Design economies of surface: can Architects learn from the manufacturing process of industry-driven projects like auto-cross racing?

Emmanouil Vermisso
Design economies of surface: can Architects learn from the manufacturing process of industry-driven projects like auto-cross racing?
Emmanouil Vermisso

Abstract
This paper discusses an in-house manufactured race-car body for the annual Formula SAE® Series competition. The driving parameters for the design and fabrication process are examined with regards to the assignment’s ‘format’ as a joint study between architecture and engineering students. Traditionally there has been an inhibition concerning communication between architects and engineers, that is perhaps successfully exemplified through Peter Rice’s example of the “Iago mentality” (Rice, 1998) where the Shakespearean confrontation between Othello and Iago is viewed as an analogy to this communication: “In the dialogue of Architecture and Engineering, the engineer is the voice of rationality and reason”. Unless dictated by construction necessities, research between these two disciplines is not sought as regularly as we would hope for; we are therefore, interested to assess the analog and computational techniques used from a design perspective, and, by understanding the implications of working among two different but similarly geared backgrounds, describe possible improvements on real-size projects that require both technical and design input, thereby affirming Rice’s belief for creative inter-disciplinary discourse. Finally, the project is a reminder of the common ground between architectural and automotive design, by examining the notion of surface from a cross-disciplinary premise.

1. INTRODUCTION

1.1. Project background

The Society of Automotive Engineers (SAE) has organized international events for open-wheel racing, since 1979. Originally a variation on the existing ‘mini-Baja’ category, organizers at the University of Texas at Austin decided to create a new category that would be less rule-driven, therefore providing ground for innovation. The series was initially called “mini-Indy” and was later renamed to “Formula SAE”. Today, FSAE competitions feature single-seaters, which are designed and manufactured by undergraduate and graduate Engineering students worldwide. The race is an annual event of international caliber with a number of spin off events; two locations host the event annually in the US: California and Michigan (Michigan being larger and longest running). Students at the FAU School of Engineering have competed in the Michigan SAE Series over the last five years (2006, 2008, 2010) and have recently finalized the car for the 2011 event, which is the topic of this commentary.

1.2. Project context: Involvement of two Schools

The work discussed here is focused on the contribution of the FAU School of Architecture towards the design and production of the 2011 SAE car, after invitation from the School of Mechanical Engineering. The impetus for this collaboration was a desire for an aesthetic consideration of the car’s design and the incorporation of CNC-manufacturing. In contrast to previous years, when attention had remained on technical aspects of the car, the Owls Racing Team wanted to produce a body which would be attractive and efficient altogether.

The design of the body was integrated within a digital fabrication course offered to Architecture students, and ran in tandem with the manufacturing and assembly of the car itself (done by the Engineering students), in an attempt to incorporate changes along the way. Six students, all enrolled in an undergraduate program for Architecture, were involved in the project over a period of 4 months, after which the project was coordinated between the instructor, a few students and Engineering students.

2. PROJECT DISCUSSION:
DESIGN, PROTOTYPING, SIMULATION, FABRICATION

During the various stages of design and production, the students were in conversation with those students from Owls racing who were responsible for Digital Modeling, Assembly and Aerodynamics. Although somewhat complex in its realization, in the interest of clarity, the project is herewith broken down to four parts: Design (Concept and Modeling), Prototyping, Simulation and Fabrication.
2.1. Design

Factors that influence the body’s design

The participation of the Architecture School is herewith discussed relative to design factors that affect the performance but do not rely solely on mechanical properties (i.e. aerodynamics). Architects can participate into this component, trying to integrate aerodynamic performance into the aesthetics of the racecar.

Components in the field of automotive engineering evolve rapidly, and these decisions are often driven by factors other than pure engineering, of a more commercial nature. An attempt to increase spectacle has for instance infiltrated the racing of categories like GP2 and Eco-formula, among others: The current trend in GP2 Racing, following up on current F1 practices is for larger front wings than rear\(^{iii}\). The vehicles in the Eco-Formula category developed by Petersons Racing, feature “a split rear spoiler which gives the car which follows a better opportunity to overtake, resulting in a better show”\(^{iii}\).

