PennState College of Engineering | ENGINEERING DESIGN, TECHNOLOGY, AND PROFESSIONAL PROGRAMS

Technical Memorandum
No. EDSGN100.001

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To: Lockheed Martin Corporation

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Subject: Penn State University
EDSGN 100: Introduction to Engineering Design
Client-Driven Design Project, Spring 2016

Purpose. The purpose of this memorandum is to give an overview of the Dream Team's design for the replacement of the heat transfer device. The objective of this project is to redesign a traditionally manufactured airflow through heat exchanger for additive manufacturing (AM). Air-flow through heat exchangers utilize metals with favorable heat transfer coefficients and thin-fin structures to remove heat from circuit card assemblies (CCA). These exchangers are typically built using a combination of CNC milling and brazing. Redesigning an exchanger for additive manufacturing would decrease the lead time from multiple months to several weeks.

Background. The purpose of this project was to create a heat transfer device using additive manufacturing that is able to cool electronic devices faster. Lockheed Martin was searching for the best design for a heat transfer for an electronic board for one of their parts. The Dream Team's plan was to increase the interior surface area of the fins, while keeping the exterior surface area constant, and keeping the weight of the total structure relatively the same. The team decided to increase the interior surface area because then this comes into contact with more air molecules, which will cool the electronic board faster.

Sponsor. Lockheed Martin is headquartered in Bethesda, Maryland. Lockheed Martin specializes in aerospace, defense, security, and advanced technology. Lockheed Martin employs over 126,000 people. Lockheed Martin has many locations nationwide.

Project Description. The team chose project one to redesign a heat exchanger to be additively manufactured. This option was chosen because the team saw a feasible solution to the issue at hand. The heat exchanger will be used to cool electrical components using fins to transfer heat. The group analyzed what would create a higher heat exchange rate which ultimately lead to the chosen design.

Procedures. The group saw the need to increase internal surface area to increase the heat exchange rate. The team altered the interior geometry of the heat exchanger in order to

increase surface area and therefore thermal conductivity. The design team utilized a pattern of overlapping circles in order to accomplish this task (**See Figures No.4, No.5)**. Using the Computer Animated Design application, Solidworks, the group was able to test the design using various materials, weight tests, and various designs. It was discovered that the surface area of the heat exchanger is directly proportional to the heat exchange rate. The group then added multiple ridges to the thin-fin structures in order to increase the surface area as well as include several more fins. The ridges were created by using overlapping cylinders that were removed in Solidworks. Fin size was reduced in order to include more fins. Aluminum 1060 was used for its high conductivity, lightweight, and low cost. Using this design the group has ultimately optimized the heat exchanger using the materials at hand as well as well as the natural heat efficiency of thinner fins and including ridges.

Results and Discussion.

Findings: In producing the alternative design, the team found that making the internal geometry more varied increased the internal surface area. The team decided to use a pattern of overlapping circles due to this being the easiest way to increase the internal surface area.

Results: The internal surface area of the Dream Team's design was 1,267.23 in^2, while the original design's internal surface area was 887.25 in^2. This accounts for a 379.98 in^2 increase in the internal surface area, which means that the team was able to increase the internal surface area by 42.83%. **See attached Figures No.6, No.7.**

Evaluation: By changing the internal geometry of the heat exchanger, the team was able to increase the surface area. Because surface area is directly proportional to heat transfer **(See Figure No. 6)** the amount of heat transfer possible was increased by 42.83%. Because the internal geometry was made to be irregular, even more heat transfer is possible due to the creation of small eddies.

Conclusions and Recommendations. This design used would not have to be exactly identical to the one made by the team. Any increase in internal surface area will increase the heat transfer abilities of the part. This part can be manufactured using additive technology or could be precisely machined from a solid block of aluminum alloy. If this part or others can be successfully manufactured, it will serve as a much better method of dissipating heat. The team was happy to help improve this part and can be contacted with questions or requests for additional improvements at smh6168@psu.edu. All members of the team thank the fine people at Lockheed Martin for providing them with this opportunity to gain engineering and collaborative experience.

References. The team used the Statement of Work, which is available here, as well as the Lockheed Martin Presentation that was presented in the Kick-Off Meeting that is available here.

Attachments. Figures Nos. 1, 2, 3, 4, 5, 6, and 7 are attached.

