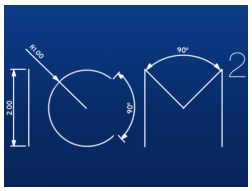
EDSGN 100 Project #2
Final Design Report

Connector Backshell

Introduction to Engineering Design
EDSGN 100 Section 8



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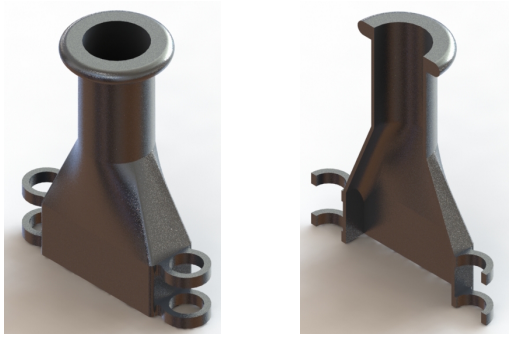

Submitted to: Dr. Thomas Colledge
Date: 04/29/2016

Executive Summary

The objective for this project was to design a connector backshell that could be produced through additive manufacturing. It had to minimize wire abrasion, stop signal loss and meet the MIL specs. Our result was a connector backshell that could be created through additive manufacturing, weighed less than traditional backshells and cost much less to produce. By having rounded insides this backshell stopped wire abrasion and by following the MIL specs it kept signal loss to a minimum. None of this would have been possible without the use of additive manufacturing.

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1.0 Introduction

This year, Penn State has teamed up with Lockheed Martin to work on a design project for Introduction to Engineering Design (EDSGN 100) students. Lockheed Martin is a global security and aerospace company that uses advanced technology and additive manufacturing to engineer a better tomorrow. With the hopes of gaining interest and ideas from college students, Lockheed Martin provided five projects for the class to work on throughout the semester. The purpose of this would be to inspire students to work with Lockheed Martin as well as find possible solutions to real life problems. The projects aimed toward additively manufacturing parts that are currently created through traditional machining.

Specifically, this report will focus on the third option, which is for connector backshells. By using additive manufacturing, these connector backshells can be produced quickly and cheaply. Our team created a gantt chart to effectively go through the necessary steps of designing our product. As seen in Table 1, we came up with specifications, created multiple design ideas, evaluated each design, created a prototype through additive manufacturing, and then evaluated that prototype. In this report, we will detail our conceptual design process beginning with gathering information before we touch on the evaluation step. This whole process was managed through the use of a gantt chart (Table 1).

Table 1-Gantt Chart

ICM^2 Gantt Chart												
Design Challege #2 Connector Backshell			Dates and Duration									
Main Task	Sub Task	Person(s) doing it	Duration (Weeks)	Start	Status	Wk 1	Wk 2	Wk 3	Wk 4	Wk 5	Wk 6	
Begin Project		All	1	Wk1	Complete							
	Team Charter	BM,BB	1	Wk1	Complete							
	Gantt Chart	All	2	Wk1	Complete							
Recognize Opportunity/Define Problem		All	2	Wk1	Complete							
Gather Information												
	Assess Customer Needs	All	1	Wk2	In Progress							
	Brainstorm Research Topics	All	1	Wk2	In Progress							
	Research Materials/Cost Minimization	JS	1	Wk2	In Progress							
	Research electrical interference	JS	1	Wk2	In Progress							
	Research existing designs	MS	1	Wk2	In Progress							
Specifications												
	Define Criteria and Constraints	All	1	Wk2	In Progress							
Brainstorm Ideas												
	Brainstorm Possible Solutions	All	1	Wk2	Not Started							
	Rough Sketches	All	1	Wk2	Not Started							
Evaluate Ideas												
	Pros and Cons of Possible Solutions	All	1	Wk2	Not Started							
Analysis												
	Decision Matrix	All	1	Wk3	Not Started							
	Choose Solution	All	1	Wk4	Not Started							
Calculations												
	Calculations on signals	All	1	Wk4	Not Started							
	Volume and Mass	All	1	Wk4	Not Started							
	Durability	All	1	Wk4	Not Started							
	Operation conditions				Not Started							
	Manufacturing process				Not Started							
Prototype Construction												
	Multiview Drawings	BM	1	Wk4	Not Started							
	CAD Drawings	JS,BM	1	Wk4	Not Started							
	Material Selection	JS,BM	2	Wk4	Not Started							
	Component Selection	All	2	Wk4	Not Started							
	Gather/Purchase Materials	JS,BM	2	Wk4	Not Started							
	Part Manufacturing	JS,BM	2	Wk4	Not Started							
	Assemble Prototype	All	2	Wk4	Not Started							
	Isometrics	B	1	Wk4	Not Started							
	Dimensions	BM	1	Wk4	Not Started							
	CAD Simulations	JS,BM	1	Wk4	Not Started							
		All	1	Wk5	Not Started							
	Specs	JS	1	Wk4	Not Started							
	Evaluate Prototype	All	1	Wk5	Not Started							
	Retrofit Prototype	All	1	Wk6	Not Started							
		all	1	Wk6	Not Started							
		all	1	Wk5	Not Started							
	Changes to prototype	all	1	Wk6	Not Started							
	Retest	all	1	Wk6								
Presentation												
	Construct Presentation	All	2	Wk4	Not Started							
	Rehearse Presentation	All	1	Wk5	Not Started							
	Give Presentation	All		4/25/2016	Not Started							
	Technical Paper	All		4/29/2016	In Progress							
End Project												

