Standardizing 1RU Chassis to PCBA Interfaces

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Abstract

Cisco currently uses a variety of custom chassis for different types of servers, routers, and switches because of the required mounting locations caused by the constraints inside. Our senior design project aims to reduce the amount of custom chassis Cisco needs to order from suppliers. Presented in the Scope of Work is research on the customer’s needs, the product, and the technical background used to understand the project scope. Through research, our group was able to find similar products, related patents, research papers on sheet metal stamping, and a list of applicable industry codes, standards, and regulations. From our research, our team will make informed decisions when analyzing Cisco’s current designs for a standardized 1RU chassis.

Table of Contents

1. Introduction

Cisco needs a way to standardize the mounting locations on the 1RU (one Rackmount Unit) chassis perimeter to save costs annually and reduce the number of custom chassis that need to be manufactured. To develop a better guideline for Cisco hardware and mechanical engineers, our senior design group will be researching a design to find new solutions for the 1RU chassis. Our initial design research will cover the customer needs and the technical scope of the product. In completing the design research, we will understand the design challenge, recognize alternative solutions, and indicate the technical challenge we are undertaking. Through our design and ideation process, our group will analyze current designs to see if there are any patterns in perimeter hole locations so we can better develop a guideline or solution for the designers.

2. Background

2.1 General Information

The 1RU chassis is an industry standard unit used in data centers for safely mounting printed circuit boards (PCBs). The 'RU' portion is an abbreviation for rack unit and the number before the RU represents the height of the rack mount. We will be focusing on is the 1RU, a chassis with a height of 1.75in and width of 19in. The height and width of the chassis are standardized throughout the data center industry [13]. However, the depth can vary depending on varying sizes of PCBs that a company may have.

After speaking with Cisco, it became apparent that finding common mounting locations on the perimeter of the chassis will help cost reduction greatly. Currently, each PCB has its own 1RU chassis since they were individually designed with varying mounting locations in mind. With over 30 different types of PCBs, the manufacturing process for each chassis also varies. This drives up cost due to the number of different hard tooling methods that are required to make each individual chassis. If we can create one chassis to account for multiple PCBs, we will be able to save money on hard tooling. Current mounting methods include toad stools and stand offs, both having their pros and cons. Toad stools are threaded into the sheet metal and do not require extra parts. There are no extra steps for assembly, but they take up more space. Stand offs, on the other hand, are threaded inserts press fit into the sheet metal assembly. They take up less space, however, they require the extra step of press fitting the inserts into the sheet metal and require that extra press fit piece. Therefore, in the re-design, we plan to use the toad stool mounting method as much as possible unless space permits us otherwise.

2.2 Product Research

From observing customer needs, there are a couple of key factors that are analyzed before a rack mount purchase. These include size, flexibility, manageability of cables, usable space post mounting, weight capacity, and cooling efficiency. As mentioned before, rack mounts have standardized heights and widths, but varying depths. Individual PCBs dictate the required chassis depth. Balancing material waste and maximizing the number of PCBs each chassis can be used for will be one trade off that our team will have to balance. Ensuring that our mounting locations do not interfere with cable and wiring pathways is another constraint for our design. Due to the previous senior project group's task to redesign the chassis structure, we are shifting our primary focus away from the structural integrity of the chassis and cooling efficiency. However, these design constraints are still being considered for rack mount designs.

Table 1. Similar Products and their Associated Specs.

Product Name	Dimensions	Weight
Cisco Network Convergence System 5000 Series [6]	Height: 1.72 in (4.3688 cm) Width: 17.44 in (44.2976 cm) Depth: 19.3 in (49.022 cm)	20.5 lbs. (9.29kg)
Cisco 9200 Switch for 24 ports [5]	Height: 1.73 in (4.4 cm) Width: 17.5 in (44.5 cm) Depth: 13.8 in (35.0 cm)	12.12 lbs. (5.5kg)
Cisco 4431 Integrated Services Router [7]	Height: 1.73 in (4.39 cm) Width: 17.25 in (43.815 cm) Depth: 19.97 in (50.72 cm)	22.4 lbs. (10.2 kg)
Cisco 4331 Integrated Services Router [7]	Height: 1.75 (4.455 cm) Width: 14.55 in (36.957 cm) Depth: 11.60 in (29.464 cm)	9.14 lbs. (4.2 kg) + 1.2 lbs. (0.66 kg) external PS
Arista DCS-7050S-52-R 7050S Series 52x 10G SFP+ Rear to Front Airflow Switch [12]	Height: 1.75 in (4.4 cm) Width: 16 in (40.64 cm) Depth: 19 in (44.5 cm)	17 lbs. (7.71 kg)

Table 1 displays four other products that we found to be similar to the 1RU chassis that we will be working with. As mentioned above, the height and width of all chassis remains relatively constant, but the length varies depending on the internal PCB.