Owls Racing has not incorporated ‘wings’ for a number of reasons. Primarily, Formula SAE series is an ‘auto-cross’ racing event, which means that cars do not compete directly with each other, but are evaluated based on a series of dynamic events, the focus being placed on performance rather than spectacle. As a result, the use of wings would differ than in other categories like GP2 or Eco-formula. Furthermore, a wing produces a great amount of down-force, which, despite giving an advantage, needs to be transferred to the wheels by proper suspension tuning. Introducing wings would require the re-consideration of the whole suspension system, which in turn, might affect other features of the car. Aerodynamic usage, therefore, would have to be considered at the outset of the design process; within the time-span of the project, it was though best to focus on the design of the side-pods, and introduce a diffuser, which was not present in previous

\(^{iii}\) These F1 ‘trends’ are mostly dictated by regulation and not aerodynamics, the scope being to encourage innovative thinking through introduction of other constraints, which would produce new solutions.

\(^{iii}\) http://www.petersonsracingcars.com/?ln=en&id=18

Figure 1. Rear spoiler found in Eco-Formula; formula GP2 rear spoiler.
models of the car during earlier years. Using an under body diffuser was considered a more flexible way to introduce aerodynamic down-force down the road (although the effects would be less radical than using wings).

**Modeling: Constraints & Design**

Architecture students developed design concepts: two teams produced full body designs (options A, B), while the third examined various surface features with regards to aerodynamic enhancement. The preliminary CAD models were presented to the SAE team for evaluation and coordination. The following comments were generated about the design of the body:

- The body should be attractive, lightweight, aerodynamic, and with low center of gravity.
- The side pod of the body must enclose the radiator. The radiator should be no less than 30 degrees from the ground plane, and should be oriented so that the front of the radiator is higher than the rear, to allow for better cooling.
- Body should wrap the frame as close as possible everywhere (front and rear).
- Diffuser should be considered as separate from the body and the two should not be blended into each other.
- The body should not intrude into the tubes surrounding the cockpit opening.
- Body would be constructed as three sections: Nose, side panels and side pods (5 pieces in total).

Among the options (see Figure 2 below), the first was selected (option A) and the prototype was refined to be tested in a wind tunnel.

The lip around the nose of the car was removed after recommendation of the aerodynamics specialist; the surface and geometry of the nose was not adequate to produce the desired effect, which can be found in Nascar racing. Unlike Nascar racecars, which feature a wide and ‘lipped’ front mask, the front part of the nose in open-wheel vehicles is long and narrow.

---

iv According to the late engineer Peter Rice, the alienation between the people and the environment resulted from Architecture serving the needs of the industry (Rice, 1998). It is worth considering whether changing the rules in F-1 and other categories of racing to promote evolution really serves those same industrial needs or can it extend beyond to benefit the design domain as well?

v The manufacturing of the wide ‘lip’ found in Nascar racing is done through shaping flat metal sheets with an English wheel (http://auto.howstuffworks.com/auto-racing/nascar/nascar-basics/nascar2.htm); in the case of SAE racecars, fabricating a narrow lip would require CNC-technology.
The third team working on surface geometry had to find an efficient way to facilitate the placement of dimpled components on a doubly curved surface. This was done with the use of a plug-in ("Paneling Tools\(^vi\)) that allowed paneling solutions. The idea to introduce a non-smooth surface came from the golf ball surface, where dimples have been known to reduce drag. This is mathematically proven by calculating their ‘Reynolds’ number, a dimensionless number that defines the transition from laminar to turbulent flow in a boundary layer (Figure 3). The boundary layer is a ‘layer of air near a moving object’s surface which effectively, changes the shape of the object’\(^vii\). It is generally desirable to expedite that transition as much as possible, and that - in golf balls- translates in higher Reynolds numbers.

In the case of a car, however, the objects are not spherical (non-uniform shape) and non-spinning. As a result, the effect of the dimples is not predictable. Wind tunnel testing or CFD (computer fluid dynamics)...

\(^vi\) http://wiki.mcneel.com/labs/panelingtools
\(^vii\) http://www.grc.nasa.gov/WWW/K-12/airplane/reynolds.html
simulation of the dimpled surface would be necessary, given more time, to determine those parameters linked to performance. The effect of dimples in racecar engineering has not been proven to work yet, but it is anticipated that the transition from laminar to turbulent will occur faster, so the flow will stay attached to the surface for longer, reducing the wake caused by the moving vehicle. As our experience of dimple technology in racing is still limited, perhaps we can employ this technique not with the intention of reducing drag, but rather, control the boundary layer transition.

