DIYROCKETS BUSINESS CASE

EXECUTIVE SUMMARY

The SEDS UCSD team has concluded that in order to meet the industry needs of the emerging small payload sector, 3-D printed engines are an invaluable resource that can cut down on the two major inhibitors of progress in the field, cost and time.

Although the data for the analysis was done through interpolation of industry research along with the expected test results of our engine design, there are many characteristics that support the replacement of machined engine parts with the superior 3-D printed parts. Some of these characteristics include:

- Slashed developmental costs
- Lower error and reduced build time
- Growing technological progress in field
- Potential for complex internal engine designs

Most of the significant benefits can be seen directly through the comparison of our engine design submission with current industry standards. Moreover, the expected saving and efficiency increase to build makes this a project with variable data quality improvement.

In summary, due to the indicative shift in key business drivers, the emerging small payload industry should shift towards 3-D printing for future benefits.

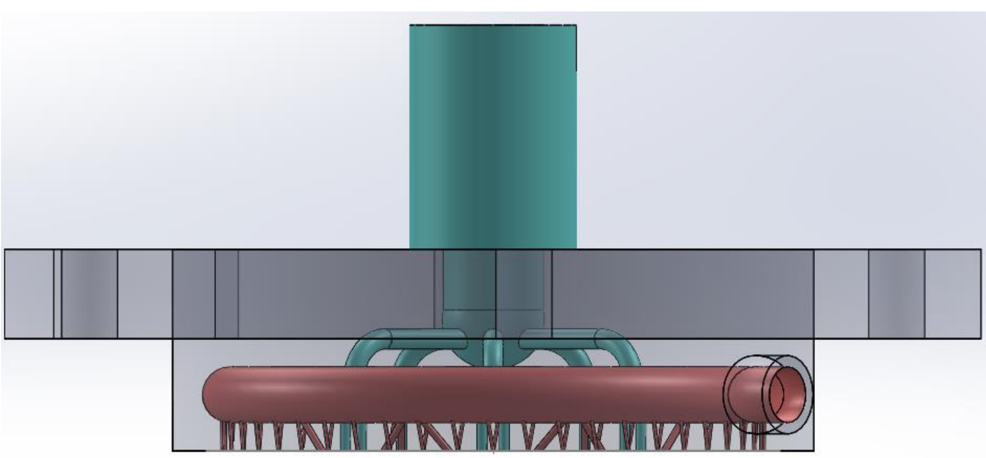

Figure 1: Front view of the SEDS UCSD injector plate design

INTRODUCTION

1.1 PURPOSE OF BUSINESS CASE

For several years now, there has been a growing interest in small payloads serving the needs of governmental as well as commercial users. Although advocates mainly reside in the traditional niches of space technology and data collection, the potential markets for the emerging industry are numerous. Studies done by groups such as the Futron Corporation have identified 33 potential markets, for low-cost small payloads in military, commercial and civil space sectors. The near-term addressable markets represent a demand for upwards of around seventy-five smallsats, which are considered small payloads, with revenue ranging between three hundred to five hundred and seventy million dollars a year. With the incorporation of better methods to provide the means of getting the small payloads into space, the potential market growth for cheap, effective procedures is sure to increase.

The advancement of small payload launches has always been slowed by its major competitor, using hosted payloads on a larger spacecraft. To truly justify the continued efforts in the small payload industry would require advocates to be able to demonstrate that small payloads can perform the same missions as larger aircrafts, and be able to do it at a fraction of the cost. If either of these conditions are not met, then its efforts are moot. The purpose of this business case is to demonstrate that 3-D printed engines can push the limits of the current small payload industry to meet the governmental, commercial and civil needs.

GENERAL PROJECT INFORMATION

1.2 PROJECT DESCRIPTION

Business Need

As stated earlier, minimizing cost and time are the main drivers when developing small payload launches. Currently, the opportunity to launch small payloads rests on the scheduling of big launch vehicles and utilizing the hosted payload method. With a cost efficient method of directly launching small payloads into space, the industry would rapidly increase as potential markets would develop their programs to work alongside effective and cheap launches. For example, with modern microprocessors getting smaller and faster every year, the technology of small satellites in space is improving and a variety of groups representing military and research organizations are keen to find reliable cheap launches. Companies such as GE Aviation have already begun printing individual jet engine components. These parts are not only lighter and more durable than traditional manufacturing methods, but are estimated to boost production speed by as much as 25%. By taking 3-D printing a step further and printing the engine all in one piece, the efficiency boost would be even more apparent.