2.3 Patents

There are five relevant patents to our design problem that can be found in Table 2 below. The first patent listed in the table is for a 1RU server but focuses on air flow and heat transfer in the chassis design [1]. Our design task centers around a 1RU server chassis, but heat transfer is a design consideration. Cisco does not patent their mechanical engineering chassis designs, but there are a few relevant categories that our proposed standardized chassis would cover. These classifications are G06F1/181 and G06F1/183. G06F1/181 describes enclosures while G06F1/183 describes "internal mounting support structures" such as "printed circuit boards (PCBs) and internal connecting means." Patents 2, 3, and 5 all contain these two classifications. Both Oracle patents consider internal mounting support, but Patent 3 has an additional classification, G11B33/128, that centers on recording devices mounted to the chassis [10].

Cisco has tasked us with examining chassis primarily used for routing and switching, but there is potential our focus can grow to include other server types. In the table, Patent 4 does not have either the G06F1/181 or G06F1/183 classification [3]. The patent is still relevant to our background research because it carries the same classification as patent 3, G11B33/128, and additional classifications centered on mounting technical hardware. From these patent classifications, a future, standardized 1RU chassis can be properly patented and classified.

Table 2. Relevant Patents

Patent Name	Classification	Company	Date Created
1. Compact Rackmount Server [1]	• H05K7/20736 Forced ventilation of a gaseous coolant within cabinets for removing heat from server blades	Sun Microsystems Inc.	September 13, 2007
2. Compact Rackmount Storage Server [2]	• H05K7/1487 Blade assembly, e.g. cases and inner arrangements • G06F1/183 Internal mounting support structures, e.g. for printed circuit boards, internal connecting means	Oracle America Inc	September 7, 2010
3. External Storage for Modular Computer Systems [10]	• G06F1/183 Internal mounting support structures, e.g. for printed circuit boards, internal connecting means • G11B33/128 Mounting arrangements of constructional parts onto a chassis if the plurality of recording/reproducing devices	Oracle America Inc	July 17, 2007
4. Computer System for Highly Dense Mounting of System Components [3]	• G06F1/184 Mounting of motherboards • G06F1/187 Mounting of fixed and removable disk drives • G11B33/128 Mounting arrangements of constructional parts onto a chassis of the plurality of recording/reproducing devices	VA LINUX SYSTEMS, California Digital Corp	December 3, 2002
5. Computer Enclosure with Input/Output Module [4]	• G06F1/181 Enclosures • G06F1/183 Internal mounting support structures, e.g. for printed circuit boards, internal connecting means	Hongfujin Precision Industry Shenzhen Co Ltd, Hon Hai Precision Industry Co Ltd	March 29, 2011

2.4 Industry Codes, Standards, and Regulations

Common for metal stamping, punched holes are eight to ten percent of material thickness. This is acceptable for our project since the opposite side of the chassis does not need any detailed features. Hole piercing is a repeatable process by hard tooling with size tolerances of 0.002”, that will be more than enough for our mounting locations. Hole to hole location punching can also be held at ± 0.002” [9]. One consideration for hard tooling is the compressive force required to punch a hole. From Newton’s third law, for every action force, there is an equal and opposite reaction force. Using this That same force applied to the steel sheet will also be applied to the tooling. Therefore, for tooling design we want to ensure perforations have a cross section greater than or equal to the thickness of the sheet metal we are punching holes into. This ensures a large area to decrease the pressure and subsequent force on the hard tool. During the stamping process, 90-degree angles are doable, however, the "spring back" of metals due their hardness properties restricts formation of angles greater than that.

Taking GD&T into consideration, we want to specify our tolerances for the toadstools and standoffs. An important tolerance that will be called out throughout our mounting location drawings will be the perpendicularity of the holes. Our datum will most likely be the PCB mounting surface. Tight tolerances and cost will have to be weighed in our considerations as tolerances have a direct relationship with cost. Screws are still functional when they are not perfectly perpendicular to a surface, so extremely tight tolerances are not necessary for our project. When using this tolerance, the location and specification of the threaded hole is determined from the thread profile form maximum material condition (MMC) [8].

Before the product can go to market, it must pass safety and compliance guidelines. For this section we focused on American and European guidelines since other country guidelines are based off these standards. Cisco's servers comply with the following safety standards: UL 60950-1 and EN 60950-1 [5]. UL 60950-1 and EN 60950-1 are the American and European safety standards applicable for information technology and focuses on preventing fires and injuries [11]. Cisco servers also comply with the following electromagnetic interference (EMI) and electromagnetic compatibility (EMC) standards: FCC Part 15 (CFR47) Class A and EN 55032 [14]. Both the FCC's and European Union's EMI and EMC standards cover telecommunications and information technology.

3. Objective

3.1 Problem Statement

Cisco needs a way to standardize the mounting locations on the Cisco 1RU chassis perimeter to cut costs annually and reduce the number of custom chassis that need to be manufactured. Manufacturing a 1RU product to fit each unique PCB/PCBA is extremely expensive and it is vital that a more modular design is attempted.

To visually understand our problem statement, Figure 1 depicts a boundary diagram of our proposed problem. The dashed lines indicate the area we will be focusing on and the two types of circles indicate the two most common types of holes we will encounter. Over the course of our project we will review existing Cisco chassis CAD files and make recommendations on hole placements around the chassis perimeter.