In accordance with the above rationale, the students modeled two variations of dimpled geometries: starting with circular ones (Fig. 4), they ultimately produced oval and hexagonal dimples for the nose of the car.

Modeling techniques and how they relate to fabrication

For the final fabrication of the body at 1:1 scale, we understood that some amendments were necessary to ensure the body fit well on the chassis, thereby achieving minimum weight. A challenge emerged at this point: bringing the body too close to the chassis, resulted in a lighter body but compromised the aesthetics (and aerodynamics) of the vehicle. On the other hand, a more aerodynamic body with a high curvature degree would remain far from the chassis, thereby being heavier. A solution had to be found, which negotiated a body of a sound aesthetic, which came as near to the chassis as possible. As a result, the selected digital model (option A) had to be slightly re-adjusted before fabrication. The complexity of the shape and the need to balance between curvature and proximity to the frame forced the team to consider various modeling techniques to yield the optimum results.Offsetting the selected surface (A) closer to the chassis was a difficult task because the surface was a little far from the frame (1.5") so once the surface came close, its geometry would be lost. The team wanted to maintain the aesthetics close to the option A also because it was aerodynamically adequate. In the end, three methods were briefly considered:
a. **Method 1** (Solidworks > Rhino): extract geometry from the original surface (option A), through contouring. Import a generic surface, which follows the frame from Solidworks, and extract geometry through contouring. Then match the contours from this surface with the ones from the original. This proved to be a difficult and time-consuming process.

b. **Method 2** (Solidworks > Rhino): Model a generic surface which follows the chassis in Solidworks, export to Rhino then drape over this surface to get a result which is more ‘organic’ yet close to the frame, and finally fine-tune that surface to match the original option A surface (Figure 5-to be included).

c. **Method 3** (Rhino > Solidworks)-preferred: The Rhino surface from Option A was imported into Solidworks, and its outline was offset inwards to achieve closer wrapping of the chassis. The offset curves were then used to create a loft over the chassis, which was used for the final fabrication of the body.
2.2. Prototyping: small scale fabrication

*Material selection*

The students used two types of foam for the fabrication of the scaled prototypes. Polyurethane (2lb, 4lb) and Styrofoam were considered because they can be milled at high speeds. A denser polyurethane foam (4lb) was considered the best choice, however the very high cost forced the team to opt for the 2lb foam, which was slightly economical. Styrofoam was used as an alternative and was applied in the larger scale prototypes (75%) versus the polyurethane that would yield more accurate results at a smaller scale. Polyurethane proved a great option as the material is easy to cut and produces very high accuracy, while Styrofoam gave a slightly 'hairy' finish that compromised the use of these prototypes for simulations.

*Scale selection (related to the aero testing)*

The model's scale was informed by the constraints of the resources available. The rule for wind tunnel testing is that the frontal cross sectional area of the model cannot be greater than 5% of the total cross sectional area of the wind tunnel; if the model is too big, the walls create an effect on the wind which affects results. It was considered acceptable to go up to 7% blockage area, which would be 60.48 square inches of the frontal cross sectional area. As the wind tunnel in the Mechanical Engineering department has a small cross sectional area (6 sq.ft), the scale model would have to be very small.

At the same time, the max. speed of the wind tunnel restricted us from reducing the scale of the prototype, because the size of the model was inversely proportional to the speed used. At 1:1 scale the car would race (and be simulated) at 60mph. Once the model was scaled to i.e. 40%, the simulation speed would need to increase to 150mph. To scale down to the 25% (Figure 6), which gave us the desired cross-sectional area (according to the rule previously stated), the simulation speed required was 240mph, which was more than the tunnel's maximum speed at 160mph. A physical prototype was produced at a 25% scale (Figure 6). The process involved CNC-routing, finishing (sanding, then layering with car-filler – the Styrofoam surface did not withstand treatment with car-filler which prompted to exclusive use of polyurethane in the future) and painting into a black color (Black is typically used during wind tunnel testing to enhance flow visibility on surface).
2.3. Wind tunnel simulation

The prototype was simulated at 90mph, which was considerably lower than the estimated 240mph. This indicated the need for using a professional wind tunnel of a larger cross-sectional area in the future. According to our means, we obtained some raw data that needs to be analyzed retrospectively, given the short duration of the project. This data may not be reliable due to the speed used; nevertheless, it is a good indication of the shape’s behavior under wind stress.
Although the design of the diffuser was completed by students from Mechanical Engineering, we would like to mention this here because it has indirectly influenced the design of the side-pods that rest directly above.

