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Cubesat 5000

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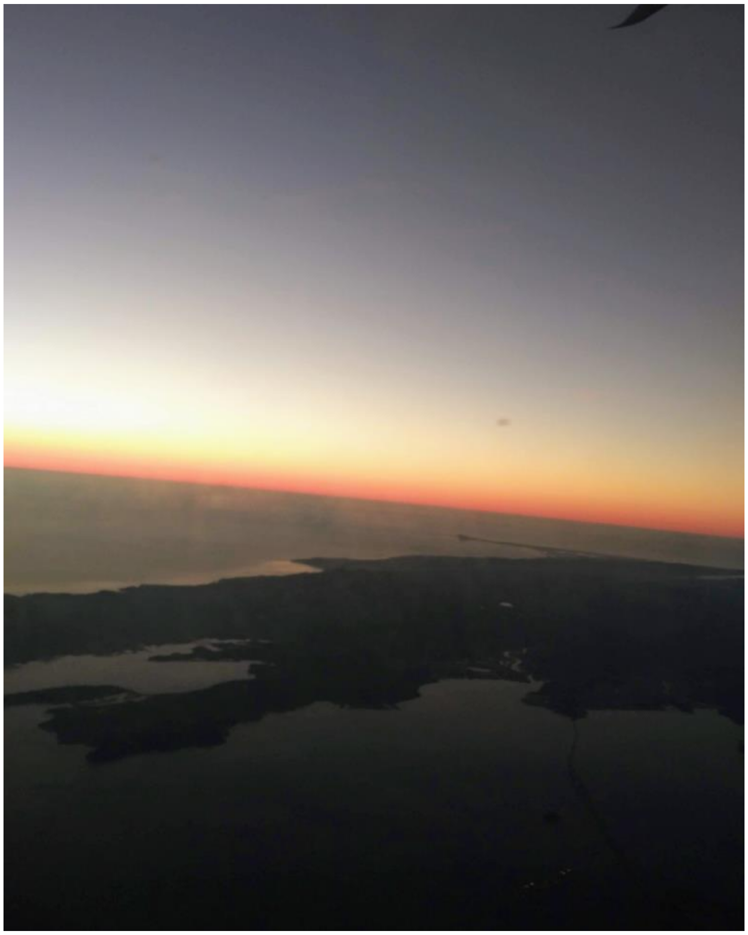

CUBESAT 5000

ABSTRACT

This is the Senior Project of Renee Redman in collaboration with the CWU MET department and CWU physics department.

Renee Redman

Cubesat 5000

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Introduction

Description

The Cubesat 5000 is being made to support the physics department in their weather balloon launch class. The Cubesat 5000 is used to contain all electronics and sensors for the payload, which will include insulation and detachable mounting panels.

The Cubesat 5000 will be attached to a payload system which contains electronics chosen by the by the weather balloon class lead by Dr. Darci Snowden including a parachute and dismounting method. The purpose of the exercise it to gather data on conditions within the stratosphere as well as the entire distance on the way there and back.

The issue with the current system is that the current class will need to design the sensors and internal electronics that need to go into their individual CubeSats as well as the payload and dismounting mechanisms and to contain all those they

current utilize cardboard boxes. The idea behind the Cubesat 5000 is that creating a more insulated lightweight design that will allow a more successful design as well as remove the need on the students to create the cubesat containment. By improving the insulation the electronics will be able to function better and by having a light weighted design the launch will proceed faster and reach better heights.

Motivation

The motivation behind this project is to improve the pay load capabilities as well as creating a more secure containment for the electronic components which will allow for more precise measurements further into the atmosphere. By keeping the containment lightweight the balloon will be able to reach greater heights and optimize the sensors to get more accurate readings. The Cubesat 5000 will also allow the students of Dr. Darci Snowden's class to focus on the electronics and sensor, as that is what the primary purpose of the weather balloon launch.

This will be done with readily available material and will create a safe containment unit for the electronics.

Function Statement

The Cubesat 5000 will contain the pay load and sensors for the physics department balloon launch.

Requirements

The requirements for the Cubesat 5000 are

i. Weight less than 400 g
ii. To withstand acceleration of 9.81 m/s^2
iii. To be within 8,000 cm^3
iv. To withstand a force of 5 N upon impact.
v. Be insulated to withstand below freezing temperatures

Engineering Merit

The engineering merit of the Cubesat 5000 is for the design to be created as efficiently as possible such that it can be recreated for continues classes and for the design to be made as accurately as possible such that the date from the balloon launch is repeatable.

All panels will need to withstand impact forces, therefore all dimensions will need to be determined off of force impact calculations.

Success requirements

The success of the Cubesat 5000 will be determined if it survives all its testing and can be successfully contain all the electronic components needed for the data collection.

The weight will need to be within 20% of the weight requirement including the external and internal paneling and not including the insulation or electronic components.

After a successful launch the Cubesat 5000 will need to be in the same amount of components prior to the launch and still remain sealed such that none of the electronics get lost or tarnished by the outside elements.

Design and Analysis

Approach: Proposed Solution

The proposed solution that the team has come up with for the Cubesat 5000 is a 3D printed assembly consisting of exterior cube five-sided cube, a lid, six pieces of beveled insulation foam, five internal, and a 'harness'. The rest of the complete weather balloon systems contains the 4ft diameter weather balloon which is filled with helium enough to lift the system, the rope to contain everything, the electronics for the payload (Arduino board, color sensor, led lights, altimeters, temperature gauges, etc.) the GoPro which will be mounted externally, and the GoPro protective casing.

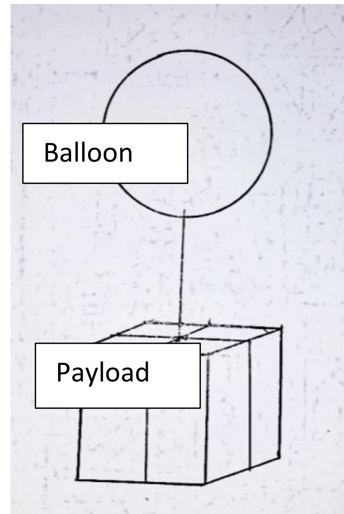


Figure 1 Concept drawings

Design Description

The design rendering (figure 1-right) shows the external panels (pink) which are isogrid to decrease to total weight. The lid (purple) is designed to slid into the slots on the top of the external panels and is primarily there to ensure the insulation will not fall out. The internal panels are panels quarter cm thick with repeated hole patterns for mounting and four attachment points to connect into the foam. The 'harness' (yellow) encases the entire cube assembly and contains tracks for the rope to maintain their position around the cubesat to avoid slippage.

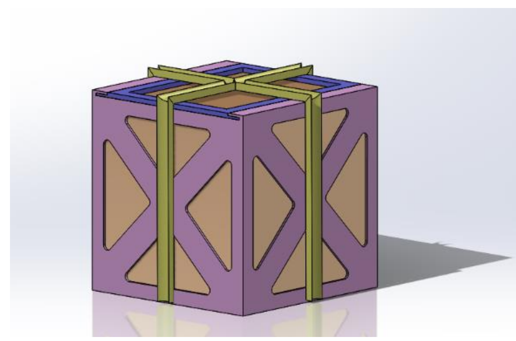


Figure 2 Design rendering

Benchmark

The current system used by the weather balloon class is simply a cardboard box which can contain additional foam insulation or a battery powered heater in order to keep the electronics at the necessary temperatures to remain functioning.

This design does to provide the same impact protection as the Cubesat 5000 and requires that the battery that cause the risk facture of not functioning or losing power and therefore risk all electronics breaking.

Performance Predictions

It is believed that the Cubesat 5000 will survive an impact up to 7 newtons and weight less than 1 kg.

Analysis Description

The analyses consist primarily of weight, impact, failure predictions, and insulation capability calculations.

Scope of Testing and Evaluation

The cubesat will be impact on the edges and center of the paneling, the k factor of the 3D printed part, and the weight of the assembly.

Analysis

The following calculations are all done and can be seen under appendix A while more in-depth descriptions on the process can be viewed here.

Terminal Velocity Calculations

These calculations were done in order to ensure the Cubesat 5000 will survive the impact with the Earth and can be viewed under appendix A.1. The terminal velocity was calculated based on the dimensions of a simple cube with an initial velocity of zero due to the release of the cube starting at apogee. From there the Cubesat 5000 will be acted upon by gravity until the drag force is equal to the downward force from gravity. The terminal velocity was calculated to be 48 m/s and will take approximately 8 seconds to be achieved (App. A.1). These values will then be used as the initial velocity after the release of the parashot in order to calculate the final velocity at impact.

Travel Under Terminal Velocity

The purpose of this calculation is to determine the portion of time the part is traveling under static equilibrium. Since the distance traveled as it accelerates (App A.1) can be calculated and the maximum distance the part travels is known it has been determined that less than 1% of the total travel will be spend decelerating before the parachute deploys.

Density of Poplar Wood

The density of Poplar wood was determined experimentally off a piece of scrap provided by the CWU wood shop. The density was necessary to determine the experimental weight of the Cubesat 5000 if the material had been made out of wood and therefore part of the decision process before the client had decided on 3D printing. The area and weight were measure and the density was found to be 976 kg/m^3 (App A.2).

Weight of a Wooden Section

This calculation done using the experimental density of poplar wood (App A.3) and the dimensions of the original design for individual external panels. Since the wooden design was rejected by the client the calculations were not redone as it was no longer relevant to the final product. The section was assumed to be a solid part with a single isotropic density.

Cumulative Weight Calculations

These calculations were done in order to ensure the weight of the external panels did not exceed the maximum weight requirement. These were also done as part of the decision process when deciding if the Cubesat 5000 would be made out of wood or 3D printed. The total weight of all external panels ended up being experimentally determined to be about .4 kg (App A.2). The calculations were done using a density calculated from a scrap piece of poplar wood provided by the CWU wood shop. Once the weight was determined the area of a panel was multiplied against the density to gain the weight which was multiplied by the six panels determined in the original design. These calculations were not redone after the redesign since it was no longer applicable in the final product.

Continued cumulative weight calculations

These calculations are a continuation of the weight calculations (App A.5) for the internal panels. The calculations continued as the external panels using the experimentally determined density of poplar wood and was determined to be 200 grams for all 6 internal panels (App A.6). These calculations were not redone after the redesign as the client did not continue with the wooden design.

Drag Force Calculations

These calculations were done to determine the drag force applied by the parachute the moment the parachute opens (App A.8) The velocity used in the equation was done using the initial force to determine the maximum force on the payload. The value of the drag force with a 1-meter radius parachute was determined to be 3 kN which is only for the instantaneous velocity at the moment the parachute opens. This value will not be exact as the parachute does not open instantaneously, however the time needed for the parachute to start deploying nor for the it to start creating drag are unknown.

Parachute Drag Calculations

The drag force calculations were done to determine the final velocity of the cube at impact as stated in section terminal velocity above. The final velocity was calculated using the initial velocity of 44 m/s (App A.1) and was then set up in an excel spreadsheet to calculate the velocity over time (App A.8 Figure 7). These values are all done with the assumption that the parachute opens instantaneously since it cannot determine the rate at which it opens.

Component Attachment Points

These analysis were done to determine weather the electronic would be securely mounted in the internal assembly during the launch. The main component for this was dependent on the shear stress in the mounting attachment points. The stress was calculated (App A.9) and determined that the maximum value was determined to be below the yield for PETG.

Lid Stress Top Force

This stress was calculated to determine what force would need to break the lip lid mechanism in the third design for the outer cube assembly. The maximum force is over yield (App A.10) which cause the redesign for version 4 of the outer assembly which doesn't rely on strength of the material and instead uses rubber bands to secure the lid. Additionally, by removing the lip lid assembly the force will transfer through the body of the outer assembly instead of into the lid.

Lid Stress Side Force

The calculation for the side force lid stress (App A.11) which relates to the impact survival aspect of the SatCube requirements. Similarly to the top force, the side force goes past yield which cause consideration for redesign.

Method

This project was conceived, analyzed and designed at CWU in collaboration with the Physics department and the MET department. The CubeSat will be constructed out of resources available to both departments and once completed will remain within the physics department. The design will need to be manufactured quickly and in large quantities in order for the entirety of the weather balloon class to complete their individual projects.

The material used will be PetG filaments as the material is more flexible than ABS filament. By being more flexible the moment of impart will be extended, decreasing the instantaneous force on the assembly.

Analysis will be based off material weight since there is a weight requirement associated with this project. Since weight is so important to the success criteria and the client, all dimensions will need to analyzed for impact and deflection of the material.

Since another requirement of the Cubesat 5000 is the ability to insulate in subzero temperatures, calculations will need to be done to determine the insulation ability. There are two different insulations available within the CWU physics department so a calculated decision will need to be made with regards to that.

The engineering areas of discipline are both statics and dynamics for the impact calculations as well as thermodynamics for the insulation calculations.

The equations used will be

Shear stress = Force/area

Displacement = Force *length/area*modulus of elasticity

The optimization will happen in the weight due to displacement calculations and stress analysis on the material. If the area of the paneling is not big enough to prevent the stress of the material from passing its yield point.

Due to the insulations being provided by the CWU physics department the choices will be limited to the available material and size being limited set by the client there isn’t much possible to optimize besides choosing the best material using a decision matrix.

Construction

The original design of the Cubesat 5000 consisted of six individual external panels which were to be mounted together using bracket joints, however due to several requests form the client this design was changed to consist of a shell like cube with a separate lid. The client has requested that the internal components could be slid out of the outer shell so that it is easy to assemble and work on. All components also had to be available within the physics department and they did not own any hardware that could have been used to secure the paneling.

The new design will only have three external components so that the insulations can be inserted, and the internal paneling can be placed onto the insulation. Once all internal components are inserted the lids will be place over top and a frame is placed over the cube for the rope to lay and to secure the lid on the assembly.

The Cubesat 5000 will be 3D printed in the Physics Department out of PETG. PETG is chosen instead of the ABS or other materials since PETG is rather flexible once 3D printed and it has better resistance to temperature change.

The internal paneling will have a repeated hole pattern for the electronics to affix to. The paneling has four spikes that come out of the four corners which get pushed into the insulation to had them in place. This is to prevent the paneling from moving around during flight and to protect the electronic from bumping into each other or coming loose.

The frame placed over the cube will cross across the middle of one cube side both horizontally and vertically and then extend over the four adjacent sides of the paneling. The frame will be flat against the cube paneling but have a concave shape on the other edge for the rope to lay against and to prevent the Cubesat 5000 from slipping out of the rope.

The design had to be changed in order to simplify the assembly for launch. The second design had a lip hanging over that the internal assembly would slid into and hold the lid down however, this would make inserting the insulation very difficult and could potentially interfere with the satellite electric component. To mitigate this design the lid has been removed as well as the front facing side of the exterior cube, leaving it with only the bottom, back, and two sides.

The harness was also redesigned to cover the edges of the cube instead of the sides, increasing the impact resistance when the corner will strike the earth.

Parts list

CubeSat 5000 contains the following

- External panel
- External panel lid
- Insulation
- Internal panel
- Harness

Parts included in the system that are not part of the CubeSat 5000 however still required the total system are

- Rope
- 4ft diameter weather balloon
- Arduino board
- Color sensor
- Led lights
- Altimeter

Manufacturing issues

The issues in manufacturing come down to either the 3D printing process such as the temperature of the heater not being set to the proper temperature needed to extract the filament or cooling too quickly.

Issues in the assembly stem from the lip area needing to be smaller than the insulation panels and therefore needing to be inserted at an angle and in a specific order.

Additional issues with manufacturing with the 3D printer come from the fill amount of each part. The internal panels does not impact with anything and therefore do not require large amounts of fill, however if there are not enough layers on the outer side of the part the mounting mechanisms will not print properly. Since the mounting is based off of a small area attached to the panels themselves, if the layers are not thick enough during printing the area the pins are actually attached too are not enough for the part to have any structural integrity. However, by increasing the fill percentage of the internal panels the total weight of the Cubesat 5000 will go up and can push the assembly past the acceptable weight limit.

