clear architectural implications. For example, the manner of hand-picking elements from related disciplines (programming, construction, boat building, architecture, database management, etc) and combining them to form a unique design and construction strategy could be applied to a custom building façade. Understanding how this approach plays out at this scale is key to the way these techniques are integrated into architectural teachings and practice. Designers are becoming increasingly adept at creating complex forms with the assistance of computers. Our ability to translate between virtual models and physical objects requires a commensurate level of adaptation and creativity.

The Rabbit is due to be installed in July 2011.

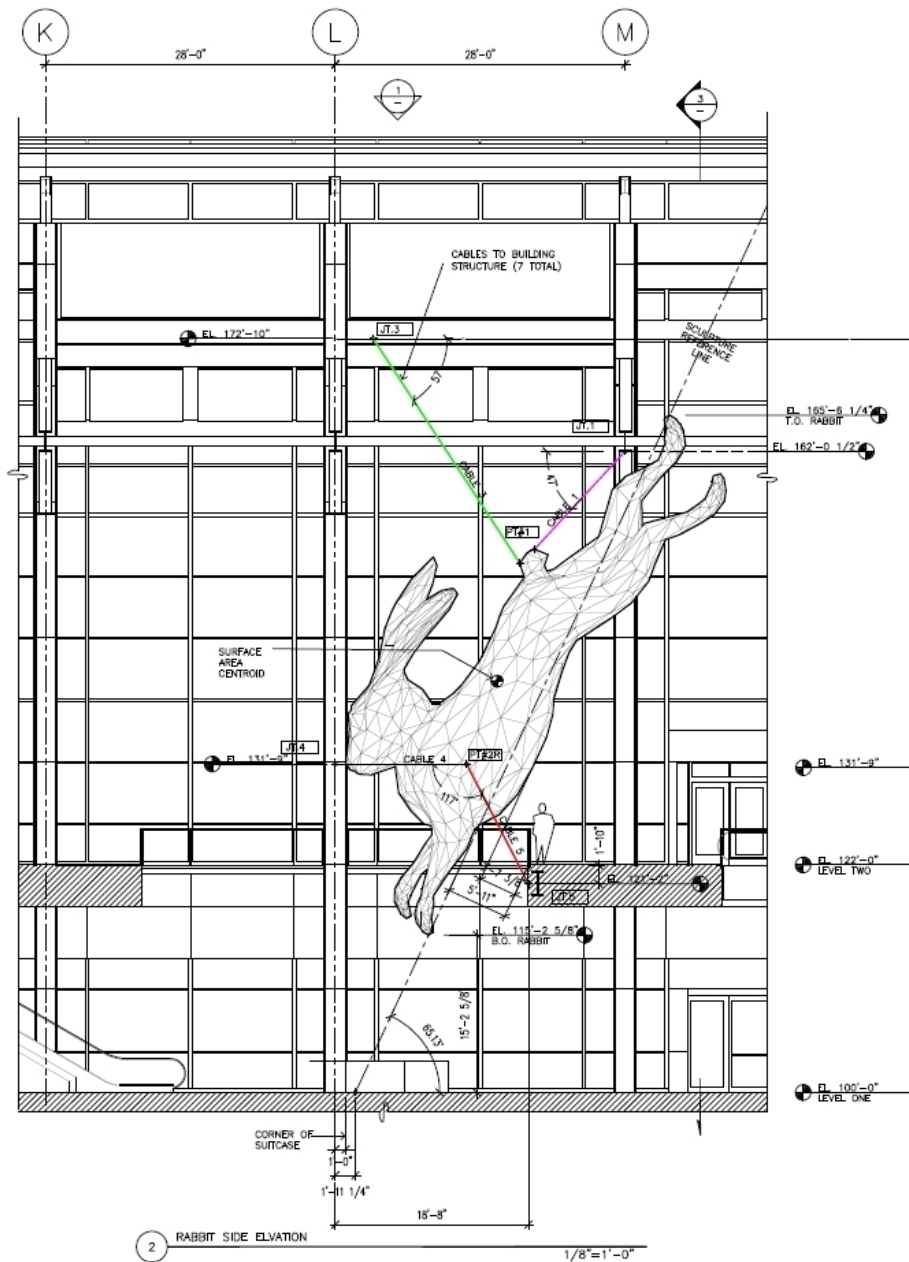


Figure 1. Left: Shop drawing, side elevation. Suspension cables shown in color. Right: Architectural rendering.