Originally, the rear section of the diffuser incorporated several fins, but that was later reduced to only two areas (each one under the left and right side-pods respectively) because the speed of the incoming air was not high enough to warrant flow separation. In the same early iteration, the diffuser span from the middle of the car all the way to the end. This caused problems as the A-arms which attach to the wheels, were in the way of the diffuser. Chassis rules and suspension geometry restricted the diffuser’s optimal design, so it would need to be funneled under the middle part of the rear, which would result in an inefficient geometry and pose manufacturing complexities (heavier due to extended length).

The final version is shorter and situated under the side-pods (Figure 8); it is not affected by the turbulent flow from the tires (In F1, this is typically overcome by more aerodynamic profiling of the ‘A-arms’ that hold the wheels).

2.4. Fabrication 1:1

Before we began the final stage of the fabrication, certain amendments had to be made, based on an updated version of the chassis. It was very important that the body fit tight around the chassis and the side-pods followed the shape of the diffuser.

1. In the interest of time and efficiency, it was considered best that both groups (architects and engineers) kept working in parallel
without waiting for each other, so we decided to divide the fabrication of components in two parts: the engineers would fabricate the ‘nose’ and side panels, while the architects would CNC-machine the side-pods using the 3-axis router, because these featured more complex geometry. A series of simulations was done for the side-pods, trying contouring along different axes, to find a balance between the optimum shape result and an acceptable time (our limitation was using a 3-axis router, which complicated the contouring process, as the machine can only move on the x, y and z axes, which means it cannot negotiate underside curvature). Having a 4th axis on a larger CNC-machine, or a 5-axis robot would have enabled us to mill the side-pod plug out of a single foam block, using only one simulation file and therefore saving significant time (mostly from the simulation and preparation stage).

2. The side-pod was contoured based on the thickness of the foam that would be used for routing. Our machine’s vertical movement, the size of our end-mills and the curvature of the part dictated that the material block thickness did not exceed 3”. That resulted in 12 pieces if contoured along the X-axis and 5 pieces along the Y-axis. The simulations gave us similar times for both directions, and so we decided to use the one which required fewer parts (and therefore less preparation time) and would yield slightly better surface finish (Y axis). The time required for CNC-milling the side-pods was estimated to be around 7.5 hours for each side-pod (ranging between 90 and 150 minutes for each of the pod’s 5 parts). That was pure routing time, excluding time spent preparing the material (cutting right size, setting up etc.) so a decision was made to manufacture this without the use of the CNC tools. The engineering students sandwiched polyurethane foam between full-size sections of plywood which they cut based on contours derived from the digital model; these sections were used as guides to trim down the foam until the desired curvature was reached, then sanding the foam and filling in any gaps to reach a perfectly smooth

---

This number is in fact slightly lower, but increases as the side-pod plug is modeled slightly wider as a contingency, therefore getting more pieces from the contouring process.
positive plug (Figure 10). (The analog nature of this process within such a technologically complex project brings up the need to consider improving computational tools to allow for more time-efficient processes!)

3. Our original plan to CNC cut the parts for achieving perfect accuracy and finish, was compromised by the meticulous planning and time involved in any CNC manufacturing process. In addition to this, the consideration for making a female plug was not realistic in the available time-frame, as that would take twice the amount of work because it requires a male plug to be made first. How could this handicap be overcome in future instances of the same project? Future planning may need implementing between the two schools due to the project’s year-long time span; performance simulations would, for example have a cut-off point before Christmas break, so that modeling for fabrication may be integrated into the design process.

It would be beneficial to compare this car iteration to those from other schools in the same event with regards to their format and strategies for manufacturing - i.e. type of plugs; in-house vs. out-source; with or w/o external design consulting, etc. (It is the author’s intention to include such data after the event...)

Design economies of surface: can Architects learn from the manufacturing process of industry-driven projects like auto-cross racing?
3. COLLABORATIVE IMPACT OF SUCH PROJECTS

3.1. What can this collaboration contribute in the way architects get involved into the design and manufacturing/construction process?

As identified earlier, there has traditionally been a rift between Architecture and Engineering through the division of labor begun by Alberti and intensified during the 19th c. with the appearance of the engineer and contractor as separate professions affiliated with construction process. At the time, a need caused the formation of the engineering discipline with the intention of introducing new tools. How is this changing today??