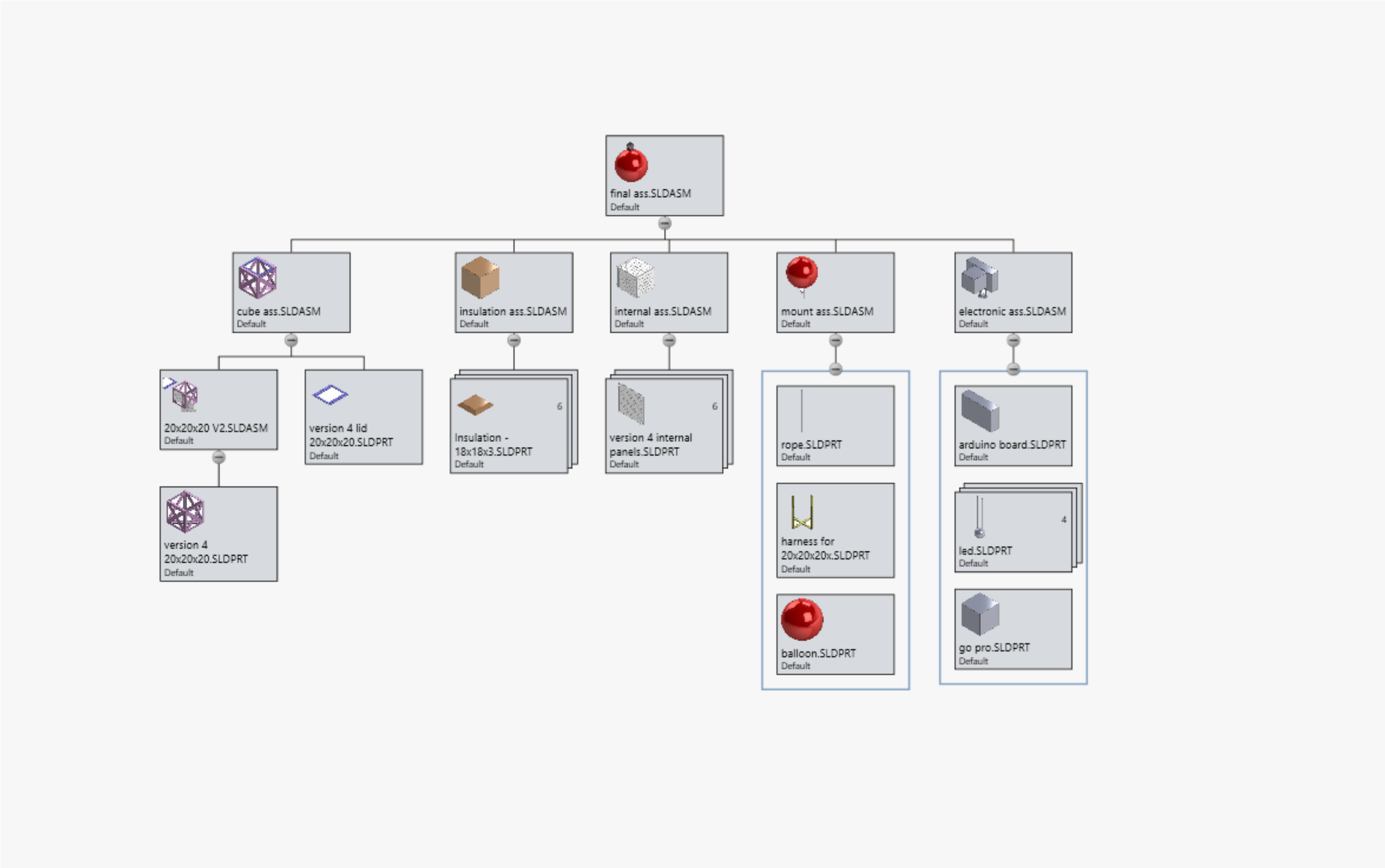


Figure 1 Drawings tree

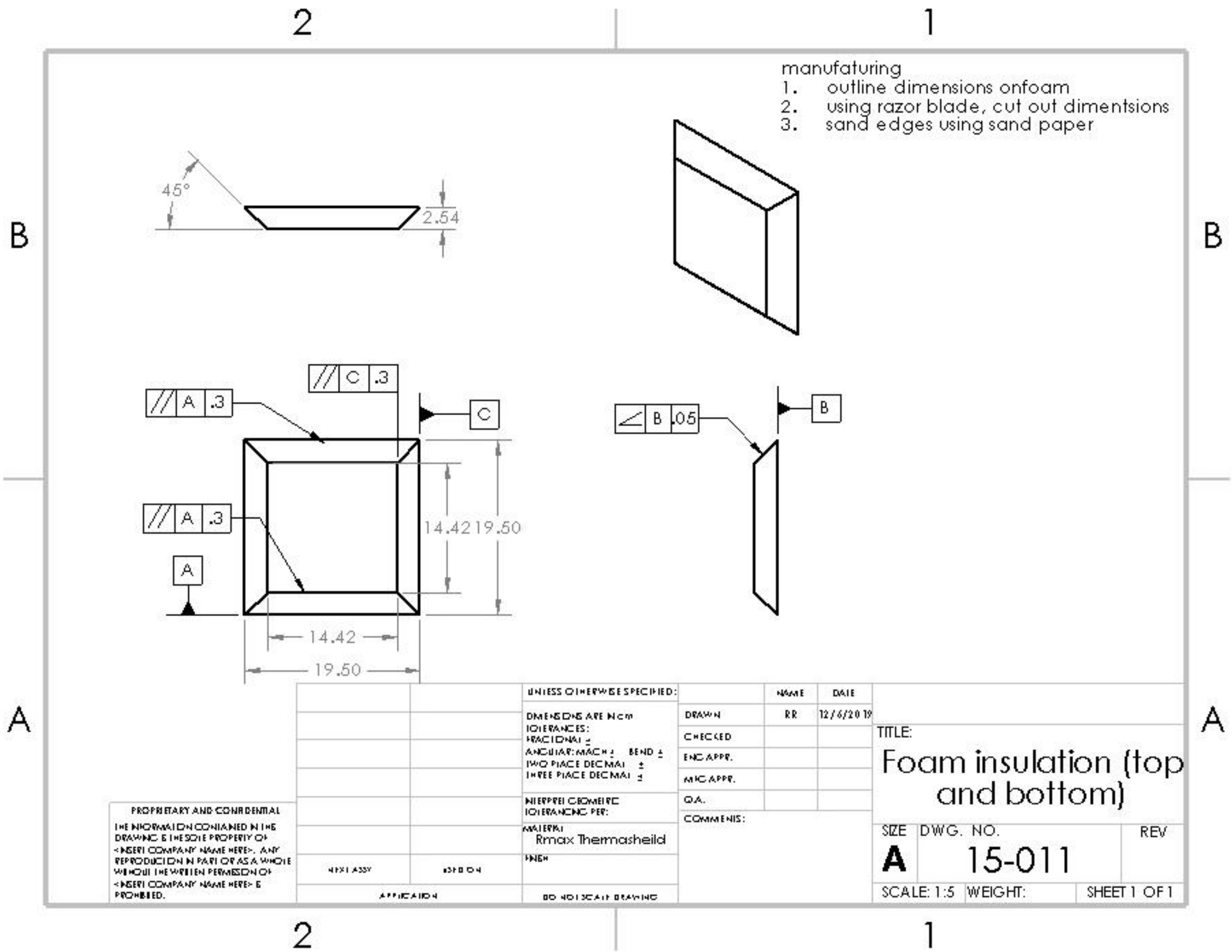


Figure 2 Insulation drawings for construction

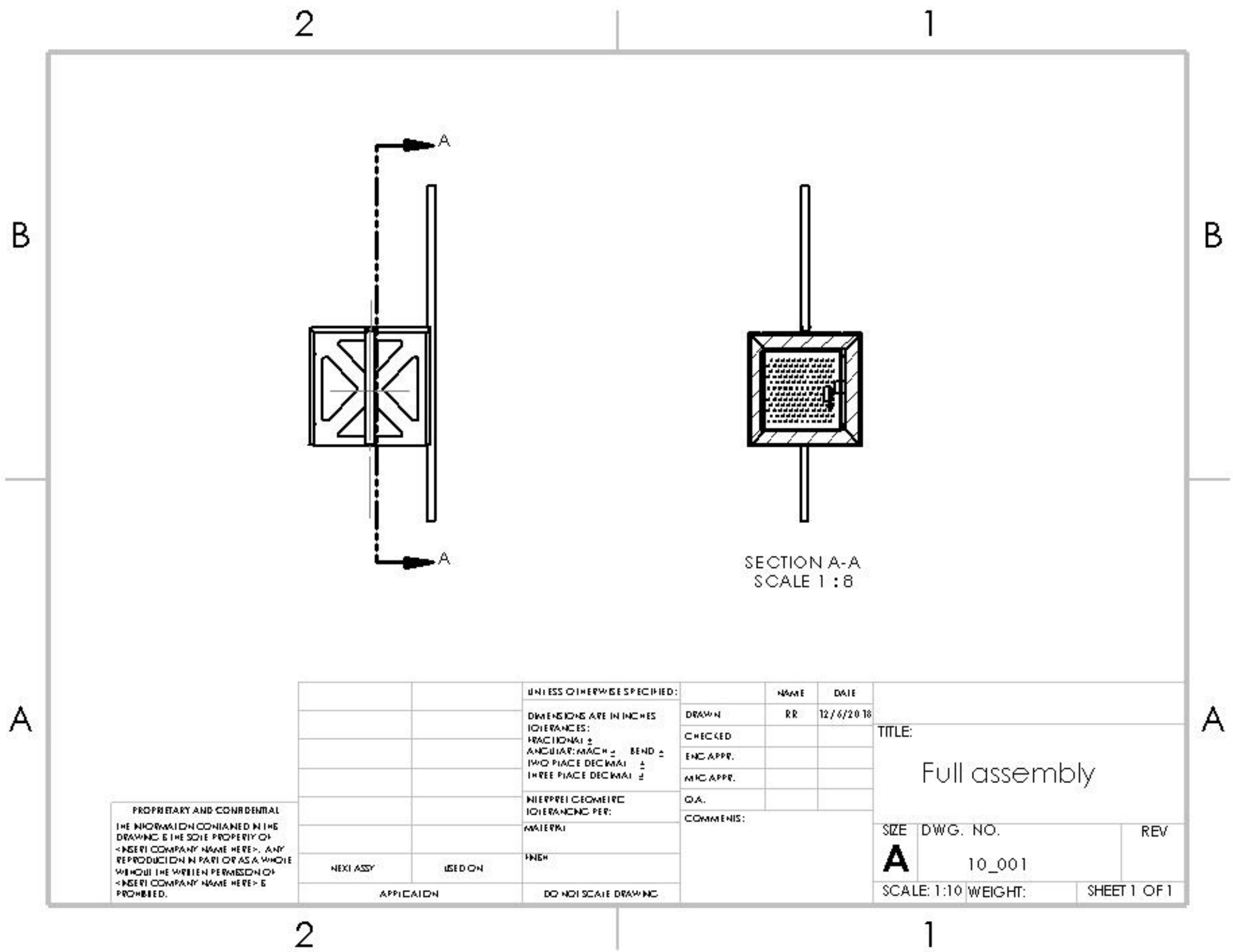


Figure 3 Full assembly Drawing

Testing

The testing of the Cubesat 5000 will consist of ensuring the weight, impact survival, and cold resistance requirements are fulfilled.

Method and Approach

Weight

The testing section of the Cubesat 5000 will consist of different material compositions to figure out which material will be the lightest however the weight requirement will likely be the last to be tested as it is already unlikely to pass requirement. It is also more important the functionality of the Cubesat 5000 remain and it is able to still function with a heavier weight, it just decreases functionality.

For the weight requirement, the final and complete assembly will be placed on a scale and weighed to determine to total weight. If the assembly is too large to fit on the scale the individual components will be weighed instead. This is the secondary option since there is room for error in the form of glue or tape that will be needed to insulate the foam and secure the internal panels.

Cold resistance

The temperature resistance will be tested however it is not determined however the option available at CWU is using a freezer as well as the potential of using liquid nitrogen.

Impact

The Cubesat 5000 paneling will go through impact testing and deflection testing to determine if it will be able to survive the impact and if the deflection of the material is sufficient to protect the internal electrical components.

For impact resistance the filament will be tested to determine it elastic and rigidity properties as well as impact testing with several weights available in the CWU materials lab.

Results

Impact

Testing for impact consisted of using a 10 oz weight and determining the energy on impact from several different heights. The initial expectation for testing would be done with different weights to determine the force on the assembly, however due to the limitation on material the calculations have been changed to Joules. All calculations are done by determining the potential energy of 10 oz. weight and releasing it for impact onto the assembly.

The test was done on the total assembly, not individual panels as initially planned, as it was a more accurate reflection of a successful launch. While the assembly was able to survive the testing with minimal damages, the results were not as expected. Due to majority of the part being made from 3D printing, the part will delaminate individual sections of filament, causing chipping to outermost edges.

The expected results were ¼ inch deflection at 2 J impact, however upon testing there was no visual deflection. The entire assembly was able to function safely with a safety factor of 2, however past that the delaminating/chipping has started (Appendix G Figure 25). As the testing is done on the edge of the assembly this is likely the worst-case scenario for impact.

Budget

While there are quite a lot of parts listed on the parts list (App D) the Cubesat 5000 team is only responsible for the parts on the Cubesat containments units and therefore do not need to concern themselves with the any parts on the budget outside of the filament and insulation.

The total cost for the final system costs about $580 with a large part of the total cost consisting of the helium needed to launch the balloon. The Cubesat 5000 will only consist of the filament and insulation and therefore only cost $60.

There are no labor or manufacturing cost that go into the budget as all parts are either 3d printed or cut from the on hand insulation. The CWU physics department has a technician on hand for the 3d printing. The CWU Physics department also already has the filament and insulation on hand which will be used for the construction of the CubeSat 5000 and therefore will donate the necessary materials to this project.

Most of the electrical components will be purchased by the physics department from the website *Adafruit.* All tools and materials such as rope are already available within the CWU physics departments and will be reused from past balloon launches.

After a couple of redesign the budge now includes a packet of rubber bands and after running through a couple of reams of filament the initial estimate was doubled.

There is also the potential to reanalyze the filament used during printing which would increase the budget cost as well as require parts to be purchased instead of using the supplies the physics department already owned.

The use of filament also increases due to many of the prints being restarted or failing and needing to be redone.

The change of print material will not change the cost of the prints already done since they will not be reprinted as the only parts printed before the repurchase are the internal panels and the lid of the cube assembly.

All testing is being done in house and therefore being done with materials already on hand. Due to this no changes are being made to the budget that would increase expected costs. The only issues experienced throughout this project would be the limited amount of supplies available in the build. When working on the insulation all cuts needed to be made if there were any errors in the initial cuts.

Due to global events the Cubesat 5000 could not actually be launched as the class in mind had to be canceled during the 2020 school year. Therefore the helium was not purchased during.

Schedule

Gantt Schedule

X to indicate work

PROJECT TITLE: CUBESAT 50000
Principal Investigator: Renee Redman

Note: March x Finals
Note: June x Presentation
Note: June y-z Spr Finals

TASK ID	Description	Duration Est. (hrs)	Actual (hrs)	%Com
1	**Proposal***			
1a	Outline	1	3	
1b	Intro	1	3	
1c	Methods	3	1.5	10
1d	Analysis	12	15	40
1e	Discussion	2	4	0
1f	Parts and Budget	5	5	20
1g	Drawings	6	20	0
1h	Schedule	2	5	10
1i	Summary & Appx	5	6	0
	Testing			
	subtotal:	37	62.5	
2	**Analyses**			
2a	termianl velocity	0.5	0.5	
2b	travel under terminal velocity	0.5	0.5	
2c	density of poplar wood	0.2	0.5	
2d	weight of wooden section	0.2	0.5	
2e	cummulative weight	0.5	0.5	
2f	continued cummulative weight	0.5	0.5	
2g	drag force calcuations	1	0.5	
2h	parachute drag calculations	1	2	
2i	impact calculations	1	1	
2j	impact (edge)	1	2	
2k	component attactment	1	1	
2l	rib calculations	2	xx	
2m	lid stress top force	5	6	
2o	lid stress side force	5	6	
2	subtotal:	19.4	21.5	
3	**Documentation**			
3a	15_001 Outer Panel V1	1	1	
3b	15_002 Internal Panel V1	2	1	
3c	15_003 outer panel V2	1	0.75	
3d	15_004 External Panel V3	0.5	0.5	
3e	15_005a Prototype Size 10x10x	0.5	0.5	
3f	15_005b Prototype Size 10x20x	0.5	0.5	
3g	15_005 Prototype Size 20x20x2	0.5	0.5	
3h	15_008 Lid V3	0.5	0.5	
3i	15_009 Harness V3	0.5	0.5	
3j	Website	2	5	
3k		xx	xx	
3l		xx	xx	
3m		xx	xx	
	subtotal:	9	10.8	
4	**Proposal Mods**			
4a	Project Robot Schedule	99	99	
4b	Project Robot Part Inv.	99	99	
4c	Crit Des Review*	99	99	
	subtotal:	297	297	
7	**Part Construction**			
7a	3d print body	4	xx	
7b	3d print lid	5	xx	
7c	3d print harness	4	xx	
7d	3d print internal panels	3	xx	
7e				
7f				
7g	Take Part Pictures	1		
7h	Update Website	2		
7i	Manufacture Plan*			
	subtotal:	19	0	

The schedule for the Cubesat 5000 is largely built around the CWU 2019-2020 school year. Most of the written work on this is done within the first week of December as that is when the initial proposal is due. The current estimate for work spent on the project will be around 120 hours which includes the proposal writing process, analysis, drawings, drawings redesigns, 3D printing and assembly, and website processing.

An unexpected consequence of decreasing thickness on all parts was that several 3d prints had to be done with the small nozzle and therefore increasing the 3d print time by multiple hours. There were also several failed prints early in the printing process that ended up causing the lid and internal panels to be reprinted doubling the time needed.

The initial plan for cutting the insulation had also changed (see more in manufacturing section). While this changed add the use of power tools to get more constant angle and decreased the cutting time, it did limit the manufacture time since the band saw is located in the CWU materials lab which require 2 people to be present when working on any machinery.

Proposal

The proposal processes ended up being completed during the first week of December. While each individual section was started throughout CWU's fall quarter, the sections were not filled out properly or updated to the most current version until December 6th, therefore making every section take more time than estimated.

Analysis

The analysis for the proposal was initially done in increments of 2 every week with the idea of having a minimum of 12 analysis by the date the proposal was due. There ended up being a total of 14 analysis as the wood design was rejected and all parts and components need to be tested to determine if they will survive impact.

Majority of the analysis were the last section of to be completed as the designs had not been finalized and were subject to change.

Documentation

The initial design was done within by November however after the first prototype the client request a change to the design, resulting in all drawings needing to be redone within the end of November and the beginning of December. All each section of the CubeSat 5000 needed to be redone therefore requiring another CAD drawing and engineering ANSI Y14.5 drawing. Each section required section was done for the initial five drawings, but all final designs had to be done the last first week of December when the design was finalized. The design was not expected to change and therefore subjected a large majority of the work to be done within the last weeks before the deadline.

Manufacturing

The manufacturing for the Cubesat 5000 can be split into the 3D printed components, manufactured components, and final touches.

The 3D printing while in the grand scheme of things didn't have many issues for the research team (Renee Redman and her advising professors) the manufacturing team (Addison Wenger, CWU physics department technician) had delays in manufacturing. Several parts needed to be reprinted as they encountered errors during the printing process. These issues consist mainly of trial and error as the printing technician had never printed components as large as some of the required assembly components. Additionally several of the issues consisted of the settings on the printer being incorrect (one of the lids initially was printed as a hollow shell).

Majority of the issues and time delays came from the initial design of the harness. Since the previous design did not have a flat surface for to lay flat on the printing bed the 3D printer needed to create a raft for it to be built on, which has an unexpected delay.

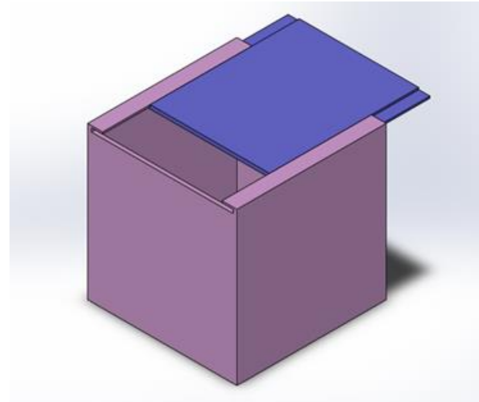
Testing

When the testing schedule was initially laid out it was expected that all testing would take place within the CWU Hogue materials lab. However, all testing place needed to take place in the Spring of 2020 which was unfortunately the time of the Covid- 19 outbreak and numerous stay at home orders. During this time access onto the CWU campus was monitored and special permission was needed in order to enter the educational buildings.   In order to continue testing as safely as possible many tests were done in personal residents using whatever materials were on hand. This lead to tests being done with nonscientific materials such as a meat thermometer instead of a temperature gauge. By using these tools testing behaviors had to be modified.