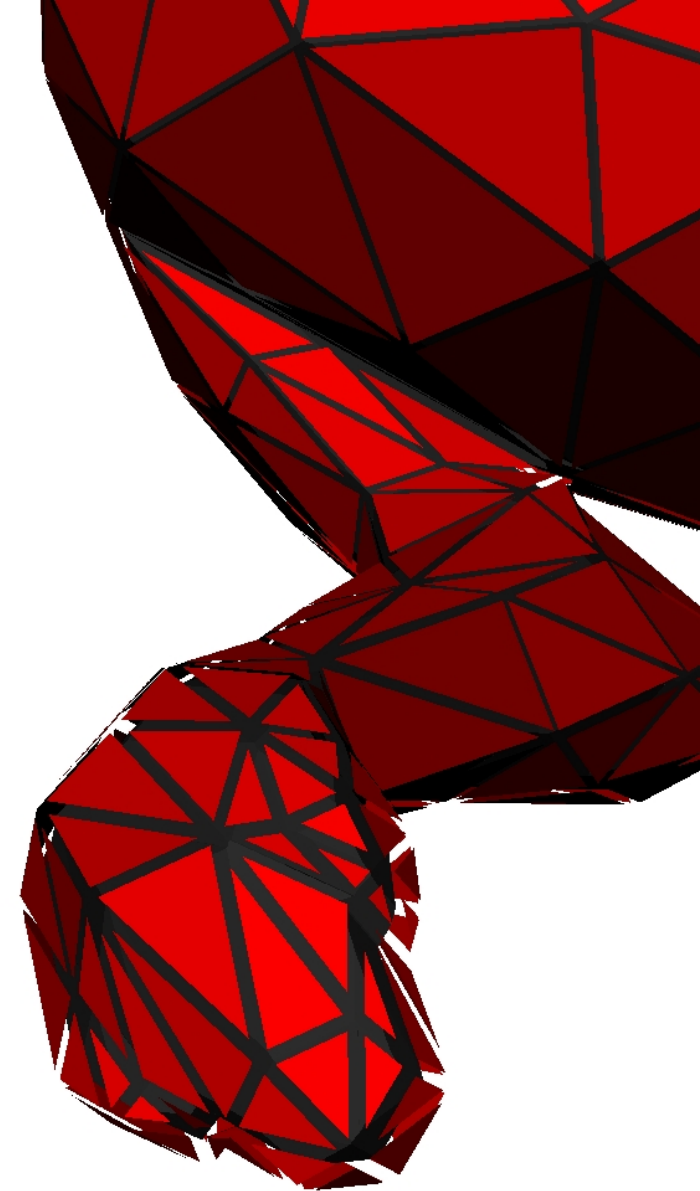
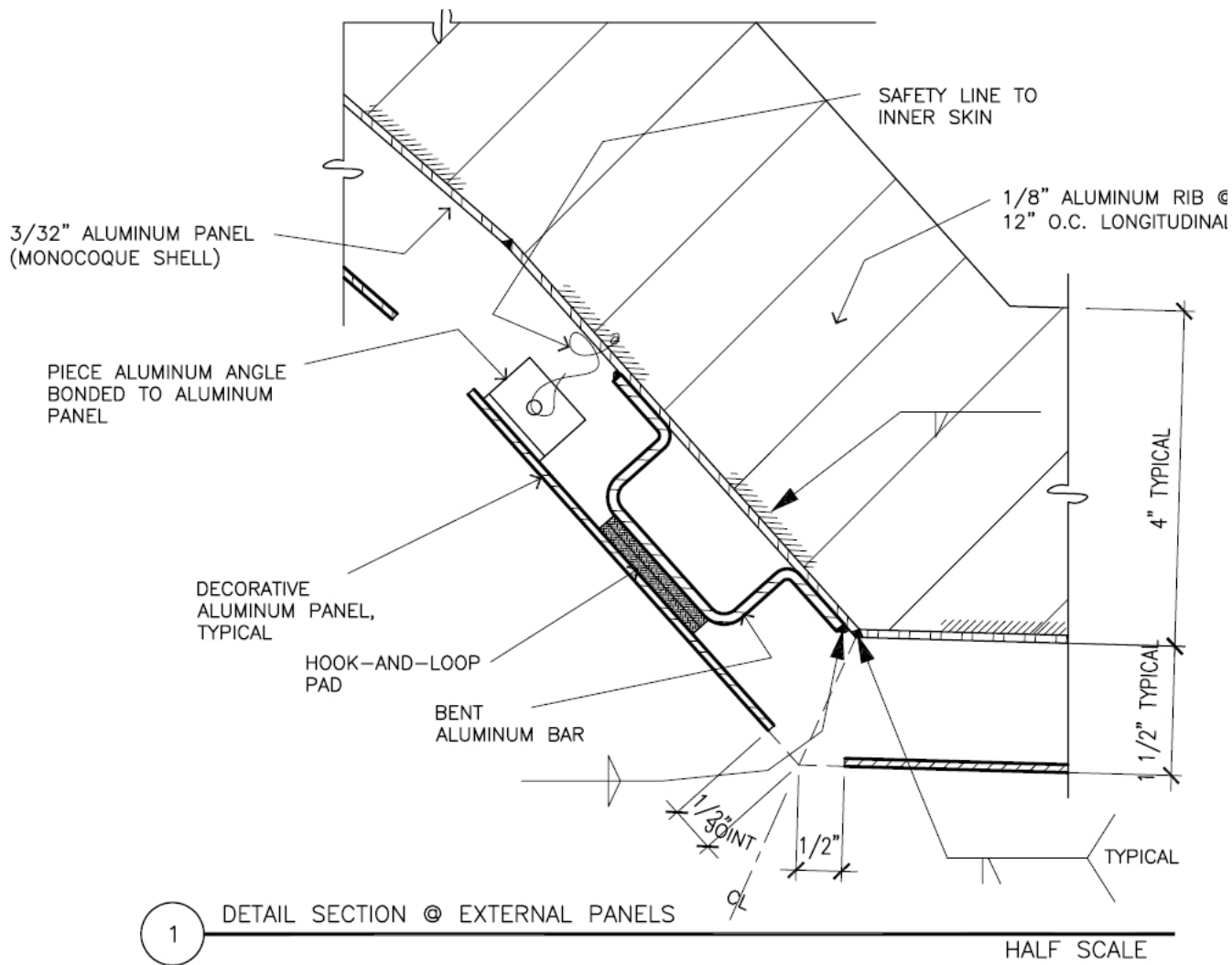