Today’s technological progress has created robust tools and methods for analysis. It may be time for engineers to make a contribution to architecture that exceeds mere quantitative data (ie. structural analysis) for buildings: designers can utilize the analysis tools available in Engineering, to develop new processes of feedback-related design!

More than any other period in our history, if one looks beyond the immediate context of Architecture into research happening in related but distinct fields, Technology emerges as a common denominator. There is a shift, within Architecture, to a paradigm of Technology, which is different to prior philosophical states. Unlike the Industrial Revolution when man used...
Technology to produce new scales of structure and space, today’s technological paradigm exceeds the creation of form/space, and points to the use of tailor-made tools in order to address spatio-material concerns through manipulation of construction process and material properties. Rather than “apply” existing means, the architect begins to “invent” new technologies and, most importantly, methodologies, which will warrant further invention of other technologies that will permit the implementation of those new methodologies.

3.2. How does this affect the Economies of design and performance?

*How can Architecture help re-think the essence of such engineering projects?*

The option of using a dimpled surface, mentioned earlier opens up a wide range of possible trajectories for process. A prototype for the dimpled version of the car body was manufactured at 75% scale (Fig. 14). A smaller scale posed a challenge, as we did not have end-mills that were small enough to produce scaled-down dimples.

The dimples visually imply their function (aerodynamic performance) by direct reference to the golf ball, but also, as a secondary layer, have mapped the process, which created these (the cnc-router). To further develop this argument one can foresee a possibility to explicitly customize the toolpaths that would produce very similar iterations of the same geometry, and prepare analysis of those mutations. These variations would not be genetic.
evolutions produced by the software but rather different footprints of the hardware used on the same digital model. Greg Lynn has discussed a similar intention to regard ornament not as applied decoration—in which case it is contrary to process or organization—but as the result of the application of CNC technologies, beginning to talk about a ‘Structure of Ornament’. This type of ornament “…is not applied but is intrinsic to the shape and mathematics of the surface, and in this way the ornament accentuates the formal qualities of the surface; like the pattern of an animal that intricately responds to the shape and structure of an animal’s form” (Lynn 2003). There’s an interesting notion that emerges here, of an invisible layer inherent in the digital model, one that is not perceived until the stage of simulation; patterns affected by the selected tool become part of the design without ever physically existing in the model!

**Development of design aspects of SAE project**

The development of the car project may therefore continue outside of, but in tandem with its engineering constraints: an additional parallel project can investigate the design of ornament for the car body, which relates aesthetic factors (color, scale, texture) to functional and performative ones “production of a new kind of art which refers back to technology?”. This concept may be similar to what some major automobile manufacturers have been doing for several years now, albeit looking at this from another perspective. BMW has commissioned artists to create a ‘canvas’ on some of its models, since 1975 (this idea was first suggested by racecar driver Hervé Poulain).

*Figure 15. BMW Art Car concept: 1975, 1992, 2010 versions*.

* Image sources: www.bmwdrives.com; www.bmwism.com
The outcome of such commissions has by and large a marketing character and creates a distinct branding for the patron; we would like to look at these creations from a designer’s perspective, and attempt to associate the art theme itself to the character and technical data of the car (i.e. its manufacturing process or performance criteria), thus reconciling the two sides of car design, technical and creative. Innovation - from BMW’s chief designer Chris Bangle’s standpoint was brought to the company with consideration of surface as differentiated entities and not as continuous lofts\textsuperscript{xii} (i.e. the Z4 model). The Z4 model by BMW features interesting surface characteristics, like sharp change in panel geometry, which enhance shadow definition. It is interesting to observe that a lighter color would enhance this effect whereas this might be lost with darker colors such as black. This correlation between geometry as a result of manufacture directed towards a certain color palette is very fitting to the logic of performance-embedded artifacts.

The students who worked on the design of the body tried to describe surfaces in this way, during the early designs for option A, by expressing the moments of geometrical transition instead of creating smooth lofts where possible. This is evident in the final part of the nose (Figure 17), where the smooth curvature of the tip breaks off to be expressed as three surfaces: more curvilinear on each side, and a flatter one in the middle.