For the insulation testing the test had to be repeated several times to gain an average as the meat thermometer was not as trusted as scientific instrumentation would have been. Additionally, the testing had to be restarted twice as there were issues in data collection due to the unconventional setup.

The impact testing had to be completely redesigned which took an hour and the redesign test ended up including an increased safety factor and a different testing method.   After further discussion with the advising faculty an additional test was also created to test the entire assembly in impact instead of just point impact.

Discussion



The client did not have any specification about the design of the Cubesat 5000 initially but as the material was decided the design was decided and redesigned four separate times.

The client initially did not portray a preference in opinion regarding the material however decided after discussing how the manufacturing process would be for a wooden cubesat decided they preferred an entirely 3D printed part. This decision was made since after the initial Cubesat 5000 was made, the weather balloon would continue to use the STL file to manufacture more Cubesat's as needed.

After selecting the manufacturing process more complex designs became available. Initially the design has consisted of 6 separate external panels that would be mounted together at the corners using corner brackets. By 3D printed the parts the individual components decrease, which will decrease the moment of inertia of the assembly as well as increase the structural integrity of the corners and edges. At this point the design consisted of a 10x10x10 cm cube with center holes on the midpoint of each panel to allow for the mounting of the GoPro. This design made it all the way to a prototype print before the client reanalyzed the dimensions and after discussion decided to increase the size and weight requirements of the cube.

With the new size requirement of 20x20x20 cm and 400 grams all parts had to be redesign. Since the volume of the cube octupled while the weight was only double, all parts now require to have cut section in order to decrease the weight. Now the analysis determines if the part will be able to survive the launch process, traveling 30 kilometers upwards, and survive the impact. Additionally, to the assembly design a harness was added, which is functionally more a cage to ensure the lid stay firmly attached as well as provides a well for the rope to sit in and avoid slippage.

After the manufacturing of the harness some concerns were brought up by the client and the technician in charge of the 3D printing. There were concerned about the weight of the harness could be decreased by manufacturing a metal harness, potentially out of sheet metal. While that would decrease the weight, it increased the difficulty for manufacturing since that requires additional training and the budget would increase due to the additional material.

After evaluating the harness, it became apparent that it could be redesigned such that the wells for the cord go over the edges of the cube in order to protect the corners which are the part of the assembly that are most likely to break on impact.

The last redesign was done to the cube and consisted of removing an additional wall and therefore creating a four sided cube with two open sides. This allowed the internal mechanisms to be reached easier and to ensure all electronic components are actually placed where they need to be. This redesign was assisted by Prof. Charles Pringle who recommended four extrusions on either side of the cube to allow rubber bands to hold the sides in along with the harness sitting over the panels.

This decreased the 3d printing time for the part but decreased the structural rigidity of the part during printing which caused the sides of the cube to warp slightly outwards. While this is not a major issue it does cause further complications in regards to assembly as the harness will not be able to sit flat against the walls.

After testing the 3D filament was determined to be more brittle than flexible. The impact testing was found that the individual pieces of filament would chip along the edge of the cube as they are the least structurally sound and do not have the support form neighboring filament. All of the energy that would have gone into deflection instead went into delaminating the filament. While the chipping was not an ideal impact response the chipping was limited to two layers of printed filament and did not decrease the structural integrity of the entire assembly. The cube can therefore classify as having passed initial impact testing and should survive impact at a single point, which would cause the most damage to the assembly.

Insulation testing had to take place within personal residence since this report was happening during the 2020 Covid- 19 outbreak. The initial testing goals included testing below zero temperatures through the use of dry ice or liquid nitrogen available within CWU Materials lab or the CWU physics department. Due to taking place in personal residence the testing took place within a box freezer which was set to 20˚F. The temperature was taken using a meat thermometer and therefore it doesn't have the same accuracy a scientific thermometer or temperature gauge would have. The success criteria for the insulation was that it would keep the internal assembly, including the electronics and instrumentation, at functioning temperatures. Dr. Darci Snowden was able provide information from past launches saying that the weather balloon will only be in the upper atmosphere for 15-20 minutes. From the data collected form the insulation testing, the Cubesat 5000 was able to keep the assembly insulated for 15 minutes. Therefor the insulation testing was considered a success.

Conclusion

The team believes that the Cubesat 5000 is viable and will success because of the cost, manufacturing time, and strength of the material.

The cost of the Cubesat 5000 assembly by itself is $70, which is a large cost for a single unit, however the material purchased will be enough to make more than 10 cubesat's, therefore making the cost of each unit $7. The materials are additionally already available to the CWU Physics department which will be manufacturing the Cubesat 5000.

Since the Cubesat 5000 assembly consists of 3D printed parts and cut insulation, the manufacturing time will be limited to 24 hours or a week if distributed into individual processes. The longest part to manufacture individually will be the external panels, as they are the largest part by volume and this expected to take six hours. All internal components will only take 30 minutes but seeing as there are five of them it will take them 2.5 hours The shortest to manufacture will be the lid component at 30 minutes to complete. The week estimate therefore constitutes making each induvial component (ei. All six internal panels) once a day, for all five components.

The current material used by the CWU Physics department is a cardboard box, which is not only made of paper, but not weather or thermal resistant. The Cubesat 5000 assembly will therefore provide better operating conditions for the electronic components than the previously used solution.

Acknowledgements

The Cubesat 5000 was completed with the support of the CWU MET program and CWU Physics department.

The projected was created and manufactured on CWU ETSC facilities using the MET educational spaces. Dr. Craig Johnson, Dr. John Choi, Prof. Charles Pringle, Dr. Darci Snowden, Matt Burvee, and Addision Wenger all advised through the creation of this project.

Appendix A- Analysis

Appendix A.1 -Terminal Velocity Calculations

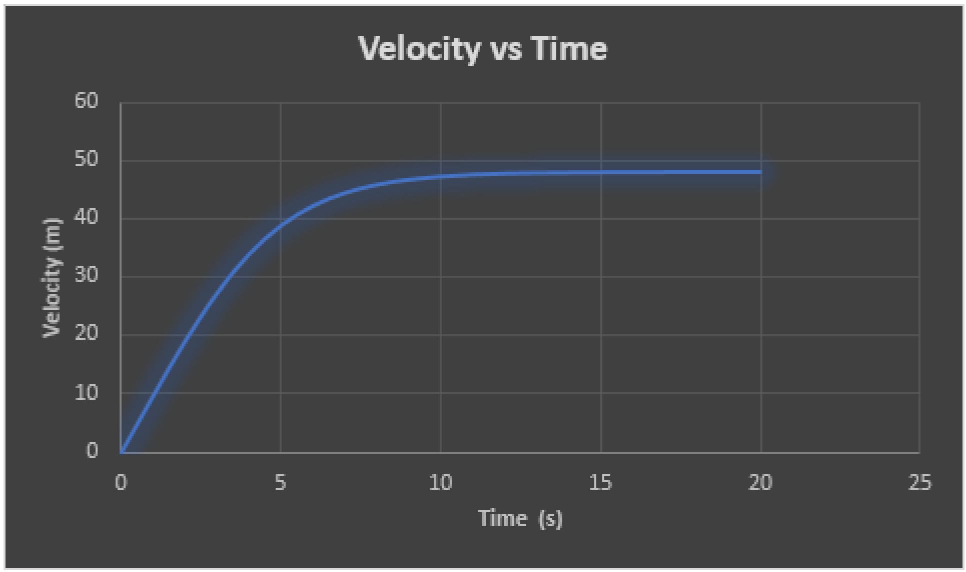
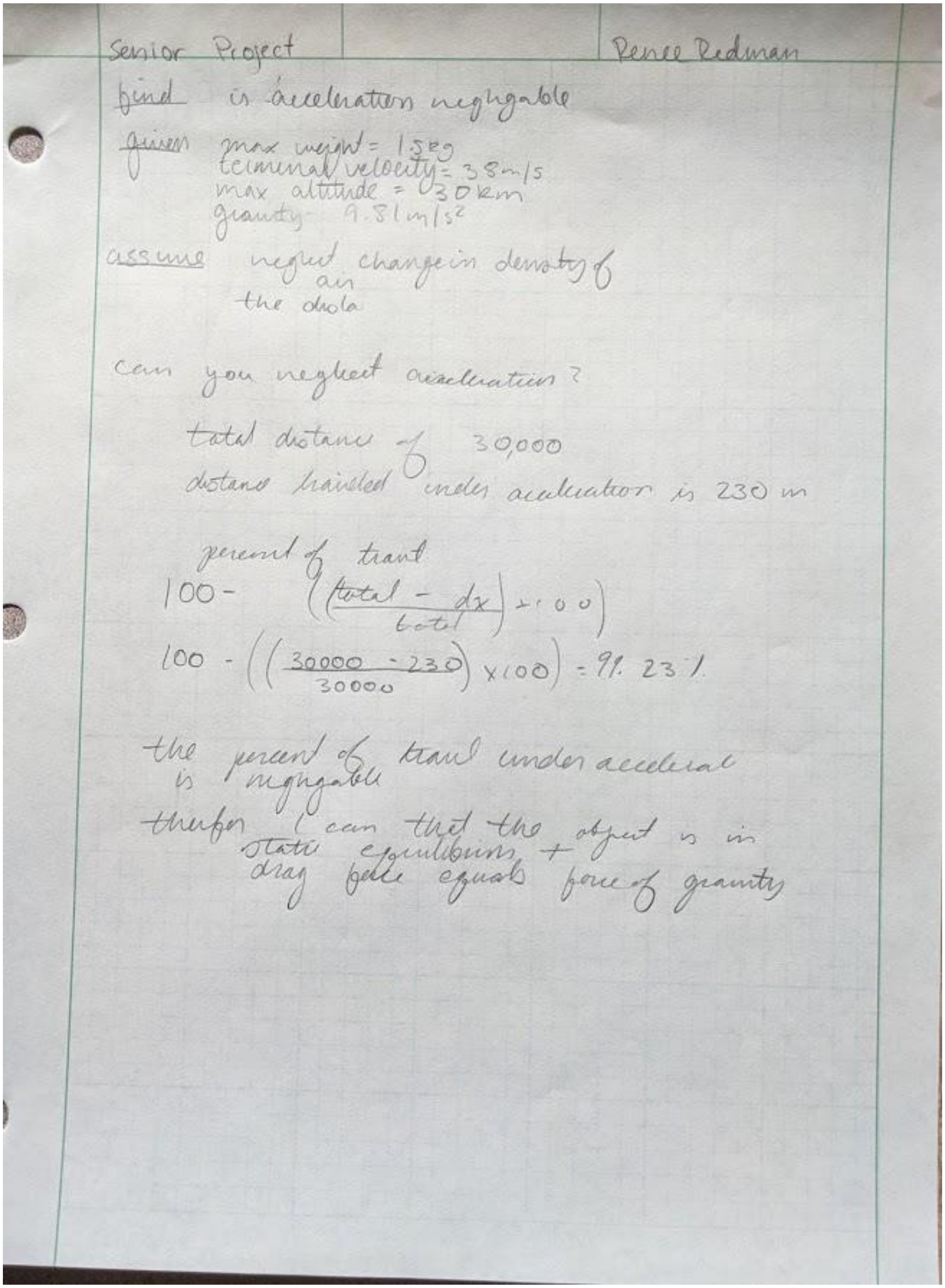


Figure 4 – Relationship between velocity and time used to interpolate distance traveled

time (s)	acceleration	Drag (N)	Net Force (N)	velocity (a*t)	Distance (m)
0	9.81	0	14.715	0	0
1	9.81	0.60830839	14.1066916	9.81	9.81
2	9.40446107	2.33368485	12.3813152	19.21446107	29.02446107
3	8.2542101	4.76937083	9.94562917	27.46867118	56.49313225
4	6.63041945	7.34972999	7.36527001	34.09909062	90.59222287
5	4.91018001	9.61881232	5.09618768	39.00927063	129.6014935
6	3.39745846	11.3672482	3.34775182	42.40672909	172.0082226
7	2.23183455	12.5952332	2.11976678	44.63856363	216.6467862
8	1.41317785	13.4053423	1.30965775	46.05174149	262.6985277
9	0.87310516	13.9184705	0.79652946	46.92484665	309.6233744
10	0.53101964	14.2352665	0.47973351	47.4558663	357.0792407
11	0.31982234	14.4277863	0.28721368	47.77568863	404.8549293
12	0.19147579	14.5436657	0.17133434	47.96716442	452.8220937
13	0.11422289	14.613013	0.10198701	48.08138731	500.903481
14	0.06799134	14.6543704	0.0606296	48.14937865	549.0528597
15	0.04041973	14.6789844	0.0360156	48.18979838	597.2426581
16	0.0240104	14.6936156	0.02138445	48.21380878	645.4564668
17	0.0142563	14.7023063	0.01269368	48.22806508	693.6845319
18	0.00846245	14.7074663	0.00753368	48.23652754	741.9210595
19	0.00502245	14.7105292	0.0044708	48.24154999	790.1626095

Table 1

Appendix A.2- Travel under Terminal Velocity Calculation



Senior Project   Renee Redman

find is acceleration negligable

given max weight = 1.5 kg
terminal velocity = 38 m/s
max altitude = 30 km
gravity = 9.81 m/s²

assume neglect change in density of air
the drola

can you neglect acceleration?

total distance of 30,000
distance traveled under acceleration is 230 m

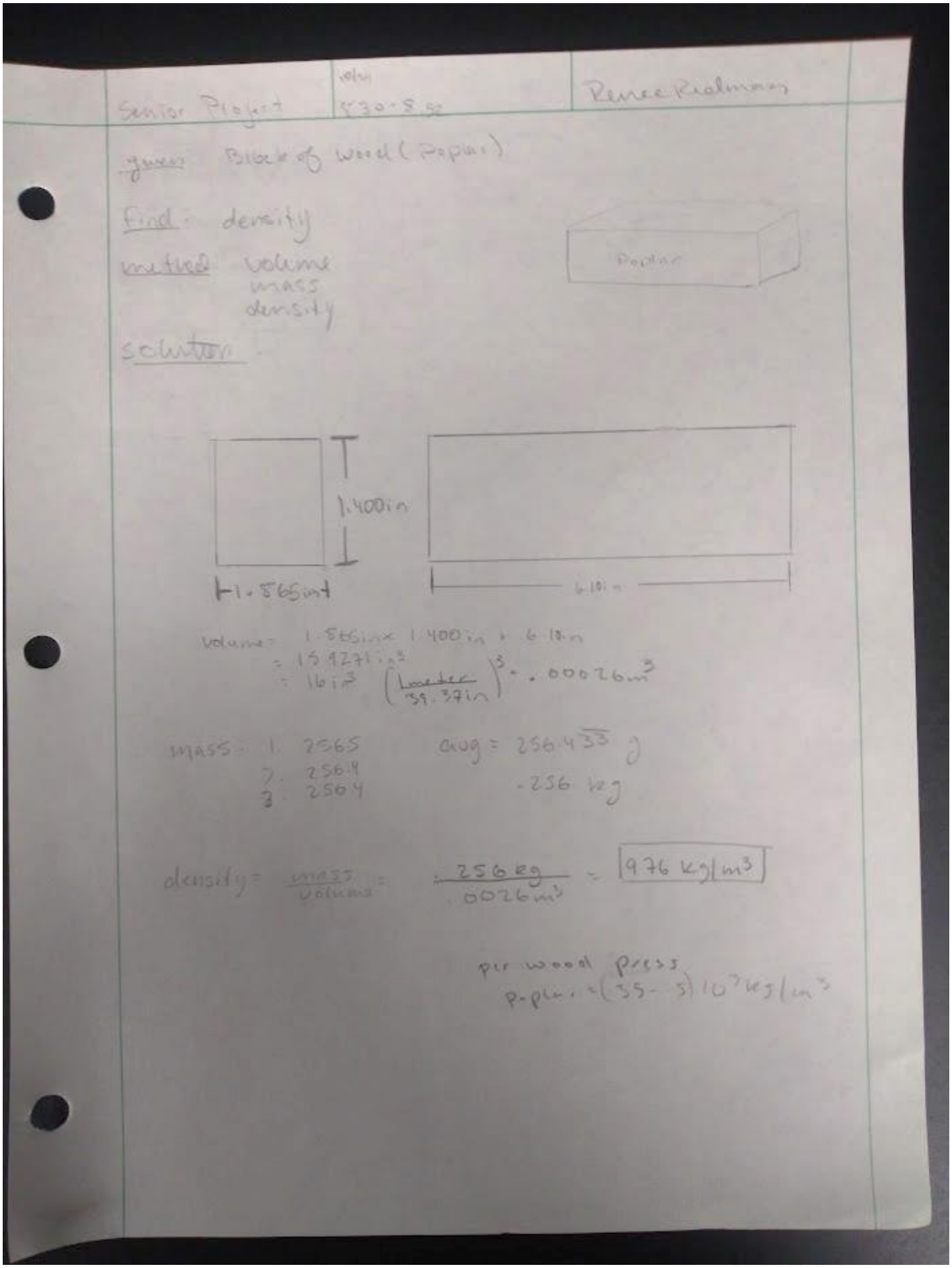
percent of travel
$100 - \left(\left(\frac{total - dx}{total}\right) \times 100\right)$

$100 - \left(\left(\frac{30000 - 230}{30000}\right) \times 100\right) = 99.23\%$

the percent of travel under acceleration is negligable
therefore I can that the object is in static equilibrium + drag force equals force of gravity

Figure 5

Appendix A.3 – Density of Poplar Wood


Senior Project

Given: Block of Wood (Poplar)

Find: density

method: volume
mass
density

solution:

1.400in

1.565in

6.10 in

volume = 1.565in × 1.400in × 6.10in
= 13.4271in³
= 16in³ (1meter / 39.37in)³ = .00026m³

mass: 1. 256.5
2. 256.4
3. 256.4

avg = 256.433 g
.256 kg

density = mass / volume = .256kg / .0026m³ = 976 kg/m³

per wood press
poplar = (35-5) 10 kg/m³

Figure 6

Appendix A.4- Weight of Wooden Section

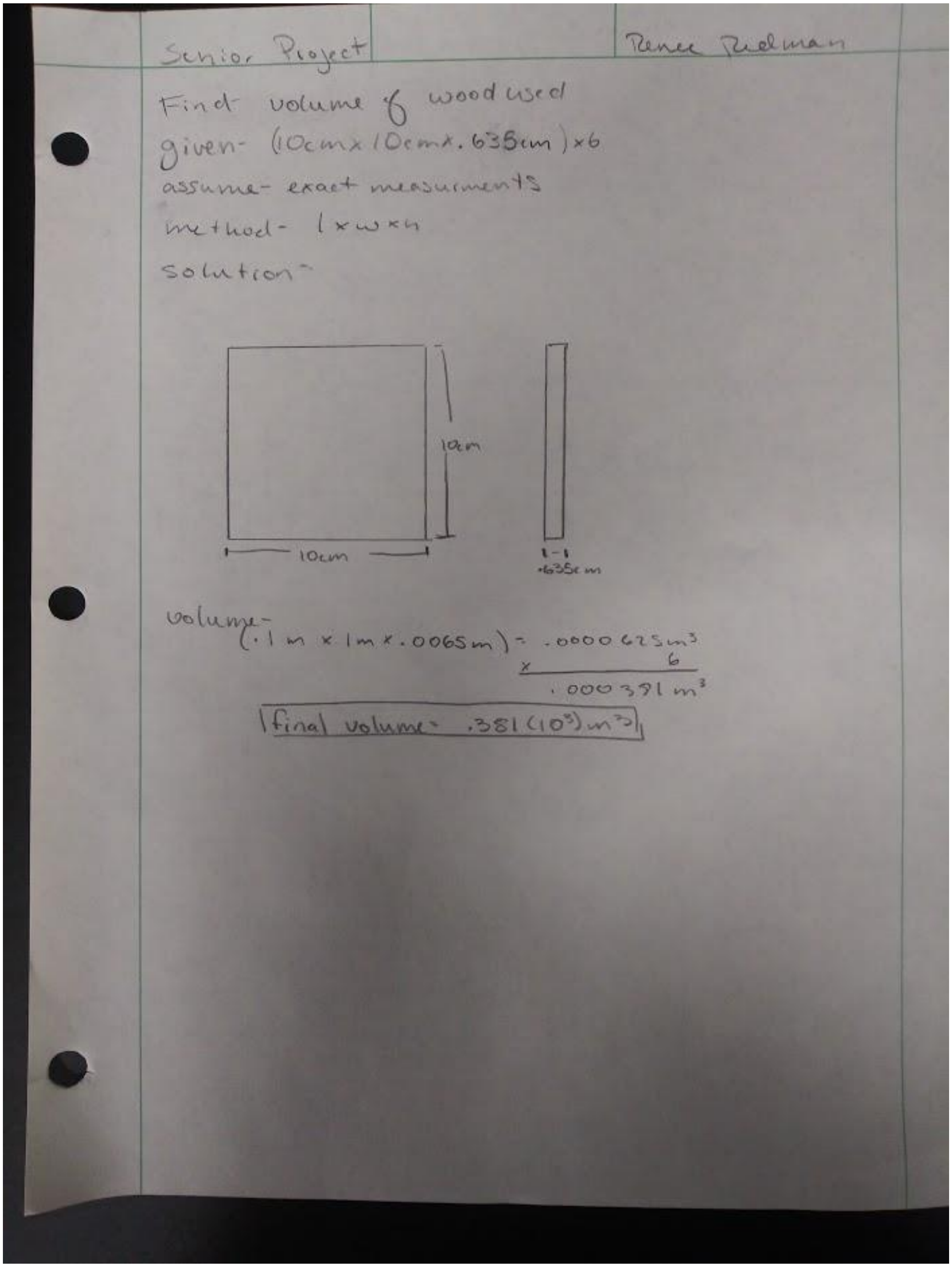
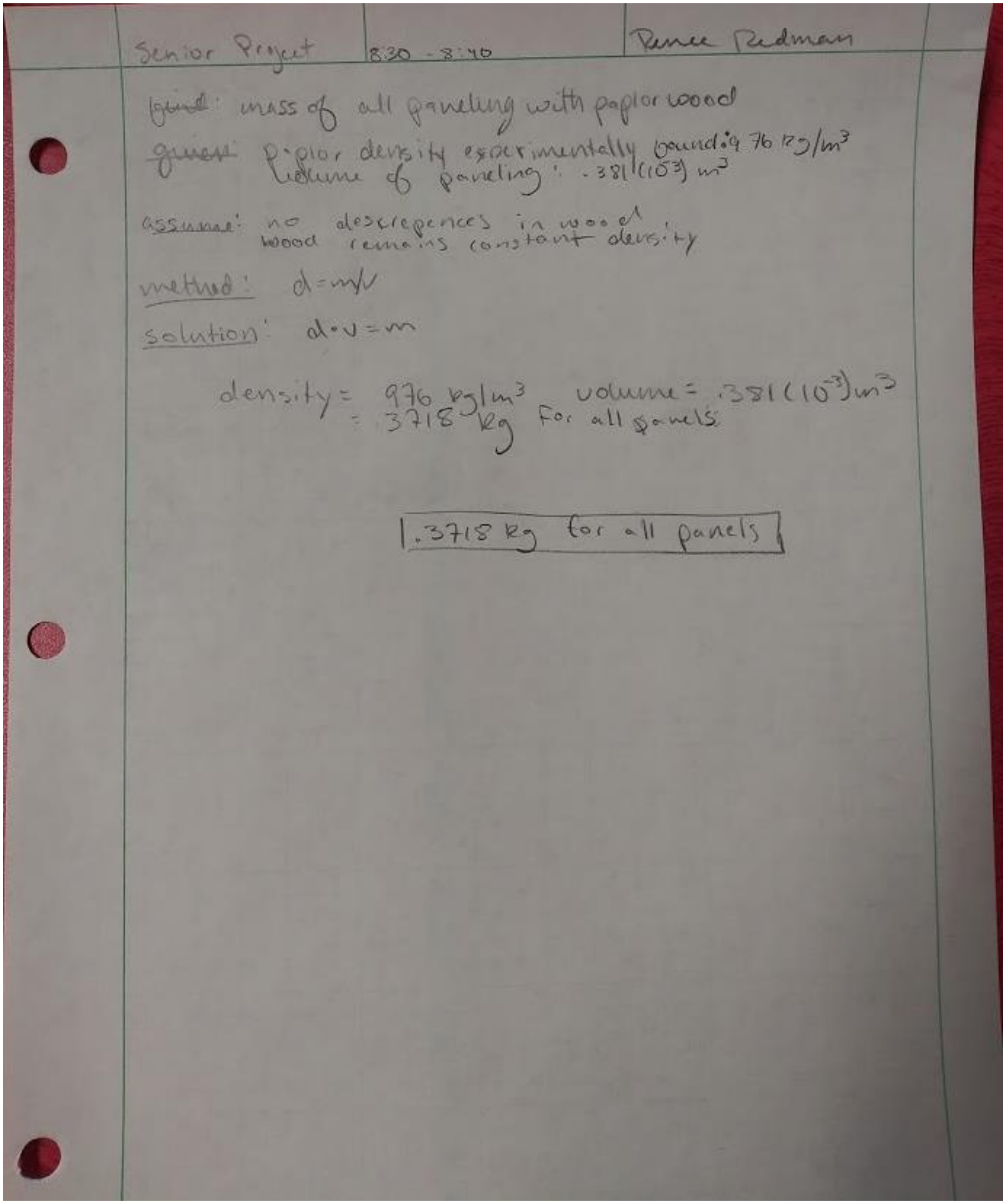


Figure 7

Appendix A.5- Cummulative Weight Calcuation



Senior Project | 8:30 - 8:40 | Renee Redman

find: mass of all paneling with poplar wood

given: poplar density experimentally found: 976 kg/m³
volume of paneling: .381 (10⁻³) m³

assume: no descrepences in wood
wood remains constant density

method: d = m/v

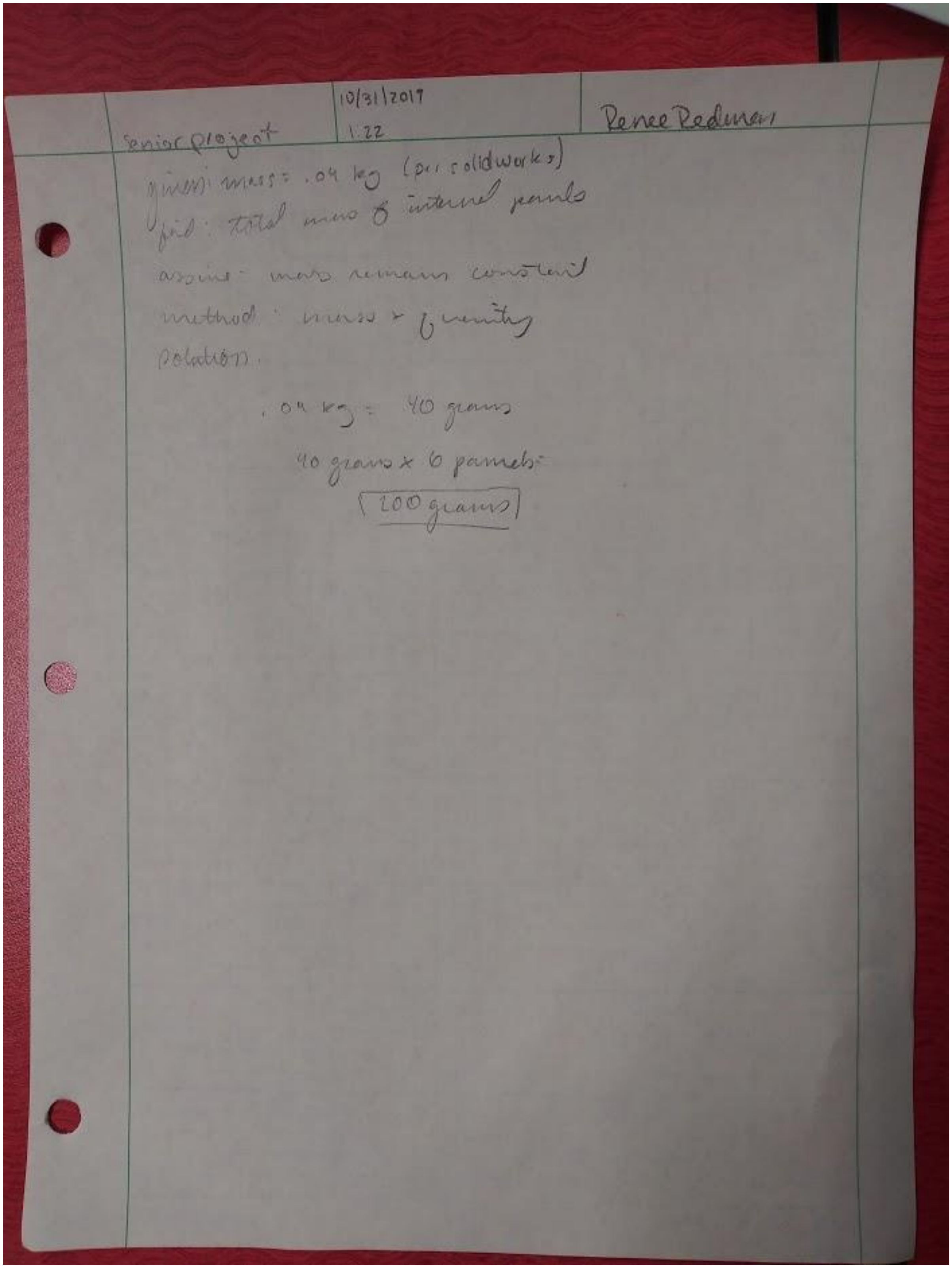
solution: d·v = m

density = 976 kg/m³ volume = .381 (10⁻³) m³
= .3718 kg for all panels

.3718 kg for all panels

Figure 8

Appendix A.6- Continued Cumulative Weight Calculations



Senior project | 10/31/2017 1:22 | Renee Redman

given: mass = .04 kg (per solidworks)
find: total mass of internal panels

assume: mass remains constant
method: mass × quantity
solution.

.04 kg = 40 grams
40 grams × 6 panels =
200 grams

Figure 9

Appendix A.7 – Drag Force Calculations

Senior Project | 11/8/2019 | Renee Redman

find: drag force from 1m radius parachute

given: radius of parachute = 1m

method: drag equation

solution: $C_D = \frac{F_D}{\frac{1}{2}\rho V^2 A}$ $\quad F_D = C_D A \rho V^2/2$

$C_D = 1.3$ per

$A = \pi D^2/4$

$F_D = 1.3 \times (\pi (2m)^2/4) \times ((35\ m/s)^2/2) \times 1.204\ kg/m^3$

$= 3\,011.79\ N$

$= 3.0\ kN$ of drag force

(revised)

Appendix A.8- Parachute Drag Calculations

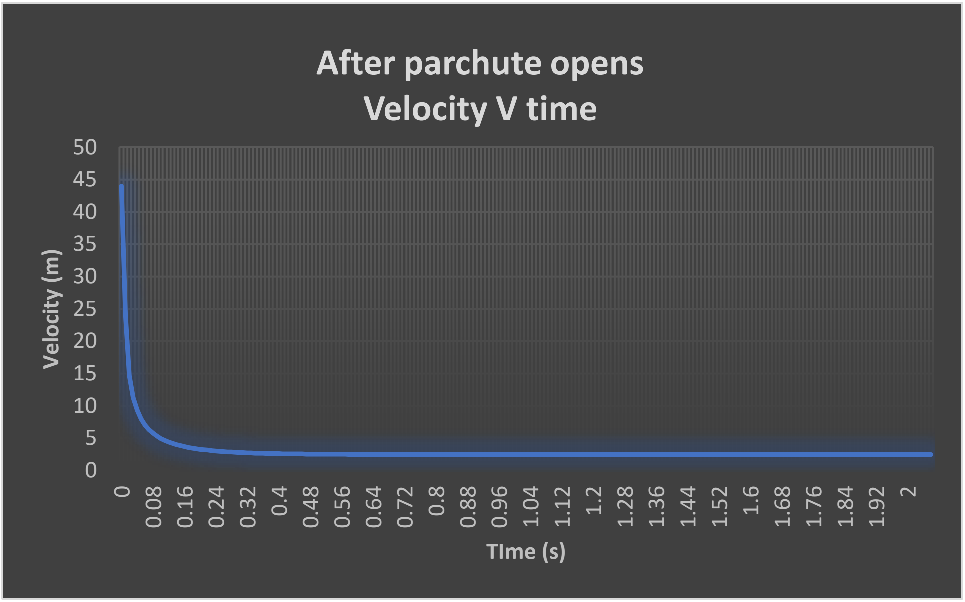


Figure 10 Velocity V Time after parachute deployment

time (s)	acceleration	Drag (N)	Net Force (N)	velocity (a*t)	Distance (m)
0	0	3000	-2985.285	44	0
0.01	-1990.19	1427.03655	-1412.3215	24.0981	0.240981
0.02	-941.5477	529.757102	-515.0421	14.68262301	0.38780723
0.03	-343.3614	310.95534	-296.24034	11.249009	0.50029732
0.04	-197.49356	211.354038	-196.63904	9.274073394	0.593038054
0.05	-131.09269	155.825633	-141.11063	7.963146477	0.672669519
0.06	-94.073755	121.183006	-106.46801	7.022408922	0.742893608
0.07	-70.978671	97.9239876	-83.208988	6.312622214	0.80601983
0.08	-55.472658	81.4698785	-66.754878	5.75789563	0.863598786
0.09	-44.503252	69.3628203	-54.64782	5.312863107	0.916727418
0.1	-36.43188	60.1761526	-45.461153	4.948544305	0.966212861
0.11	-30.307435	53.0308762	-38.315876	4.645469954	1.01266756
0.12	-25.543917	47.3592288	-32.644229	4.390030779	1.056567868

0.13	-21.762819	42.7801107	-28.065111	4.172402587	1.098291894
0.14	-18.710074	39.0294052	-24.314405	3.985301849	1.138144912
0.15	-16.209603	35.9190505	-21.20405	3.823205815	1.17637697
0.16	-14.136034	33.3119923	-18.596992	3.681845478	1.213195425
0.17	-12.397995	31.106314	-16.391314	3.557865529	1.24877408
0.18	-10.927543	29.2248739	-14.509874	3.448590103	1.283259982
0.19	-9.6732493	27.6083603	-12.89336	3.35185761	1.316778558
0.2	-8.5955735	26.2105272	-11.495527	3.265901875	1.349437576
0.21	-7.6636848	24.9948602	-10.27986	3.189265027	1.381330227
0.22	-6.8532402	23.9321995	-9.2171995	3.120732625	1.412537553
0.23	-6.1447997	22.9990163	-8.2840163	3.059284629	1.443130399
0.24	-5.5226775	22.1761462	-7.4611462	3.004057854	1.473170978
0.25	-4.9740975	21.447844	-6.732844	2.954316879	1.502714147
0.26	-4.4885627	20.8010707	-6.0860707	2.909431252	1.531808459
0.27	-4.0573805	20.2249487	-5.5099487	2.868857447	1.560497033
0.28	-3.6732991	19.710342	-4.995342	2.832124456	1.588818278
0.29	-3.330228	19.2495288	-4.5345288	2.798822176	1.6168065
0.3	-3.0230192	18.8359447	-4.1209447	2.768591983	1.64449242
0.31	-2.7472964	18.4639781	-3.7489781	2.741119019	1.67190361
0.32	-2.4993188	18.1288086	-3.4138086	2.716125831	1.699064868
0.33	-2.2758724	17.8262747	-3.1112747	2.693367107	1.725998539
0.34	-2.0741832	17.5527689	-2.8377689	2.672625276	1.752724792
0.35	-1.8918459	17.3051501	-2.5901501	2.653706817	1.77926186
0.36	-1.7267668	17.0806737	-2.3656737	2.636439149	1.805626252
0.37	-1.5771158	16.876932	-2.161932	2.620667991	1.831832932
0.38	-1.441288	16.6918064	-1.9768064	2.606255111	1.857895483