Figure 2. Left: Shop drawing of detail section showing connection detail between inner and outer skin. Right: CAD model, detail perspective at right front paw.

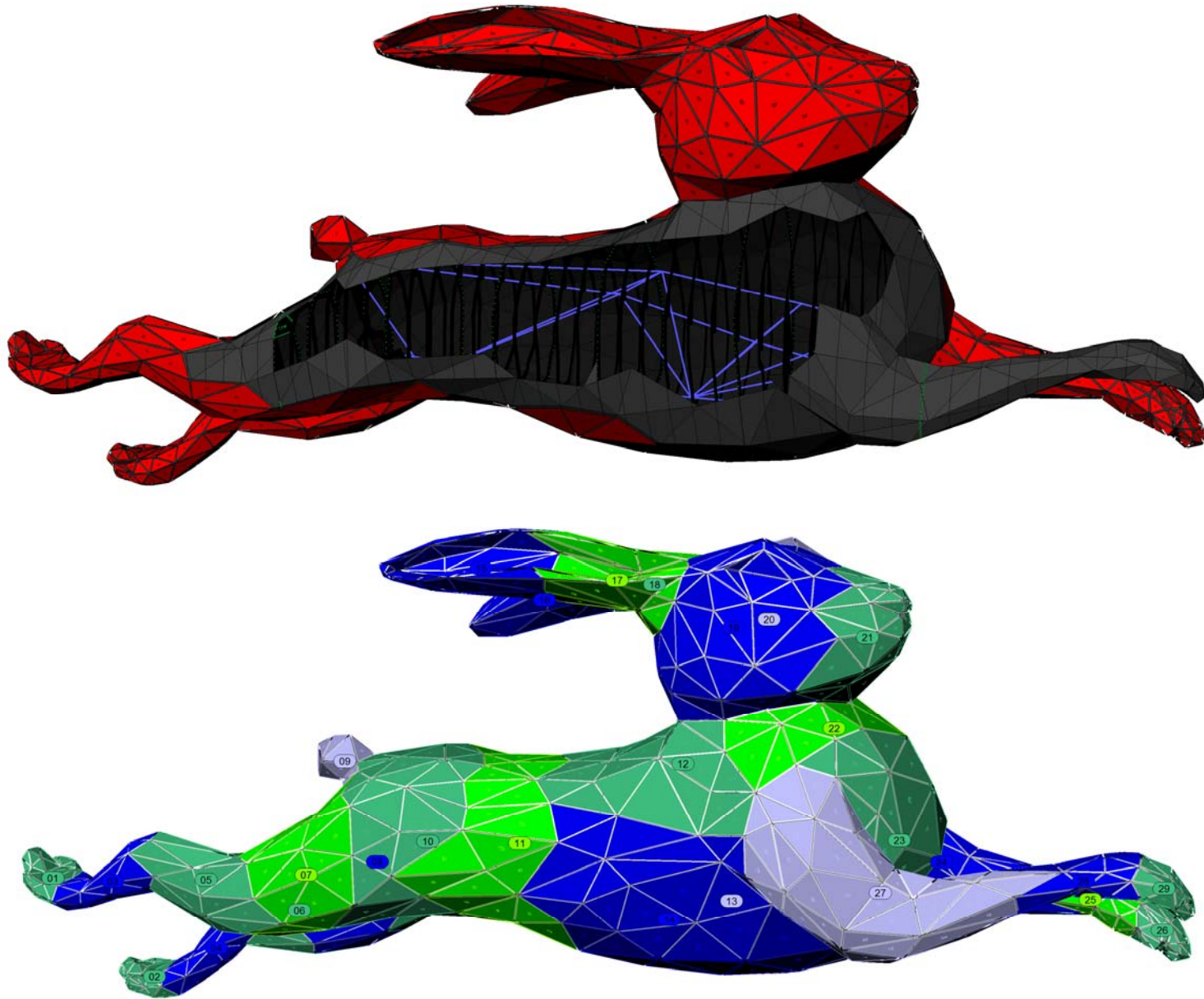
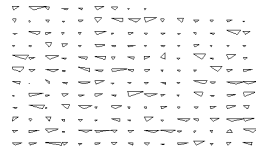