Design/Scope

With the current industry standard of launching payloads into space, it is a $15000-40000 USD per kilogram, plus a fixed cost of about fifteen million dollars, depending on the size of the launch vehicle and scope of the mission. A 3-D printer slashes development costs by reducing the number of procedures. For example, all the intricacies can be printed out in one piece and the rocket engine portion, which includes the injector plate and its orifices, need not be machined. This reduces the build time and eliminates many possible sources of error that could result from having to machine individual small components that require high precision.

We took advantage of this technology in our design by creating curved and circular channels that would otherwise be impossible to machine. These passages are designed to provide the shortest route through the injector plate while minimizing any sharp turns the flow may encounter, increasing the efficiency of the rocket. Due to the rocket motor being printed in one piece, a regenerative cooling system is able to be integrated into the walls, which greatly increases the engine's performance and reduces the labor of building it separately. In addition, we incorporated a boundary film cooling that is spirally oriented in an attempt to concentrate the combustion towards the centerline, thus reducing the heat flux into the walls of the combustion chamber. Our rocket engine has been printed out using a DMLS (Direct Metal Laser Sintering) 3-D printer with cobalt-chromium as the material of choice. The printing service was done by GPI Prototype & Manufacturing, Inc. and cost approximately $5,000.

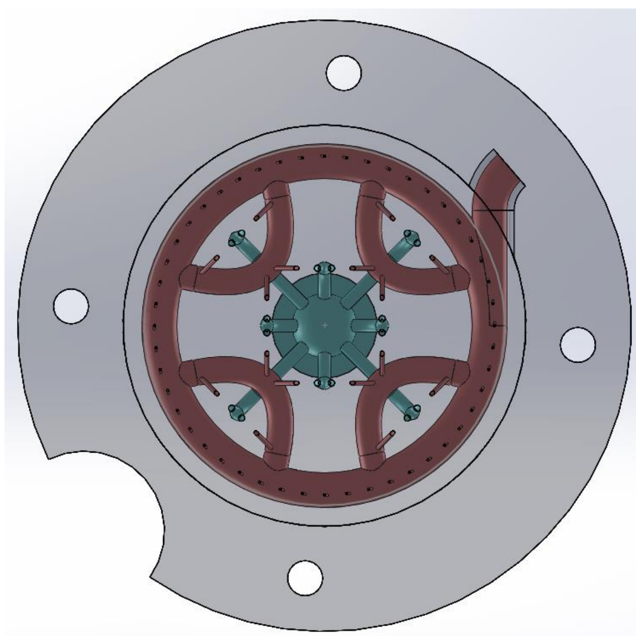

Figure 2: Injector plate face view to illustrate curved channels.

Barriers to Utilization/Risks/Issues

As with most methods of manufacturing, there are advantages and disadvantages associated with each method. 3-D printing technology has its advantages and disadvantages as well. Most people don't understand that there are limitations to 3-D printing. One of the disadvantages associated with 3-D printing is scaffolding. DMLS printing is done by laying down a thin layer of the chosen material in powder form, and using a high powered laser to melt it locally. This is done over many iterations, layer by layer until the entire part is printed out. This method poses two challenges to design. The main disadvantage is that when printing layer by layer, material cannot suddenly appear in a new layer, meaning as the 3-D printing machine sees a new layer, all of the portions which need to be sintered must be attached to the previous layer of a portion that was sintered. This may be solved by reorienting the way the part is to be printed; however, this does not solve for every situation, such as when both orientations require the same geometric configuration. This drawback requires engineers to take this limiting factor into account in the design stage of their project. Despite this negative aspect, the possibility of creating engines that perform at the required level at a fraction of the cost and development time, as evidenced by the design of our rocket engine, will allow for a promising future in 3-D printing technology, especially for small payload 3-D printed rocket engines.