0.39	-1.317871	16.5234267	-1.8084267	2.593076402	1.883826247
0.4	-1.2056178	16.3701367	-1.6551367	2.581020224	1.909636449
0.41	-1.1034245	16.2304664	-1.5154664	2.569985979	1.935336309
0.42	-1.0103109	16.103107	-1.388107	2.55988287	1.960935137
0.43	-0.9254047	15.9868911	-1.2718911	2.550628823	1.986441426
0.44	-0.8479274	15.8807746	-1.1657746	2.542149549	2.011862921
0.45	-0.7771831	15.783822	-1.068822	2.534377718	2.037206698
0.46	-0.712548	15.6951934	-0.9801934	2.527252238	2.062479221
0.47	-0.6534623	15.6141334	-0.8991334	2.520717615	2.087686397
0.48	-0.5994222	15.5399614	-0.8249614	2.514723393	2.112833631
0.49	-0.5499743	15.4720634	-0.7570634	2.50922365	2.137925867
0.5	-0.5047089	15.4098845	-0.6948845	2.504176561	2.162967633

Table 2 Excel spread sheet of velocity after parachute deployment

Appendix A.9- Component attachment points

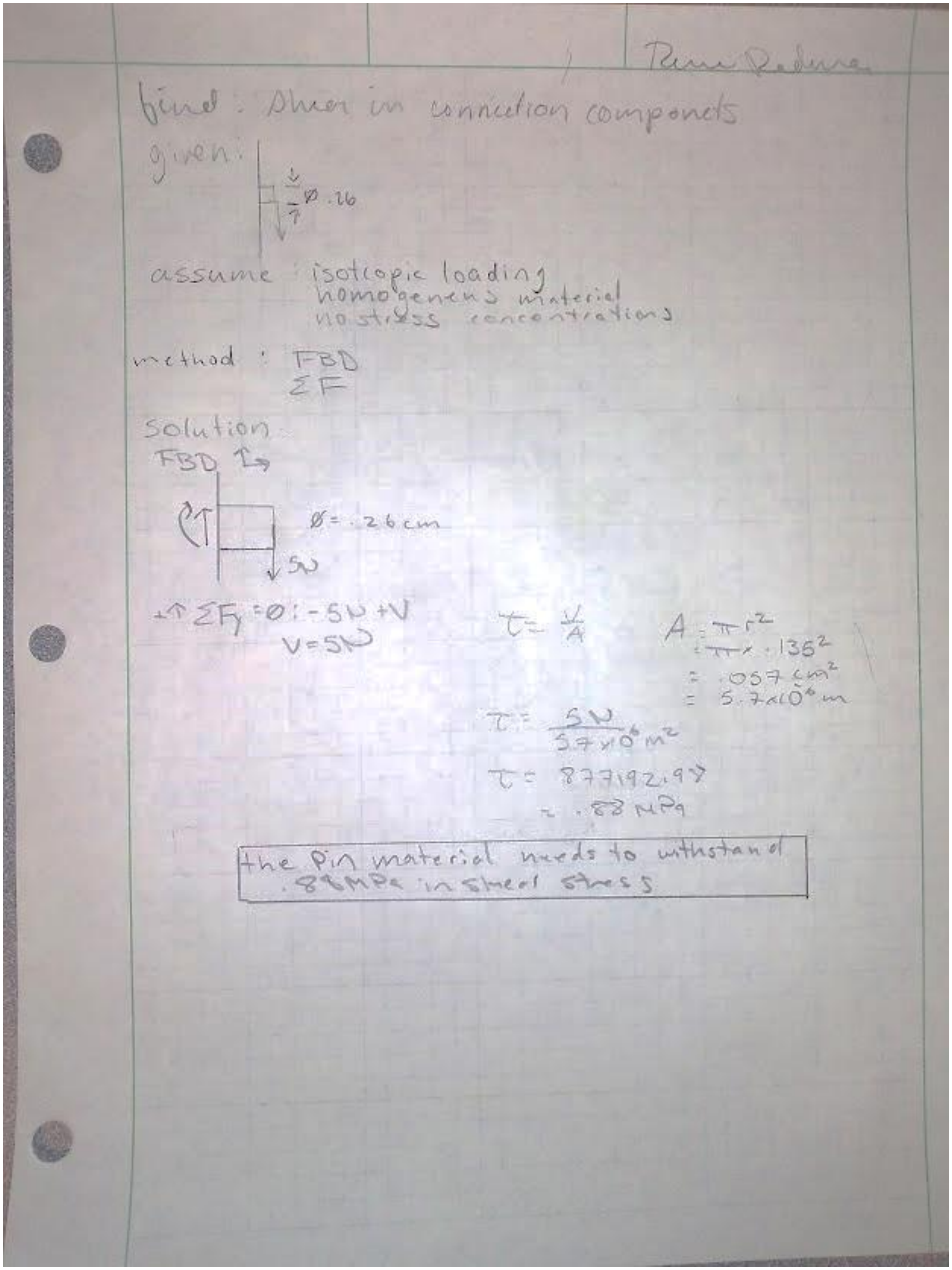
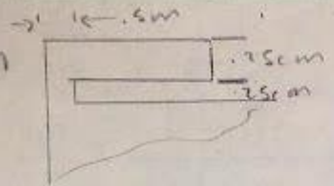


Figure 11 pin yield calculation

Appendix A.10- Lid Stress Top Force

Renee Redman

Given



Find: failure force

assume: $\tau = 62$ MPa

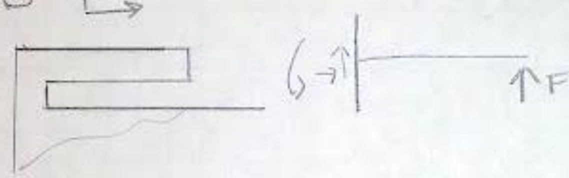
$\sigma_0 = 50$ MPa

isotropic loading

method: FBD

$\Sigma F, \Sigma M$

FBD



Area

$(.2m)(.005m) = .001m$

$c = .0025m$

$$I = \frac{bh^3}{12} = \frac{(.002m)(.005m)^3}{12} = 2\times10^{-9} m^4$$

$S_y = 50$ MPa $= \sigma$

$$\sigma = \frac{Mc}{I} \qquad M_c = \frac{\sigma I}{c}$$

$$= \frac{50\text{ MPa} \times 2\times10^{-9} m^4}{.0025 m}$$

$= 40$ N/m

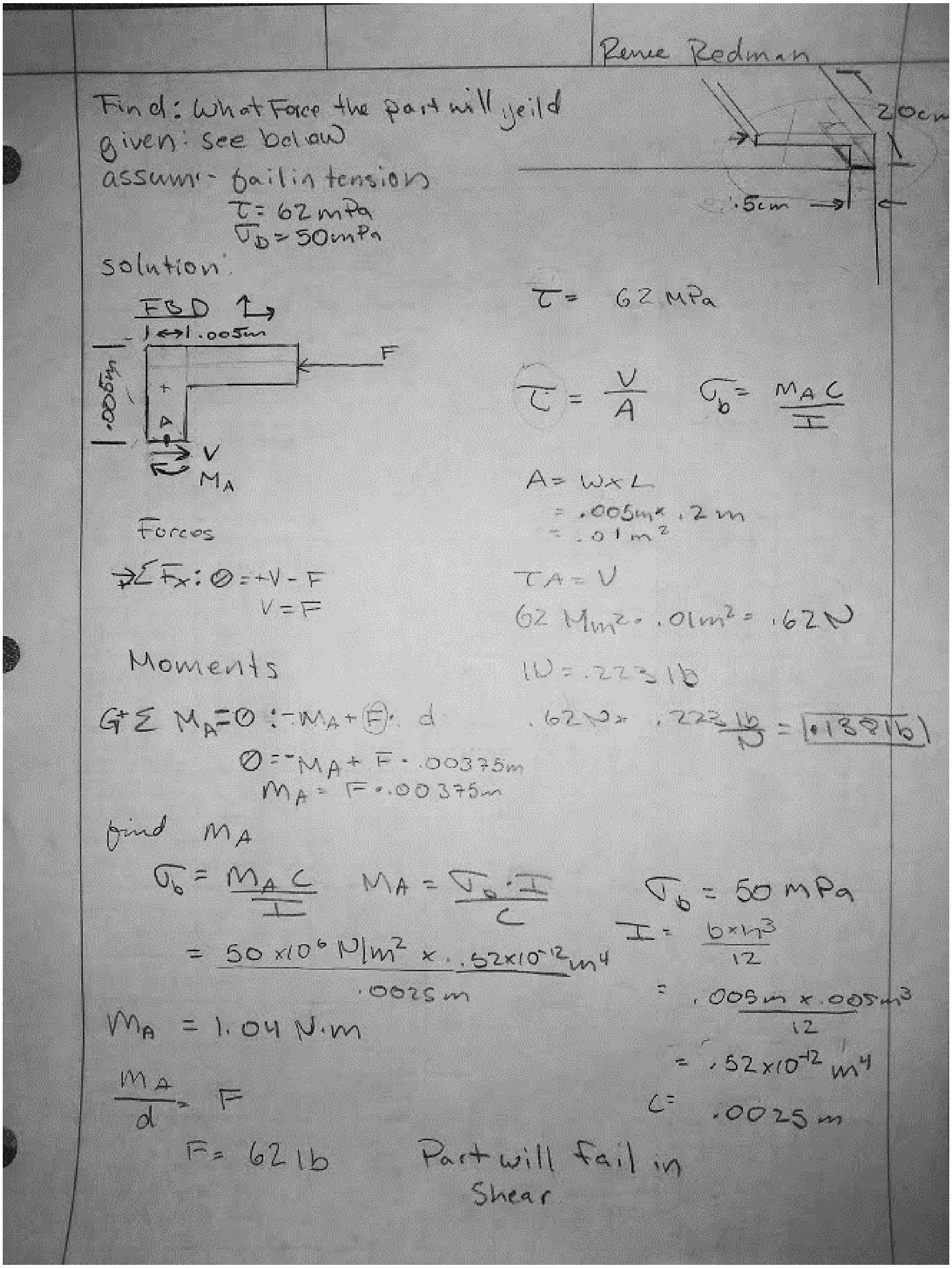
$M = F/d$

$F = 40$ N/m $\div .015m = 594.6$ N

Redo!

Figure 12 lid yield force calculation top force

Appendix A.11- Lid Stress Side Force


Renee Redman

Find: What Force the part will yeild
given: see below
assum - fail in tension
$\tau = 62\ mPa$
$\sigma_b = 50\ mPa$

2.0cm
.5cm

solution:

FBD
.005m
.005m
F
V
M_A

$\tau = 62\ MPa$

$\tau = \frac{V}{A}$ $\sigma_b = \frac{M_A C}{I}$

$A = W \times L$
$= .005m \times .2m$
$= .01m^2$

Forces

$\rightarrow \Sigma F_x: \emptyset = +V - F$
$V = F$

$\tau A = V$
$62\ M/m^2 \cdot .01m^2 = .62N$

Moments

$1N = .223\ lb$

$\circlearrowleft^{+} \Sigma M_A = \emptyset: -M_A + F \cdot d$
$\emptyset = -M_A + F \cdot .00375m$
$M_A = F \cdot .00375m$