Figure 4. CAD model views – Top: Perspective section exposing inner skin, ribs, and internal steel space frame (shown in blue). Bottom: Illustration of outer skin panel grouping.

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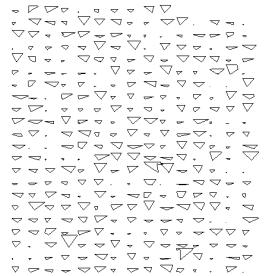
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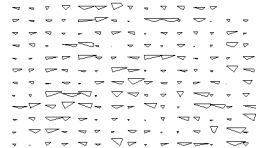
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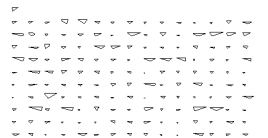
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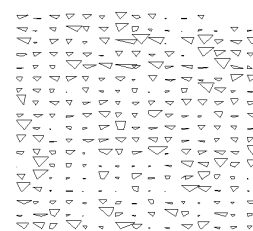
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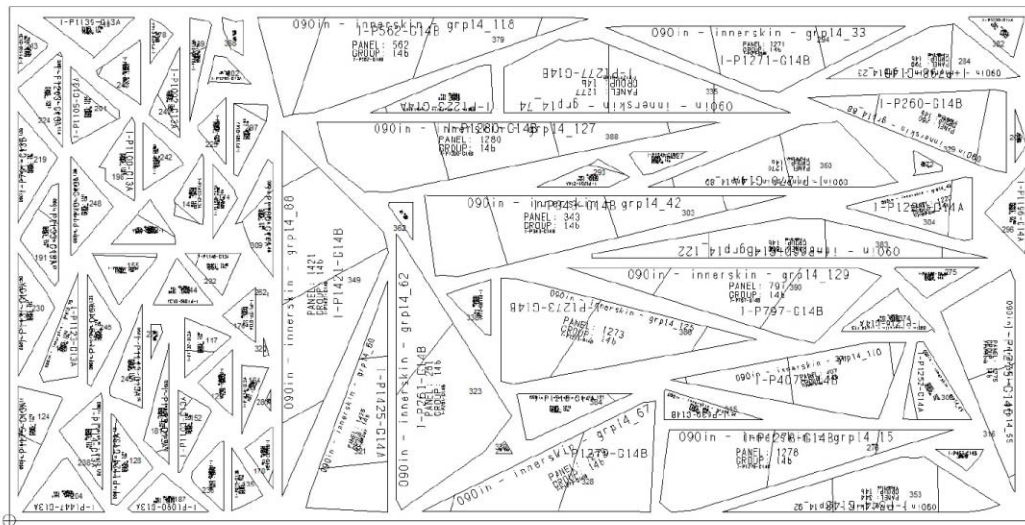
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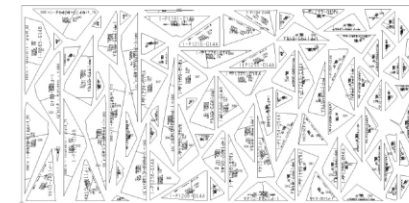
Layout Detail