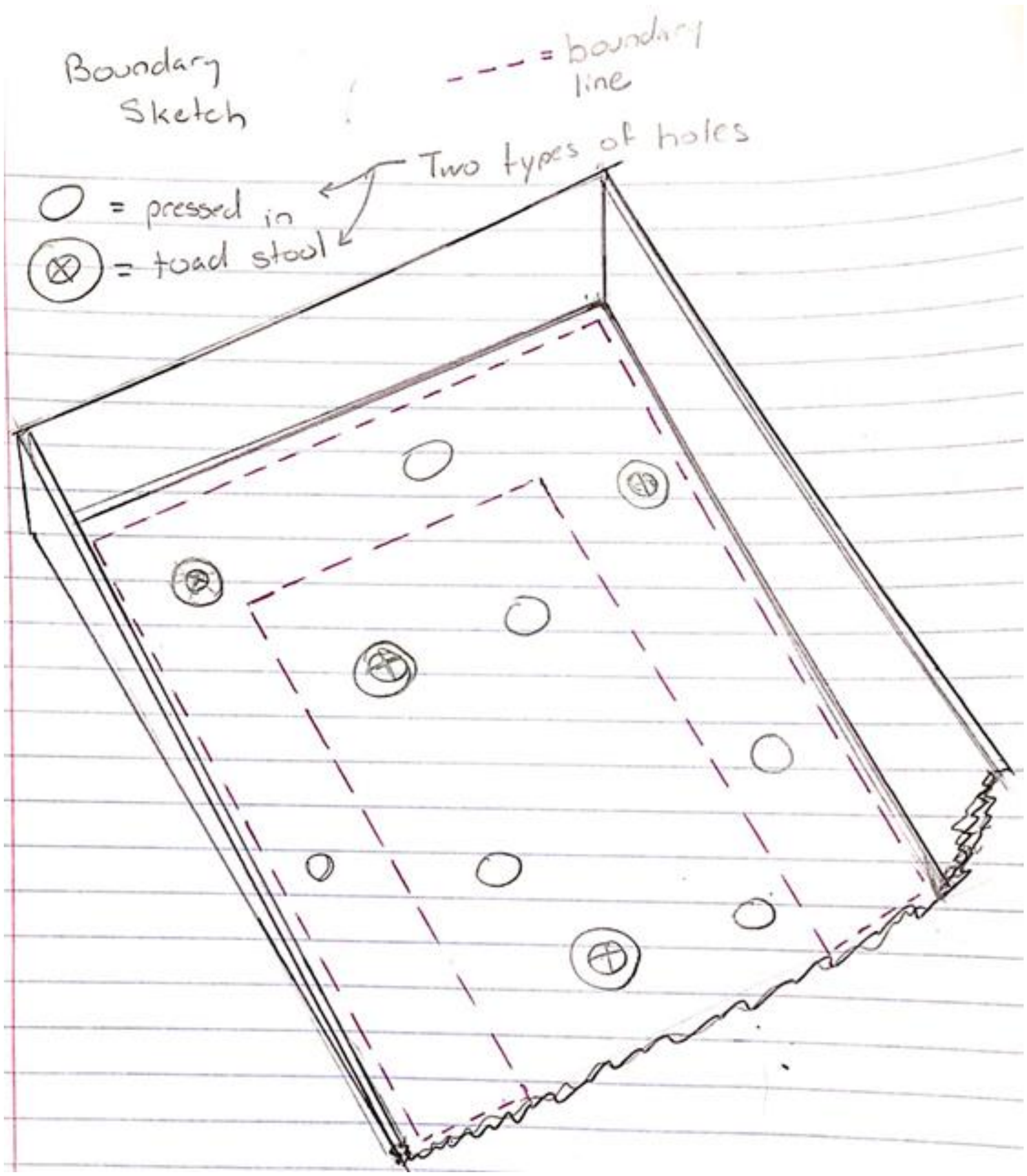

Figure 1. Boundary Diagram of 1RU Standardization Problem

3.2 Quality Function Deployment

Cisco currently has 30 different PCBs with a customized chassis for each. Our sponsor has asked our team to come up with a way to design a chassis that will serve multiple PCBs with an emphasis on the mounting locations. Table 3 below is a list of wants and needs for the rack mount.

Table 3. Sponsor Wants and Needs

Wants/Needs	Why this is desired
Common Geometry	-The 1RU had standard height and width -Reduce drastic alterations to avoid unexpected assembly/manufacturing consequences
Safe Assembly	-Ensuring no one gets hurt in the process of manufacturing or handling this design
Good Ergonomics/Easy Assembly	-Minimize the chances of error in assembly that could prohibit proper functionality
Simplified Production	-Cost savings in hard tooling
Manufacturability	-Meeting specifications for outsourced vendors to design the chassis in mass production
Transportable	-The chassis is getting shipped from an external vendor to be used by Cisco
Maintenance Friendly	-Want to be able to maintain chassis to avoid constant replacement
Cheap	-All cost reductions help Cisco in the long run
Durable	-Needs to house the PCB and prevent damage to the PCB

The QFD (Quality Function Deployment), commonly referred to as the House of Quality, helps identify specific design parameters to accurately meet the needs and wants of the sponsor. For the 1-9 criteria in the WHO section, a 1 indicates little relevance and a 9 indicates extreme importance for a given customer requirement. For the rest of the chart, a 1-5-point scheme is followed where a 1 indicates a low correlation and a 5 indicates a high correlation. The initial QFD was created from the wants and needs of our sponsor, seen in Table 3. Our full House of Quality diagram can be found in Appendix A.