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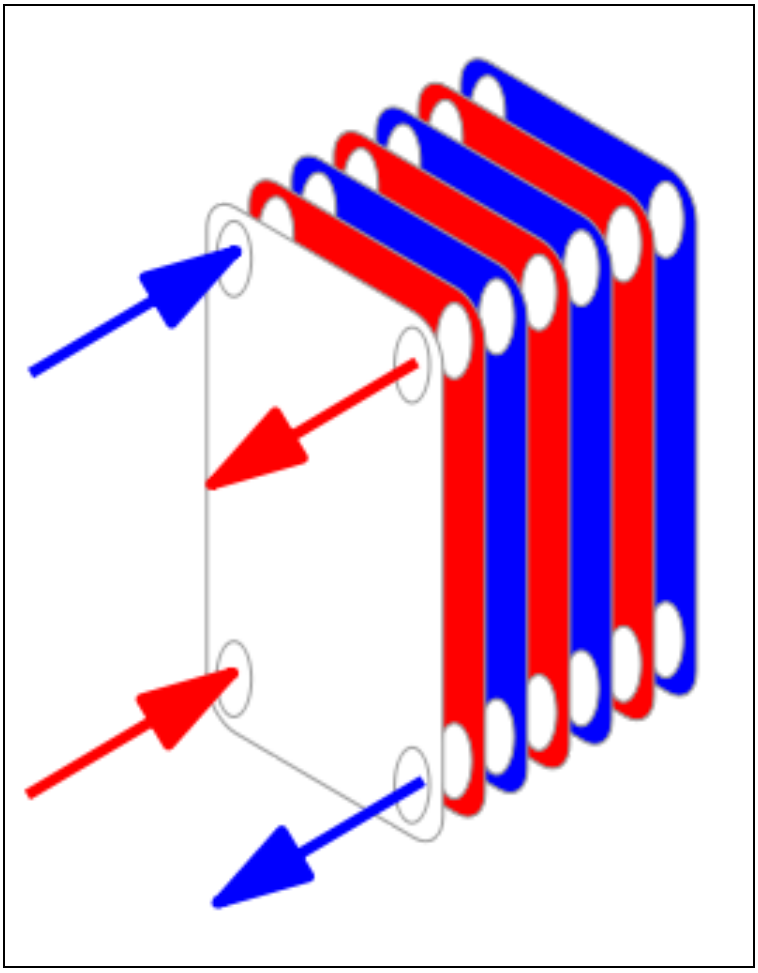