$.62N \times .223\frac{lb}{N} = .138\ lb$

find M_A

$\sigma_b = \frac{M_A C}{I}$ $M_A = \frac{\sigma_b \cdot I}{C}$

$\sigma_b = 50\ MPa$

$I = \frac{b \times h^3}{12}$

$= \frac{50 \times 10^6\ N/m^2 \times .52 \times 10^{-12} m^4}{.0025m}$

$= \frac{.005m \times .005m^3}{12}$

$M_A = 1.04\ N \cdot m$

$= .52 \times 10^{-12}\ m^4$

$\frac{M_A}{d} = F$

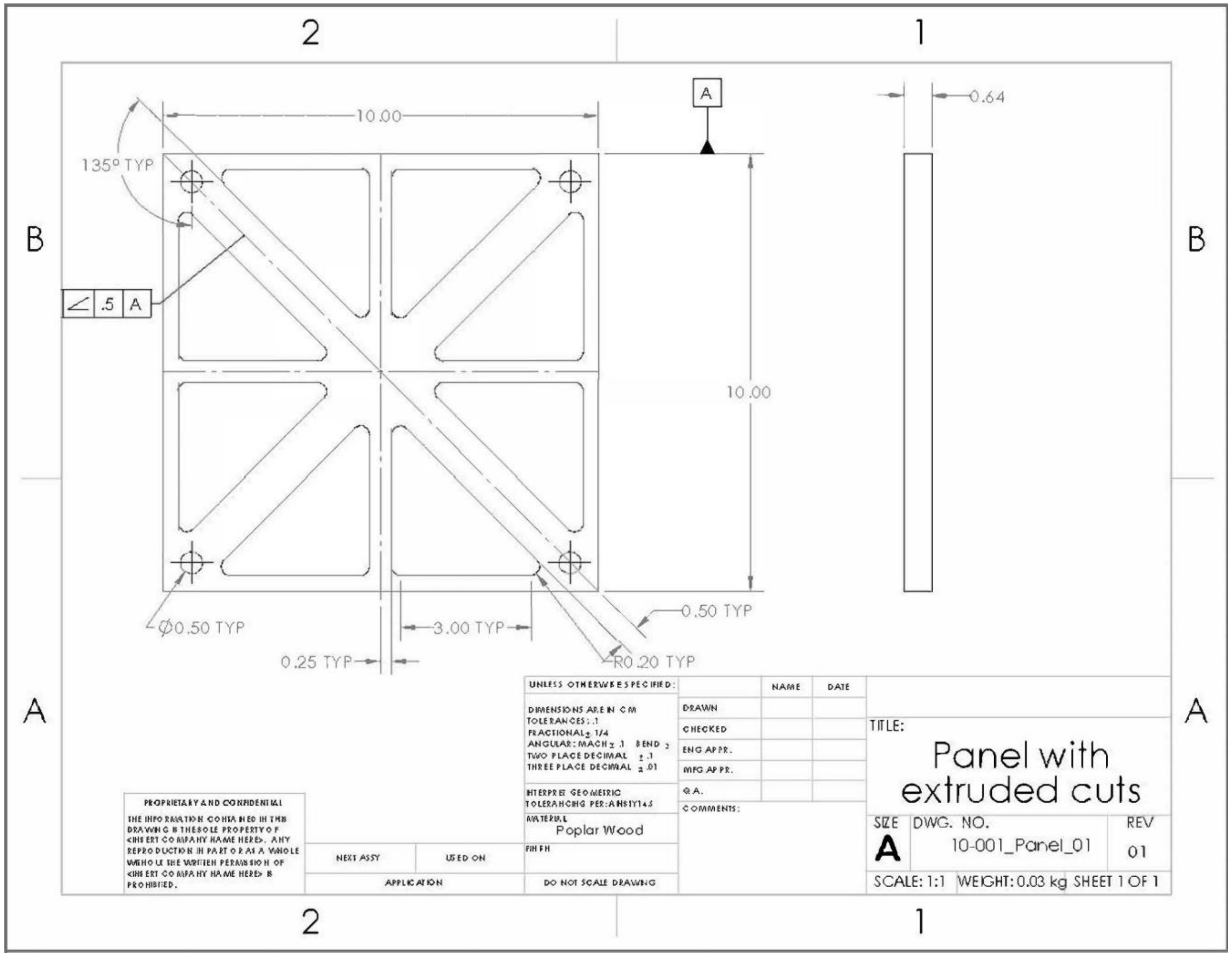
$C = .0025m$

$F = 62\ lb$ Part will fail in Shear

Figure 13 calculated yield force lid edge

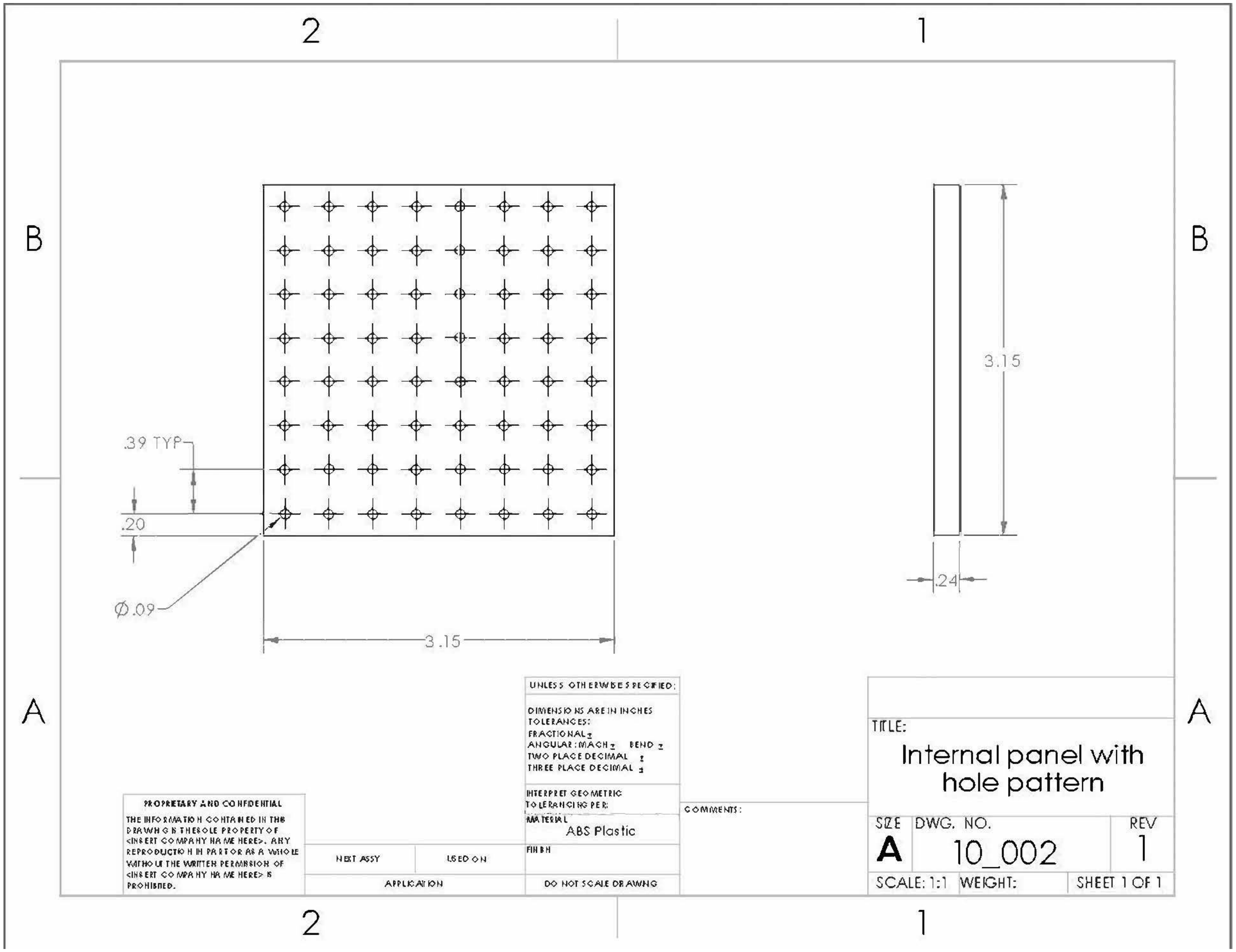
Appendix B – Drawings

Appendix B.1- Outer Shell design V1



Drawing 1 External panels for V1

Appendix B.2- Internal Panel V1



Drawing 2 Internal panels for V1

Appendix B.3- Lid V2

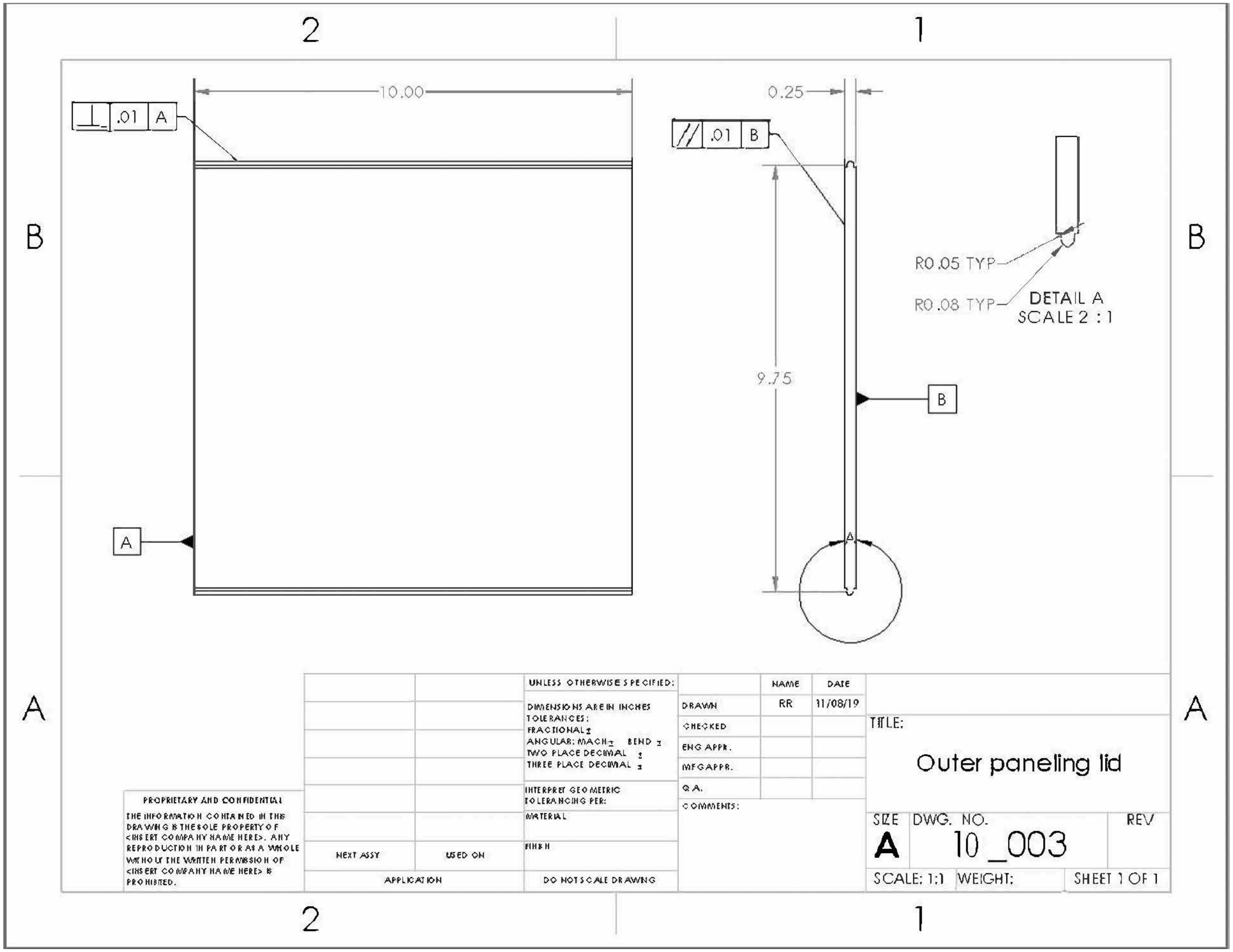


Figure 14 Lid Drawing V2

Appendix B.4- Outer Panel V2

