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NRJ RC Baja Vehicle Project - Transmission, Suspension, and Body Systems

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CENTRAL WASHINGTON UNIVERSITY

Mechanical Engineering Technology

MET 489 SENIOR PROJECT

NRJ RC BAJA VEHICLE PROJECT

ASME RC Baja Project Team #3

TRANSMISSION, SUSPENSION, AND BODY SYSTEMS

By

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Team Members: Naoki Masuda, Ryder Satak

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ABSTRACT

Students of Central Washington University's Mechanical Engineering technology program were tasked with designing, manufacturing, and testing a remote-controlled scale vehicle for the American Society of Mechanical Engineers (ASME) Radio-Controlled (RC) Baja Car Contest sanctioned by Remotely Operated Auto Racers (ROAR). A team of three students was assembled and responsibility over the sections of the RC vehicle were divided amongst the three students. This report focuses on the design, manufacture, testing, and evaluation of the suspension and transmission systems of the RC vehicle.

A suspension tower component and transmission housing assembly were conceived to satisfy the RC suspension and transmission systems. Engineering analyses were conducted on various aspects of the then to-be-manufactured parts to achieve optimal dimensions. The parts were 3D-modeled using SolidWorks software, and were manufactured using 3D printing methods and machining methods. The various parts were then tested and evaluated to ensure they satisfied their basic requirements and met the criteria of the ASME Contest.

The suspension towers and transmission covers conceived in this project are easily manufactured, interchangeable, require less than three tools to disassemble, and are able to be assembled and disassembled in less than five minutes. The transmission covers and suspension towers successfully completed a one-hour continuous operation test without any disassembly or reduction in function. The covers also successfully withstood the required exterior forces specified in the report. Both components resisted a drop from two feet, along with the entire RC vehicle.

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1. INTRODUCTION

a. Description

The Central Washington University RC Baja Team #3 comprising of Naoki Masuda, Ryder Satak, and Jeffrey Harn are tasked to produce a remote-controlled vehicle for the ASME Radio-Controlled Baja Car Contest sanctioned by Remotely Operated Auto Racers (ROAR) and hosted by Central Washington University.

The RC Baja Team #3, also known as NRJ RC, will use the knowledge and skills obtained so far from their ongoing Mechanical Engineering Technology degrees at Central Washington University to design, manufacture, and assemble the necessary parts of a functional RC Baja vehicle. NRJ RC is permitted to use any literature or knowledge applicable to vehicle design and are restricted to use any direct involvement of professional engineers, automotive engineers, or related professionals.

b. Motivation

Entirely store purchased radio remote control vehicles are prohibited in the ASME Radio-Controlled Baja Car Contest. In order to participate, attending teams must design and manufacture portions of their vehicles. Therefore, as a team, NRJ RC is motivated to design, manufacture, and assemble a vehicle to enter into the competition.

The entire remote-controlled vehicle does not need to be designed and manufactured as per the competition rules. According to said rules, only the differential needs to be designed and manufactured by the student teams. For this project, NRJ RC will design and manufacture the following vehicle components:

- Chassis (N)
- A-arms (N)
- Asset/Electronic Layout (N)
- Differential (R)
- Gear-up/Transmission (R)
- Differential Housing (R)
- Transmission Housing (J)
- Suspension Towers (J)
- Body/Fuselage (J)

This report will focus on the last three components of the list: the transmission housing, the suspension towers, and the optional body/fuselage. These three components will be designed and manufactured by team member Jeffrey Harn.

c. Function Statement

Please see the below function statements for the transmission housing, the suspension towers, and the optional body:

Transmission Housing

Function: to completely enclose the transmission body and gear assembly and protect the aforementioned from dust, debris, and harmful impact.

Suspension Towers

Function: to act as a secure base for the suspension arms (shocks and springs) to actuate against when undergoing forces and serve as a mounting point for a body/fuselage.

Optional Body/Fuselage

Function: to mount to the suspension towers of the vehicle and serve as rollover protection, protect vehicle components, and stylize the vehicle.

d. Requirements

Please see the below requirement statements for the transmission housing, the suspension towers, and the optional body:

Transmission Housing

- Must be able to prevent all amounts of dust, water, and mud from entering the transmission housing interior.
- Must fit within a 3 x 3 x 3 in cubic area.
- Must not self-disassemble or be damaged crucially in any fashion after one hour of straight operation.
- Must require no greater than two tools to assemble and disassemble.
- Must be assembled and disassembled in no longer than ten minutes.

Suspension Towers

- Must withstand a direct impact from a two-foot drop while secured to the chassis.
- Must withstand a maximum 10 [lbs] of force from suspension arm actuation.
- Must vertically hold up to 5 [lbs] when inverted.
- Must secure body/fuselage and resist up to 5 [lbs] of force.
- Must be disassembled using no greater than three tools.
- Must connect to the chassis via four mounting points.
- Must not self-disassemble or be damaged crucially in any fashion after one hour of straight operation.

Optional Body/Fuselage

- Must mount to the suspension towers via four mounting locations.
- Must require only one tool to disassemble.
- Must not self-disassemble or be damaged crucially in any fashion after one hour of straight operation.
- Must withstand an impact of 5 [lbs] of force in any direction.
- Must stimulate at least 100 visual dendrites.

e. Engineering Merit

This project requires engineering tactics and procedures as it proposes a problem to student teams and requires them to solve it within defined guidelines and regulations. Although a remote-controlled Baja vehicle can be aimlessly assembled and still perform well, detailed and effortful planning, design, calculation, meaningful manufacture, and design will ensure the produced RC vehicle will perform as intended.

f. Scope of Effort

Please also see **Section 1.b**. The scope of this particular proposal focuses on the efforts, planning, design, and manufacturing of the transmission housing, the suspension towers, and the optional body/fuselage of the remote control vehicle to be entered into the ASME competition. Team member Jeffrey Harn of RC Baja Team #3, otherwise known as NRJ RC, will the efforts and work that go into the design, manufacture, assembly, testing, and other operation of the above mentioned three vehicle components.

g. Success Criteria

The success of this project as a whole depends on the overall ability of the remote controlled Baja vehicle to pass official inspection of competition requirements and regulations for the ASME Radio-Controlled Baja Car Contest on competition day. Also, the success of this project as a whole depends on the actual physical performance of the vehicle on competition day, more specifically, the successful completion of all competition events. Lastly, the success of this project is weighed in part by the manufactured RC to meet the specified requirements.

2. DESIGN & ANALYSIS

a. Approach: Proposed Solution

This design was one of the three proposed senior projects for Central Washington University for the Fall 2020 to Spring 2021 school year. Selection of this design was motivated by prior experience with, and an interest in the operation of RC vehicles, specifically aircraft.

NRJ RC Baja intends to combine personally designed and manufactured components along with professionally designed purchased parts. NRJ hopes to create parts that are lightweight, inexpensive, and strong. Therefore, NRJ originally decided to create their parts from wood and reinforce them with fiber glass and resin.

b. Design Description

The initial design of the suspension towers was sketched out. These sketches and designs are subject to change throughout the quarter but served to be a foundation for more ideas and revisions to grow off of. Please see the scanned image of the sketches in **APPENDIX B-18**.

c. Benchmark

The benchmark that NRJ RC Baja tends to use as inspiration for the design of the Baja vehicle are those vehicles and parts designed by Traxxas RC. Traxxas produces high quality parts and full assemblies. NRJ has a tangible example from Traxxas that is owned by Ryder Satak, and NRJ intends to practice operating RC's with said example, utilize the vehicle for design inspiration, and use legal parts off of the vehicle to use on the project vehicle.

d. Performance Predictions

By the nature of this project, NRJ RC Baja's remote-controlled Baja vehicle will by no means be anywhere near the quality, precision, or functionality of a fully professional remote-controlled Baja vehicle. However, NRJ's project RC will certainly be functional, durable, and operational.

NRJ RC Baja predicts that the project RC will survive an impact from two feet high, reach speeds up to 20 [mph], have the agility to maneuver as needed on the various tracks of the ASME competition, and finish a day of use intact.

e. Description of Analysis

Many analyses will be conducted in order to determine component and part requirements in terms of aspects such as size, material, position, shape, etc. These analyses are done on green calculation sheets and utilize the skills and knowledge obtained from the MET program at Central Washington University up to this point. Please see **Section 2.g.** for detailed information on each individual analysis.

f. Scope of Testing and Evaluation

The three component assemblies being designed in this report will be evaluated and tested by Jeffrey Harn. These include the suspension tower, the transmission covering, and the RC body.

Testing will be conducted at Central Washington University using the various instruments and machines made available to students. Careful documentation will be kept over the progress and results of the testing, and design alterations will be made if needed upon the review of the testing results.

g. Analysis

i. Analysis 1 – Motor Power

This analysis addresses the issue of the motor's minimal power requirement. An estimated total RC vehicle mass of 6 [kg] was used, and a coefficient of rolling friction of a bicycle tire on rough pavement was used[1]. This analysis was performed utilizing the principle of rolling friction to calculate how much force is required to move an RC vehicle beyond the restrictions of rolling friction. Then, the power required to overcome this force and maintain a velocity of 40 [mph] was calculated.

The amount of power required to move a 6 [kg] RC vehicle with rubber tires on rough pavement at 40 [mph] is 16 [W]. Therefore, an electric motor capable of producing at least 16 [W] of power will be required for this project. Please see **APPENDIX A-1** for the green sheet used in this analysis.

ii. Analysis 2 – Part A: Maximum Forces in Suspension Arm Section

This analysis was revised from its original state. The below information reflects the historical values of the analysis but does not reflect the current values. Please see the last paragraph in this section to learn about the changes made to this analysis.

This is a multi-part analysis that aims to estimate the required cross-sectional area and dimension of the arm portion of the suspension tower. Part A looks into a section of the suspension tower and evaluates the forces acting on it based off a defined load and load angle.

An estimated maximum external load of 10 [lbs] was given. This is the load that the suspension strut will deliver to the suspension tower arm. An arm length of one inch is assumed, and the suspension tower arm is sectioned such that the resulting member is straight with no curvature. Thus, the arm can be evaluated just as a simple beam undergoing load. The force from the suspension arm is assumed to act at an angle of 30 degrees from the vertical. The suspension arm is 45 degrees from the horizontal. Thus, the force acting on the arm section has an angle of attack of 15 degrees.

Free body, shear, and moment diagrams were constructed and the results are as follows. The maximum direct shear force is calculated to be 9.6 [lbs], the maximum normal compressive force is calculated to be 2.6 [lbs], and the maximum moment across the one inch section is 9.6 [lb-in]. Please refer to **APPENDIX A-2** for the green sheet calculations.

A formal revision of this analysis was conducted on 23 May 2021 using red graphite. The material in question was changed from balsa wood to PLA plastic.

iii. Analysis 3 – Part B: Maximum Forces in Suspension Arm Section

This analysis was revised from its original state. The below information reflects the historical values of the analysis but does not reflect the current values. Please see the last paragraph in this section to learn about the changes made to this analysis.

Analysis three looks to continue the evaluations conducted in **Analysis 2**. Analysis three examines the bending stress present in the section of the suspension tower arm and compares it to the ultimate compressive strength of the material chosen, balsa wood.

From **Analysis 2** it was discovered that a 10 [lb] force from the suspension strut would cause a maximum moment of 9.6 [lb-in]. This moment will cause bending stress in the section of the suspension arm. A dimension parameter is needed to be found for the cross-sectional dimensions of the suspension arm section. To do this, the ultimate compressive and tensile strengths of plywood were found on MatWeb[2]. Picking the lower of the two, the compressive strength, this value was inputted into the flexure formula to solve for *c*, assuming that the value of *c* equals the value of the dimension of a square cross section.

Dimensions of 0.351 [in] by 0.351 [in] are found to be the minimum dimension to avoid failure. These dimensions were rounded up to standard dimension sizes of 0.5 [in] by 0.5 [in]. This increase in dimensions provides a safety factor of roughly 1.6. Please refer to **APPENDIX A-3** for the green sheet calculations.

A formal revision of this analysis was conducted on 23 May 2021 using red graphite. The material in question was changed from balsa wood to MakerBot PLA plastic. The ultimate stress used in the calculations was changed from 1840 [psi] to 5710 [psi]. The calculated dimension was corrected from 0.315 [in] to 0.216 [in], with 7 [mm] being chosen for the design dimension. This dimension yielded a safety factor of two.

iv. Analysis 4 – Part C: Maximum Forces in Suspension Arm Section

This analysis was revised from its original state. The below information reflects the historical values of the analysis but does not reflect the current values. Please see the last paragraph in this section to learn about the changes made to this analysis.

Analysis four continues the work done in **Analysis 3**. This analysis moves on from bending stress to evaluate the transverse shear stress that will be present in the beam due to bending caused by the forces coming from the suspension strut.

The 9.6 [lb] shear force found in **Analysis 2** will be used to calculate the transverse shear stress present in the suspension tower arm section. The purpose of this analysis is to yield a dimension parameter and verify that the parameter found in **Analysis 3** will be enough to withstand the transverse shear stress. Using MatWeb[2] as a reference, the ultimate shear strength is found and is equated to the transverse shear equation for a rectangle. The equation is rearranged to solve for area.