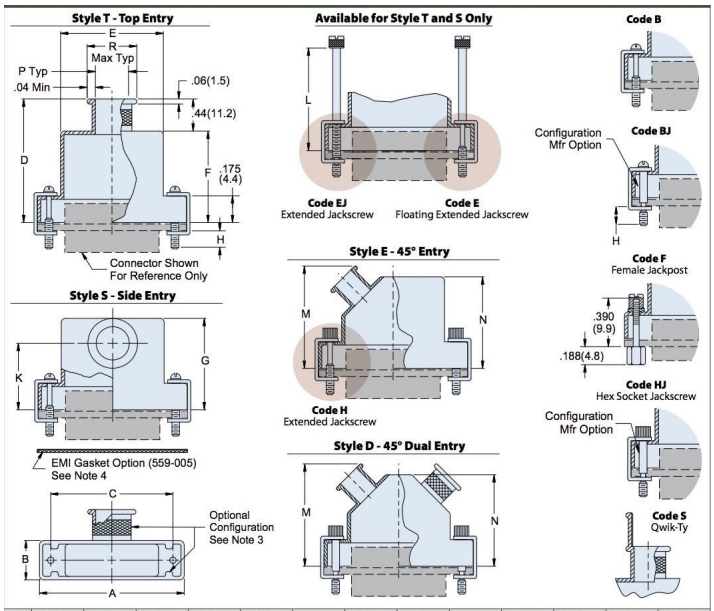
1.1 Design Principles (working on it)

We identified four key subsystems: cost effectiveness, manufacturability, wire safety, and signal separation. We also looked into sustainability. As for constraints, we followed strict protocol when following federal government regulations regarding the minimum and maximum dimensions for the connector backshell. With this in mind, we looked into the minimal dimensions coupled with the best material of aluminum to create a cheap and light product that would be sufficient enough for use.

2.0 Project Background (Project at hand)

Lockheed Martin provided 5 unique projects for student groups to work on. Our group chose project three concerning the design and functionality of connector backshells. Specifically we were asked to produce a redesigned backshell based on a current model from Glenair, that focused on the elimination of interior sharp edges and the ability to separate signals out of a single connector easily. This was all to be achieved via additive manufacturing. We were further instructed to select a specific Military Specification model to develop, and for this purpose we chose the MIL-DTL-83513-15 seen below.

Table 2-Existing Part Dimensions



Size	A Max.		B Max.		C		D Max.		E Max.		F Max		G Max		H Max.		J Max.		K		L Max.		M Max.		N Max.	
	In.	mm.	In.	mm.	In.	mm.	In.	mm.	In.	mm.	In.	mm.	In.	mm.	In.	mm.	In.	mm.	In.	mm.	In.	mm.	In.	mm.	In.	mm.
09	.850	21.59	.370	9.40	.565	14.35	.780	19.81	.410	10.41	.350	8.89	.637	16.18	.350	8.89	.637	16.18	.435	11.05	1.040	26.42	1.000	25.40	.680	17.27
15	1.000	25.40	.370	9.40	.715	18.16	.910	23.11	.580	14.73	.470	11.94	.673	17.09	.470	11.94	.673	17.09	.440	11.2	1.170	29.72	1.030	26.16	.730	18.54

Fig. 1- Existing Parts

3.0 Project Objectives (good)

After supplementing what we had with some additional researched information, that being dimensions from GlenAir and further constraints from the Federal Government, we determined that our main objectives should indeed be:

-to focus on removing interior sharps as to keep wires from severing unintentionally due to rubbing damage from the housing

-to effectively separate signals through a variety of out-port configurations.

We also determined that the best use of additive manufacturing would be achieved by creating the minimum required features (i.e. ports, fittings, etc.) and then creating a thin lofted casing in between the features to enclose everything. Furthermore, we felt that it would be best to make our fittings and features compatible with the existing band clamps, and jackscrew assemblies and have done so in our final product.