Analyzing our QFD, the compact design specification has strong relationships with a lot of customer wants/needs and dimensions/geometry and has a lot of impact on our engineering specifications. We plan to narrow our focus on mounting location placement by analyzing pattern possibilities in multiple CAD files. Also, our QFD shows that good airflow has a lot of negative relationships with important specifications like cost, assembly, and common mounting locations so it is reasonable to work on these issues separately.

Table 4. Engineering Specifications Table

Spec #	Parameter Description	Requirements or Target	Tolerance	Risk	Compliance
1	Good Airflow (Thermal Management)	Temp of server does not exceed PCB component max. temp	N/A	M	A, T
2	Compact	19 in. in width	±4 in	M	S
3	Easy assembly	No specialized training required	N/A	M	I
4	Mounting Locations	Minimize perimeter locations	N/A	H	A, T
5	Toadstool/Standoff Usage	# of Toadstools > # of Standoffs	Max	H	A, T
6	Production Cost	Decrease by minimum of 10%	Min	M	A, I
7	Manufacturing Time	Decrease by minimum of 10%	Min	L	A, I
8	Drop Durability	Intact after an 84 in drop (48U height)	Min	M	A, T, I
9	Weight	25 lbs. or less	Max	L	S, I
10	Versatility	Usable for more than 3 different PCBS	Min	H	A

The criteria for the risk column are defined as follows; H = high risk (upmost importance for this project), M = medium risk (should be considered in final design, but not fully emphasized), and L = low risk (can be considered negligible for the scope of the entire project). The criteria for the compliance column are defined as follows; A = Analysis of certain parts/regions of the chassis, T = Testing of certain specification, S = Similarity to existing products, and I = Inspection of entire chassis.

A medium-risk specification includes ease of assembly. This is a safety concern because a complicated assembly will increase the risk for installation errors and potentially cause PCBs to slide out from the chassis and hit someone. The chassis are carried around and mounted individually in data centers. We want to reduce the risk of injury to any technician or to the board and chassis.

Thermal management is another medium-risk specification. As we standardize mounting locations, we must also take into consideration the LED locations, port locations, connectors, PS locations, and fan locations. Ensuring that the overall temperature of the chassis and PCB assembly is at an appropriate temperature during operation. Overheating of the assembly could become a fire hazard risk, jeopardizing other 1RU's and potentially putting lives at risk.

Two other high-risk specifications are the mounting locations and the versatility of the chassis. These specifications cover the vast majority of analyses that we are tasked with completing. Normalizing the mounting locations and allowing for unique PCB's to fit into a single chassis design will reduce manufacturing times and production costs greatly. Creative usage of embossed toadstools and standoffs will help us maximize the versatility of our chassis.

4. Project Management

Since our project centers around reviewing existing designs, we will shift our focus from brainstorming to analysis. We expect to receive approximately 30 CAD files from our sponsor that we will use to determine patterns. Patterns include placements and types of holes along the chassis perimeter. For example, if multiple CAD files indicate a standoff hole is located within 0.001” of each other, a pattern has been determined. After all patterns have been determined, we will make a case of a standardized feature for every pattern. Once our standardized design is complete, we will move into the manufacturing phase and build a prototype of our design.

Table 5. Due Dates of Important Deliverables

Deliverable	Due Date
Scope of Work	10/12/2020
Preliminary Design Review	11/15/2020
Critical Design Review	2/15/2021
Complete Prototype Build	4/30/2021
Final Design Review	6/08/2021

Table 5 shares the due dates of important deliverables. The entire timeline of deliverables can be found in our Gantt Chart in Appendix B. Since we are not creating a 1RU chassis from scratch, our design techniques rely on our observation and CAD analysis skills. We will primarily use SolidWorks to understand and analyze the CAD files we receive. Now that the research phase of our project is completed, we will begin our CAD analysis phase.

5. Conclusion

In this senior design project, our goal is to help Cisco save money by reducing the amount of custom chassis needed to be manufactured. The document above includes background research on the customer needs, the product, and the technicality of the project. Through research, our group was able to better understand the problem and find solutions to help Cisco designers. We then were able to utilize the QFD method and Gantt Chart to establish goals, evaluate criteria and deliverables for the project. Our next project deliverables will be to implement the SOW feedback to our existing report and start analyzing current CAD files provided by our sponsors.