With a shear force of 9.6 [lbs], and using the cross sectional area based on the dimensions found in **Analysis 3**, it is discovered that 3.6 [psi] of transverse shear stress will be present in the beam. This is much lower than the ultimate shear strength of the selected plywood. This verifies the dimensions found in **Analysis 3**. For speculative purposes, the minimum area was calculated based on the ultimate shear stress and it was found to be 0.03 [in^2]. The cross-sectional area found in **Analysis 3** of 0.25 [in^2] provides a safety factor of roughly 3 when compared to the minimum area. Please refer to **APPENDIX A-4** for the green sheet calculations.

A formal revision of this analysis was conducted on 23 May 2021 using red graphite. The material in question was changed from balsa wood to MakerBot PLA plastic. The trial-run dimension was changed from 0.25 [in] to 0.275 [in] based off the results from **Analysis 3**. The estimated shear strength of the material was corrected from 435 [psi] to 2855 [psi] and the maximum shear in the material was corrected to 190.41 [psi]. The design dimension was corrected from 0.5 [in] to 0.275 [in]. This dimension yielded a safety factor of 13.5.

v. Analysis 5 – Bending Stress in Suspension Tower Main Section

This analysis was revised from its original state. The below information reflects the historical values of the analysis but does not reflect the current values. Please see the last paragraph in this section to learn about the changes made to this analysis.

Analysis five looks to satisfy the requirement that the suspension tower must withstand a horizontal 10 [lb] force acting on the top of the suspension tower. This requirement ensures the suspension tower will not succumb to yielding when the RC may collide with an object.

This analysis yields a dimension parameter for the thickness of the main rectangular section of the suspension towers, not including the arm sections. ABS Polymer is used as the material and material properties are found utilizing MatWeb[2]. The flexural yielding stress is used and is equated with the flexure formula to isolate and solve for the height of the cross-section of the suspension tower rectangular section.

Due to the 10 [lb] force, a moment of 15 [lb-in] is created considering the height of the section is 1.5 [in]. Using a flexural yield strength of 10700 [psi], the strength is equated to the flexure formula and the minimum height of the cross section is found to be 0.04585 [in]. Rounding up to a standard value of 1/16 [in] of a section thickness, this provides a safety factor of 1.36, approximately. Please refer to **APPENDIX A-5** for the green sheet calculations.

A formal revision of this analysis was conducted on 23 May 2021 using red graphite. The material in question was changed from ABS plastic to MakerBot PLA plastic. The material property used in the analysis was switched from a flexural yield of 10700 [psi] to a tensile yield of 5710 [psi]. A force vector was applied to the diagram. The new calculated minimum dimension is 0.08 [mm], with the old being 0.05 [in]. This resulted in a design dimension of 7 [mm]. This dimension yielded a safety factor of 9.5.

vi. Analysis 6 – Shear Stress

Analysis six sees to calculate the required fasteners size in order to successfully secure the suspension towers to the chassis. This will ensure that the suspension towers remain stable and present on the chassis when undergoing loading.

This analysis returns a fastener diameter. The fastener material is chosen to be SAE grade 1 steel. The material properties for this material are refenced from Table 19-1 in Mott[6]. To conduct the analysis, a shear force of 10 [lb] is assumed and acts on one fastener. The equation for direct shear is used and the diameter in the area component is isolated and solved for.

SAE grade 1 fastener steel has a yield strength of 36 [ksi]. Equating this to the shear formula, a diameter of 0.018 [in] is found. Rounding up to the next standard size, a fastener diameter of 1/4 [in] is used. This is a very generous increase in diameter and offers a safety factor of roughly 14! Please refer to **APPENDIX A-6** for the green sheet calculations.

vii. Analysis 7 – Suspension Tower Stress Concentration

This analysis was revised from its original state. The below information reflects the historical values of the analysis but does not reflect the current values. Please see the last paragraph in this section to learn about the changes made to this analysis.

Analysis seven focuses in on the area in which the suspension strut attaches to the suspension tower. Since the geometry of this area consists of a hole with material surrounding it, and considering it will undergo some portion of axial loading when in use, it is identified as an area of stress concentration. A section width *w* of this area that will effectively withstand the stress under use needs to be known to be sure it will not fail when being used.

The material of the suspension tower is chosen to be ABS molded plastic. Material properties are referenced from MatWeb[2] in order to complete this analysis. A force of 10 [lb] acting on the hole from the screw is assumed. A graph for a stress concentration that best represents the situation is referenced from Appendix A18-4 on page 832 in Mott[6]. The nominal stress and maximum stresses are calculated, then compared to the yield stress.

The ABS plastic material on MatWeb[2] has a tensile strength yield of an average of 45 [MPa], or roughly 6527 [psi]. A reasonable trial-and-error "w" value of 0.5 [in] is chosen to be tested. Using a thickness of 0.5 [in], the nominal stress is calculated to be 52.37 [psi]. Applying the K_t factor of 5.0 found from the table, a maximum stress of 262 [psi] is calculated. Since this is much less than the yield strength value, a *w* value of 0.5 [in] is safe and will be used. Please refer to **APPENDIX A-7** for the green sheet calculations.

A formal revision of this analysis was conducted on 23 May 2021 using red graphite. The material in question was changed from ABS plastic to MakerBot PLA plastic. The tensile yield of the material was updated from 45 [MPa] to 39.3 [MPa] and the given thickness was updated to be 7 [mm]. Nominal stress in the analysis was corrected to be 231 [psi], giving a maximum stress of 1158.89 [psi]. A design dimension of 7 [mm] was verified versus the old of 0.5 [in].

viii. Analysis 8 – Suspension Tower Stress Concentration 2

This analysis was revised from its original state. The below information reflects the historical values of the analysis but does not reflect the current values. Please see the last paragraph in this section to learn about the changes made to this analysis.

Analysis eight focuses in on the area in which the camber link attaches to the suspension tower. Since the geometry of this area consists of a hole with material all around it, and will undergo some portion of axial loading when in use, it is considered an area of stress concentration. A section width *w* of this area that will effectively withstand the stress under use needs to be known to be sure it will not fail when operated.

The material of the suspension tower is chosen to be ABS molded plastic. Material properties are referenced from MatWeb[2] in order to complete this analysis. A force of 10 [lb] acting on the hole from the pin is assumed. A graph for a stress concentration that best represents the situation is referenced from Appendix A18-4 on page 832 in Mott[6]. The nominal stress and maximum stresses are calculated, then compared to the yield stress.

The ABS plastic material on MatWeb[2] has a tensile strength yield of an average of 45 [MPa], or roughly 6527 [psi]. A reasonable trial-and-error "w" value of 0.25 [in] is chosen to be tested. Using a thickness of 0.25 [in], the nominal stress is calculated to be 303.28 [psi]. Applying the K_t factor of 2.6 found from the table, a maximum stress of 788.54 [psi] is calculated. Since this is much less than the yield strength value, a *w* value of 0.25 [in] is safe and will be used. Please refer to **APPENDIX A-8** for the green sheet calculations.

A formal revision of this analysis was conducted on 23 May 2021 using red graphite. The material in question was changed from ABS plastic to MakerBot PLA plastic. The tensile yield strength of the material was updated from 45 [MPa] to 5710 [psi].

ix. Analysis 9 – Suspension Tower Stress Concentration 2

This analysis was revised from its original state. The below information reflects the historical values of the analysis but does not reflect the current values. Please see the last paragraph in this section to learn about the changes made to this analysis.

Analysis nine focuses again on the area in which the suspension strut attaches to the suspension tower. This time, however, the material surrounding the pin hole is analyzed. The pin hole is required to withstand a 10 [lb] force without failing. The material around the pin hole will be under direct shear force due to forces acting on the suspension strut.

This analysis yields a dimension parameter for the radius of the boss section that contains the pin hole. ABS polymer is used as the material and material properties were found utilizing the databases on MatWeb[2]. Unfortunately, no data on the shear strength of ABS could be found so the tensile yield strength was used as this was the next best option. The shear area of the material is defined, a free body diagram is drawn for the section that contains the area, and the shear force is found. The direct shear equation is used and equated to the tensile yield strength of the material. A section width of 0.50 [in] is assumed. With this equation, the length, *l*, of the area is found by isolating the area in the equation.

From the free body diagram, it is found that due to a 10 [lb] force from the pin, one area plane of the section is subjected to a 5 [lb] shear force. Using a tensile yield strength of 45 [MPa] or 6526.69 [psi], a length, *l*, of 0.1 [mm] is enough to withstand the shear force acting on the section. Please refer to **APPENDIX A-9** for the green sheet calculations.

A formal revision of this analysis was conducted on 23 May 2021 using red graphite. The material in question was changed from ABS plastic to MakerBot PLA plastic. The shear yield strength of the material was updated from 45 [MPa] to 5710 [psi]. The thickness dimension was updated from 0.5 [in] to 0.275 [in].

x. Analysis 10 – Suspension Tower Stress Concentration 2

This analysis was revised from its original state. The below information reflects the historical values of the analysis but does not reflect the current values. Please see the last paragraph in this section to learn about the changes made to this analysis.

Very similar to **Analysis 9**, analysis ten focuses on the area in which the camber link attaches to on the suspension tower. The pin hole is required to withstand a 10 [lb] force without failing. The material around the pin hole will be under direct shear force due to forces acting on the suspension strut.

This analysis yields a dimension parameter for the radius of the boss section that contains the pin hole. ABS polymer is used as the material and material properties were found utilizing the databases on MatWeb[2]. Unfortunately, no data on the shear strength of ABS could be found so the tensile yield strength was used as this was the next best option. The shear area of the material is defined, a free body diagram is drawn for the section that contains the area, and the shear force is found. The direct shear equation is used and equated to the tensile yield strength of the material. A section width of 0.25 [in] is assumed. With this equation, the length, *l*, of the area is found by isolating the area in the equation.

From the free body diagram, it is found that due to a 10 [lb] force from the pin, one area plane of the section is subjected to a 5 [lb] shear force. Using a tensile yield strength of 45 [MPa] or 6526.69 [psi], a length, *l*, of 0.1 [mm] is enough to withstand the shear force acting on the section. Please refer to **APPENDIX A-10** for the green sheet calculations.

A formal revision of this analysis was conducted on 23 May 2021 using red graphite. The material in question was changed from ABS plastic to MakerBot PLA plastic. The shear yield strength of the material was updated from 45 [MPa] to 5710 [psi].

xi. Analysis 11 – Car Body Drag Coefficients

Analysis eleven was conducted in order to assist in the decision of the RC car body design. This analysis takes the frontal profiles of three possible body designs and evaluates their aerodynamic properties. The first body, Body 1, examples medium car coverage and medium weight. Body 2 examples maximum coverage and maximum weight. Finally, Body 3 examples minimum coverage and minimum weight.

This analysis solves for the drag coefficients for each car body frontal profile. The dimensions of the car body and the properties of air at an assumed 70 degrees Fahrenheit and an atmospheric pressure of 1 [atm] are known. The air speed assumed to flow over the car bodies is 20 [mph]. The typical drag force for a full-size passenger vehicle was referenced from The Fundamentals of Thermal Fluid Sciences[5] to be approximately 70 [lb]. Knowing that the scale of the RC is 1:10, the force can therefore be scaled down by ten to achieve an approximate drag force of 7 [lb]. This assumption is necessary to make as access to a wind tunnel is not possible for this project.

The frontal areas of the car bodies were estimated using basic geometry to be 26.5 [in^2], 43.57 [in^2], and 13 [in^2] for car bodies 1, 2, and 3, respectively. The areas were converted into units of square feet. The drag coefficients were calculated using the equation found in The Fundamentals of Thermal Fluid Sciences[5]. Drag coefficients of 38.0, 23.1, and 77.5 for bodies 1, 2, and 3, respectively, were calculated. These values are used in the decision-making process for car body design as seen in **APPENDIX F-2**. Please refer to **APPENDIX A-11** for the green sheet calculations.

xii. Analysis 12 – Shear Stress 2

Analysis twelve sees to calculate the required fastener size in order to successfully secure the two pieces of the transmission cover. This will ensure that the transmission cover pieces maintain a tight seal to prevent debris from entering the gear inside, and to ensure the gears stay aligned.

This analysis returns a fastener diameter. The fastener material is chosen to be metric steel fastener grade 4.6. The material properties for this material are refenced from Table 19-3 in Mott[6]. To conduct the analysis, a shear force of 10 [lb] is assumed and acts on one fastener. The equation for direct shear is used and the diameter in the area component is isolated and solved for.

Metric steel fastener grade 4.6 has a listed yield strength of 240 [MPa]. Equating this to the shear formula, a diameter of 0.118 [nm] is found. Rounding up to the next standard size, a fastener diameter of 1.6 [mm] is used. This is a very generous increase in diameter and offers a safety factor of roughly 13560! Please refer to **APPENDIX A-12** for the green sheet calculations.

h. Device: Parts, Shapes, and Conformation

The RC components designed in this report were designed with a central theme in mind. This theme is such that the RC components are spartan and rudimentary. To explain, these parts are created using the simplest possible design that meets all the basic requirements and completes the task effectively and efficiently. Excluding the body, minimal fancy aesthetic characteristics were added to any of the component designs, rather, the designs emulate the basic requirements themselves.