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Machine

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Stack Quantity	1	Rect Scrap	-2.376	Qty Nested	95	



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Thickness	0.090	Sheet Width	60.000"	Sheet Y Used	58.990"	Sheet Location			
Sheet Name	RABBIT090	Cutting Time		Cutting Length	7108.975"				
Part ID	Part Name	Qty Req	Qty Nested	Net Weight	Drawing Number	WO Number	Customer		
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265	I-P910-G14B	1	1	0.04b 090in - inner skin - grp14.dwg	CTX02758	Kreysler & Associates			
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Figure 5. Top: All 1,466 panels comprising the rabbit's inner skin. A program that groups and flattens the panels was written in Rhinoscript. Bottom-left: A typical sheet of nested panels. Bottom-right: Once nested, layout documents were generated by Sigmanest detailing the contents of each aluminum sheet, quantities, nesting efficiency, even the weight of each panel.



Figure 6. Top-left: The 2D CNC machine used to cut all of the panels. Top-right: The panels cuts were perforated so they could be delivered attached to the sheet they were cut out of. They were then snipped out for assembly as needed. Bottom-right: a label created by the CNC laser etching head indicating panel type, panel number, and group number. Bottom-left: A working surface with a 1-foot grid to assist alignment during assembly.

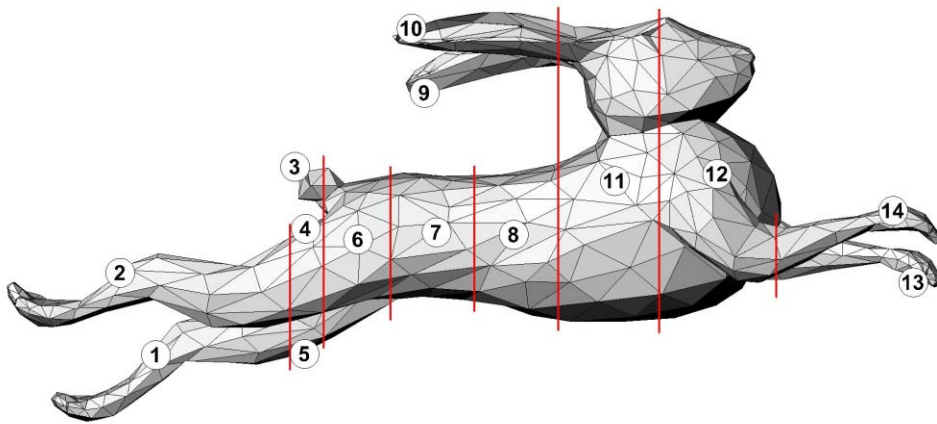
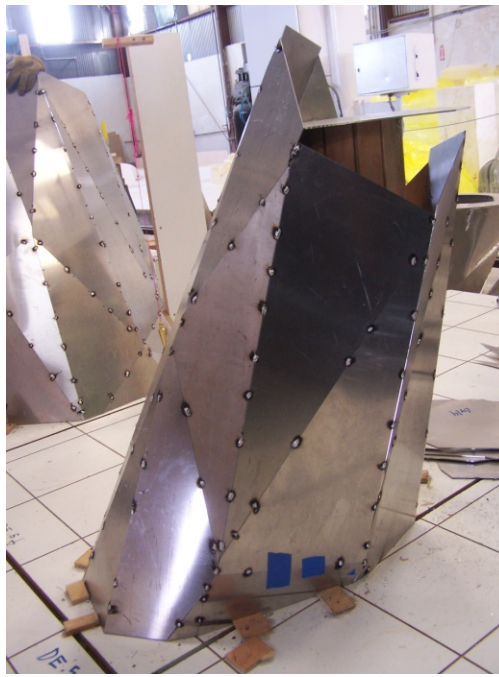


Figure 8. Assembly in various stages. The grid on the floor was supplemented with 1-foot wide, kerf-cut plywood spacers, and lasers. Once the bulkheads were in place (top-left), the inner skin panels are temporarily held in place with blue masking tape, tack welded, and set aside for final welding and finishing. Bottom-left: a graphic index of the assembly groups. The photos, from left to right correspond with groups 14, 13, and 7.