6. References

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7. Appendix

A. QFD: House of Quality
B. Gantt Chart

QFD: House of Quality

Correlations	
Positive	+
Negative	−
No Correlation	

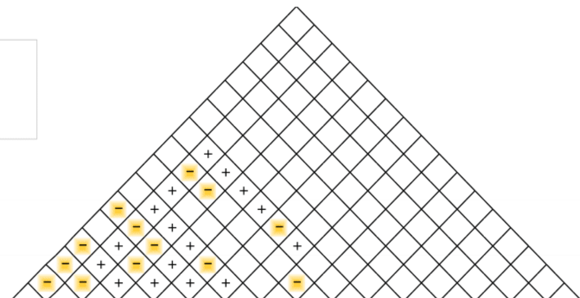
Relationships	
Strong	●
Moderate	○
Weak	▽

Direction of Improvement	
Maximize	▲
Target	◇
Minimize	▼

QFD House of Quality

Project: Cisco 1RU Chassis

Revision Date: 10/6/2020



Column #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Direction of Improvement	▲	▼	◇	▲	◇	▼	▼	▲	▼							
HOW: Engineering Specifications (Tests) / WHAT: Customer Requirements (Needs/Wants)	Good Airflow	Compact Design	Easy to assemble	Common Mounting Locations	Toadstool/standoff usage	Production Cost	Time of manufacturing proces	Durability if dropped	Weight	Ability to fit different PCB's						
Dimensions/Geometry	○	●	○	●	●			●		●						
Safe Assembly			●	○			○		○							
Ergonomics/easily mountable		●					○		○							
Simplified Production		○	●			○				▽						
Quality Control			○				●									
Manufacturable		●	▽		○					○						
Transportable Assembly		●						○	●							
Maintenance	●		▽		○	▽	▽	○	▽	○						
Cheap			○			●	○		▽							
Durable Assembly		●	○			○										

WHO: Customers

Row #	Weight Chart	Relative Weight	Cisco	Small Companies	Manufacturers	Technicians	Maximum Relationship	WHAT: Customer Requirements (Needs/Wants)
1		11%	9	3	8	6	9	Dimensions/Geometry
2		10%	6	5	9	5	9	Safe Assembly
3		10%	7	8	2	8	9	Ergonomics/easily mountable
4		11%	9	6	9	4	9	Simplified Production
5		8%	8	4	6	2	9	Quality Control
6		8%	6	2	8	3	9	Manufacturable
7		10%	2	8	7	7	9	Transportable Assembly
8		10%	4	9	3	9	9	Maintenance
9		9%	6	9	2	4	9	Cheap
10		12%	10	7	4	8	9	Durable Assembly
11		0%						
12		0%						
13		0%						
14		0%						
15		0%						
16		0%						

NOW: Curr. Products

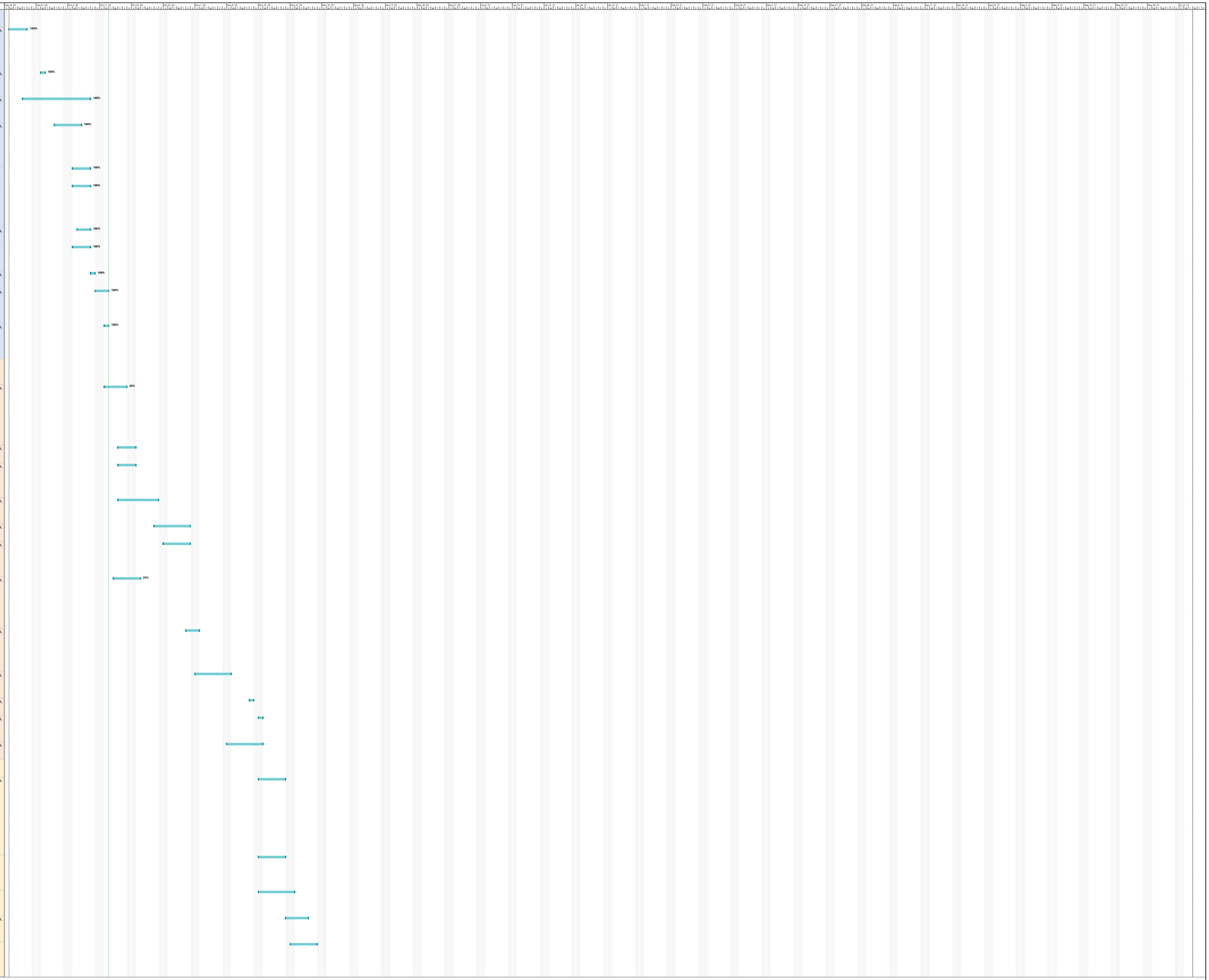
Cisco Network Covergence Sys	Cisco 9200 Switch for 32 ports	Cisco 4431 Integrated Services	Cisco 4331 Integrated Services	Arista DCS-7050S-52-R 7050S	Row #
3	3	4	4	3	1
5	5	5	5	3	2
1	1	5	5	3	3
1	1	1	2	1	4
4	4	3	4	3	5
3	5	4	5	5	6
5	5	4	5	5	7
3	3	3	3	5	8
1	2	3	3	3	9
5	5	4	3	5	10
					11
					12
					13
					14
					15
					16