Safety factors above the value of one are all used. Most safety factors of the component parts in this report range from safety factors of 1.3-15. The safety factors of these components did not drive the design of the components, rather, they are results of the designs, particularly, they are results of the analyses. The design parameters obtained from the analyses produce safety factors of a value of one, for the analyses solved for minimum dimensions using failure values. The safety factors are then obtained when these minimum values are rounded upwards to common/standard dimensional values.

The tolerances associated with the designs found in this proposal are assigned such that the various RC parts will mesh together properly. Tolerances are determined with additive manufacturing in mind.

i. Device Assembly

The overall assembly of this project is a fully-operational, remote-controlled, 1/10 scale automobile specified for Baja style competition. The final assembly will successfully perform in two racing events as specified by the ASME Radio-Controlled Baja Car Contest. These two racing events are the Slalom-and-Sprint event and the Baja event.

The RC vehicle assembly will be successful in both of these events as the assembly will feature adequate control from the electrical components, adequate handling from the suspension, wheel, and steering components, adequate durability from the chassis components, and adequate power transmission from the gearing components.

j. Technical Risk Analysis

This RC Baja vehicle project design optimizes minimal weight and simplicity. Therefore, a multitude of mechanical risks arise. Below are descriptions of the technical risks present in this project.

The RC being designed in this project is optimized for its weight. This means the RC is being designed to the lightest weight allowable while maintaining minimum strength requirements. This is completed by using balsa wood as a chassis material and designing printed PLA plastic with relatively low safety factors. The technical risk of component failure arises here. Dimensional parameters were calculated by assuming the forces that are to act on the RC during use. It is possible that said forces are underestimated which will lead to component failure when in use.

The electrical components being used for this project are both simple components, and non-specialized components—in other words, not made specifically for RC Baja vehicles. The focus of this project lies in the mechanical design of the RC, not the electrical component and circuit design. The NRJ RC Baja team has no professional experience in electrical RC component design. Therefore, the following technical risks arise. First off, the RC vehicle will be limited to simple features and will lack many advanced electronic and radio features that may be found in other commercial RC. Thus, this RC has the risk of being outperformed by RC's with more advanced circuitry. Also, there is the risk of electrical component incompatibility as various brands and styles of electrical components will be used.

One last technical risk may be defined as follows. The evaluation of the success of the RC vehicle at the end of this project consists of two races. The RC vehicle is not capable of autonomously completing said races. Consequently, a human operator is need. This allows the technical risk of operator error to arise as the RC success will depend largely on the success of its pilot during the testing.

k. Failure Mode Analysis

There are many failure modes addressed in this portion of the project. All said failure modes fall under one category. This failure mode category is structural integrity. The suspension assembly, transmission body assembly, and body are all non-electronic and serve the purpose of transmitting or manipulating force in one way or another. Thus, the only failure mode that is considered relates to the forces experienced by the components designed in this project.

The suspension tower, transmission cover, and the vehicle body will all undergo static, dynamic, and shock loading. The suspension tower will experience bending, tension, and compression from the suspension struts, and shear from the fasteners. The transmission cover will be subject to shear from its fasteners and have to resist compression from outside forces. The body likewise must resist shear from its fasteners and compression from outside forces. Considering the components are to be manufactured using polymers, the failure modes that will occur in this project are ductile failures from the various stresses and fatigue from use.

l. Operation Limits and Safety

The majority of the operational limits of this project are dependent on the technical specifications and various limits of each commercially purchased electronic component. To explain, the motor, steering servo, speed controller, and receiver must all operate on the same voltage and ampage rating of the power source used. Also, the ASME Radio-Controlled Baja Car Contest rules establish regulations for the RC Baja vehicles that limit the allowed RC components in order to maintain a fair competition. Furthermore, there are other, broader operation limits of the RC vehicle when considering the vehicle’s operation environment and overall ability. To explain, the environment in which the RC is being driven must include obstacles that are scaled to itself as a 1/10 scale RC Baja vehicle will have no success over obstacles that a full-size Baja vehicle can conquer.

There are two main areas of safety concern for this project: electrical shock and possible harm from moving components. Being an electrically driven system, circuitry and electrical components will be present and “live” while holding and operating this device. Thus, the risk of electrical shock is ever present. The other safety risk is the risk of bodily injuring from moving components on the device. Namely, the transmission gearing, powered axels, and wheels pose a threat to hands and fingers if not handled carefully.

3. METHODS & CONSTRUCTION

a. Methods

The NRJ RC Baja project was initiated to meet the requirements of the Mechanical Engineering Technology program at Central Washington University. The NRJ team brainstormed and networked between its members to produce solutions to the problem defined by the ASME Radio-Controlled Baja Car Contest, namely, the need for a competition-ready RC vehicle. This project requires the team to design and manufacture multiple RC components and assemble them in conjunction with other purchased RC vehicle parts. The NRJ RC team equally distributed roles on these various components.

Each team member defined their problem, employed a solution, conducted analyses for design parameters, designed functioning solutions, and manufactured said solutions. Following the milestones in the CWU MET 489 Senior Project class series, the team will manufacture and continue to analyze their components in winter quarter and test their components in spring quarter. The manufacturing of RC components will occur within the constraints of CWU's resources and tooling using training received from CWU classes and existing experience. Testing will be conducted by the team and, in part, utilize testing instruments from CWU.

i. Process Decisions

Two main decisions were made during the design portion of this project. These two decisions are the decision over material type and vehicle body style. At the beginning of this quarter, it was informally decided among the NRJ RC team that most of the manufactured parts were going to be of balsa wood. Balsa wood was chosen for its light weight and inexpensiveness. However, after an analysis over the suspension tower's required dimensions and a discussion with project mentors Charles Pringle and Dr. Jeunghwan Choi, it was decided to reconsider the material choice for the team-manufactured components. Printable ABS and printable PLA polymers were then considered as viable material options. Printable PLA plastic polymer was proposed in replace to balsa wood for all parts other than the vehicle chassis. A decision matrix was constructed later to formalize and review the decisions. To view this decision matrix, please visit **APPENDIX F-1**.

After another discussion with mentoring professors on the project over the availability of materials in winter quarter, the material decision for the majority of parts was formally altered. MakerBot Tough Filament PLA polymer material was chosen. PLA plastic was currently available to print at CWU and was compatible with the 3D printing machine. After a following team discussion, it was decided that PLA will be a better choice in material considering its greater elasticity over ABS.

Throughout the manufacturing process during winter quarter, some modifications had to be made to the parts in order for them to be completely compatible with both the other team members' parts, and the parts purchased or donated. Some examples of the modifications that occurred are filing material, drilling originally unplanned holes, drilling larger holes, modifying purchased parts, and overall improvising the designs "off the drawing board." All modifications and revisions may be viewed in **APPENDIX B.**

The other main project decision regards the vehicle body style. It was decided early by the NRJ RC Baja team that a polymer vehicle "fuselage" would be beneficial to include as the body will add vehicle aesthetic and protect the internal components from outside forces and debris. Having decided on the use of a body, the decision had to be made for what style of vehicle body is going to be used. Three options were generated and are as follows: Body 1 offers medium coverage with medium weight, Body 2 offers maximum coverage with maximum weight, and Body 3 offers minimum coverage with minimum weight. A decision matrix was employed that considers weight, aesthetic, and drag coefficients for each style. Body 1 was chosen. To view this decision matrix, please visit **APPENDIX F-2**. Unfortunately, manufacturing of the vehicle body did not occur during this project.

b. Construction

i. Description

This RC vehicle will consist of three main subgroups of assemblies, of which are the assemblies under the jurisdiction of the three members of the team, Ryder Satak, Naoki Masuda, and Jeffrey Harn. Combining the team members' assemblies together will create the full RC Baja vehicle assembly.

Most of the RC vehicle will consist of purchased and obtained parts, sourced from Traxxas and Castle Motors, purchased online and from local hobby retailers. The purchasing of specific RC vehicle parts is required as a number of components comprising the RC vehicle extend beyond the scope and ability of the team members in terms of manufacturing. The larger, more design-oriented parts of this RC are designed by the team and will be manufactured in full by the team using CWU facilities. Each team member will be responsible for the manufacturing of their individual assemblies and parts with assistance of the other team members.

ii. Drawing Tree, Drawing ID's

A drawing tree of the various team members' assemblies, subassemblies, and parts may be found in **APPENDIX B-1**. This tree lays out all of the manufactured and purchased parts, and details the many sub-assemblies that comprise the RC vehicle.

iii. Parts

A parts list including part numbers, quantity, part description, source description, cost, and disposition may be found in **APPENDIX C-1**. The parts containing the part number prefix "20-" will be fully designed and manufactured by the team using the facilities at the CWU engineering labs. These parts, excluding part number "20-001" will be 3D printed and machined to tolerance. Parts to utilize fasteners will be tapped to the specified threading to match the fasteners.

Parts with a part number of "55-" will be obtained commercially and will require no modification. Rather, the team member-designed parts will be designed with the compatibility of purchased components in mind and thus will cooperate together.

Parts with a part number of "50-" are fasteners and will be obtained commercially and will require no modification. Some fasteners are also previously owned. Again, the team member-designed parts will be designed with the compatibility of purchased components in mind and thus will cooperate together.

Parts with a part number of "10-" are assemblies and sub-assemblies, each assembled fully by the team member. All sub-assemblies consist of parts designed and manufactured by the team. Said sub-assemblies comply with each other and the collection of purchased parts to form the main RC assembly.

iv. Manufacturing Issues

Additive manufacturing has yet to be perfected at semi-professional levels, so issues are very likely to arise when manufacturing the various parts of this project. Issues may arise with the printer itself. Namely, the printer may be off calibration, experience feeding issues, or be unable to maintain optimal temperatures. Such issues will compromise the entire manufacturing process.

Less detrimental issues may include the printer not printing within acceptable tolerance. If such situation occurs, further machining will be conducted on the printed components to ensure they fall within tolerance. Mitigating techniques will be employed to reduce the issue of tolerance. For example, the holes on the model of a part that will be printed will be downsized so the holes can be machined to tolerance following the printing. Each part will be inspected and machined if needed regardless of whether the printer is able to print within tolerance to ensure part quality.

One final manufacturing issue may occur when the various components are to be assembled. It is possible for the parts to dimensionally differ from each other in such a way that mating parts do not properly mesh. In such case, one or both parts will be modified or remanufactured until proper meshing occurs. Geometric dimensioning and tolerancing will be employed to mitigate this risk.

v. Discussion of Assembly

The overall assembly of this RC vehicle consists of the six assemblies that follow: 10-002, 10-003, 10-004, 10-005, and 10-006. Please refer to **APPENDIX B-1** for more details. Ryder Satak overseas the transmission gear assembly and the differential assembly. Naoki Masuda overseas the chassis and electrical component assemblies, and Jeffrey Harn overseas the suspension tower, transmission cover, and body assemblies. Each assembly stated prior may contain subassemblies.

Combining the above stated assemblies will yield the complete assembly of NRJ RC's Baja vehicle. This vehicle will have all simple functions of the benchmark Traxxas Slash at a lower degree, about a 75% total performance rating when compared to the Slash commercial model. NRJ RC's vehicle will be slightly larger in size (1-2 [in]), weigh more, and cost about the same price considering only the part and material costs. Please see **APPENDIX D-1** for more details regarding part and material costs.

4. TESTING

a. Introduction

Three components of the RC Baja vehicle will be tested and evaluated in this portion of the NRJ RC Baja project. Namely, the components that are specific to Jeffrey Harn's division of the project. These include the suspension tower, the transmission cover, and the body.

The suspension tower will undergo force testing, based on the load requirements specified, a chassis and component mounting feasibility test, and an operation integrity test.

The transmission cover will undergo an operation integrity test, a dirt, water, mud, and other debris test, an assembly and disassembly test, and a mounting and feasibility test to verify it meets the requirements.

The body will undergo an operation integrity test, and the body will undergo a loading test to ensure it meets the requirements specified. Please note that the manufacturing of the body had to be abandoned due to inability to manufacture in the current conditions of winter quarter. For further definitions and details of the testing conducted, visit the entirety of **APPENDIX G**.

b. Method/Approach

Summarizing all the testing needed to be done, the main tests that will be conducted are operation integrity tests, loading tests, an environmental test, an assembly and disassembly test, and mounting and feasibility tests. The three main tests that will be extensively documented are the transmission cover disassembly and assembly test, the entire RC operation integrity test, and the suspension tower loading test. All the requirements stated in **Section 1.d.** of this report will be evaluated in some manner, some more extensively than others.

The operation integrity tests will be conducted by running the RC at normal use for a specified amount of time and be recalled after said time to be inspected. During this operation, the RC vehicle will undergo light, medium, and heavy use. This test will happen in conjunction when the NRJ RC Baja team practices operating their RC.