4.0 Connector Backshell Background

5.0 Specifications

5.1 Pairwise Comparison

5.0 Conceptual Designs (minus specifications/criteria)

Conceptual Designs for this project had to be based on the government's specifications. We were able to come up with three different design solutions that fit the requirements. When coming up with our solutions we needed to take into consideration what would best utilize additive manufacturing while still meeting the specifications set by our stakeholders. We ended up creating a list of criteria to focus on when seeking different designs. These criterion helped us determine a pair-wise comparison to see the importance of each specification when brainstorming and evaluating possible

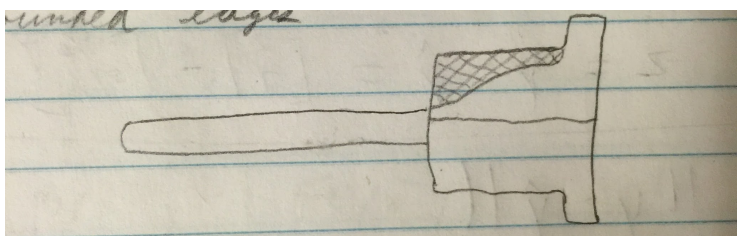
solutions. The selected criteria included weight, specifications, functionality, cost, and additive manufacturability. Thanks to the matrix, we were able to differentiate the importance of all aspects for the purpose of evaluating and ranking each design.

Table 3-Pairwise Comparison

Pairwise Comparison	Weight	Specifications	Functionality	Cost	Manufacturability	Row Totals	Row Total/Total
Weight	1.00	0.14	0.20	0.50	0.17	2.01	4.70%
Specs	7.00	1.00	2.00	4.00	1.50	15.50	36.25%
Functionality	5.00	0.50	1.00	3.00	1.00	10.50	24.56%
Cost	2.00	0.25	0.67	1.00	2.00	5.92	13.84%
Additive Manufactuability	6.00	0.33	1.00	0.50	1.00	8.83	20.66%
						42.76	

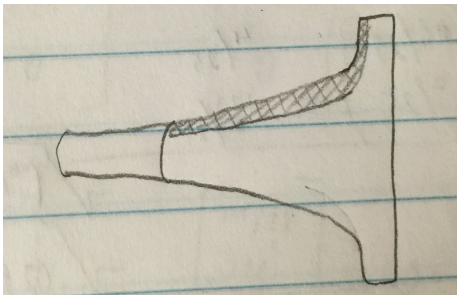
4.1 Descriptions (good)

Our first brainstormed design shown in Figure # had the same overall shape of the original backshell but incorporated additive manufacturing's ability to incorporate an internal lattice structure that could solve the issue of sharp internal edges that were causing wire wear. Also the lattice structure would improve the overall strength of the backshell.

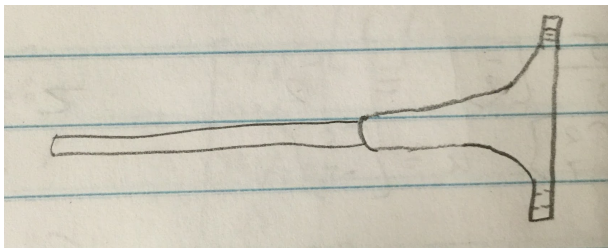


Our second possible design solution shown in Figure # was aimed at better utilizing additive manufacturing, decreasing weight, and lowering cost. The design incorporated the lattice structure while decreasing the overall size of the backshell. This results in a strong shell made out of less material than the previous design.

Our third design shown in Figure # was unique by not incorporating the lattice structure but instead focusing on creating a solid shell out of the least amount of material possible without compromising the structural integrity of the shell.



Through research we found that this would minimize cost, decrease weight, and that the lattice structure was completely necessary considering that these shells will be made out of durable aluminum. Also the lattice structure had little if any benefit in terms of protecting the connector from environmental conditions such as signal interference.



4.3 Concept Selection (Minus specifications)

In order to select the best design, our team created a concept screening matrix and a concept scoring matrix. Both of these matrices ranked the designs based on how well they met the criteria we came up with. These criteria include the weight, cost, specs, functionality and additive manufacturability of the idea. We weighed these criteria through a pairwise comparison so that they would be useful when analyzing these design ideas. Two different comparison matrices were used to improve the overall accuracy choosing the best design. The first evaluation was a concept screening that took the sum of the overall pros and cons of each idea and ranked them. After the analysis was completed, design C ranked the highest. Designs A and B scored very poorly, with neither coming close to C. We then used the concept scoring to rank them one more time. Through the concept scoring, each idea was given a number on a scale of 1-3 based on it's overall rating. The rating was then weighted based on criteria value before evaluating all three designs. Design C ranked the highest again. Design A still scored poorly, and was eliminated, but design B was much closer to design C in rank than last time. Since design C scored the highest through both comparisons, it was chosen as our solution. Through these comparisons it became clear that design C satisfied the criteria and fit in with the objectives for this project. Both of these comparison matrices can be seen on the next page.