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	HOW MUCH: Target Values	2 times Max temp of system < PCB max	1.73 feet in length max	Doesn't require special training	4 Mounting Locations	More utilized (#)	Production Cost (lowered by ##%)	Mnfg. time (lowered by ##%)	Chassis doesn't break from 84 inch	Weight - 30lbs or less	1 Chassis Commonized for 3						
	Max Relationship	9	9	9	9	9	9	9	9	9	9						
	Technical Importance Rating	126.6	493	333.1	127.6	151.4	157.8	171.3	158.4	172.7	162.9	0	0	0	0	0	0
	Relative Weight	6%	24%	16%	6%	7%	8%	8%	8%	8%	8%	0%	0%	0%	0%	0%	0%
Curr. Products	k Covergence System 5000 Series	5	5	4	4	4	3	3	2	5	2						
	Cisco 9200 Switch for 32 ports	5	4	4	4	4	4	4	2	5	2						
	4431 Integrated Services Router	4	2	3	2	3	3	3	2	3	2						
	4331 Integrated Services Router	4	2	3	2	3	3	3	2	3	2						
	SFP+ Rear to Front Airflow Switch	5	2	2	1	3	2	3	2	4	2						
	Column #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

Gantt Chart

(On next page due to quality issues when converting pdf to png)