Loading tests will be conducted in a lab with force meters or weights. Forces and loads will be applied to a degree of accuracy and the components undergoing the test will be inspected for any yielding or failures. Stress-diagrams will be produced and compared to standard material engineering tests of the same material. The preceding was the ideal plan, however, loading tests had to be conducted at-home with rudimentary materials and procedures.

The environmental test will consist of exposing the transmission cover to water-splashing, dust, mud and other small debris. The transmission cover will be inspected after being exposed to the environment.

The assembly and disassembly test will test the transmission cover's ease of use. Both the assembly and disassembly of the transmission cover assembly will be timed. The transmission cover must also be disassembled using only three tools.

Finally, the component mounting and feasibility test will consist of mounting the components in question to their designated spots and ensuring they function as intended. How well secured a component is and how well a component actuates, if applicable, will also be evaluated.

For further details on the methods specific to each test, visit **APPENDIX G-1**.

c. Test Procedure

Tests will either occur outside the Hogue technology building on Central Washington University's campus, inside a CWU Houge Hall lab, or indoors/outdoors on private property. Only the loading tests will require the use of advanced equipment. The other tests will be done outside lab facilities and data will be obtained from either visual inspection or simple measurements. A simple neighborhood street will serve as the testing grounds for the use and mounting/feasibility test. Outside natural materials will be used for the environmental test. Simple measuring devices such as a ruler or tape measure will be used during the feasibility and mounting tests. Timers will be used for the assembly and disassembly tests. Finally, force meters and weights will be used for the loading tests. For detailed test procedures, visit **APPENDIX G-1**.

d. Deliverables

While testing, data will be temporarily stored in an engineering "field" notebook for ease. This data will then be transferred onto an official document that lists the test name, purpose of the test, the requirements being tested, the results, and a discussion of the results. Photos will be taken during the testing and will be attached as figures or appendices in said official documents. For blank data sheets, completed data sheets with results, and images, visit **APPENDIX G-3** and **APPENDIX G-3**, respectively.

5. BUDGET

a. Parts

Other than the parts being designed and manufactured by the NRJ RC Baja team, essential RC components will need to be purchased to add to the overall assembly. This will ensure the complete function of the RC and will fulfill the general requirements one would expect from a typical RC vehicle.

The parts needing to be purchased are detailed in the project parts list as seen in **APPENDIX C-1**. A fair amount of parts are being donated by Ryder Satak and Jeffrey Harn, and the rest will be purchased from the local hobby store, Jerrol’s. Some exceptions are the motor, speed controller, and receiver, which will be purchased and ordered via an online shopping website.

On the first team part acquisition venture, 95% of the total parts needed were obtained and purchased from the local Jerrol’s store. A quantity of five packages of 55-017 are needed for the project and only three were in stock at Jerrols on the first part acquisition venture. Also, a component piece of part 55-016 was not available on the first venture. All other required parts were obtained. Parts left that need to be obtained were obtained on the next two parts acquisition ventures and did not adversely affect the overall progress of the project.

Mistakes were made during the three-dimensional printing process and reprints were required. These mistakes included printing failures and errors, and design mistakes. The reprinting of designed parts did not affect the budget as printing costs were covered by Central Washington University’s MET department. After the first round of printing, more precise measurements and more care were incorporated into the new designs to prevent future need for reprinting and redesign. Also, closer collaborative work was completed with the team regarding mating components so that needs were clearly identified.

On the first part acquisition venture, it was discovered that insufficient control arms/steering arms were purchased. The control arms purchased were not long enough to successfully link the front camber control to the chassis, and they were not long enough to successfully link the front steering control to the servo motor wheel. These insufficient control arms/steering arms had already been opened and were thus unable to be returned. Another set of control arm/steering arms of sufficient length had to be purchased. The opened and unused control arms/steering arms are now considered a sunk cost as a mistake was made that cannot be recuperated.

b. Outsourcing

At this current moment in time, no outsourcing is expected for this project other than the use of Central Washington University’s lab facilities in Hogue Hall. The manufacturing of the designed parts of this project will be completed by Ryder Satak, Naoki Masuda, and Jeffrey Harn. Therefore, the cost estimate for outsourced expenses is zero dollars and zero cents.

c. Labor

Similar to outsourcing costs, no external labor is planned to be used at the current moment in time when writing the proposal for this project. All labor was planned to be conducted by the three members of NRJ RC Baja with assistance from Professor Pringle, Dr. Choi, and other Central Washington University Staff. However, a soldering service was used for the battery connectors and purchased for $30. No other outside labor was utilized.

d. Estimated Total Project Cost

The total cost of necessary parts is budgeted to be $200.00 which will include any taxes and shipping, with a cushioned budget of $100.00 for any material costs. An emergency budget of $50.00 is planned. Therefore, the total estimated project cost at this point in time is $350.00. It is important to note that this budget estimate is not absolutely fixed. Due to the likelihood of unforeseen events, actual expenditures may fall below or above the actual estimated budget. As a general statement, the budget is allowed to flex a maximum of $75 above and $100 below the estimate. For the current actual cost of parts, please see **APPENDIX D-1**.

With all purchases made and no further expenditures required, the total cost of the project is $340.74. This falls below the estimated total project cost.

e. Funding Source

The funding source of this project is covered by the three members of the NRJ RC Baja team, Ryder Satak, Naoki Masuda, and Jeffrey Harn. Expenses will be distributed evenly between the three members, and paid with out-of-pocket money. Masuda and Harn each contributed $100 upon agreement that Satak would cover the remaining $40 due to personal gain of the RC components and the RC vehicle itself.

6. SCHEDULE

a. Overview

Attached in **APPENDIX E-1** is a Gantt chart that summarizes tasks, predicted and actual hours, and the overall project timeline. This project was conducted across the span of the early days of September to the early days of June. One major break was taken during the November and December months, and one minor break was taken at the end of March.

The total estimated hours of work for this project are approximately 200 hours. The total actual hours of work required for this project are approximately 190 hours as of 7 June 2021 at 2030 hours.

Most all tasks were started on time and completed on time give or take the occasional early finish or late start. One major task that was finished way ahead of schedule was the assembly of the RC vehicle. The team set a mock deadline that was a week before the actual deadline and succeeded the mock deadline by a few days. Two major tasks that were completed late were the 3D part models and drawings, and this report. The 3D models and drawings were not completely finalized until winter quarter (completion was required in fall quarter). The report was unpolished for the fall and winter submissions, and finishing work was completed on the report half a day late of the final submission.

b. Design

The design portion of this project occurs during the Fall quarter of the academic year and looks to complete three major components. These components include the work and completion of this proposal, analyses constituting 12 computational engineering sheets that employ RADD techniques, as well as designing, modeling, and detail drawing project components that comply with ANSI Y14.5.

The twelve computational green sheets are submitted weekly throughout the fall quarter and require the student to define a problem, present a solution, define a requirement, analyze the situation, yield a design parameter from said analysis, and finally, incorporate said parameter into the design of a component and produce a detail drawing of the component based off ANSI Y14.5 standards. These analyses and drawings are then incorporated into this report. Please see **APPENDIX E-1** for a Gant chart detailing the design quarter schedule.

c. Construction

The construction portion of this project occurs during the Winter quarter of the academic year and looks to complete the manufacturing of all the student-designed parts for the RC Baja project. All manufacturing is completed by the students. Due to the effects of the COVID-19 pandemic, MET faculty intervention is at times required to aid in efforts such as 3D printing qualifying parts. The purchase and acquisition of non-student designed parts that are necessary for the operation of the RC Baja vehicle also occur in this portion of the project.

Part inspection, compatibility testing, and evaluation of practicality also occur in this portion of the project. After a part is manufactured, the NRJ RC Baja team will inspect the part and test its compatibility with other parts of the various RC assemblies and discern whether or not the part successfully serves its function. If any issues arise, revisions and redesigns will be instituted. Thus, multiple builds of a single part may occur in order to optimize the part's function and design. Please see **APPENDIX E-1** for a Gant chart detailing the manufacturing quarter schedule.

The end of this portion of the project will yield a fully functional RC Baja vehicle ready to move on to the testing portion of the project.

d. Testing

The testing portion of this project occurs during the Spring quarter of the academic year and looks to complete the testing and evaluation of the student-designed and student-manufactured parts for the RC Baja Project and the complete RC itself. The requirements defined for each component, assembly, or system are to be evaluated. With the pandemic and public restrictions still present in this phase of the project, access to facilities and other resources are still slightly hindered. A portion of testing had to be completed "at-home" with less professional equipment.

The systems to be tested are the suspension and transmission systems. The three main tests that will occur in this phase are an assembly and disassembly test for the transmission cover, an operation test for all the RC components together, and a loading test for the suspension tower. Other smaller, less extensive tests will be completed to evaluate all the requirements defined in the **INTRODUCTION** section. Please see **APPENDIX E-1** for a Gant chart detailing the testing quarter schedule.

The tests results will be documented, analyzed, and discussed. A test report will be created overviewing the three main tests mentioned above. Please see **APPENDIX G** for the attached test report document, and specifically, **APPENDIX G-5** for the Gantt Chart testing schedule.

7. PROJECT MANAGEMENT

a. Human Resources

The following human resource groups are present in this project: principal engineers, supporting engineers, and mentors. The principal engineer of this portion of the project is Jeffrey Harn. Ryder Satak and Naoki Masuda act as supporting engineers of the design and manufacturing to be completed by Harn. The resume for Harn may be found in **APPENDIX H-1**.

When discussing the NRJ RC project as a whole, not just the portion discussed in this report, Satak and Masuda fill the roles of principal engineers for the respective project portions they spearhead. Masuda and Harn act as supporting engineers to principal engineer Satak in his portion of the project, and Satak and Harn act as supporting engineers to principal engineer Masuda in his portion of the project.

Mentors are a part of the human resources utilized in this project. Two mentors serve in the design portion of this project, Central Washington University faculty Charles Pringle and Dr. Jeunghwan Choi. Mr. Pringle and Dr. Choi overview the progress of the NRJ RC Baja team and support them with professional guidance and are a resource for professional engineering knowledge.

Since this project is a three-man endeavor, meeting times and communication must be brokered between the team in order to collaborate and advance the project. This brings up the risk of availability for each member. Each team member becomes dependent on the other member's schedules. Since the CWU faculty must also appeal to the needs of the other mechanical engineering technology senior students, the same risk stated prior arises as the two mentors have schedules of their own and limited availability.

b. Physical Resources

The physical resources to be used in this project will all be available to the NRJ RC Baja team through Central Washington University's engineering labs. A 3D printer will be used which is located in the materials lab. Reamers, taps, and files will be required to satisfy tolerances and are located in the machining lab.

Due to the fact that the NRJ RC Baja team rely on the use of borrowed equipment, the equipment is subject to availability. This both refers to availability in terms of open hours, and also availability in terms of physical presence. This creates the risk of not having access to the various machines, tools, and operations needed to complete the project.

c. Soft Resources

There are two main types of soft resource being used throughout the duration of this project: text processing software, and 3D modeling software. Microsoft word is used for the creation of this report document and all other deliverables required throughout the year that require basic word processing. Microsoft Excel is used to create the various lists, charts, and matrices used throughout the year for this project. Finally, SolidWorks is used to 3D model, prototype, and create detail drawings for the design portion of this project.

d. Financial Resources

No project sponsors, grants, scholarships, or any other method or type of financial assistance is being used for this project. The only technical donation is the use of CWU facilities and materials. All expenses come out-of-pocket from the three members of the NRJ RC Baja team. Various previously owned RC electrical components and hardware are being temporarily donated by the team members.

8. DISCUSSION

a. Design

The RC Baja project in the Central Washington University mechanical engineering technology program requires a team of two members and limits to only two members. Ryder Satak and Naoki Masuda had agreed to work together on the project. When it came time to make team selections official, it was discovered Jeffrey Harn did not have a team member in order to fulfill the two member requirement for the RC project. After private discussion with the project mentors, Charles Pringle and Jeunghwan Choi, it was decided that a RC Baja group of three will be acceptable and manageable. The NRJ RC Baja team was formed.

In the early days of the design period, Satak, Masuda, and Harn discussed amongst themselves and shared their level of expertise in RC vehicles. Satak had high expertise while Masuda and Harn had intermediate to low expertise. Discussion was made regarding overall project outcomes and direction, and initial project "roles" were assigned. The term "roles" here refers to the various component groups each member would take lead on. Over the duration of the first two weeks of the quarter, alterations to the role assignments were made. The project roles were eventually finalized by 15 September 2020 and serious work on the project began.

The first four weeks of the design period saw the completion of initial analyses, initial proposal work, and the start of a project website. The next five weeks continued regular analyses, regular proposal work, regular integration of the proposal into the website, and detail drawings. The final two weeks saw the submission of an assembly drawing and the completed proposal for the design period of this project. Various smaller deliverables such as a parts lists and project status reports were submitted throughout the duration of the design period. Along the weeks saw frequent meetings of the NRJ RC team, and frequent meetings with mentors.

Notable successes of this project include quality communication between the team members, ability to work both independently and together effectively, and general adherence to the project schedule. The team supported each other and assisted each other when needed. A lot of knowledge over RC vehicles, mechanical systems, and analysis and design skills were achieved.