\textsuperscript{xii} Ibid, p. 43.
Constraint-defined Art: Embedded Performance

Perhaps we can take advantage of such gestures and compare these with performance criteria; the moment of separation on a surface can, for example, determine the threshold where the surface becomes dimpled (this in turn would be derived from aero testing). A possibility for employing un-homogeneous dimple patterns may be worth examining, where size would vary as appropriate relating to air impact. Ultimately, these patterns could be used to derive a paint scheme for the car, even if the surface does not include dimples, showing the possible design options that were considered, and therefore making the body itself a template for the car’s ‘history’.

To begin implementation of this sort of process, a short assignment titled “manufactured ornament” was carried out as an additional investigation after the 2011 car was completed, but which I believe can inform subsequent versions of the car. The students worked on examining the notion of an ornamental strategy that could be integrated with the design process and would be suitable to the artifact that it decorates; the exercise focused on the side-pods as these were the more fluid shapes and also the ones that are more complex to manufacture. As a result, the ornamental scheme could reference the complexities involved in the fabrication, or some other process-related parameter. The students attempted to create two distinct geometrical features that could improve aerodynamic performance on the sides of the car\textsuperscript{\textasteriskcentered}, by using a geometry that is influenced by the shark skin (v.1) and one more consisting of dimpled elements (v.2) - (Fig. 18). During this process we have tried to employ the technology available to us in an “honest” way: by using parallel finishing on the side-pod, the same parallel tool-paths create interesting results only because of the difference in surface curvature. We would like to think about how our tools can be further used in such a “generative” fashion to create material effect, albeit linking it more to performance.

\textsuperscript{\textasteriskcentered} The time available was not enough for data acquisition and so this stage of the assignment used other criteria for the allocation of dimples. One such criterion, worth considering may be how to remove dimples so the contouring of the side-pod into pieces can make fabrication possible using our own resources which are limited to a 3-axis router (as opposed to a 4-axis, etc).
A possibly problematic issue is the increase in surface area through introduction of dimples, which in turn increase the component’s weight. As mentioned earlier, this ‘performance-based’ design could be converted to a 2-dimensional image and applied as a color scheme on the car, thereby maintaining inherently a reference to the desired performance intentions (although this would not enhance performance itself).

Is the use of industrial technologies antipodean to the honesty of materials in such projects?

This is interesting with regards to engineer Peter Rice’s discussion of authorship in design, and what he calls a “Traces de la main” solution: “A building does not have to be made of brick or stone to achieve this, but rather it is the honesty and immediacy in the use of its principal materials which determines its tactile quality” (Rice, 1998). That claim contains a slight irony, coming from an engineer, as such tools were first used in industrial engineering contexts. And yet, does the acceptance of this dismiss the CNC technologies’ use for optimizing such projects? As we explained above, the finish produced by the CNC tool-paths on the respective curved geometry is very true to the medium used. Can we find, in this process a logic similar to the “traces de la main” (trace of the hand)? Perhaps this exists not in relation to the material, but rather in the material ‘effect’.

Constraint-defined Art: Embedded Process & Production Technique

Another way to consider ‘Art’ within this context can refer to the actual production stage: the manufacturing steps; designers could generate aesthetic schemes, whether entirely literal, or ones that fuse the precision of CNC-machining with the volatility of art (Figures 19, 20).

In both instances, this artistic expression reflects the philosophy within car design, that every element within a production car is absolutely intentional (Bangle 2008). If that is true, then it is only logical that even the...
Art, which is born out of such premise, be intentional and meaningful, extending beyond marketing and branding strategies (see previous reference to the BMW Art car).

**Figure 19. Technologically informed Art: using sectioning of side-pod along X-axis as a generator of ornamental pattern. In plan, the sections are faithful to the fabrication logic, in elevation; the contour lines diffuse into more fluid sections creating a conceptual ‘boundary’ within the object.**

**Figure 20. Side-pod Elevation showing the original contouring for manufacturing (expressed through color variation) and the secondary ornamental scheme derived from the former.**

3.3. Race-related feedback, steps taken and suggested development of the project

*Architecture and Engineering rationales: Peter Rice*

The art-related topics discussed above are possible successful branding strategies, but undeniably require funding for development. SAE needs sponsors who would finance Research and Development, as we have seen in some cases in the past, with architects who tried to push the envelope by applying elements from other industries into Architecture. Peter Rice believed that economy and innovation were compatible values within the design equation. *But how might one combine both?*

Norman Foster’s HSBC headquarters use floor panels developed for the Boeing aircraft. During the project’s design phase, research and development costs were shared between the manufacturers and the client (Chris Abel, 1989). While the client’s gain is obvious, one should not overlook a substantial opportunity for manufacturers to optimize their work methods and sometimes re-invent the way they use their tools. *xiv To re-visit Peter Rice’s claim on innovation, we may think of his belief on the singularity of solutions devised by engineers: their work involves ‘objective’ parameters and so, they usually respond accordingly. One might say that this is an*

*xiv Another project with references to other industries is the Renault Centre, also by Norman Foster (1980-82).*
economical approach, but the truth is that it could remain sterile unless it carries the benefit of creative thinking (as argued by Rice who was, after all, an engineer).