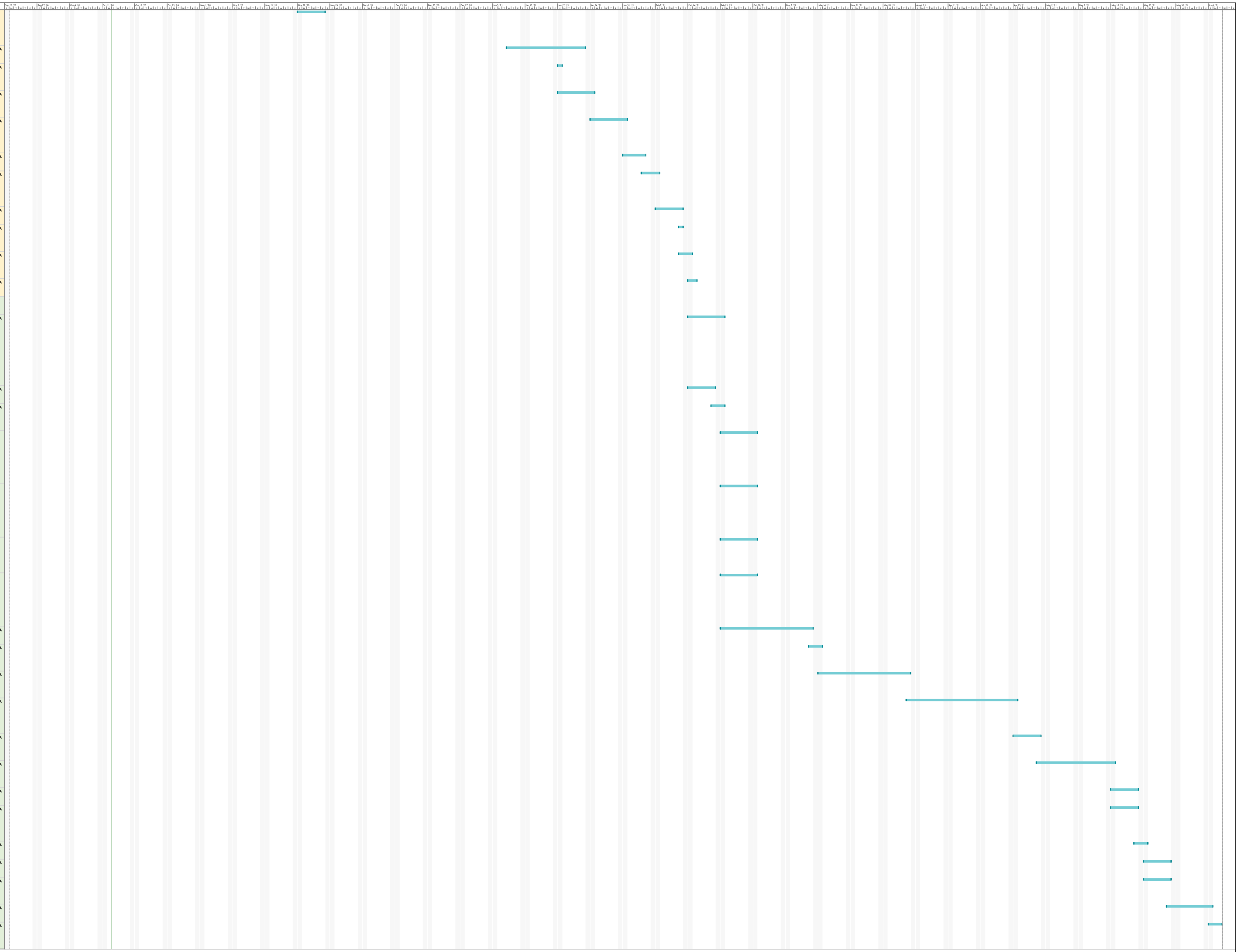
ID	Task Name	Duration	Start	Finish	Progress	Assigned To
1	Scope of Work (SOW)					
2	Conduct Initial Background Research before meeting with sponsor	4 days	Mon 9/21/20	Thu 9/24/20	100%	Bryce, Sarika, Leia, John
3	Meet with Sponsor for Initial Meeting	1 day	Mon 9/28/20	Mon 9/28/20	100%	Bryce, Sarika, Leia, John
4	Complete Technical Research	11 days	Thu 9/24/20	Thu 10/8/20	100%	Bryce, Sarika, Leia, John
5	Develop a Problem Statement and Boundary Diagram	4 days	Thu 10/1/20	Tue 10/6/20	100%	Bryce, Sarika, Leia, John
6	Create House of Quality	4 days	Mon 10/5/20	Thu 10/8/20	100%	Bryce, Leia
7	Complete Engineering Specifications from House of Quality	4 days	Mon 10/5/20	Thu 10/8/20	100%	Bryce, Leia
8	Complete Rough Draft of SOW	3 days	Tue 10/6/20	Thu 10/8/20	100%	Bryce, Sarika, Leia, John
9	Create Gantt Chart for the Project	4 days	Mon 10/5/20	Thu 10/8/20	100%	Sarika, John
10	Peer Review Scope of Work	1 day	Fri 10/9/20	Fri 10/9/20	100%	Bryce, Sarika, Leia, John
11	Complete revisions and edits of Scope of Work	2 days	Sat 10/10/20	Mon 10/12/20	100%	Bryce, Sarika, Leia, John
12	Deliver Final Scope of Work to Advisor and Sponsor	1 day	Mon 10/12/20	Mon 10/12/20	100%	Bryce, Sarika, Leia, John
13	Preliminary Design Review (PDR)					
14	Update Abstract, Introduction, Conclusion and Background Sections in Report using SOW feedback	5 days	Mon 10/12/20	Fri 10/16/20	50%	Bryce, Sarika, Leia, John
15	Begin Intial Ideation Stage	3 days	Thu 10/15/20	Sun 10/18/20		Bryce, Sarika, Leia, John
16	Complete Functional Decomposition Breakdown	3 days	Thu 10/15/20	Sun 10/18/20		Bryce, Sarika, Leia, John
17	Complete building of Ideation Models	7 days	Thu 10/15/20	Fri 10/23/20		Bryce, Sarika, Leia, John
18	Finalize Ideation Concept Designs	6 days	Fri 10/23/20	Fri 10/30/20		Bryce, Sarika, Leia, John
19	Create and Add Concept Designs/Ideation to Report	6 days	Sun 10/25/20	Fri 10/30/20		Bryce, Sarika, Leia, John
20	Update Project Management and Objective Section in Report using SOW feedback	4 days	Wed 10/14/20	Mon 10/19/20	25%	Bryce, Sarika, Leia, John
21	Create prototype models in SolidWorks and add Screenshots to Report	2 days	Fri 10/30/20	Sun 11/1/20		Bryce, Sarika, Leia, John
22	Complete Final Draft of PDR Report	7 days	Sun 11/1/20	Sun 11/8/20		Bryce, Sarika, Leia, John
23	Deliver PDR Lab Presentation	1 day	Fri 11/13/20	Fri 11/13/20		Bryce, Sarika, Leia, John
24	Deliver PDR Presentation to Sponsor	1 day	Sun 11/15/20	Sun 11/15/20		Bryce, Sarika, Leia, John
25	Deliver PDR Report	7 days	Sun 11/8/20	Sun 11/15/20		Bryce, Sarika, Leia, John
26	Critical Design Review (CDR)					
27	Update Introduction, Conclusion, Background, Objectives and Concept Designs from the Report using feedback from PDR	6 days	Sun 11/15/20	Fri 11/20/20		Bryce, Sarika, Leia, John
28	Complete Design Considerations for Safty and FMEA	6 days	Sun 11/15/20	Fri 11/20/20		Sarika, Leia
29	Complete Design Considerations for DFMA	7 days	Sun 11/15/20	Sun 11/22/20		Bryce, John
30	Decide on Final Design and add to the report	4 days	Sat 11/21/20	Wed 11/25/20		Bryce, Sarika, Leia, John
31	Create a Manufacturing Plan for the Final Design	6 days	Sun 11/22/20	Fri 11/27/20		Sarika, Leia