Concept Screening

		Concepts	
Selection Criteria	Concept A	Concept B	Concept C
Weight	Minus	Same	Plus
Specifications	Same	Plus	Plus
Functionaility	Same	Plus	Plus
Cost	Plus	Minus	Same
Additive Manufacturability	Minus	Same	Plus
Pluses	1	2	4
Minuses	2	1	0
Sames	2	2	1
Net	-1	1	4
Rank	3	2	1
Continue?	No	No	Yes

Concept Scoring

				Concepts			
		Idea A		Idea B		Idea C	
Selection Criteria	Weight	Rating	Weight Scored	Rating	Weight Scored	Rating	Weight Scored
Weight	0.05	1.00	0.05	2.00	0.09	3.00	0.14
Specifications	0.36	2.00	0.72	3.00	1.09	3.00	1.09
Functionality	0.25	2.00	0.49	3.00	0.74	3.00	0.74
Cost	0.14	3.00	0.42	1.00	0.14	2.00	0.28
Additive Manufactuability	0.21	1.00	0.21	2.00	0.41	3.00	0.62
	Total score		1.88		2.47		2.86
	Rank		3rd		2nd		1st
	Continue		No		No		Yes

4.2 Research ???

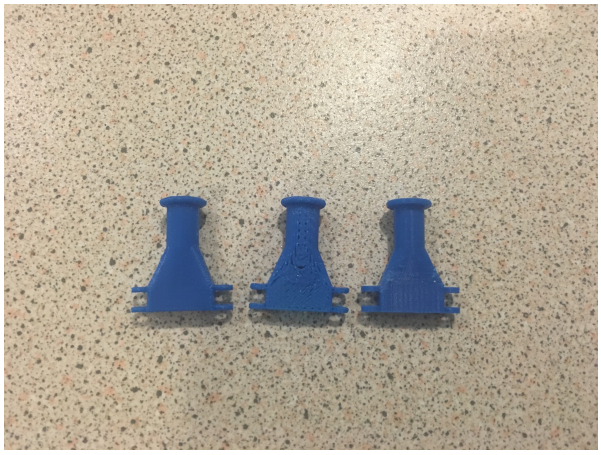
A lot of the information we needed to know was provided by Lockheed Martin, but we also conducted additional research. Some of our group members were able to incorporate prior knowledge gained from previous work experience in the electronics industry. A portion of the additional external research consisted of internet research across industry and government sites. (See links in References) Analyzing

performance proved difficult and much of it would need to consist of experiments to ensure performance under certain environmental conditions. Lockheed Martin provided us with details on the existing Glenair product that they have been using. Dr. Colledge and the Penn State 3-D Printing Club provided us with knowledge of additive manufacturing and how to utilize the technology.

5.0 Detailed Design (Analysis)

All of the above has culminated in our final design. It consists of a simple, one piece aluminum body designed to minimize material, smooth out interior surfaces, and interface seamlessly with existing I/O.

The connector is placed in the bottom opening of the apparatus shown above. It is then held in place by the current industry standard clips and jack screws with the help of the jackscrew mounting points seen on the side. The wires crimped to the rear of the connector are then collated and fed through the hole at the top from which they then travel to their terminus. Casing material can be



attached at the top of the backshell with existing banding clamps on the cylindrical surface. A full sized 3D printed mockup in plastic can be seen below.

In addition, in order to facilitate signal separation and space constraints we created several alternate exit port configurations with potential for a plethora of other configurations. The three shown on the next page are the long side entry, 45 entry and dual 45 entry.

6.0 Conclusions

In conclusion, we designed a final connector backshell with multiple alternative designs as seen above. Thanks to our gantt chart and team roles, our group was able to split up tasks and fluidly go through the iterative design process. We found through our research that by implementing the absolute minimum dimensions as listed by Glenair, we could design a smaller, safer, and more effective connector backshell that could be produced at a fraction of the original cost. Through the use of additive manufacturing, we printed models of the design and prepared quotes for final product manufacturing in aluminum. Through product testing and comparison to Glenair's existing product we would be able to prove the superiority of our design.

7.0 References

Consulted Documentation-

Existing Parts-
http://www.glenair.com/micro_d/pdf/m/500_010.pdf

MIL Spec- http://www.landandmaritime.dla.mil/Downloads/MilSpec/Docs/MIL-DTL-83513/dtl83513.pdf

Consulted Firms-

Starn Tool and Manufacturing Company - Meadville, PA - starn.com

-Quoting, Engineering

Mecal By Starn - Meadville, PA - mecalbystarn.com

-Electrical Expertise

Kuhn Tool and Die - Meadville, PA - kuhntool.com

-3D Printing, 3D Printing Expertise

AW Miller - Harmony, PA - awmiller.com

-Metal 3D Printing Expertise