ASME SETTING THE STANDARD http://go.asme.org/HPVC	**Vehicle Description Form** (Form 6) Updated 12/3/13 **Human Powered Vehicle Challenge** **Competition Location: San Jose, California** **Competition Date: April 22-24, 2016**

This required document for all teams is to be incorporated in to your Design Report. Please Observe Your Due Dates; see the ASME HPVC for due dates.

Vehicle Description

School name: Olin College of Engineering
Vehicle name: Gold Trans Am
Vehicle number: 5

Vehicle configuration

Upright		Semi-recumbent	X
Prone		Other (specify)	

Frame material: Carbon Fiber-Aluminum Monocoque

Fairing material(s): Carbon Fiber, Nomex Honeycomb, Kevlar

Number of wheels: 3

Vehicle Dimensions *(please use in, in^3, lbf)*

Length	95.0 in	Width	30.3 in
Height	46.0 in	Wheelbase	45.1 in

Weight Distribution: Front 60%* Rear 40% Total Weight TBD**
Wheel Size: Front 16 in Rear 20 in
Frontal area: 968 in^2
Steering: Front X Rear
Braking: Front X Rear Both
Estimated Cd: 0.087

Vehicle history (e.g., has it competed before? where? when?) *Gold Trans Am was designed and built exclusively for the 2016 ASME HPV Challenge and has not yet competed before.*

**Vehicle has not been completed - weight distribution estimated.*
*** Expected weight is 84 lpf.*

Olin College OF ENGINEERING **Human Powered Vehicles**

2015-2016 Innovation Report

Gold Trans Am

Vehicle #5

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In 2016, the Olin College Human Powered Vehicle Team experimented with lightening methods for use in the competition vehicle. The team developed a novel approach to making complex parts by utilizing a fiber-reinforced 3D printing process. The process was tested on last year's competition vehicle before being implemented in the design of the team's 2016 vehicle, *Gold Trans Am*.

1 Design

Background: Many components on human powered vehicles are heavy and time consuming to fabricate. Parts are usually fabricated out of aluminum, steel, or titanium components with CNC mills.

Need: Metal parts fabricated on a mill have design limitations and can be time consuming to machine. Additionally, metal parts can add substantially to the weight of the vehicle, decreasing performance.

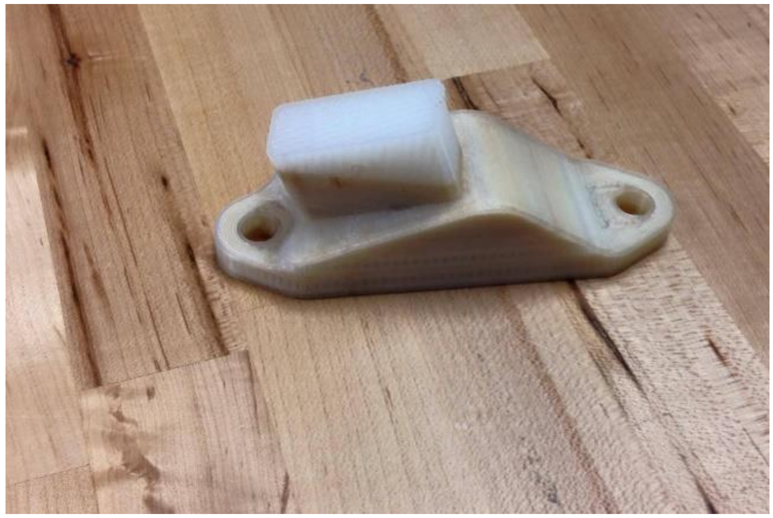

Figure 1: A 3D printed steering knuckle.

Description: The team's 3D printing process uses fiberglass reinforced nylon filament to create parts. The process allowed the team to create strong and lightweight parts for use on the vehicle.

Impact on Human Powered Vehicle Design: The process allows for sturdy parts to be created in more complex shapes with less fabrication effort than with machined metal alternatives. The parts produced from this method are also lighter than similar parts made from metal. The lighter parts allow for a lighter overall vehicle while maintaining similar strength in the components, improving vehicle performance.

Feasibility: The 3D printing process was implemented on a previous year's vehicle. Although there were challenges associated with the 3D printed part's durability, particularly the nylon layers, the parts easily interfaced with the existing vehicle. The parts were printed on an existing printer that is available commercially, so the process can be used by anyone with access to the technology.

1.1 Literature and Patent Review

Research into the field of fiber 3D printing was done through a thorough patent search and investigation of technical literature. Past human powered vehicles were also researched and inspected.