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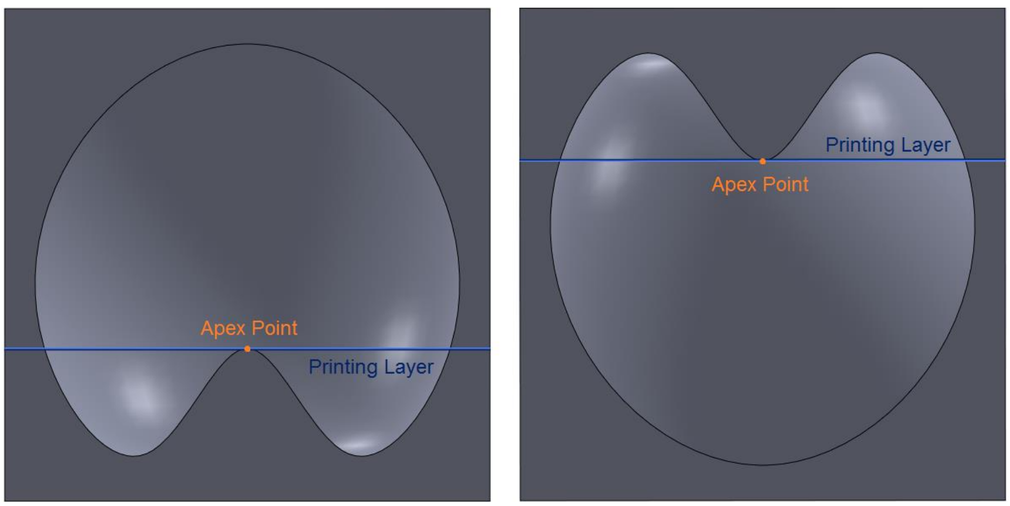

BOTTOM PLATE BOTTOM PLATE

Figure 3: Example of a printable and unprintable component

Another limiting factor of 3-D printing is that it is not constrained by the amount of material or complexity of the part that needs to be printed, but rather the time it takes for a part to be printed is what determines the cost. There are currently a limited number of printers available for an abundant amount of customers who need their part printed. Therefore, this forces the price model to be based on the height of the part to be printed, as the time to print the part is directly correlated to how tall the part is. Rocket engines are traditionally long structures, which creates the problem of having a relatively high cost to print out. Initial quotes estimated the Tri-D rocket at $15,000. Printing the rocket sideways is a possibility, but it would need to fit within the printable area of the printer and may need supports to be printed additionally in order to stabilize the part while it is being printed. This would add additional manufacturing to the process as the supports would likely need to be removed after the part is finished.

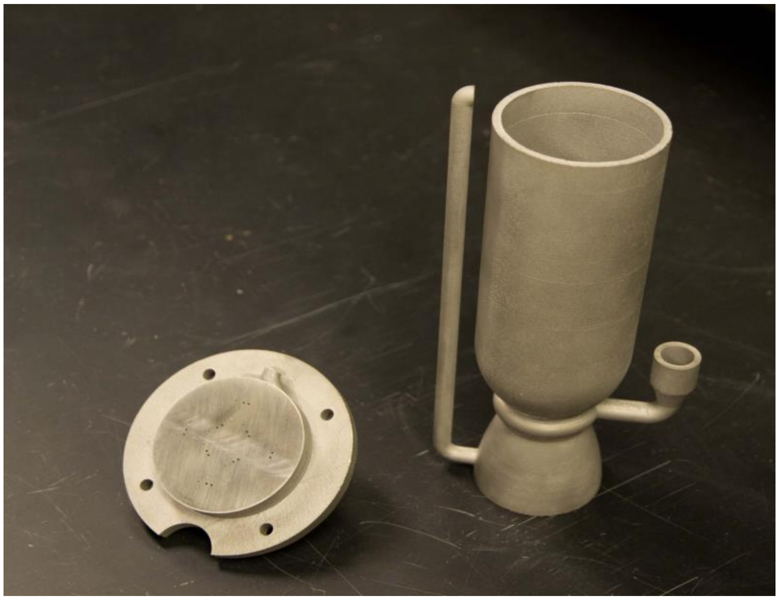

Figure 4: DMLS Printed Rocket Engine (Tri-D)

Furthermore, as with most issues that are associated with current 3-D printing technology, much of the printing is contained to smaller models and parts. Although at this time it is not necessarily applicable to large scale engines and components, in terms of the small payload industry, 3-D printing can and should be utilized. Although the limits of 3-D printing are constraining the full potential of mass printing parts, the current rate of technological growth makes the next few years a promising one in which many more opportunities will become available.

HIGH-LEVEL BUSINESS IMPACT

Investments in 3-D printed small payload engines will benefit the aerospace and small satellite industry. The ability to replicate each designed engine exactly as any other will revolutionize rocketry and allow for identical engines to be shared and used worldwide. In addition, 3-D printing rocket engines would allow for rapid prototypes of new and improved designs and would guarantee success in future missions at lower costs and fabrication times.

Investment in 3-D printed small payload engines benefits not only the industry but the scientific and commercial community as a whole in both near and long term projections. For years, the small payload industry has been slowed by the constraints set by aspects such as access to orbit as well as cost and effective manufacturing. Although not perfect in any way, the current technology gives access to extended research in fully printed engines, which can only improve if given more attention. Our design is meant to utilize the technical competitive advantages offered through 3-D printing as well as create a sustainable and efficient model for future business applications of the procedure.