Perhaps the dimpled experiments suggested earlier are indicative of this economy of thought: the rules for ensuring dimple effectiveness can dictate what the aesthetic and design of the surface will be; once a decision is made to apply dimples the surface has to follow an explicit geometry to best take advantage of this feature. In some respect, this is a singular process, which can reconcile the way that an architect thinks, and an engineer designs.

**Future development scope**

It is important to note that this collaboration is not perceived as episodic but rather, as one of iterative character, as it falls within the broader context of an annual event. Both the students and instructor regard this as an ‘evolutionary’ endeavor, where each subsequent team may build on the expertise of the previous car design, both mechanically and aesthetically. The long-term scope would be designing a body, which responds tightly to the mechanical properties of the car itself.

With regards to the above developments the team would like to: either devise an efficient way to split the side-pod into more than one pieces, something that would permit the fabrication of such dimpled geometry, or, along the lines of the manufacturer/client relationship discussed earlier, we would like to secure the use of a 4-axis or 5-axis robot to mill the final molds. In addition, we would like to investigate further how the decisions impact the overall project by examining, for example, cost relative to aesthetics. An interesting example within SAE is the 2011 car by the University of Michigan (Fig 13); according to the Michigan team designers, their color scheme addresses aesthetic concerns but also uses less paint by exposing the carbon fiber, therefore keeping the pod lighter.

The above color scheme exemplifies the importance of accurate measurements within a project like SAE. It is a matter of ‘tolerances’: Chris Abel has commented on architectural projects which have drawn upon...
industrial expertise and re-conceptualized mass-production so they can respond to minimal tolerances which are closer to Engineering than Architecture, as early as the 1970s and '80s; namely, the Sainsbury Center for the Visual Arts and the Hong Kong and Shanghai Bank by Norman Foster. (Abel, 1989)

4. CONCLUSION

4.1. What is the impact of interdisciplinary work?

Is this project primarily important from a Design or Engineering perspective? Can we learn from Automotive design?

During the first paradigm in car design (before the 1930s), the designer needed to possess skills of a naval draftsman in order to produce such drawings. This is interesting considering today’s expansion of the architect’s skills that is primarily a result of the emergence of digital techniques over the last 15-20 years. Architecture can be associated with car designers through the ‘common’ ground of product design (i.e. furniture, etc). The scale involved in product design is perhaps forcing both these professionals to think outside their immediate framework and -at least in the architects’ case- has resulted in augmenting their set of skills. The possession, today, of a wide range of skills, which in the past required product or industrial design training underlines the converging gap between Architectural and Automotive design. This is partly owed to the visionary attitude of some architects from the ‘high-tech’ generation, like Norman Foster, who were keen to directly engage the manufacturers because they saw early on the benefits of treating components as prototypes within some standardization context. Foster’s work ethic helped him to better understand existing materials and the way these are utilized by the industry. Subsequently, he developed the know-how to design projects outside his immediate architectural spectrum, such as furniture, and marine vessels. Together with Piano, and Buckminster Fuller before them, he set the foundation for expanding the architect’s skills to what they are today, bringing us closer to other design professionals, like car designers.

Chris Bangle has compared architects to car designers for a number of reasons:

---

xv The tolerances for fixing the aluminum sub-frames of the Sainsbury Center’s exterior fell were plus or minus 3mm, whereas those internal tolerances of some components of the HSBC building, (bearings that connect truss members) were as small as 0.033mm! (Abel, C, From Hard to Soft Machines, 1989).

xvi The design for “Izamari” yacht combined architectural and marine knowledge to produce a distinct product, that exceeds conventions (i.e. The rolled panels are slightly convex to achieve an ‘entasis’-like effect).

xvii Piano and Fuller both worked on prototypes of cars (Fiat ‘VSS’ prototype, and ‘Dymaxion’ car, respectively).
a. Tuning their creative egos towards aesthetic exploration
b. Having a strong perception of their social impact on their clients’ lives
c. Attracting clients through achieving successful precedent in the form of physical artifacts (buildings - cars)

In both cases, when the client permits, they are able to achieve extraordinary results! This is something that presupposes ideal circumstances and in our case was pursued through our early attempt to look at dimpled features, but later abandoned because of time limitations. Nevertheless, it remains a theoretical and prospective attempt within the project (and maybe in future cases) to achieve a high level of performance, which transcends the yearlong life span of the SAE project.