There were notable hardships and unsuccess experienced throughout the design portion of this project. One such hardship was the reality that class, most meetings, and general project work had to be completed at home via online resources. This is due to the world Coronavirus pandemic that occurred during the design period of this project. This made learning, collaboration, and general project work much more difficult for the NRJ RC team members. Passion and motivation for the project was much more difficult to come by due to the lack of physical interaction with both team members, and the project itself. This is a main factor that caused Jeffrey Harn to start to fall behind schedule starting at week eight. As the reality that the construction period of the project will suffer the same online fate, a solution must be employed to prevent falling behind schedule. Efforts will be made to construct an environment and schedule that simulates a normal school environment as much as possible, and efforts to construct and remain on a rigorous personal routine will be made for the next period of the project. Catch-up work will be completed over winter break.

b. Construction

The construction phase of this project took place in winter quarter of 2021. With the fallout of the pandemic still affecting life and practices, a large complication arose. At the beginning of winter quarter, a school-wide “welcome-back” lockdown was instituted in order to mitigate the spread of the virus—that was assumed would be caused by the influx of returning students—which prevented students, faculty, and staff from venturing onto campus for the first two weeks. This meant that all classes that were to be in-person, were conducted online for the first two weeks of the quarter, and all lab locations were closed for the first two weeks of the quarter. This halted the NRJ RC Baja team—and other senior project teams—from utilizing the lab locations to aid in the manufacturing of parts.

In response to this, the first two weeks were used for the revision and redesign of parts for Harn’s portion of the project. During the design in fall quarter, a lot of assumptions and guesses were made in regards to practical decisions in part design due to the lack of RC experience and the lack of knowledge of proper part functionality. Over the quarter, however, more intellect was gained over general mechanics of an RC assembly and tangible parts were able to be inspected to achieve a better understanding of their functionality requirements. Thus, with knowledge that had not been present in the initial design of most parts druing fall quarter, parts have been modified and optimized in winter quarter to ensure their true functionality. Put simpler, the initial design of this project was completed almost solely online—very little hands on experience and practical observation of RC systems. However, to this point, much hands-on experience and observations were made that helped aid in the understanding of the functionality and cooperation of parts.

The transmission cover was overhauled and optimized to better suit the purchased gears as they were on hand and measured with precise devices, namely, a depth micrometer and a caliper. Considering the two-week lockdown, Harn was unable to enter the lab to utilize the 3D printer. So, the .stl files were sent to Professor Pringle as he was able to access the lab at that time. Professor Pringle printed the two transmission covers and returned them to Harn. The covers were inspected, machined, and compatibility-tested.

Upon compatibility testing, it was discovered that the current transmission cover design was not compatible with Satak’s existing differential design, as the assembled differential measured near 3 [mm] too wide for the space in the transmission cover. So, the transmission cover was remodeled and reprinted, now possessing the required accommodations to be compatible with Satak’s differential. The new transmission cover was machined and assembled together with Satak’s differential, the motor, the gears, and the axels all operated as expected.

The old wood 3D model of the suspension tower was overhauled and optimized for the new material choice of PLA plastic. The related analyses were reconducted, replacing the values associated with balsa wood with values associated with PLA plastic. The basic dimensions of the suspension tower components were calculated and applied. The suspension towers were sent off for printing and were machined.

Some modifications to the printed transmission covers were made—such as filing in some areas—in order to optimize the transmission covers’ effectiveness. A larger hole had to be drilled on the transmission cover for the main gear shaft, so the clutch assembly would not rub against the plastic. Two originally unplanned holes were drilled into the rear suspension tower to fasten the rear control arms to the suspension tower.

With all components working and compatible with each other, assembly planning begun. The components were laid out onto the chassis and their most effective positionings were marked. Multiple originally-unplanned edits to the chassis had to be made due to unforeseen component conflicts and the difficulty of laying out components before they were on-hand. With mounting to the suspension towers being impossible for the front control arms, a wood dowel system was conceived and two large holes were drilled in the front of the chassis to insert two vertical dowels to act as mounting points for the front control arms. A slot was cut with a jig saw in order to mount the steering servo device.

With all modifications out of the way and all components compatible and working, the NRJ RC Baja team sat down on Wednesday, March 3, and assembled the RC vehicle. The RC began its maiden drive directly after and all systems functioned well.

c. Testing

The testing phase of this project occurred in the spring quarter of 2021. The abstract of the report was formulated in the first week of the quarter and reviewed by the mentors of the project and a SOURCE (Symposium for University Research and Creative Expression) representative. The abstract was submitted to SOURCE the first week of the quarter.

The first testing round was conducted across the second and third week of the quarter. Due to a miscommunication amongst the team members of who was to take charge of the drop test, team-member Harn had to discard his drop test procedure and switch over to a different test. Harn conducted a test that evaluated the assembly and disassembly of the transmission cover, Masuda conducted the two-foot drop test, and Satak conducted a temperature evaluation test of the motor. These tests were recorded and presented to the class during the third week of the quarter. Career accounts on LinkedIn and the Wildcat Career Network were created.

As the quarter progressed, the project saw preparation for the second testing round and the creation of a project poster draft to be presented virtually at SOURCE 2021. The second round of testing was completed--the operation integrity test—and the results were presented to the class for criticism. Various work on the project report and the project website was completed in the middle weeks of the quarter. This period of the project also saw the creation of the project testing report.

On 23 April 2020, the ASME RC Baja contest was held. This contest was not the official contest that would have originally taken place, as the pandemic and restrictions would not have allowed that. This competition was a small, informal competition between the four RC Baja teams at Central. The team for this project, NRJ RC Baja, placed first in all categories of the competition. The third major test, the suspension tower load test, was completed.

Approaching the end of the quarter, from week eight and on, the project work started to pick up. Multiple presentations were given. The first was the attendance of the SOURCE 2021 event in which comments had to be responded to. The second was a presentation over the entire project report given virtually in front of the senior project class. This project presentation was recorded and required the use of the project website. This report was submitted in week ten of the quarter, and the rest of the quarter included the clean up or project work, a jump-drive submission of project files, and end of year surveys.

9. CONCLUSION

a. Conclusion

The NRJ RC Baja RC vehicle team looked to design and manufacture a fully functional RC Baja vehicle to be able to compete in the ASME Radio-Controlled Baja Car Contest sanctioned by Remotely Operated Auto Racers (ROAR) and hosted by Central Washington University. Using the Traxxas Slash model as a suitable benchmark, the NRJ RC team conducted multiple analyses to obtain dimension parameters for the chassis, A-arms, suspension tower, transmission, differential, and car body. Designs for the prior stated components, 3D models, and detail drawings were created that meet basic RC vehicle requirements and functions and comply with current ANSI Y14.5 standards.

With the designs and relevant information at hand, the NRJ RC Baja team successfully finished manufacturing and assembling the RC Baja vehicle. The chassis was constructed out of wood and all other student-designed components were 3D printed and machined to tolerances. The RC vehicle was fully assembled ahead of schedule and enjoyed its maiden-drive right after assembly had finished.

Come time for testing, the NRJ RC Baja team focused their testing around their individual leads and divisions on the project. All requirements stated in this report were evaluated and tested. Across-the-board success was not achieved with this RC vehicle design, but the failures that did occur were not completely detrimental to the RC itself. This allows the RC vehicle design to be acclaimed an overall success.

10. ACKNOWLEDGEMENTS

a. Acknowledgements

The NRJ RC Baja team would like to sincerely thank the two mentors of this project, Professor Charles Pringle and Dr. Jeunghwan Choi. These two professors of the Central Washington University mechanical engineering technology senior project class provided much insight, review, criticism, and overall sincere support to this project. Both professors have extreme care for their students and their understanding of fundamental engineering skills and principles.

The NRJ RC Baja team would also like to thank Ryder Satak for his generous donation of many of the RC parts incorporated into the project RC.

The NRJ RC Baja team would like to thank CWU's MET program for the use of 3D printing material, wood material, and facility use.

11. REFERENCES

a. Internet Resources

Please see the below internet resources referenced for this project:

1. Engineering ToolBox – Rolling Resistance. This article was referenced during the completion of **Analysis 1**. Please see the below link: https://www.engineeringtoolbox.com/rolling-friction-resistance-d_1303.html
2. MatWeb – DIAB PB Balsa wood. This website was used to obtain material data for balsa wood used in the analyses.
3. GrabCAD – Various Traxxas models. This website was used to obtain models for the suspension strut and steering arm models.
4. MakerBot Tough Filament Datasheet – This document was referenced when revising the analyses with updated material data for MakerBot PLA material.

a. Engineering Text

Please see the below textbook resources referenced for this project:

5. Fundamentals of Thermal-Fluid Sciences, Fifth Edition.
   Yunus A. Cengel, John M. Cimbala, Robert H. Turner.
6. Machine Elements in Mechanical Design, Sixth Edition.
   Robert L. Mott, Edward M. Vavrek, Jyhwen Wang.

APPENDIX A – Analysis

Appendix A-1 – Analysis 1: Motor Power

Please view the below green sheet detailing the analysis over the required motor power to overcome static friction of the wheels:

JEFFREY HARN | MET 489A | ROLLING RESISTANCE | ANALYSIS 1 | 1/1 | 25 SEPT 2020

DESCRIPTION: The following analysis calculates the required power to move a typical RC Baja vehicle at a velocity of 40 MPH.

GIVEN: TOTAL RC WEIGHT OF 6 kg
WHEEL DIAMETER OF 134 mm
ROLLING FRICTION COEFFICIENT OF 0.008 (engineeringtoolbox.com)
(bicycle tire on rough pavement)

FIND: POWER REQUIRED FOR RC TO TRAVEL AT 40 MPH

ASSUMPTIONS: NEGLECT AIR RESISTANCE AND ALL OTHER RESISTANCE BESIDES THAT OF ROLLING RESISTANCE
NEGLECT INTERNAL DAMPENING OF RC MOTOR / DRIVETRAIN
NO DEFORMATION OF ANY KIND OCCURS
EFFECTS FROM TEMPERATURE ARE NEGLECTED
NO SLIPPING OF WHEELS OCCURS
NO LOSSES FROM MOTOR TO WHEEL OCCUR

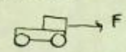
METHOD: CALCULATE VERTICAL LOAD ON WHEELS
CALCULATE FORCE REQUIRED TO OVERCOME ROLLING FRICTION
MULTIPLY FORCE BY DESIRED VELOCITY

SOLUTION: $F = C \cdot L$ — C = coefficient, L = Load (weight)

LOAD ON EACH WHEEL: 6 kg / 4 wheels = 1.5 kg per wheel

$F = 0.008 \cdot 1.5\,kg(9.81\,m/s^2) = 0.11772\,N$

THIS SOLVED FOR THE FORCE SEEN ON THE DIAGRAM FOR ONE WHEEL



THE FORCE REQUIRED TO MOVE THE ENTIRE RC WITH 4 WHEELS IS

$0.11772\,N\,(4\ \text{wheels}) = 0.47088\,N$

THUS, THE POWER REQUIRED FROM THE MOTOR TO DRIVE THE RC 40 MPH IS

$$\frac{40\,mi}{hr} \cdot \frac{1609.35\,m}{1\,mi} \cdot \frac{1\,hr}{60\,min} \cdot \frac{1\,min}{60\,sec} = 17.88\,m/s$$