Figure 1. Conceptual diagram of a plate and frame heat exchanger

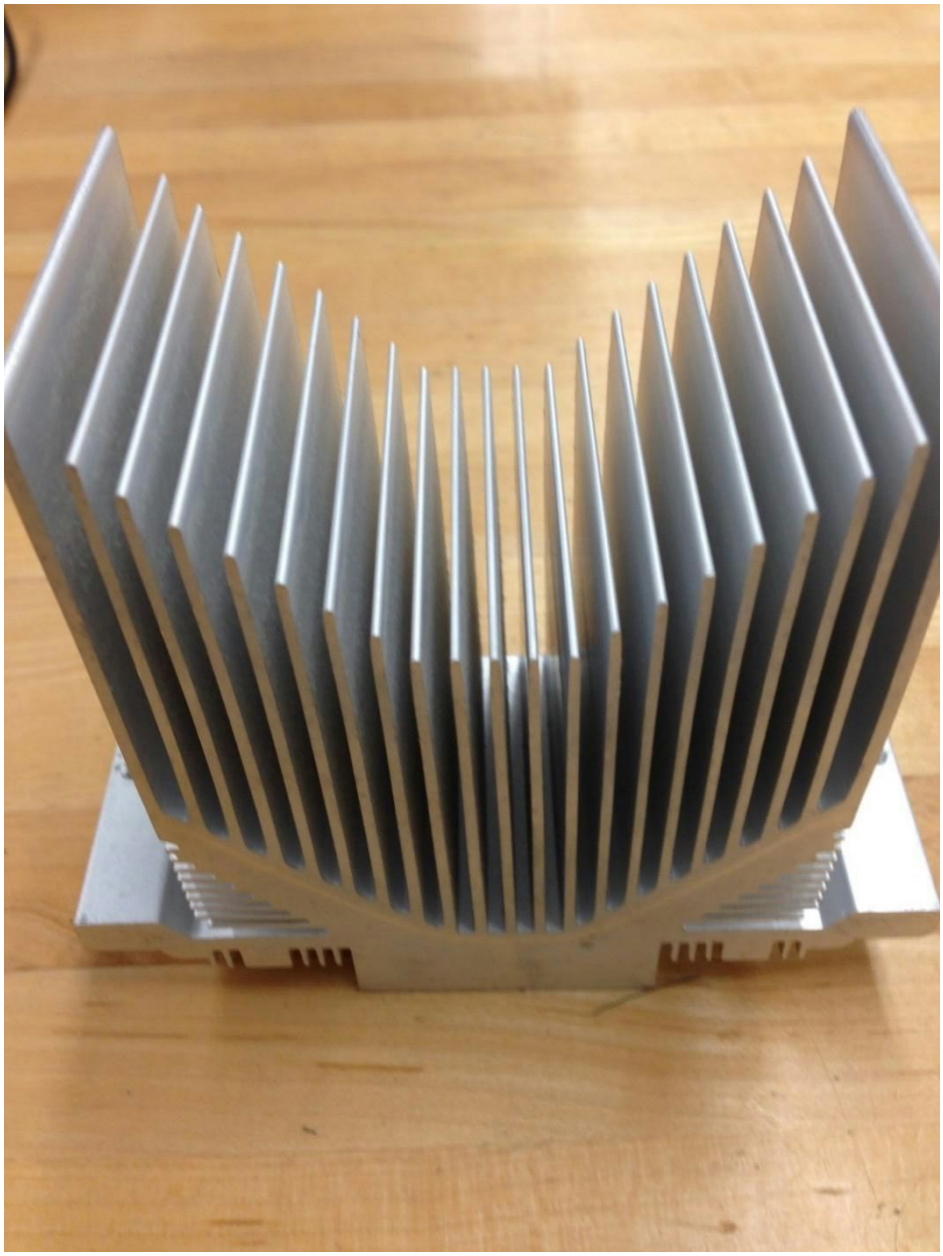

Figure 2. Typical heat exchanger

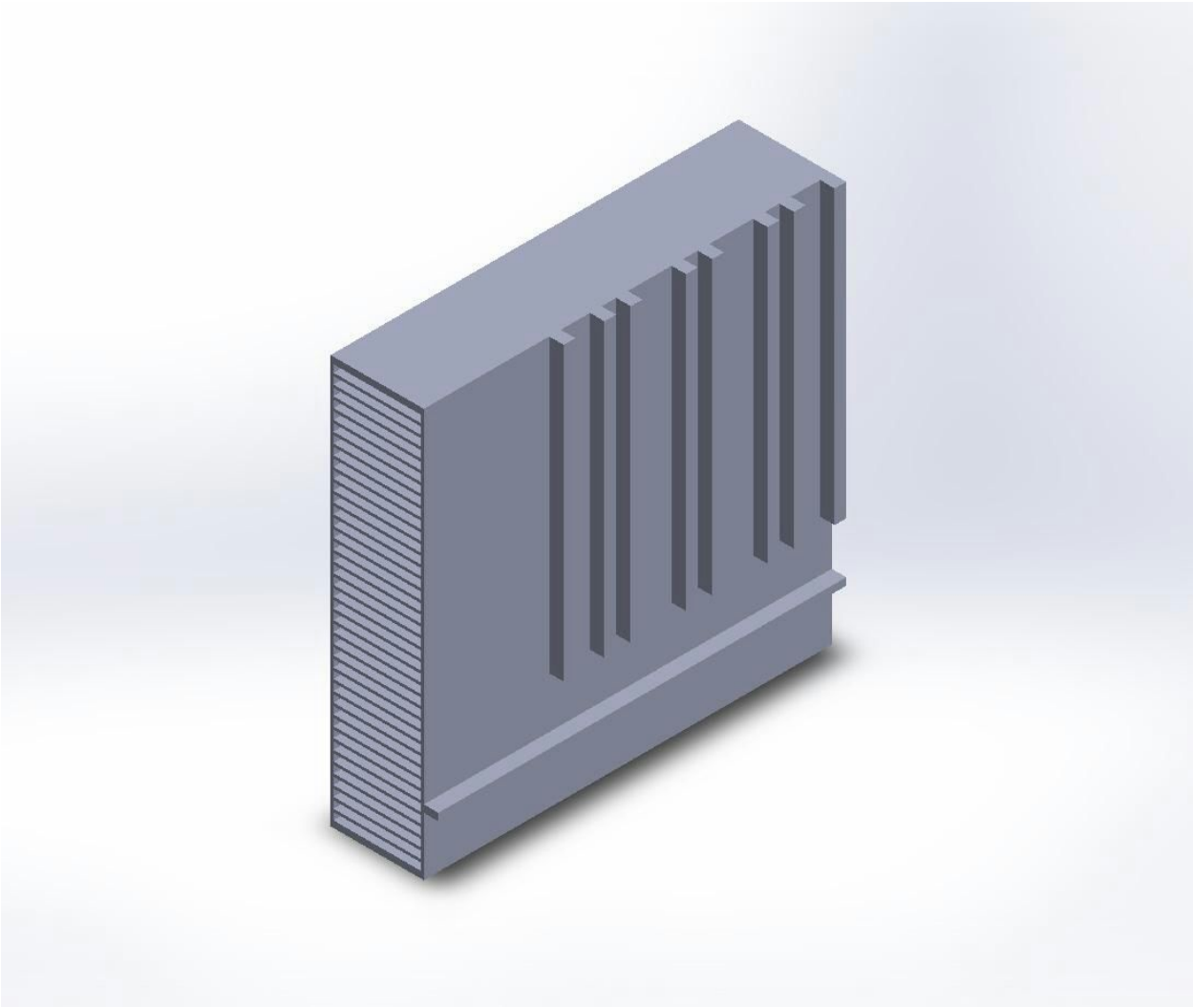

Figure 3. Original heat exchanger

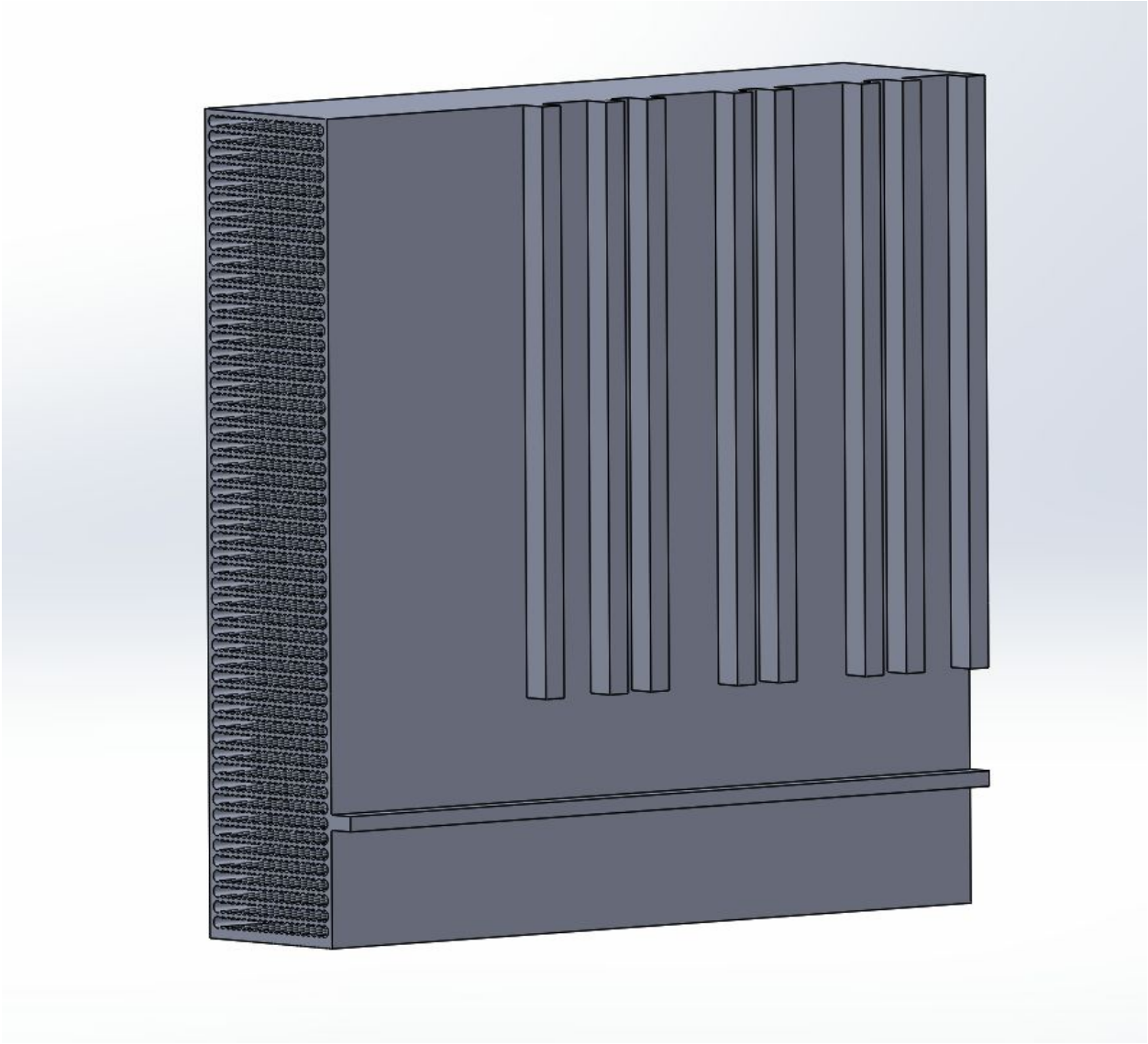