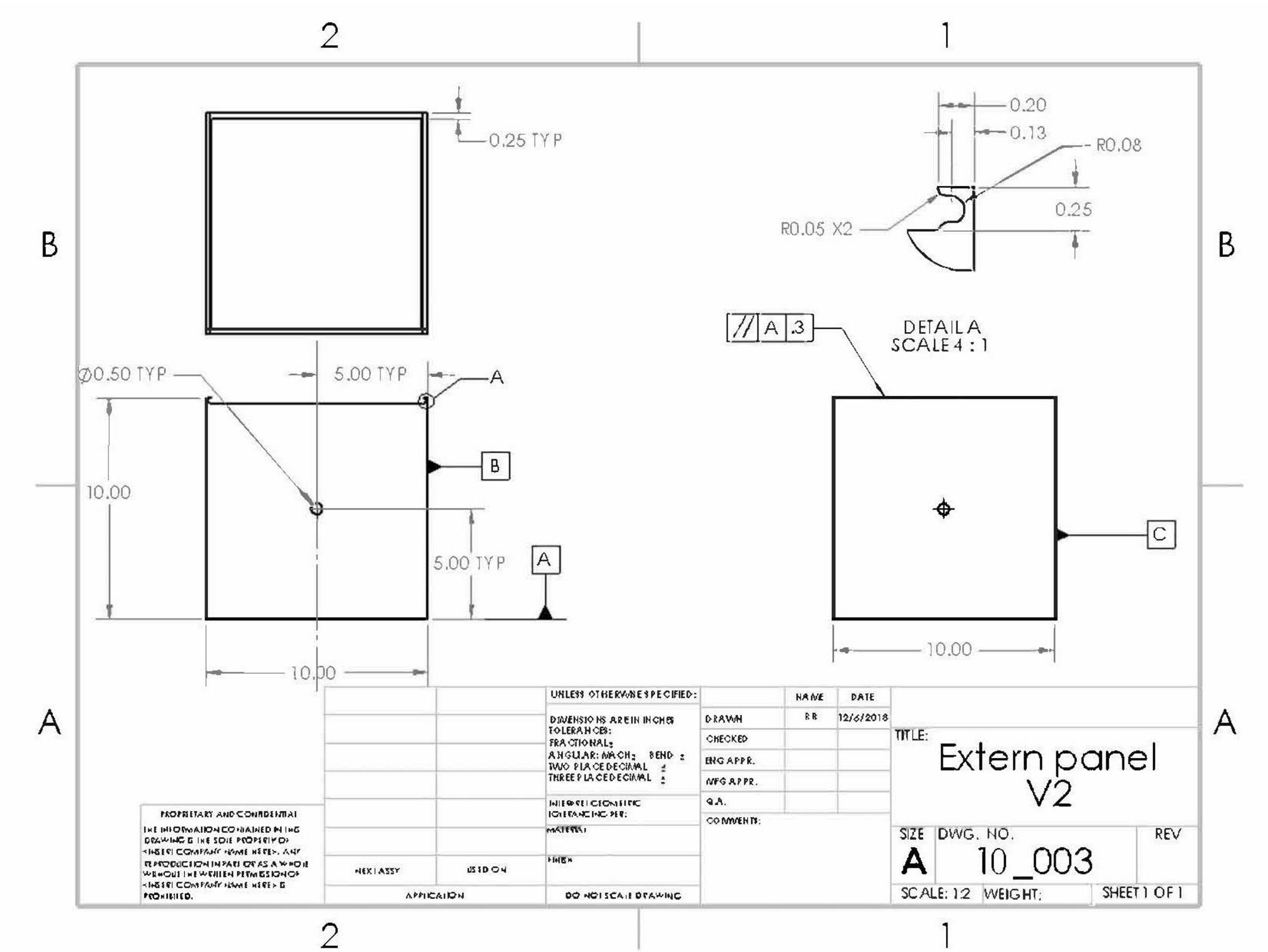


Figure 15 Externa panel V2

Appendix B.5- External Panel V3

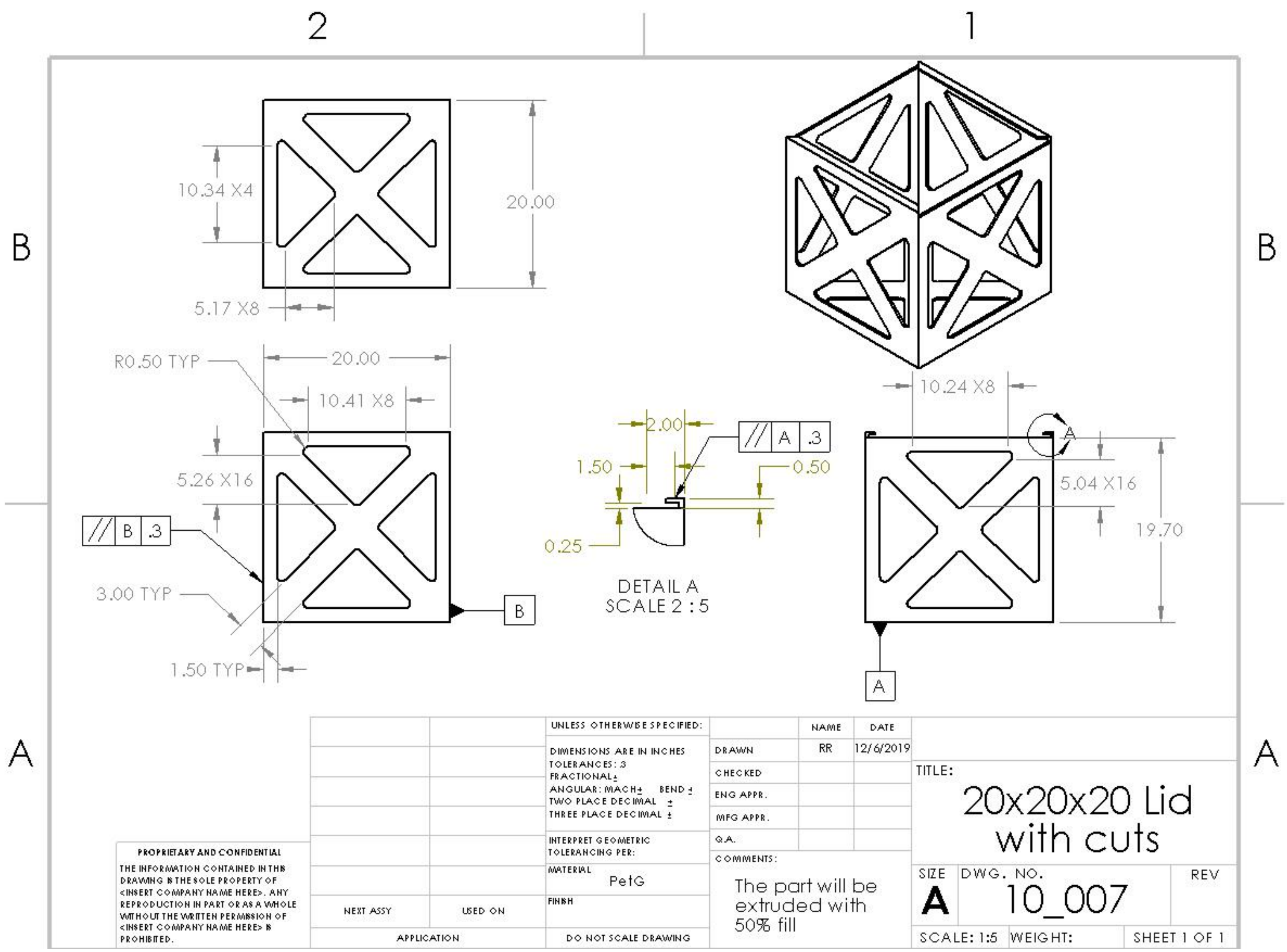


Figure 16 External Panels V3

Appendix B.6- Lid V3

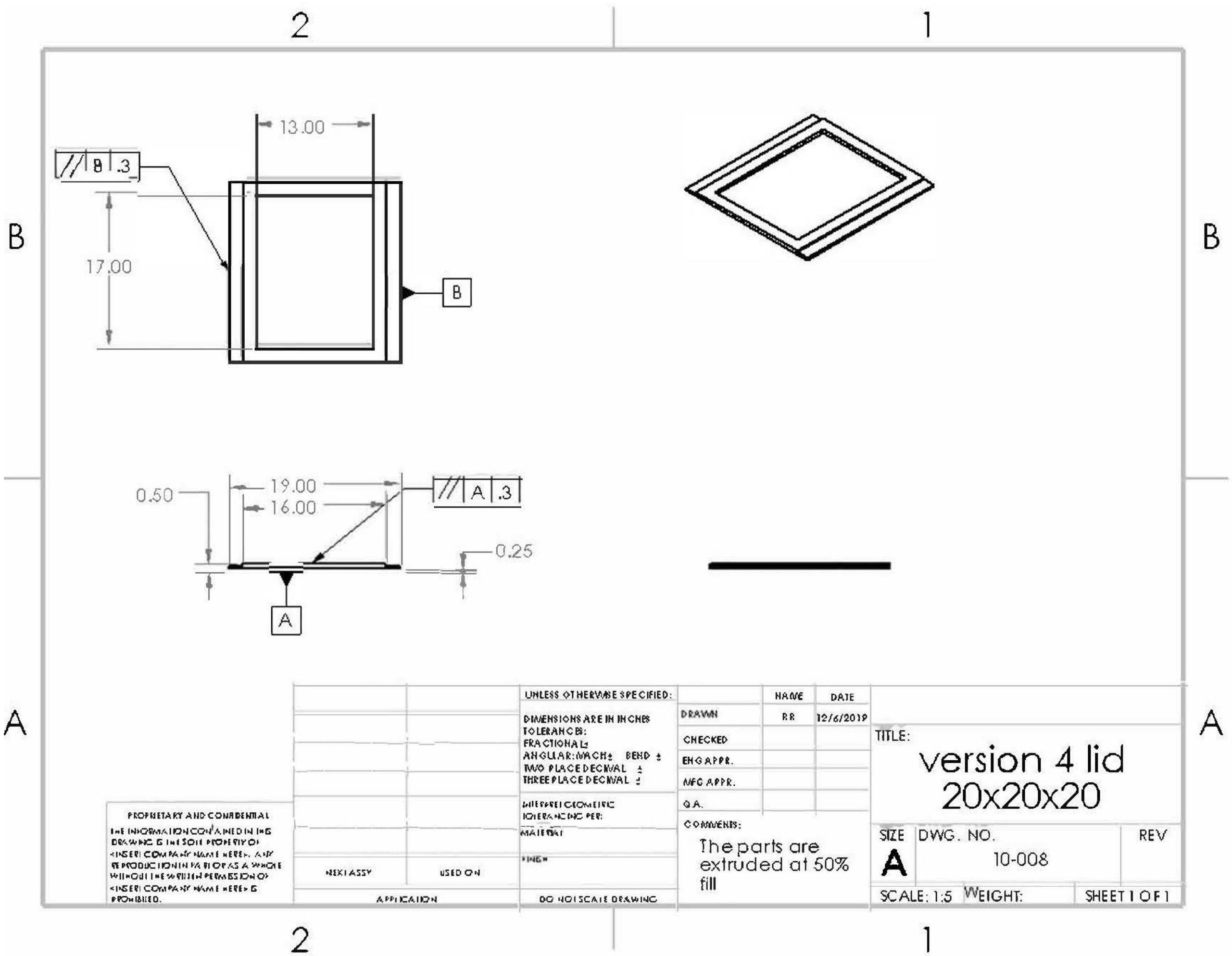


Figure 17 Lid V3

Appendix B.7- Insulation V3

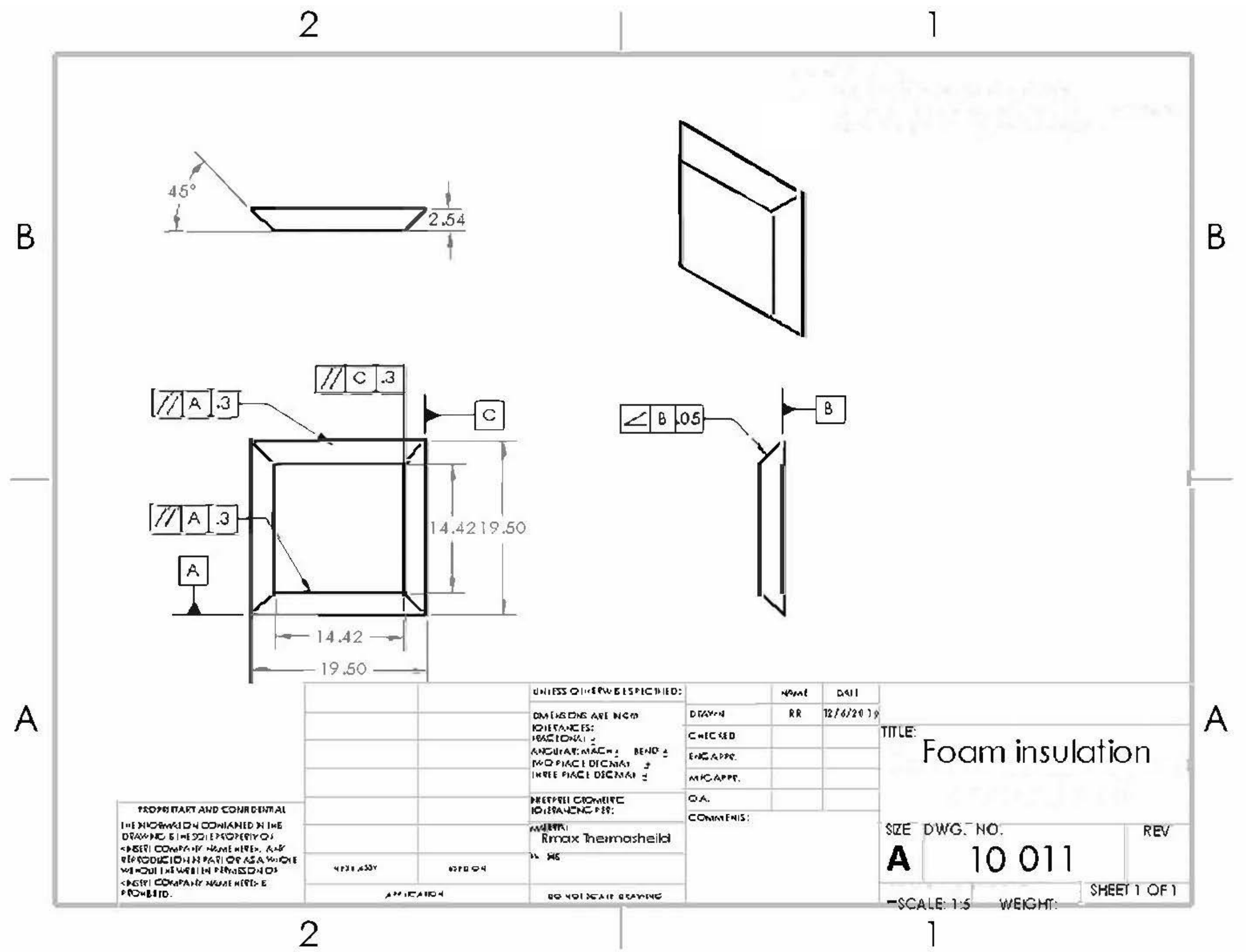


Figure 18 Insulation for internal components

Appendix B.8- Internal Panels V3

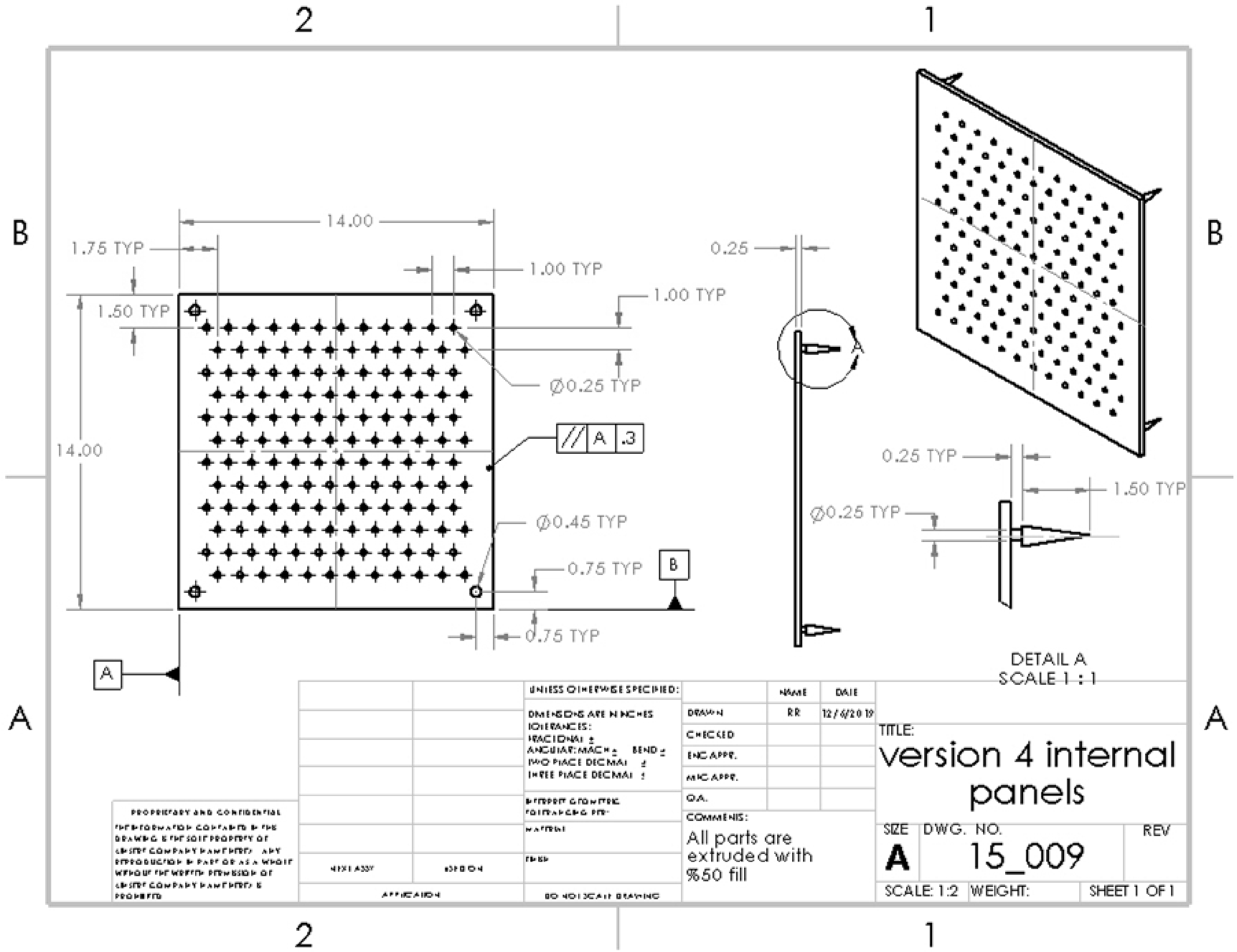


Figure 19 Internal Panels V3

Appendix B.9-Harness V3

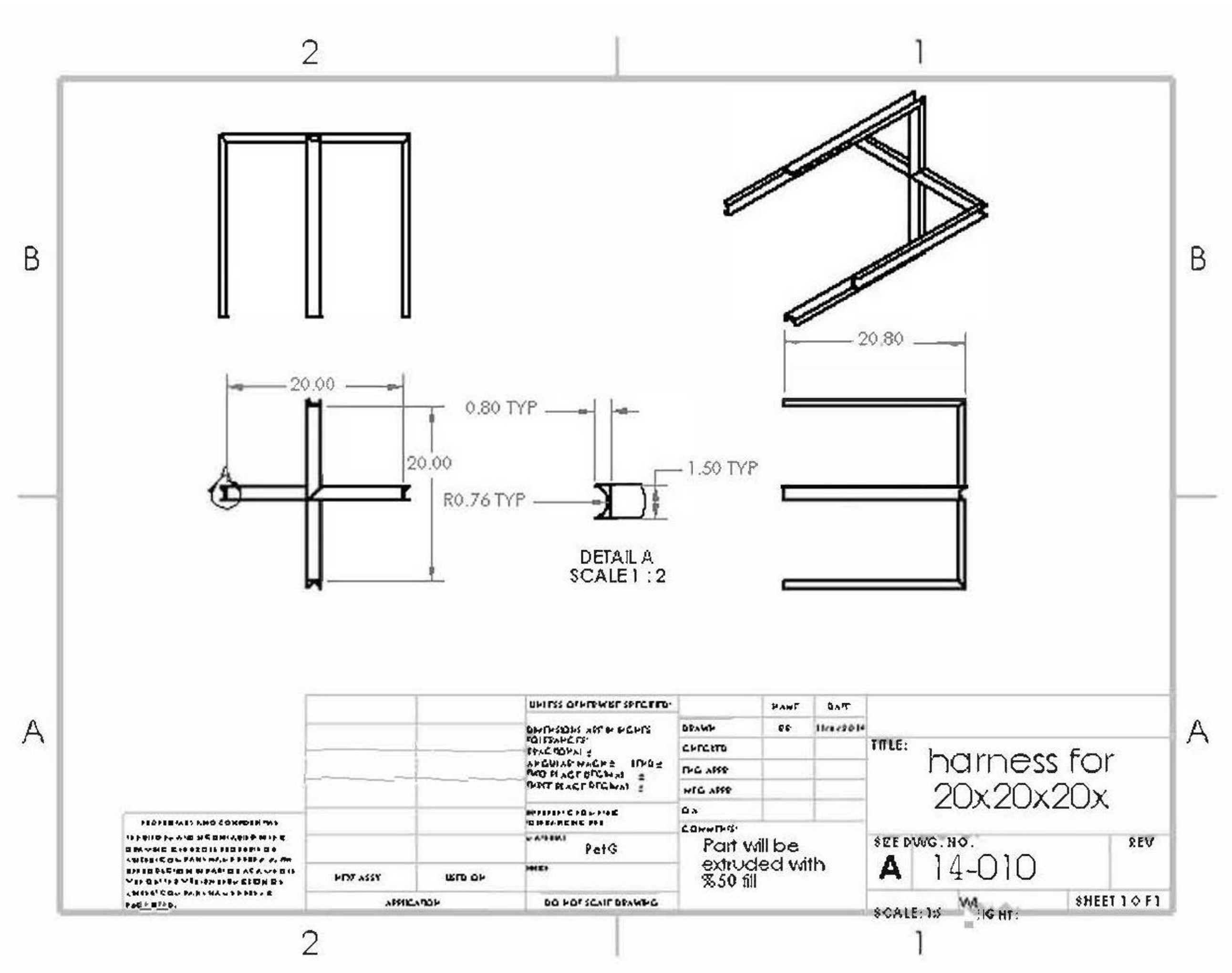


Figure 20 Harness for V3

Appendix B.10- External Panel V4

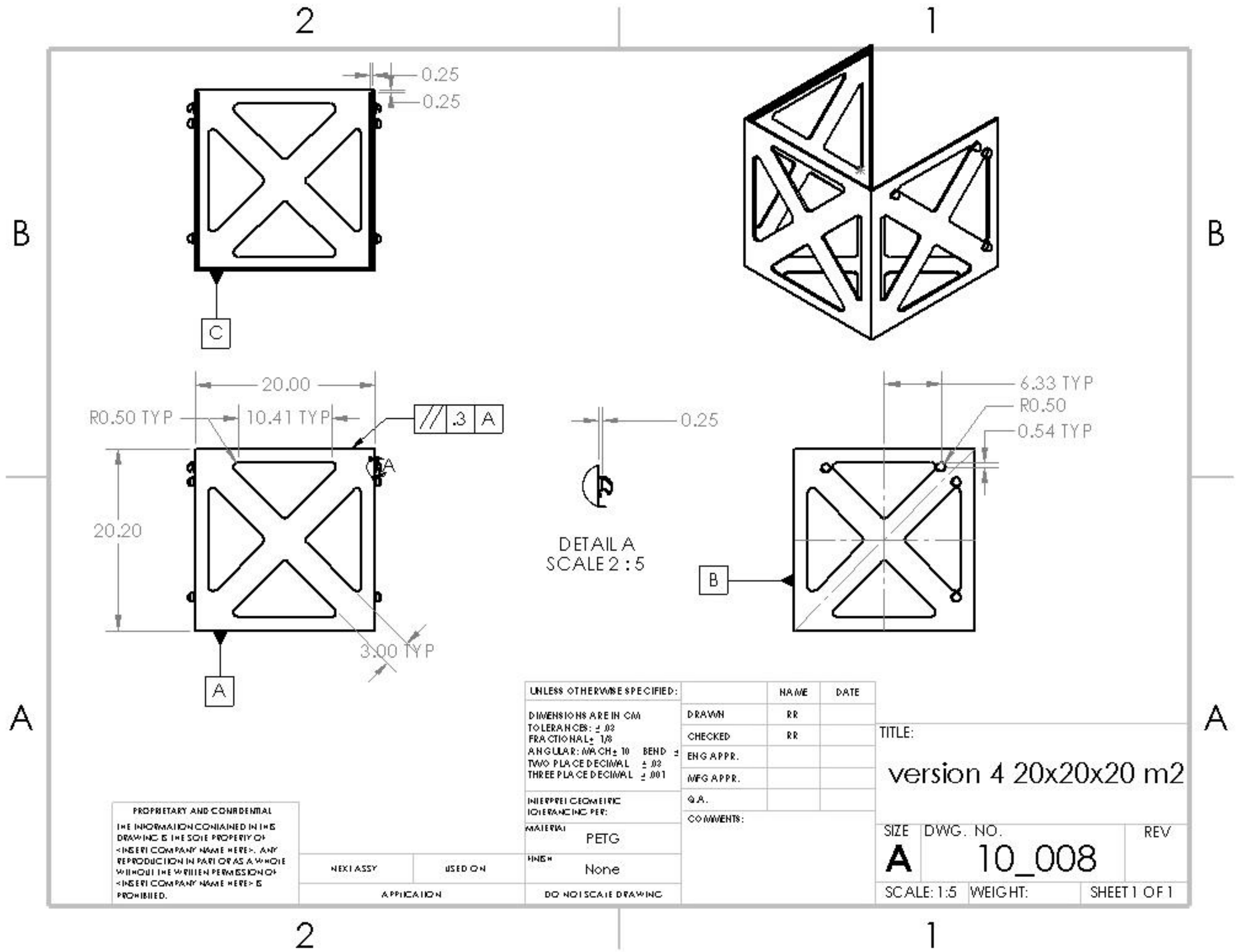


Figure 21 External Panels V4

Appendix B.10- Assembly

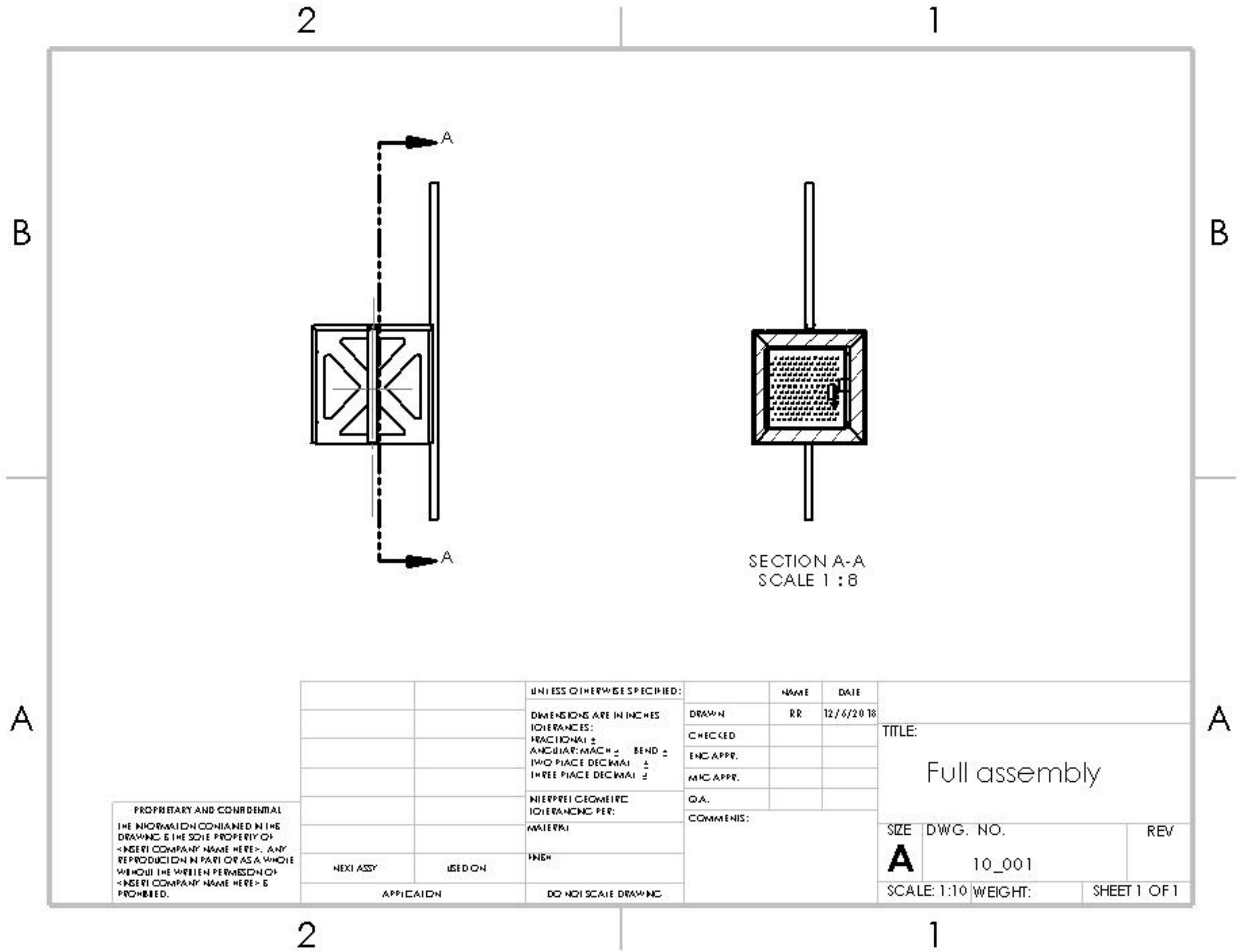
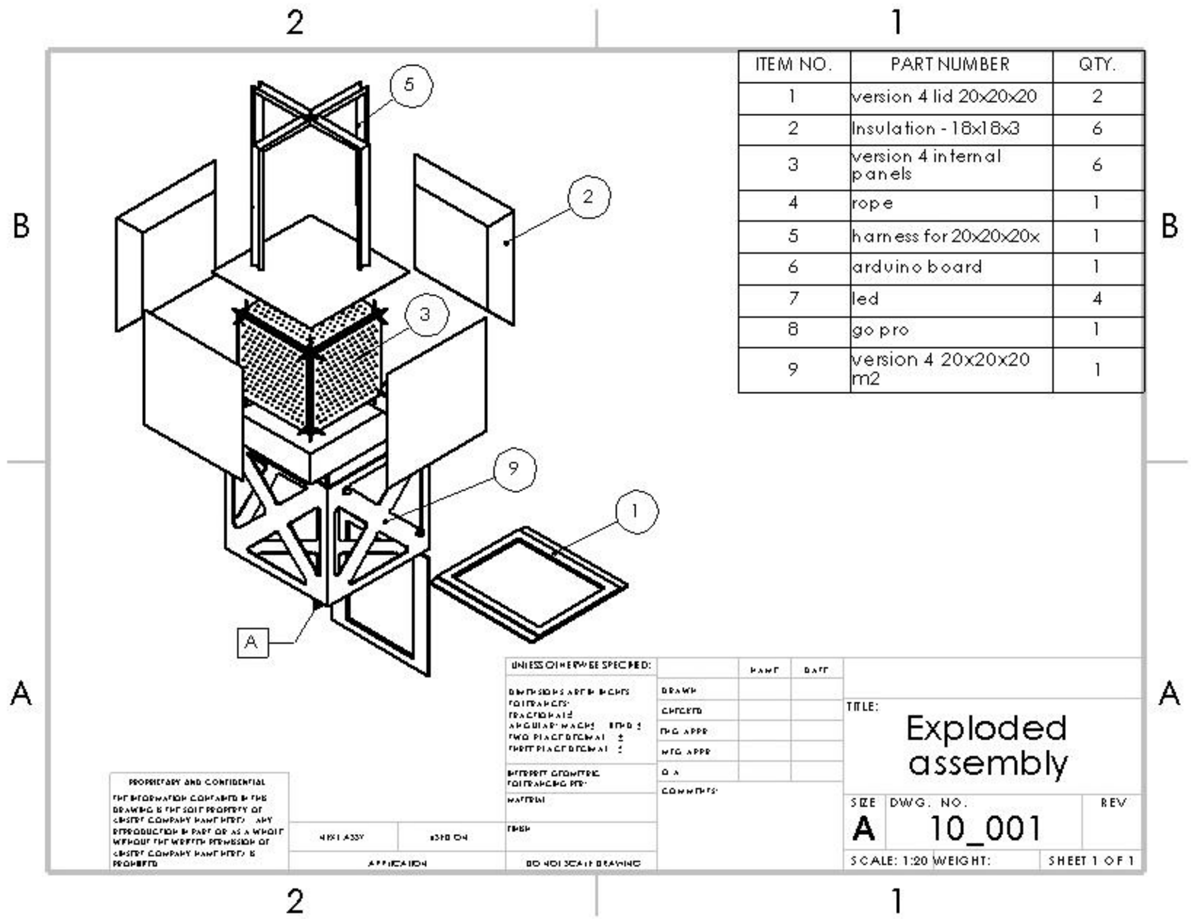