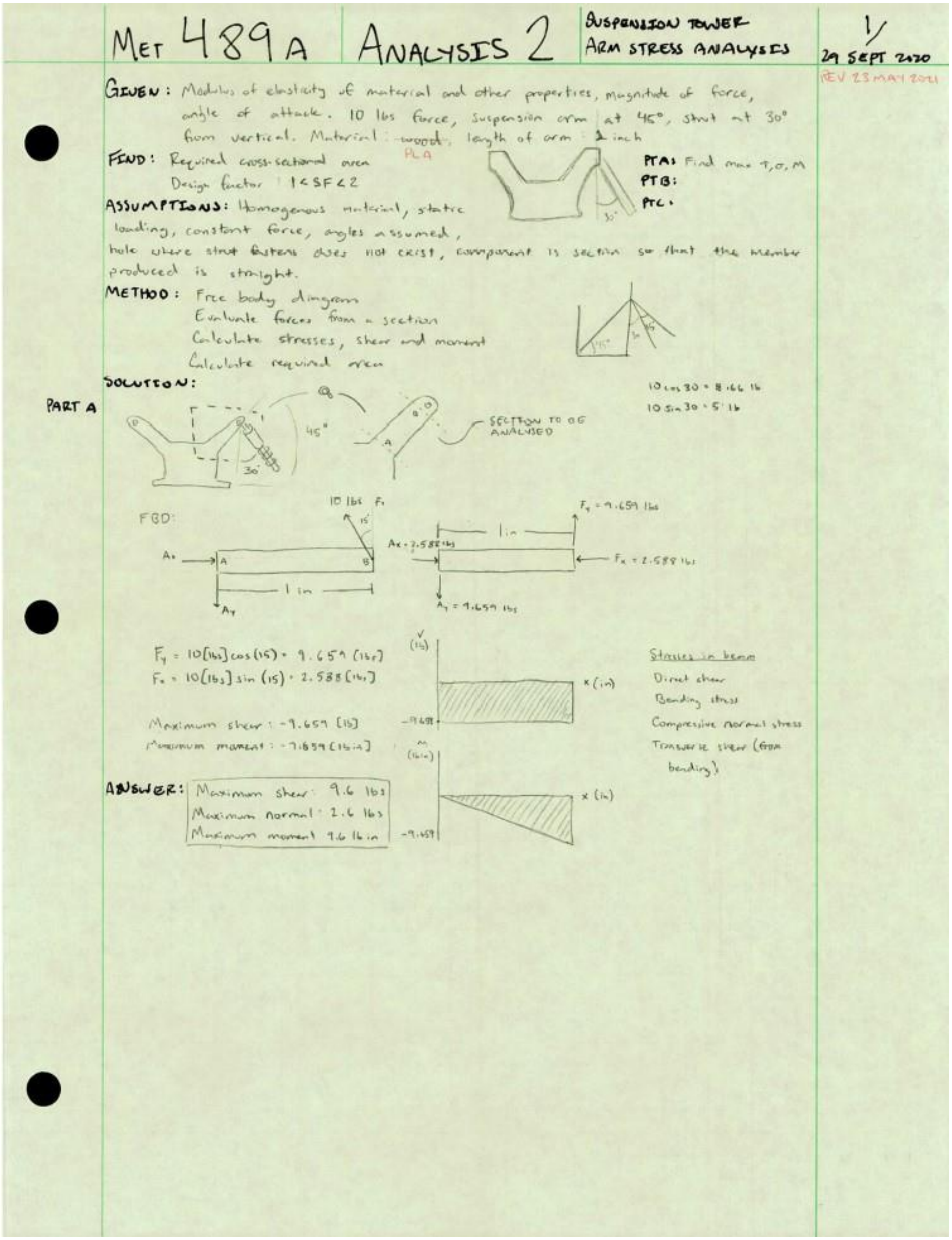
$$P = Fv = 0.47088\,N \cdot 17.88\,m/s = 8.42\,W$$

ANSWER: THE POWER REQUIRED TO MOVE A 6 kg RC AT 40 MPH IS 8 W. THEREFORE, A MOTOR OF CAPABLE OF PRODUCING AT LEAST 16 W IS REQUIRED.

(POWER DOUBLED TO ACCOUNT FOR OTHER RESISTANCES THAT WERE NOT CALCULATED HERE)

Appendix A-2 – Analysis 2 (2A): Maximum Forces in Suspension Arm Section

Please view the following green sheet detailing the analysis over the forces acting on a section of the suspension arm, Part A:



MET 489A | ANALYSIS 2 | SUSPENSION TOWER ARM STRESS ANALYSIS | 1/ | 29 SEPT 2020 | REV 23 MAY 2021

GIVEN: Modulus of elasticity of material and other properties, magnitude of force, angle of attack. 10 lbs force, suspension arm at 45°, strut at 30° from vertical. Material: ~~wood~~ PLA, length of arm: 1 inch

FIND: Required cross-sectional area
Design factor: 1 < SF < 2

PT A: Find max τ, σ, M
PT B:
PT C:

ASSUMPTIONS: Homogenous material, static loading, constant force, angles assumed, hole where strut fastens does not exist, component is section so that the member produced is straight.

METHOD: Free body diagram
Evaluate forces from a section
Calculate stresses, shear and moment
Calculate required area

SOLUTION:

PART A

$10 \cos 30 = 8.66$ lb
$10 \sin 30 = 5$ lb

SECTION TO BE ANALYSED

FBD:

$F_y = 10[\text{lbs}]\cos(15) = 9.659\ [\text{lbs}]$
$F_x = 10[\text{lbs}]\sin(15) = 2.588\ [\text{lbs}]$

Maximum shear: -9.659 [lb]
Maximum moment: -9.659 [lb·in]

Stresses in beam
Direct shear
Bending stress
Compressive normal stress
Transverse shear (from bending)

ANSWER:

Maximum shear	9.6 lbs
Maximum normal	2.6 lbs
Maximum moment	9.6 lb·in

Appendix A-3 – Analysis 3 (2B): Maximum Forces in Suspension Arm Section

Please view the following green sheet detailing the analysis over the bending stresses acting on a section of the suspension arm, Part B:

7 OCT 2020 | MET 489A | ANALYSIS 3 | SUSPENSION TOWER ARM STRESS ANALYSIS PT B | 2/

REV 23 MAY 2021

GIVEN: E of material, answers from PT A, length of arm: 1 inch, material: ~~Balsa wood~~ PLA Plastic
~~Balsa~~ PLA compressive strength, Matweb: ~~DIAB PB Standard~~ MATERIAL: MAKERBOT TOUGH FILAMENT

FIND: Required cross-sectional area

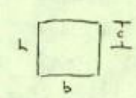
ASSUMPTIONS: HOMOGENEOUS MATERIAL, STATIC LOADING, CONSTANT FORCE, SECTIONED PORTION OF SUSPENSION TOWER ARM IS STRAIGHT AND HAS NO HOLES

METHOD: Obtain maximum stresses
Obtain critical material stresses
Bending moment equation, stress equation, flexural strength of ~~DIAB PB Balsa~~ PLA Plastic

SOLUTION: ~~Ultimate compressive strength: 1840 psi~~ FLEXURAL STRENGTH: 9,190 psi
Ultimate Tensile strength: ~~1960 psi~~ 5,710 psi MAKERBOT TOUGH FILAMENT

Since ~~ultimate compressive~~ TENSILE strength is lower, this value will be used to calculate cross-sectional dimension as the component will fail in compression before tension when bending.

Cross section



$b = h$
$c = \frac{1}{2}b$

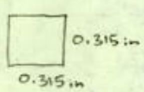
$\sigma_u = \sout{1840\,psi}\ 5{,}710\,psi = \frac{Mc}{I}$

$I = \frac{1}{12}bh^3 = \frac{1}{12}b^4$

$\sigma = \frac{M(\frac{1}{2}b)}{\frac{1}{12}b^4} = \frac{12Mb}{2b^4} = \frac{6M}{b^3}$

$b = \sqrt[3]{\frac{6M}{\sigma}} = \sqrt[3]{\frac{6(9.6\,lb\,in)}{1840\,psi}} = 0.315\,in = b$

$b = \sqrt[3]{\frac{6(9.6\,lb \cdot in)}{5{,}710\,psi}} = 0.216\,in$



0.216 in → 5.48 mm
7 mm is sufficient → 0.275 in

$\sigma = \frac{9.6\,lb \cdot in(\frac{1}{2}0.275\,in)}{\frac{1}{12}(0.275\,in)^4} = 2769.64\,psi$

Next standard size: 0.5 inch
~~This produces a factor of safety of 1.6 (Roughly)~~

$SF = \frac{5{,}710\,psi}{2769.64\,psi} = \boxed{2}$

REVISION 18 FEB

5710 psi → 0.216 in → 5.48 mm → 7 mm thick square
↘ 2751.88 psi

$I = \frac{Mc}{\sigma}$ ASSUME c

6-20-48

NOTES: REVIEW REQUIREMENTS ON PG 105 - TALK WITH PROFESSOR
NOTES: 1/4 inch tubs on bottom may be trivial, talk to Pringle and do an analysis
REVIEW FACTOR OF SAFETY (APPLIED TO STRESS, NOT DIMS)

Appendix A-4 – Analysis 4 (2C): Shear Stresses in Suspension Arm Section

Please view the following green sheet detailing the analysis over the shear stress acting on a section of the suspension arm, Part C:

MET 489A | ANALYSIS 4 | SUSPENSION TOWER ARM SHEAR ANALYSIS (PT C) | 3/3

REV 23 MAY 2021

GIVEN: Solutions from part A, dimensions from part B, all previous information from parts A + B, Shear strength of ~~DI+B PB Standard Balsa~~ PLA Plastic

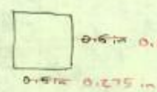
FIND: REQUIRED CROSS SECTIONAL AREA TO RESIST SHEARING FORCES

ASSUMPTIONS: HOMOGENOUS MATERIAL, STATIC LOADING, CONSTANT FORCE, SUSPENSION ARM PORTION IS SECTIONED SUCH THAT IT IS A STRAIGHT MEMBER WITH NO HOLES

METHOD: Obtain maximum shear, maximum moment
Calculate ~~direct shear stress~~ and transverse shear
Evaluate if current dimensions are suitable

SOLUTION:

$\tau_{max} = \frac{3V}{2A}$ (eq 3-18 Mott)



$A = b \cdot h = 0.5\,in \cdot 0.5\,in = 0.25\,in^2$

~~A =~~ $0.275\,in \cdot 0.275\,in = 0.0756\,in^2$

$V = 9.6\,lb$

$\tau_{max} = \frac{3V}{2A} = \frac{3(9.6\,lb)}{2(0.25\,in^2)} = 3.6\,psi$ $\quad \frac{3(9.6\,lb)}{2(0.0756\,in^2)} = 190.41\,psi$

Shear strength = ~~435 psi~~, well above actual shear   PLA : 2855 psi

$S_{ys} = S_y/2 = 5710\,psi/2$
$S_{ys} = 2855\,psi$
* PAGE 24 EQ 2-3 MOTT

What would maximum cross-sectional area be?

DISREGARD:

$A = \frac{3V}{2\tau_{max}} = \frac{3(9.6\,lb)}{2(435\,psi)} = 0.03\,in^2 \rightarrow \sqrt{0.03\,in^2} = 0.17\,in$

A 0.17 × 0.17 in square cross section is the smallest possible dimensions in order to resist transverse shear

Dimensions of 0.5 · 0.5 in are well more than enough and provide a safety factor of 3 (roughly)

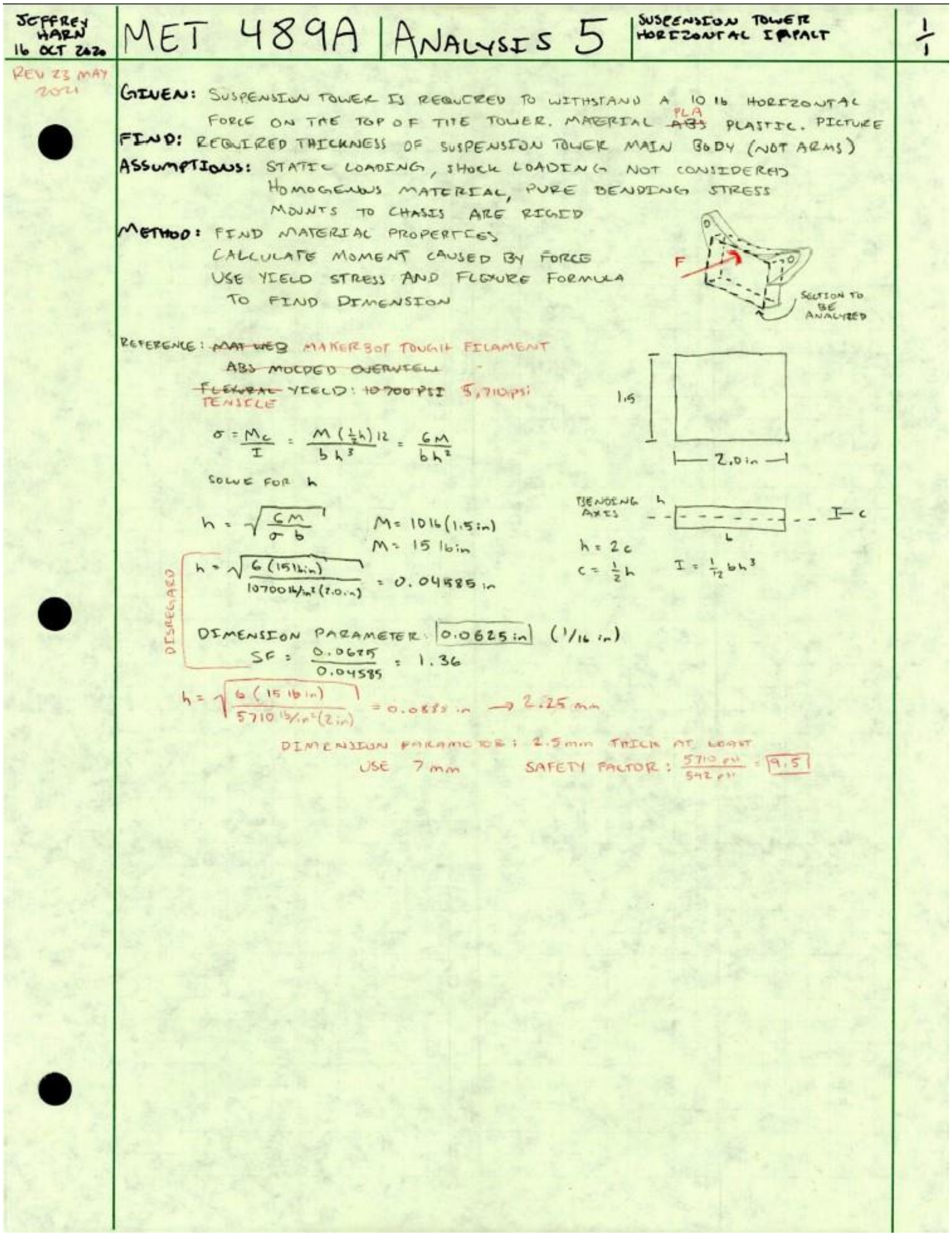
$A = \frac{3(9.6\,lb)}{2(2{,}855\,psi)} = 0.00504\,in^2 \rightarrow \sqrt{0.00504\,in^2} = 0.07\,in$