Project: Gantt Chart
Date: Tue 10/13/20

Task | Split | Milestone | Summary | Project Summary | Inactive Task | Inactive Milestone | Inactive Summary | Manual Task | Duration-only | Manual Summary Rollup | Manual Summary | Start-only | Finish-only | External Tasks | External Milestone | Deadline | Progress | Manual Progress

ID	Task Name	Duration	Start	Finish	Progress	Assigned To
32	Create a Design Verification Plan for the Final Design	6 days	Sun 11/22/20	Fri 11/27/20		Bryce, John
33	Conduct Design Analysis	13 days	Wed 1/6/21	Fri 1/22/21		Bryce, Sarika, Leia, John
34	Present Interim Design Review in Lab	1 day	Sun 1/17/21	Sun 1/17/21		Bryce, Sarika, Leia, John
35	Complete CAD/Part Selection	7 days	Sun 1/17/21	Sun 1/24/21		Bryce, Sarika, Leia, John
36	Complete Manufacturing Plan, DBP, and Drawings	7 days	Sun 1/24/21	Sun 1/31/21		Bryce, Sarika, Leia, John
37	Complete Yellow Tag Test	5 days	Sun 1/31/21	Thu 2/4/21		Bryce, Sarika, Leia, John
38	Deliver Drawings and Manufacturing Plan Review	3 days	Thu 2/4/21	Sun 2/7/21		Bryce, Sarika, Leia, John
39	Create CDR Presentation	6 days	Sun 2/7/21	Fri 2/12/21		Bryce, Sarika, Leia, John
40	Deliver CDR Presentation in Lab	1 day	Fri 2/12/21	Fri 2/12/21		Bryce, Sarika, Leia, John
41	Update CDR Report Based on Feedback	2 days	Fri 2/12/21	Sun 2/14/21		Bryce, Sarika, Leia, John
42	Deliver CDR to Sponsor	2 days	Sun 2/14/21	Mon 2/15/21		Bryce, Sarika, Leia, John
43	Final Design Review (FDR)					
44	Update Introduction, Conclusion, Background, Objectives from the Report using feedback from PDR	7 days	Sun 2/14/21	Sun 2/21/21		Bryce, Sarika, Leia, John
45	Complete Risk Assesment	6 days	Sun 2/14/21	Fri 2/19/21		Bryce, Sarika, Leia, John
46	Complete Safety Review and Order Parts	2 days	Fri 2/19/21	Sun 2/21/21		Bryce, Sarika, Leia, John
47	Convert and Add to Manufacturing Plan from CDR (Label Manufacturing)	7 days	Sun 2/21/21	Sun 2/28/21		Sarika, Leia
48	Convert and Add to Design Verification Plan from CDR (Label Design Verification)	7 days	Sun 2/21/21	Sun 2/28/21		Bryce, John
49	Modify Project Management Section using CDR feedback	7 days	Sun 2/21/21	Sun 2/28/21		Sarika
50	Update Conclusion and Recommendation Section of Report using CDR feedback	7 days	Sun 2/21/21	Sun 2/28/21		John
51	Begin Builiding Prototype	16 days	Sun 2/21/21	Fri 3/12/21		Bryce, Sarika, Leia, John
52	Conduct Manufacturing and Test Review	2 days	Fri 3/12/21	Sun 3/14/21		Bryce, Sarika, Leia, John
53	Complete Experiemntal Design	16 days	Sun 3/14/21	Fri 4/2/21		Bryce, Sarika, Leia, John
54	Continue Building and Refining Prototype	17 days	Fri 4/2/21	Sun 4/25/21		Bryce, Sarika, Leia, John
55	Complete Building Prototype	6 days	Sun 4/25/21	Fri 4/30/21		Bryce, Sarika, Leia, John
56	Complete Prototype Testing	12 days	Fri 4/30/21	Sun 5/16/21		Bryce, Sarika, Leia, John
57	Achieve DVPR Sign Off	6 days	Sun 5/16/21	Fri 5/21/21		Bryce, Sarika, Leia, John
58	Create Senior Design Project Poster/Final Presentation	6 days	Sun 5/16/21	Fri 5/21/21		Bryce, Sarika, Leia, John
59	Conduct Poster Peer Review	2 days	Fri 5/21/21	Sun 5/23/21		Bryce, Sarika, Leia, John
60	Complete Rough Draft of FDR	6 days	Sun 5/23/21	Fri 5/28/21		Bryce, Sarika, Leia, John
61	Finish Preparing for Expo and Print Poster	6 days	Sun 5/23/21	Fri 5/28/21		Bryce, Sarika, Leia, John
62	Complete FDR Reprt Revisions	7 days	Fri 5/28/21	Sun 6/6/21		Bryce, Sarika, Leia, John
63	Deliver FDR to Advisor and Sponsor	3 days	Sun 6/6/21	Tue 6/8/21		Bryce, Sarika, Leia, John



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