A need for justifying these synergetic relationships—which, are increasingly occurring among the sciences today- becomes clear, both from Bangle’s point of view (creative – corporate relationship), and our own experience, as far as bringing together academic departments.

What is more, the process of involvement in SAE racing can become a ‘lesson’ for an architectural designer, not only as an opportunity to examine full-scale manufacturing, but also as an intuitive process to better understand the surface culture behind car design. Considering the increasing preoccupation with surface in Architecture recently, maybe this can help overcome the ‘immaturity’ of surface that Bangle attributes to several -if not most- built works\textsuperscript{viii}, and render architects more self-aware of our modeling techniques and the impact these may have on, i.e. façade design.

Re-consideration of Technology as a driving force into other fields

Art has traditionally been influenced by society, religion and politics - now we need to acknowledge that Technology is a driving factor not only in the production of Art, but also as a generator of its content!!

This project demonstrates the ubiquity of technology today present in industry and how this has expanded into academic research. One sees the need to encourage its appropriate application in such collaborative projects, which capitalize on this technological dissemination and bring architects closer to the applied nature of their profession. Those other disciplines, may, after all, not be that dissimilar, as the author discovered, writing the concluding remarks for the early manuscript inside the SAE pits of Michigan International Speedway.

According to Viollet-le-Duc, “Architecture can only equip itself with new forms if it seeks them in the rigorous application of new structure”\textsuperscript{(Abel, 1989)}. Form finding can originate in the examination of structure and material properties: this can be conveyed to all kind of analysis, which can inform architectural decision-making. The design process of architects in the

past\textsuperscript{\textasteriskcentered} (i.e. Foster) has occasionally pointed towards a system finding; a similar process ought to be improved in the SAE project so any design decision on the car’s body relates back to analysis data. Extensively, the value of this approach needs to be reminded to architects, so that decisions may be derived not from apparent function or aesthetics but a more subtle, yet informed process of analysis which can relate to both those parameters (function, aesthetics). (Facades, for instance may be designed by data obtained through FEA analysis also used to design the surface of the SAE car).

Twenty years ago, Chris Abel wrote that “…Though special purpose mass-production lines still play an important part, their role in the manufacture of consumer goods, including automobiles, has been increasingly displaced over the last quarter of the century by more flexible production machinery (Fig. 21), much of it now computer-controlled” (Abel, 1989).

Can Architects learn from industry-related projects? It seems that historically, we have extrapolated lessons from the aerospace, automotive and marine industries in terms of both “process” and “technological means” (see Norman Foster’s work during the ‘80s). It is the author’s hope that we may continue to do so within the ever-evolving context of our time.

Acknowledgements

Many thanks to the following students from Architecture: Monica Arcila, Jammy Chong, Mauricio Feldsberg, Juan Mora, Xavier Salas, Jose Torres for their enthusiasm and eagerness to collaborate with the Mechanical Engineering students, and to the other students from my digital fabrication seminar. Special gratitude to Owls Racing for taking me along to all SAE events, a truly eye-opening experience, and for their advice revising this manuscript: EJ Abed, Nick Cernjul, Alex Figliolini and Elio Saenz. Finally I am grateful to Professor Oren Masory from the College of Engineering for inviting us to participate in this collaboration.

\textsuperscript{xx} For example, Foster, has followed this kind of rationale, particularly in the ‘Sainsbury’ and ‘HSBC’ projects.
\textsuperscript{xx} Abel, C, From Hard to Soft Machines, in: On Foster…Foster On, Prestel Verlag, Munich, 2000, p. 238.
References


Emmanouil Vermisso
Florida Atlantic University
Department of Architecture
111 East Las Olas Boulevard, Fort Lauderdale, FL
evermiss@fau.edu; archi_trek@hotmail.com

Design economies of surface: can Architects learn from the manufacturing process of industry-driven projects like auto-cross racing?