0.275 in >> 0.07 in THIS DESIGN WILL RESIST SHEAR WITH A FACTOR OF SAFETY OF **13.5**

NOTE: IS THERE DIRECT SHEAR IN BEAMS? OR ONLY TRANSVERSE SHEAR?
POSSIBLY NEXT ANALYSES: TORSION IN ARM, BENDING OF WHOLE TOWER, SIDE LOAD OF ARM

Appendix A-5 – Analysis 5: Bending Stress in Suspension Tower Main Section

Please view the following green sheet detailing the analysis over the bending stress acting on a section of the suspension tower:



JEFFREY HARN
16 OCT 2020
REV 23 MAY 2021

MET 489A | ANALYSIS 5 | SUSPENSION TOWER HORIZONTAL IMPACT | 1/1

GIVEN: SUSPENSION TOWER IS REQUIRED TO WITHSTAND A 10 lb HORIZONTAL FORCE ON THE TOP OF THE TOWER. MATERIAL ~~ABS~~ PLA PLASTIC. PICTURE

FIND: REQUIRED THICKNESS OF SUSPENSION TOWER MAIN BODY (NOT ARMS)

ASSUMPTIONS: STATIC LOADING, SHOCK LOADING NOT CONSIDERED
HOMOGENOUS MATERIAL, PURE BENDING STRESS
MOUNTS TO CHASIS ARE RIGID

METHOD: FIND MATERIAL PROPERTIES
CALCULATE MOMENT CAUSED BY FORCE
USE YIELD STRESS AND FLEXURE FORMULA
TO FIND DIMENSION

REFERENCE: ~~MAT WEB~~ MAKERBOT TOUGH FILAMENT
~~ABS MOLDED OVERALL~~
~~FLEXURAL~~ TENSILE YIELD: ~~10700 PSI~~ 5,710 psi

$\sigma = \frac{Mc}{I} = \frac{M(\frac{1}{2}h)12}{bh^3} = \frac{6M}{bh^2}$

SOLVE FOR h

$h = \sqrt{\frac{6M}{\sigma b}}$ $M = 10 lb (1.5 in)$
$M = 15\ lb in$

DISREGARD:

$h = \sqrt{\frac{6(15 lb in)}{10700 lb/in^2 (2.0 in)}} = 0.04585\ in$

DIMENSION PARAMETER: 0.0625 in ($1/16$ in)

$SF = \frac{0.0625}{0.04585} = 1.36$

$h = \sqrt{\frac{6(15 lb in)}{5710 lb/in^2 (2 in)}} = 0.0888\ in \rightarrow 2.25\ mm$

$h = 2c$
$c = \frac{1}{2}h$
$I = \frac{1}{12}bh^3$

DIMENSION PARAMETER: 2.5 mm THICK AT LEAST
USE 7 mm SAFETY FACTOR: $\frac{5710\ psi}{542\ psi} = 9.5$

Appendix A-6 – Analysis 6: Shear Stress in Suspension Tower to Chassis Fasteners

Please view the following green sheet detailing the analysis over the shear stress present in the fasteners to be used to secure the suspension tower to the chassis:

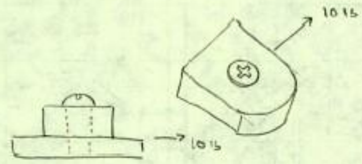
JEFFREY HARN
16 OCT 2020

MET 489A | ANALYSIS 6 | TRANSMISSION TOWER BOLT SHEAR BOTTOM MOUNTING POINTS | 1/

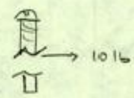
GIVEN: 10 lb SHEAR FORCE, SCREW MATERIAL OF SAE FASTENER STEEL GRADE 1

FIND: REQUIRED SCREW SIZE (DIAMETER)

ASSUMPTIONS: DIRECT SHEAR FORCE
MATERIALS DELIVERING SHEAR FORCE ARE RIGID AND DO NOT YIELD
HOMOGENOUS SCREW MATERIAL



METHOD: DEFINE SCREW MATERIAL PROPERTIES
SHEAR EQUATION $\frac{V}{A}$
FIND DIAMETER



YIELD STRENGTH SAE G1 (TABLE 19-1 MOTT)

$S_y = 36\ ksi$

$\tau = \frac{V}{A}$ $A = \pi r^2$

$\tau = \frac{V}{\pi r^2}$ → SOLVE FOR r → $r = \sqrt{\frac{V}{\pi \tau}}$

$r = \sqrt{\frac{10\ lb}{36{,}000\ psi\ (\pi)}} = 0.009$ in radius

DIAMETER PARAMETER: 0.018 in

SMALLEST DIAMETER AVAILABLE **1/4 in**

$SF = \frac{0.25}{0.018} = 13.9!$

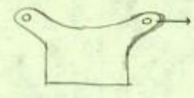
Appendix A-7 – Analysis 7: Stress Concentration at the Suspension Strut Pin Connection Hole

Please view the following green sheet detailing the analysis over the required width dimension around the hole area in which the suspension strut will attach to:

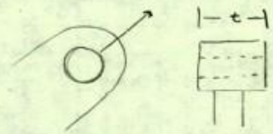
JEFFREY HARN
22 OCT 2020
REV 23 MAY 2021

MET 489A | ANAYSIS 7 | SUSPENSION TOWER SUSPENSION STRUT PIN STRESS | 1/1

GIVEN: HOLE DIAMETER OF 3mm (FITS 3X14MM SCREW)
MATERIAL: ~~ABS MOLDED (MATWEB)~~ PLA MAKERBOT, 10 lb FORCE
TENSILE STRENGTH YIELD: ~~45 MPa~~ 39.3 MPa
THICKNESS OF ~~1/2"~~ 7mm OR 0.275 in

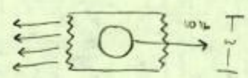


FIND: FIND SECTION HEIGHT "w"



ASSUMPTIONS: ASSUMED SECTION OF UNIFORM PLATE CONTAINING HOLE, HOMOGENOUS MATERIAL, STATIC LOAD, ANGLE FROM STRUT IS IGNORED, SO THERE IS A DIRECT FORCE (AXIAL LOAD).

ASSUMED STATE



METHOD: CHOOSE ARBITRARY "w" VALUE TO TEST
CALCULATE NOMINAL STRESS
CALCULATE MAXIMUM STRESS
COMPARE σ_{max} TO σ_{yield}

SOLUTION: $\sigma_{max} = K_t \sigma_{nom}$ $\quad \sigma_{nom} = \frac{F}{(w-d)t}$ $\quad t = 1/2"$

2.54 cm : 1 in
25.4 mm : 1 in

$3mm \rightarrow \frac{1 in}{25.4mm} = 0.118 in$ which is about $1/8 in$

TRIAL AND ERROR
TEST $w = 0.5$ in $\quad$ d/w value $= \frac{(3/25.4) in}{0.5 in} = 0.236$ yields K_t factor of 5.0
(VALUE OBTAINED FROM Pg 832 MOTT)

NOMINAL STRESS + MAXIMUM STRESS

$\sigma_{nom} = \frac{F}{(w-d)t} = \frac{10 lb}{(0.5 in - (3/25.4) in)(0.5 in)} = \sout{52.37 psi}$ $\quad \sigma_{nom} = \frac{10 lb}{(0.275 in - (3/25.4) in)(0.275 in)}$

$\sigma_{max} = K_t(\sigma_{nom}) = (5.0)(52.37 psi) = 261.856 psi \rightarrow 262 psi << 6526.69 psi$

A w-value of $\boxed{0.5 in}$ will work.

$\sigma_{nom} = 231 psi$
$\sigma_{max} = 231 psi (5) = 1158.89 psi$
$1158.89 psi << 5710 psi$
$\boxed{7mm}$ THICKNESS WILL WORK

REVISION IS FOR

TENSILE STRENGTH 5710 psi
THICKNESS 7mm 0.275 in $\quad \frac{10}{(0.275 - 3/25.4)(0.275)} = 231 psi$
$231 \cdot 5 = 1158.89 psi$

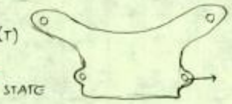
Appendix A-8 – Analysis 8: Stress Concentration at the Camber Link Pin Connection Hole

Please view the following green sheet detailing the analysis over the required width dimension around the hole area in which the camber link will attach to:

JEFFREY HARN
23 OCT 2020
REV 23 MAY 2021

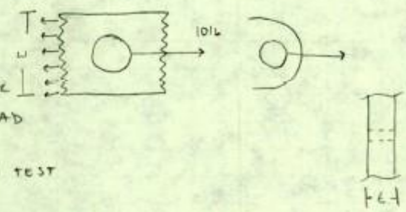
MET 489A | ANALYSIS 8 | CAMBER LINK PIN HOLE STRESS CONCENTRATION | 1/1

GIVEN: HOLE DIAMETER OF 3 mm (FITS 3x15 FCS PIN)
MATERIAL: ~~ABS MOLDED (MATWEB)~~ PLA MAKERBOT, 10 lb FORCE (T)
TENSILE STRENGTH YIELD: ~~45 MPa = 6526.69 psi~~ 5710 psi
THICKNESS OF ~~1/4"~~ 7mm



ASSUMED STATE

FIND: FIND SECTION HEIGHT "w"



ASSUMPTIONS: SEE ASSUMED SECTION, NO CURVES, HOMOGENOUS MATERIAL, STATIC LOAD, PURE AXIAL LOAD

METHOD: CHOOSE ARBITRARY "w" VALUE TO TEST
CALCULATE NOMINAL STRESS
CALCULATE MAXIMUM STRESS
COMPARE σ_{max} to σ_{yield}

SOLUTION: $\sigma_{max} = K_t \sigma_{nom}$ $\sigma_{nom} = \frac{F}{(w-d)t}$ $t = 1/4"$

$3mm \rightarrow \frac{1in}{25.4mm} = 0.118$ in which is about $1/8$ in

TRIAL AND ERROR (w VALUE ESTIMATED AND WILL BE TESTED)
TEST $w = 0.25$ in d/w value $= \frac{(3/25.4)in}{0.25in} = \sout{0.472}$

0.472 YIELDS K-FACTOR OF ~~2.6~~
(VALUE OBTAINED FROM PG 832 MOTT)

NOMINAL STRESS AND MAXIMUM STRESS CALCULATIONS

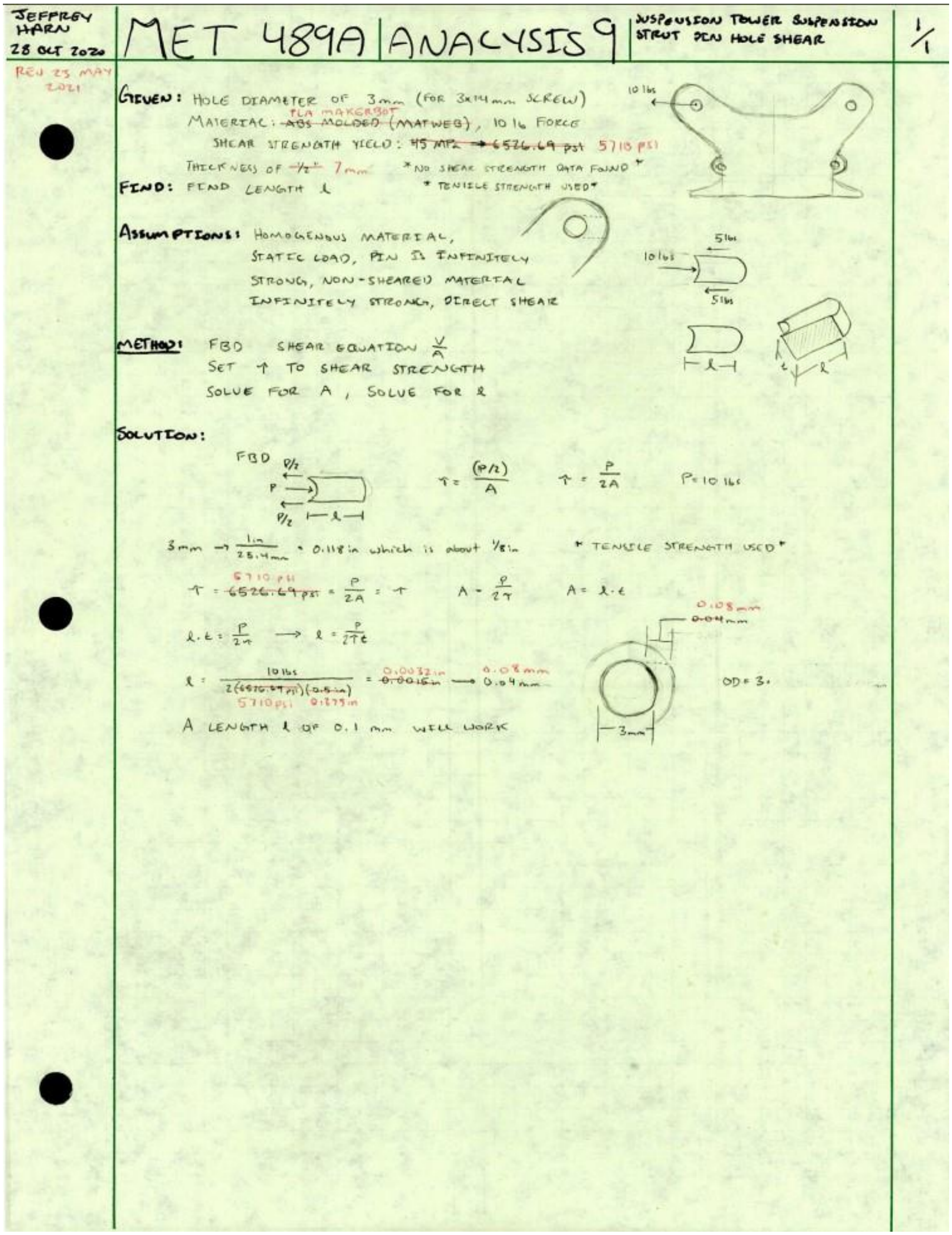
$\sigma_{nom} = \frac{F}{(w-d)t} = \frac{10 lb}{(0.25in-(3/25.4)in)(0.25in)} = \sout{303.28 psi}$

$\sigma_{max} = K_t(\sigma_{nom}) = (2.6)(303.28 psi) = 788.54 psi << \sout{6526.69}$ 5710 psi

A w-value of $\boxed{0.25 in}$ will work.