Figure 4. Modified heat exchanger to improve efficiency

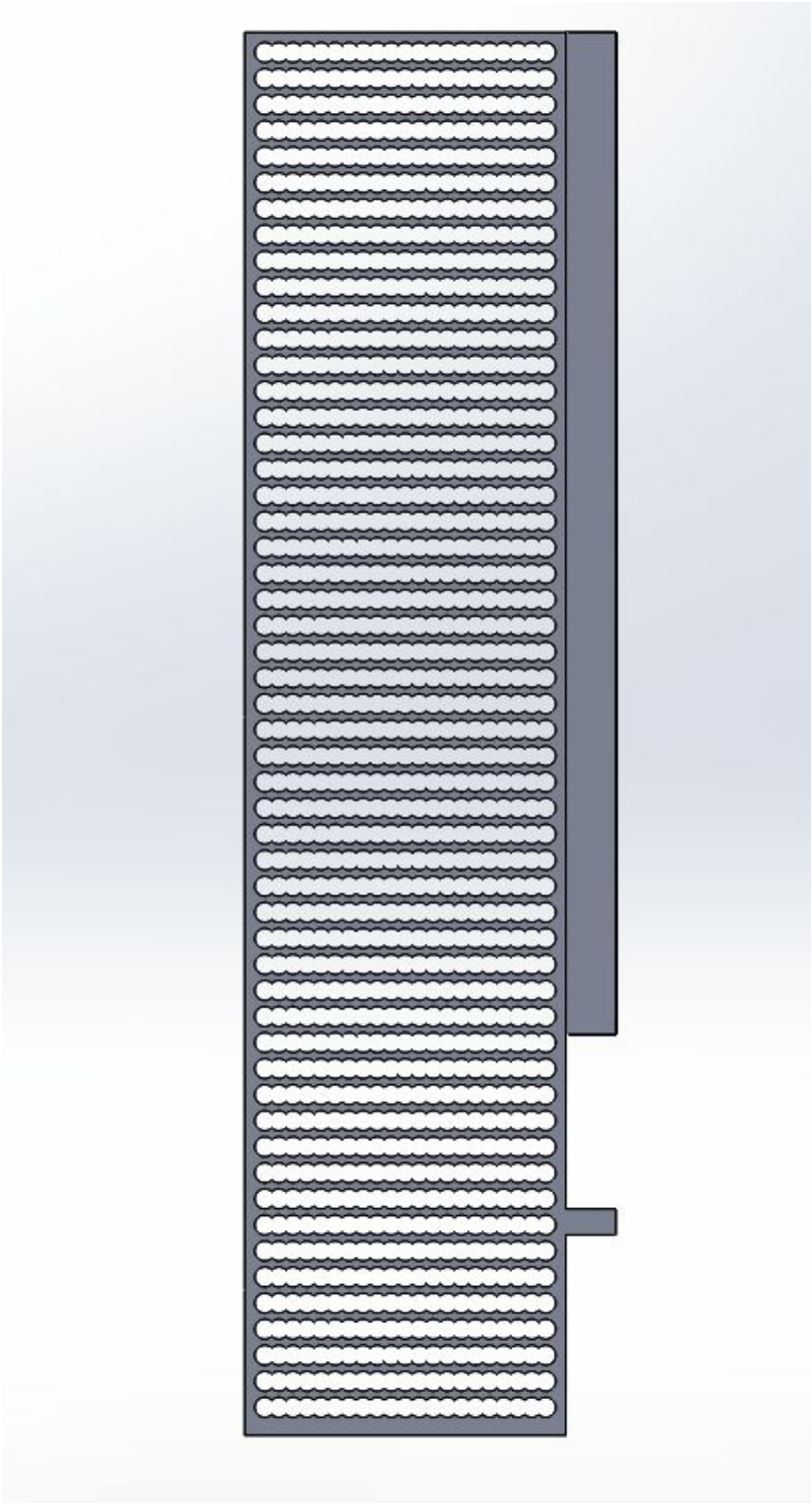

Figure 5. Alternative view of modified heat exchanger to improve efficiency

An alternative method of integrating the convection heat loss could be used.

$$q = \int_0^L hP(T - T_\infty)\,dx = \int_0^L hP\theta\,dx$$

Figure 6. Formula used to demonstrate heat exchange rate

Part	Internal SA (in^2)
Original	887.25
Improved	1267.23

1267.23 - 887.25 = 379.98

379.98 / 887.25 = 0.4283

42.83 %

Figure 7. Calculations for Surface area increase percentage