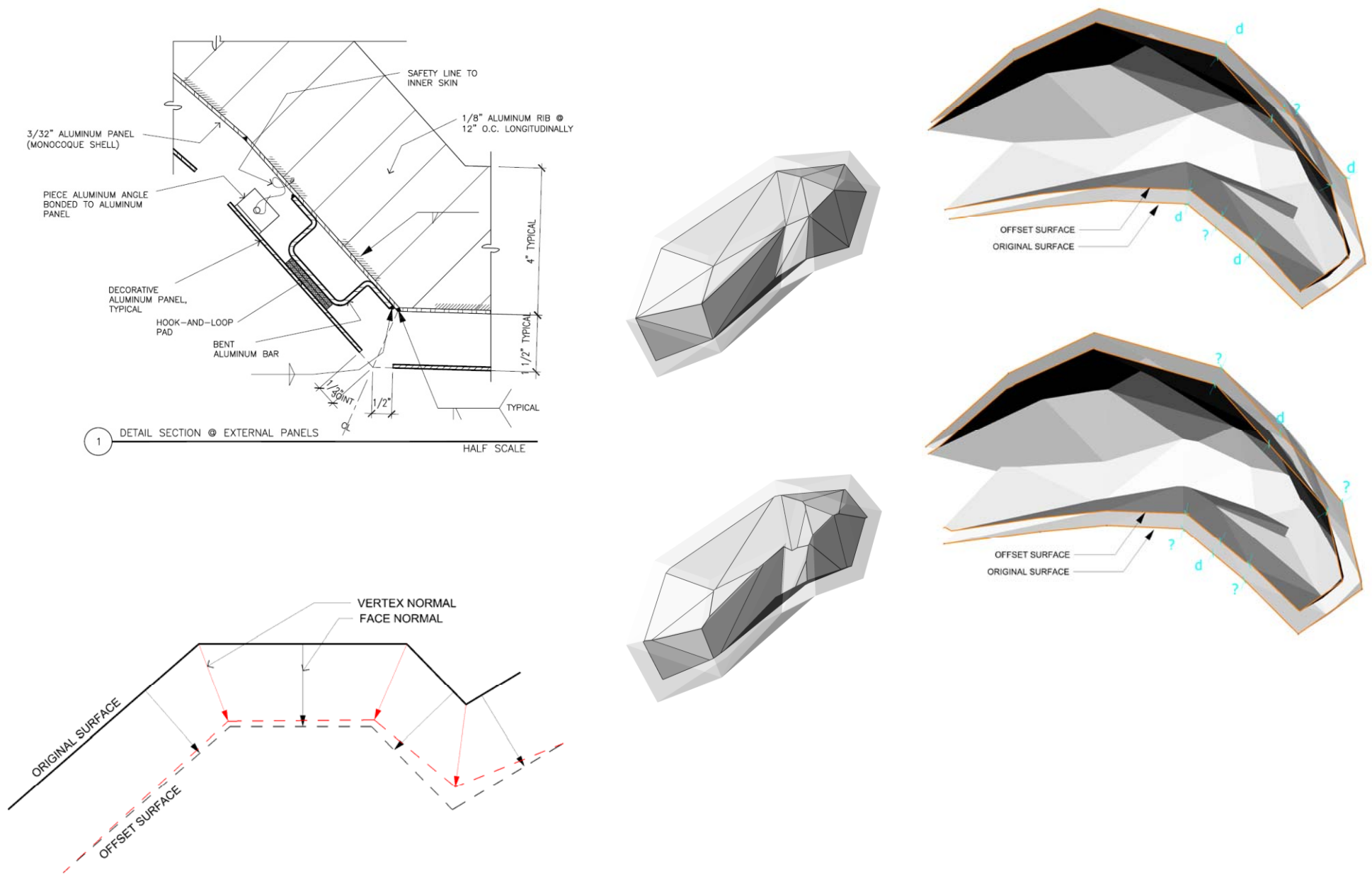


Figure 8. The difference between offsetting according to vertex normals vs face normals is subtle, but significant. Keeping the assembly of the rabbit simple relied on the “bent aluminum bar” shown in the top-left detail to be the same size for every panel. The diagram in the lower-left helps illustrate the difference in results. Extrapolating this into 3D makes the issue much more complicated. For example, if the original surface consists of triangular facets, the facets of a face-normal offset surface will not be triangular, and will not necessarily be convex polygons.