Figure 22 Assembly drawing

Appendix B.11- Exploded Assembly View



ITEM NO.	PART NUMBER	QTY.
1	version 4 lid 20x20x20	2
2	Insulation - 18x18x3	6
3	version 4 internal panels	6
4	rope	1
5	harness for 20x20x20x	1
6	arduino board	1
7	led	4
8	go pro	1
9	version 4 20x20x20 m2	1

Figure 23 exploded assembly

Appendix B.12- Drawing Tree

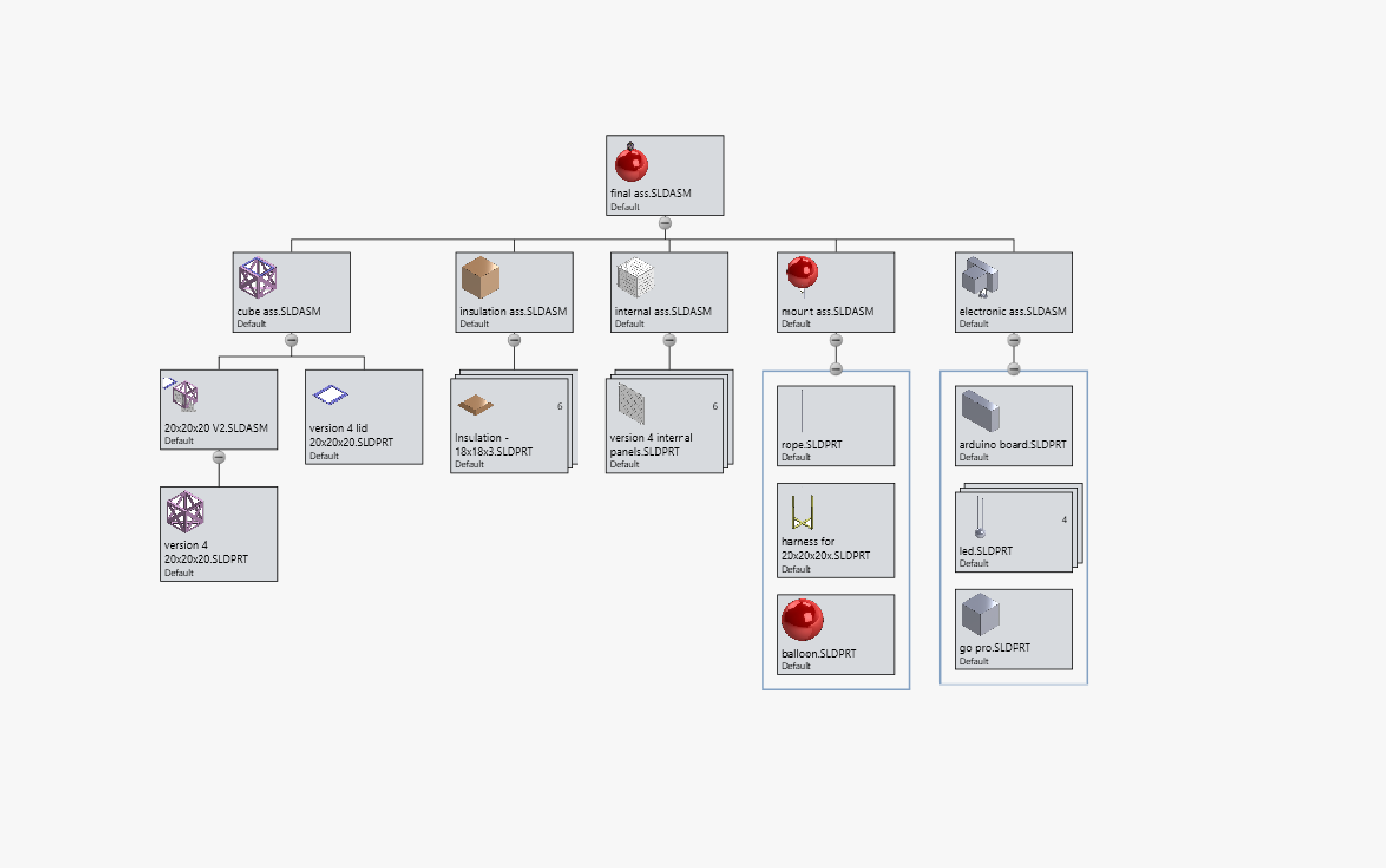
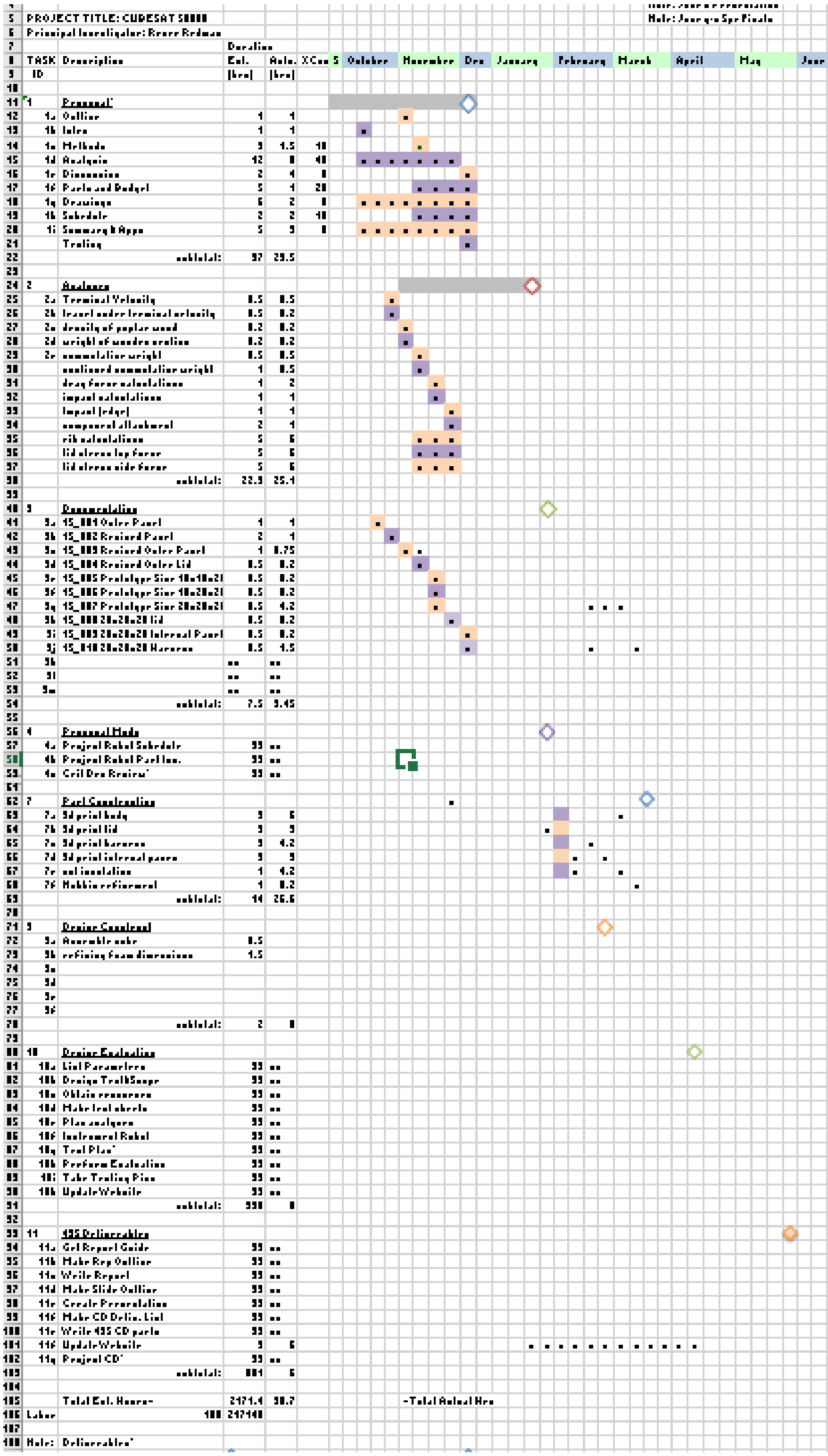


Figure 24 Drawings tree for entire system

Apendix D – Parts and Cost

Item Description	Item Source	Cost	Quantity	Subtotal	Taxes
PetG filament	Matter Hackers	19.99	1	$19.99	$1.30
Rmax Thermasheath®-3	Home Depot	34.88	1	$34.88	$2.27
weather balloon	Scientific Sales	35.00	1	$35.00	$2.28
Polypropylene Diamond Braid Rope	Home Depot	12.98	1	$12.98	$0.84
3mm LED Pack - 25 pack	Adafruit	2.95	1	$2.95	$0.19
Color sensors	Adafruit	7.95	1	$7.95	$0.52
Lithium Ion Polymer Battery - 3.7v	Adafruit	14.95	1	$14.95	$0.97
Adafruit METRO 328 - Arduino Compatible - with Headers	Adafruit	17.50	1	$17.50	$1.14
Go Pro Protective Housing	Go pro	49.99	1	$49.99	$3.25
Go Pro Hero7	Go Pro	199.99	1	$199.99	$13.00
breadboarding wire bundle	adafruit	4.95	1	$4.95	$0.32
Helium - 73 ft^3	ozarc	143.30	1	$143.30	$9.31
			Total	$579.82	

Appendix E – Schedule



PROJECT TITLE: CUBESAT S[illegible]

Principal Investigator: [illegible]

TASK ID	Description	Duration Est. (hrs)	Duration Actu. (hrs)	XCom
1	Proposal'			
1a	Outline	1	1	
1b	Intro	1	1	
1c	Methods	3	1.5	10
1d	Analysis	12	0	40
1e	Discussion	2	4	0
1f	Parts and Budget	5	4	20
1g	Drawings	6	2	0
1h	Schedule	2	2	10
1i	Summary & Apps	5	3	0
	Testing			
	subtotal:	37	29.5	
2	Analyses			
2a	Terminal Velocity	0.5	0.5	
2b	impact under terminal velocity	0.5	0.2	
2c	density of poplar wood	0.2	0.2	
2d	weight of wooden sealing	0.2	0.2	
2e	cumulative weight	0.5	0.5	
	combined cumulative weight	1	0.5	
	drag force calculations	1	2	
	impact calculations	1	1	
	Impact (edge)	1	1	
	component attachment	2	1	
	rib calculations	5	6	
	lid stress top force	5	6	
	lid stress side force	5	6	
	subtotal:	22.9	25.1	
3	Documentation			
3a	15_001 Outer Panel	1	1	
3b	15_002 Revised Panel	2	1	
3c	15_003 Revised Outer Panel	1	0.75	
3d	15_004 Revised Outer Lid	0.5	0.2	
3e	15_005 Prototype Size 10x10x21	0.5	0.2	
3f	15_006 Prototype Size 10x20x21	0.5	0.2	
3g	15_007 Prototype Size 20x20x21	0.5	4.2	
3h	15_008 20x20x20 lid	0.5	0.2	
3i	15_009 20x20x20 Internal Panel	0.5	0.2	
3j	15_010 20x20x20 Harness	0.5	1.5	
3k		--	--	
3l		--	--	
3m		--	--	
	subtotal:	7.5	9.45	
4	Proposal Mods			
4a	Project Robot Schedule	99	--	
4b	Project Robot Part Inv.	99	--	
4c	Crit Des Review'	99	--	
7	Part Construction			
7a	3d print body	3	6	
7b	3d print lid	3	3	
7c	3d print harness	3	4.2	
7d	3d print internal pieces	3	3	
7e	cut insulation	1	4.2	
7f	Hobbie refinement	1	0.2	
	subtotal:	14	26.6	
9	Design Construct			
9a	Assemble cube	0.5		
9b	refining foam dimensions	1.5		
9c				
9d				
9e				
9f				
	subtotal:	2	0	
10	Design Evaluation			
10a	List Parameters	99	--	
10b	Design TruthScope	99	--	
10c	Obtain resources	99	--	
10d	Make test sheets	99	--	
10e	Plan analyses	99	--	
10f	Instrument Robot	99	--	
10g	Test Plan'	99	--	
10h	Perform Evaluation	99	--	
10i	Take Testing Pics	99	--	
10k	Update Website	99	--	
	subtotal:	990	0	
11	495 Deliverables			
11a	Get Report Guide	99	--	
11b	Make Rep Outline	99	--	
11c	Write Report	99	--	
11d	Make Slide Outline	99	--	
11e	Create Presentation	99	--	
11f	Make CD Deliv. List	99	--	
11e	Write 495 CD parts	99	--	
11f	Update Website	3	6	
11g	Project CD'	99	--	
	subtotal:	801	6	
	Total Est. Hours=	2171.4	58.7	
Labor	100	217140		
Note:	Deliverables'			

Months: S, October, November, Dec, January, February, March, April, May, June

=Total Actual Hrs

Appendix J - Job Hazard Analysis

JOB HAZARD ANALYSIS
CUBESAT 5000

Prepared by: Renee Redman	Reviewed by: Approved by:

Location of Task:	Multimodal Education Center in Samuelson Central Washington University
Required Equipment / Training for Task:	Eye Protection, Protective clothing, gloves
Reference Materials as appropriate:	3d Printer instructions and SOP Read and understanding appropriate first aid

Personal Protective Equipment (PPE) Required (Check the box for required PPE and list any additional/specific PPE to be used in "Controls" section)						
Gloves	Dust Mask	Eye Protection	Welding Mask	Appropriate Footwear	Hearing Protection	Protective Clothing
☒	☐	☒	☐	☐	☐	☒
Use of any respiratory protective device beyond a filtering facepiece respirator (dust mask) is voluntary by the user.						

TASK DESCRIPTION	HAZARDS	CONTROLS
Access to work area: is it clear of obstructions and slip/trip hazards	**Slip, Trips or Fall**	**Remove any obstructions or trip hazards. Maintain dry floor.**
3d printing heat hazard from nozzle tip temperatures	**Injury due to touching of nozzle tip temperature**	**Wear leather gloves and stay away form the nozzle head as the printer prints. Stop printing before accessing any part of the printer.**
General use of Cubesat assembly and weather balloon launch	**Overhead hazards**	**When using the Cubesat and other weather balloon related assemblies, ensure that you are not near any power cables**
General use of CubeSat and weather balloon launch	**Falling hazard**	**Ensure that you are not near highly populated areas as the balloon path is hard to predict.**
Removal of printed part	**Injury due to poor removal of part form platform bed** **Cut or eye damage due to sharp/ rough**	**Wear leather gloves. Use proper tooling for removal of part following the tutorial training. Wear gloves, safety glasses, and avoid handing rough edges. Wear**

	edges while removing support material on part. Injury due to platform bed temperature	**gloves**
Clean the printer bed and surrounding area	**Hot surfaces, flying debris**	**Wear safety glasses to prevent eye injury while removing small pieces of plastic from printer bed Use a vacuum or blower to remove debris form inside the printer.**

Refercenses

Tulane University – Safety instructions and Job hazard analysis: 3D printer

https://makerspace.tulane.edu/images/b/b8/3D_Printer_JHA_2017_03_04.pdf

Nasa – Job Hazard Analysis Worksheet: 3D printer

https://www.nasa.gov/sites/default/files/files/UP3DprinterJHA.pdf

Appendix F- Expertise and Resources

Addison Wenger- Physic department Technician responsible for all 3D printing

CWU Physics- Donated and provided all material and resources

Appendix G- Testing Report

				weight	10	oz
height (ft)	height (m)	energy (J)	Deflection		0.28	kg
1	0.3048	0.837225	none			
2	0.6096	1.674449	none			
3	0.9144	2.511674	none			
4	1.2192	3.348899	chipping			
5	1.524	4.186123	chipping			

Figure 25 Impact results 1

Appendix H- Resume/Vita

RENEE **REDMAN**

2109B North Yellowstone St. Ellensburg 98926 · 360-224-2364
· TheReneeRedman@gmail.com ·

Mechanical Engineering Technology student at Central Washington University.

EXPERIENCE

2016 – 2017

DETAILER, SPOTLESS AIR DETAILING

Contracted detailer for Spotless Air Detailing, working on automotive, aircrafts, and hangers.

2016 – 2018

ASSISTANT TENNIS COACH, LACEY PARKS AND REC.

Worked for Andrea Lipper each summer as an assistant coach, leading drills, instructing students, and managing equipment.

2017 – PRESENT

PRESIDENT, CWU ROCK CLIMBING TEAM

Managed the CWU competitive rock climbing team competing in the Northwestern Collegiate Climbing Circuit.

EDUCATION

JUNE 2016

HIGH SCHOOL GRADUATE, TIMBERLINE HIGH SCHOOL

Graduated with honors and a 3.5 GPA. Participated in band for 4 years with 2 years as the lead drum major. Tennis team for 4 years with 2 on Varsity. Took and passed 5 AP classes.

2016-2020 YEAR

CURRENTLY ENROLED, CENTRAL WASHINGTON UNIVERSITY

3.3 Current GPA.