Fiber 3D printing is an existing but relatively new technology. According to the American Chemistry Council's Vice President of Plastics Steve Russell, plastics reinforced with carbon fiber are lighter than conventional metals while maintaining stiffness [1]. This makes them appealing to vehicle manufacturers. 3D printing companies have only recently begun to prototype and build the first 3D printed cars, the first of which are expected in 2017 [2],[3],[4],[5]. To the team's knowledge, fiber 3D printing has not been used as a manufacturing technique in human powered vehicles. The technique is still very much in the experimental and development phase.

2 Concept Evaluation

The team tested 3D printed steering knuckles on the team's 2015 entry into the ASME Human Powered Vehicles Competition, *Llama Del Rey*. The prototype was constructed on a MarkForged Mark One 3D printer with fiberglass fiber material and nylon filament. The knuckles were then attached to *Llama's* frame with eye bolts and lock nuts, with washers used to distribute force on the knuckle face.

Intended Benefits: The process tests confirmed that the process was feasible and that it led to lightweight, high strength parts while reducing machining time for team members.

- The team spent less time setting up and supervising the printing of the test parts than they would have spent machining similar parts.
- The parts were extremely stiff and were printed to within tolerance.
- Each steering part was half the weight of the equivalent aluminum part used on *Llama Del Rey*.
- The team was able to print the parts overnight, as opposed to needing to be physically present during all stages of the machining process.

Unanticipated Benefits: In addition to the projected benefits, the team was able to involve team members that were less skilled with machine shop tools in the fabrication process. This decreased the load on team members making machined parts.

3 Learnings

In the creation of the prototype knuckles, the team encountered issues that will influence future iterations:

- While layers reinforced with fiber are very strong, layers that only have nylon filament are substantially weaker and are prone to shearing along the layer boundaries.
- The design of the part is substantially limited by the type of printer used to make the part. MarkForged, the company that makes the 3D printer the team used, has two different models of 3D printer. As the team used the older version, which has a

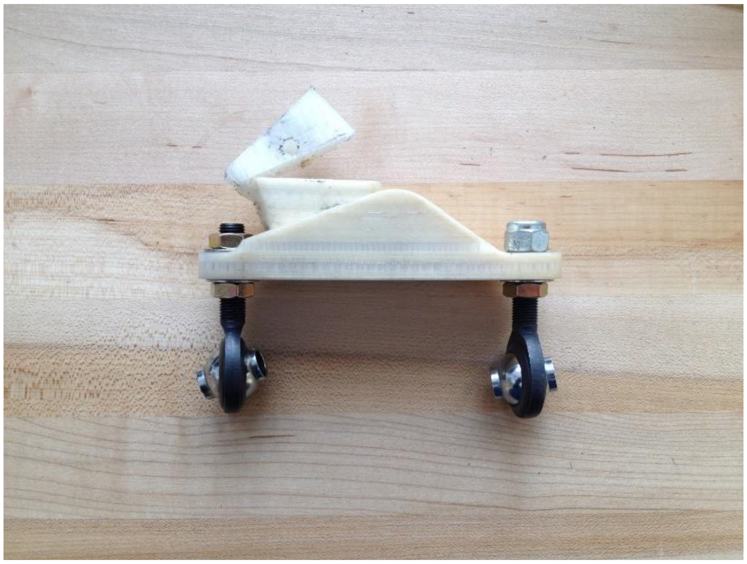

Figure 2: A steering knuckle that sheared along a layer boundary.

minimum fiber length it can lay down on a print, the team was not able to put as many fiber layers in the part tested, leading to durability issues.
- The team had to alter the design of the steering parts used for testing in order to get them to be 3D printed properly. Although 3D printing does allow for greater flexibility in many aspects of the part design process, there are some constraints, such as not being able to 3D print parts with threaded holes. The team got around this issue by using nuts on both sides of the steering knuckles to lock the eye bolt attachment in place.

In the future, the team will test multiple parts with different configurations to find the ideal orientations of fiber in 3D printed parts and to test the limitations of the fiber-reinforced 3D printing process.

Negative Aspects of Process: Parts with many fiber layers take a very long time to print. The steering test parts each took 24 hours to print. If the parts were machined on a mill, they would have taken around six hours total. The process is effective if the goal is to decrease the amount of human machining time, but if a part needs to be made very quickly, fiber-reinforced 3D printing is not ideal.

References

[1] Washington Post. “So, this exists: A working car has been 3D-printed out of carbon fiber plastic,” Web.
[2] Popular Mechanics. “Urbee 2, the 3D-printed car that will drive across the country,” Web.
[3] KOR Ecologic. “About Urbee 2,” Web.
[4] Divergent3D. “Blade: The world’s first 3D printed super car,” Web.
[5] Local Motors. “3D printed car,” Web.