Appendix A-9 – Analysis 9: Shear Stress at the Camber Link Pin Connection Hole

Please view the following green sheet detailing the analysis over the required material around the hole area in which the camber link will attach to:



JEFFREY HARN
28 OCT 2020
REV 23 MAY 2021

MET 489A | ANALYSIS 9 | SUSPENSION TOWER SUSPENSION STRUT PIN HOLE SHEAR | 1/1

GIVEN: HOLE DIAMETER OF 3mm (FOR 3x14mm SCREW)
MATERIAL: ~~ABS MOLDED~~ PLA MAKERBOT (MATWEB), 10 lb FORCE
SHEAR STRENGTH YIELD: ~~45 MPa → 6526.69 psi~~ 5710 psi
THICKNESS OF ~~1/2"~~ 7mm
NO SHEAR STRENGTH DATA FOUND
TENSILE STRENGTH USED

FIND: FIND LENGTH ℓ

ASSUMPTIONS: HOMOGENOUS MATERIAL, STATIC LOAD, PIN IS INFINITELY STRONG, NON-SHEARED MATERIAL INFINITELY STRONG, DIRECT SHEAR

METHOD: FBD SHEAR EQUATION $\frac{V}{A}$
SET τ TO SHEAR STRENGTH
SOLVE FOR A, SOLVE FOR ℓ

SOLUTION:

FBD

$\tau = \frac{(P/2)}{A}$ $\quad \tau = \frac{P}{2A}$ $\quad P = 10\text{ lbs}$

$3\text{mm} \rightarrow \frac{1\text{in}}{25.4\text{mm}} = 0.118\text{in}$ which is about $1/8$ in

TENSILE STRENGTH USED

$\tau = ~~6526.69\text{ psi}~~\ 5710\text{ psi} = \frac{P}{2A} = \tau$ $\quad A = \frac{P}{2\tau}$ $\quad A = \ell \cdot t$

$\ell \cdot t = \frac{P}{2\tau} \longrightarrow \ell = \frac{P}{2\tau t}$

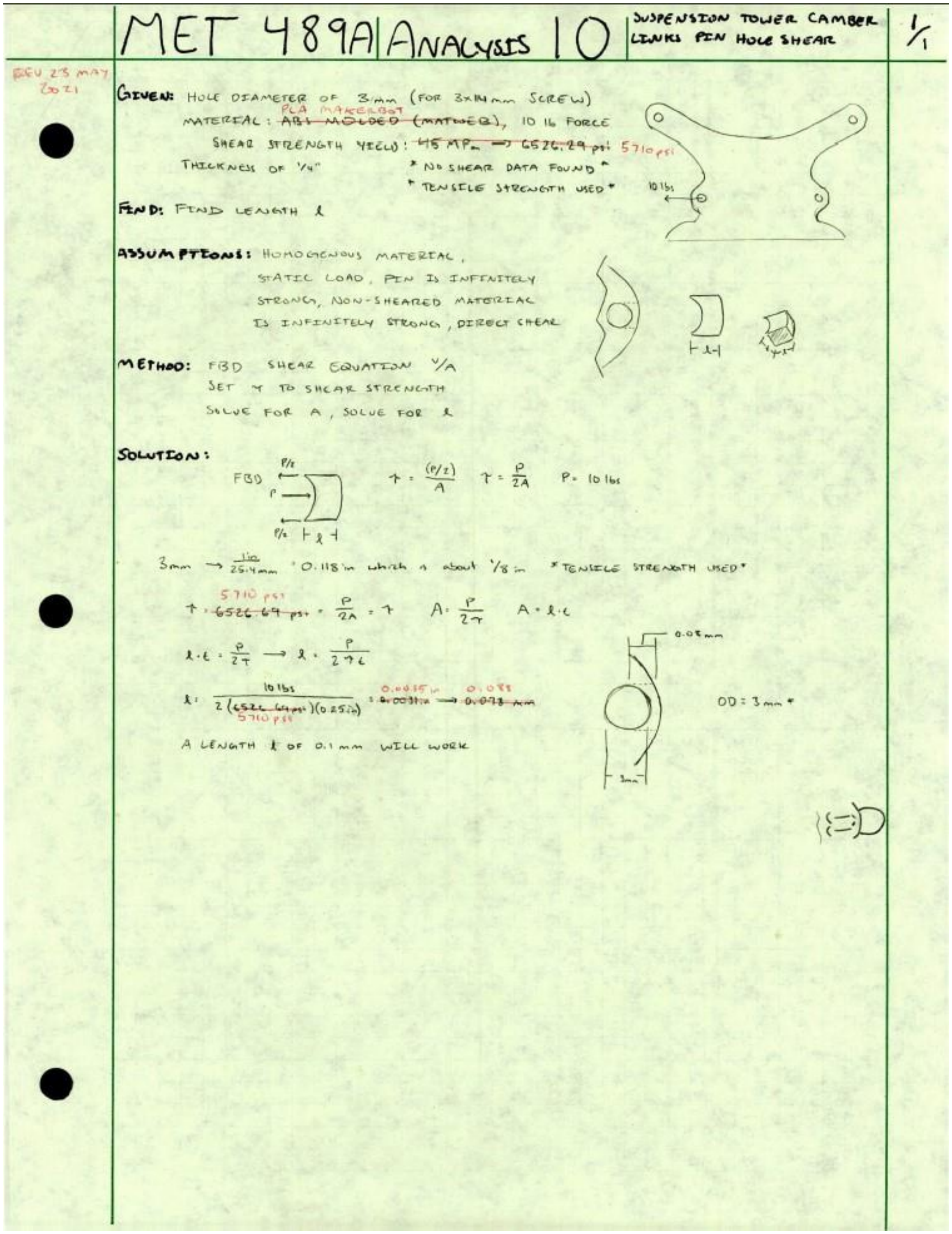
$\ell = \frac{10\text{ lbs}}{2(~~6526.69~~\ 5710\text{ psi})(~~0.5\text{ in}~~\ 0.275\text{ in})} = ~~0.0016\text{ in}~~\ 0.0032\text{ in} \longrightarrow ~~0.04\text{ mm}~~\ 0.08\text{ mm}$

A LENGTH ℓ OF 0.1 mm WILL WORK

~~0.04 mm~~ 0.08 mm
OD = 3.
3mm

Appendix A-10 – Analysis 10: Shear Stress at the Camber Link Pin Connection Hole

Please view the following green sheet detailing the analysis over the required material around the hole area in which the camber link will attach to:



MET 489A | ANALYSIS 10 | SUSPENSION TOWER CAMBER LINKS PIN HOLE SHEAR | 1/1

REV 23 MAY 2021

GIVEN: HOLE DIAMETER OF 3 mm (FOR 3x14 mm SCREW)
MATERIAL: ~~ABS MOLDED (MATWEB)~~ PLA MAKERBOT, 10 lb FORCE
SHEAR STRENGTH YIELD: ~~45 MPa → 6526.29 psi~~ 5710 psi
THICKNESS OF 1/4"
* NO SHEAR DATA FOUND *
* TENSILE STRENGTH USED *

FIND: FIND LENGTH ℓ

ASSUMPTIONS: HOMOGENOUS MATERIAL, STATIC LOAD, PIN IS INFINITELY STRONG, NON-SHEARED MATERIAL IS INFINITELY STRONG, DIRECT SHEAR

METHOD: FBD SHEAR EQUATION V/A
SET τ TO SHEAR STRENGTH
SOLVE FOR A, SOLVE FOR ℓ

SOLUTION:

FBD $\quad \tau = \frac{(P/2)}{A} \quad \tau = \frac{P}{2A} \quad P = 10\ \text{lbs}$

$3\text{mm} \rightarrow \frac{1\text{in}}{25.4\text{mm}} = 0.118\text{in}$ which is about 1/8 in *TENSILE STRENGTH USED*

$\tau = $ ~~6526.69 psi~~ 5710 psi $= \frac{P}{2A} = \tau \quad A = \frac{P}{2\tau} \quad A = \ell \cdot t$

$\ell \cdot t = \frac{P}{2\tau} \rightarrow \ell = \frac{P}{2\tau t}$

$\ell = \frac{10\ \text{lbs}}{2(\text{~~6526.69 psi~~ } 5710\ \text{psi})(0.25\text{in})}$ = ~~0.0031 in → 0.078 mm~~ 0.0035 in → 0.088 mm

A LENGTH ℓ OF 0.1 mm WILL WORK

Appendix A-11 – Analysis 11: Car Body Frontal Area Drag Coefficient

Please view the following green sheet detailing the analysis over the drag coefficients for different body designs:

JEFFREY HARN
5 NOV 2020

MET 489A | ANALYSIS 11 | CAR BODY FRONTAL AREA DRAG COEFFICIENTS | 1/1

GIVEN: 3 RC BODY FRONT PROFILES + DIMENSIONS, 20 mph VELOCITY
AIR PROPERTIES AT 70°F AT 1 ATM

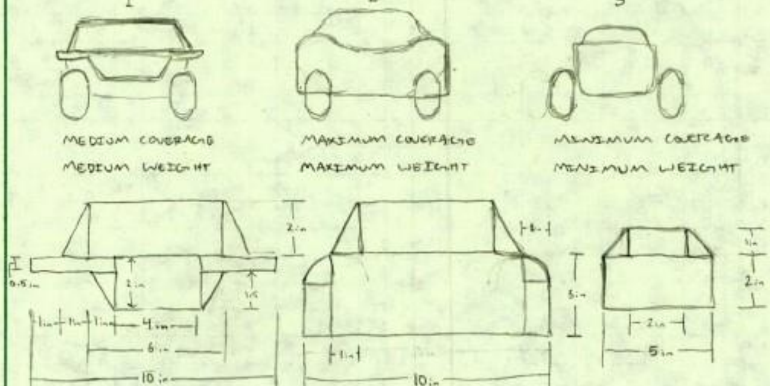
FIND: DRAG COEFFICIENTS FOR EACH BODY OPTION

ASSUMPTIONS: NORMAL CAR 70 lbf DRAG → 1:10 SCALE RC → RC 7 lbf DRAG
AREAS ESTIMATED, AIR FLOW STEADY + INCOMPRESSIBLE

REFERENCE: PGS 594/582 – 595/583 FNDMTLS OF THERMAL FLUID SCIENCES 5TH

METHOD: CALCULATE PROFILE AREAS
CALCULATE DRAG COEFFICIENTS

SOLUTION:



$A_1 = 2(0.5\,in \cdot 3\,in) + 2(\tfrac{1}{2}(1.5\,in \cdot 1\,in)) + 2(\tfrac{1}{2}(2\,in \cdot 1\,in)) + (2\,in \cdot 6\,in) + (4\,in \cdot 2\,in) = 26.5\,in^2$

$A_2 = \tfrac{1}{2}(\pi (1\,in)^2) + 2(\tfrac{1}{2}(2\,in \cdot 1\,in)) + 2(1\,in \cdot 2\,in) + (6\,in \cdot 2\,in) + (8\,in \cdot 3\,in) = 43.57\,in^2$

$A_3 = 2(\tfrac{1}{2}(1\,in \cdot 1\,in)) + (2\,in \cdot 1\,in) + (2\,in \cdot 5\,in) = 13\,in^2$

DRAG COEFFICIENT $\quad C_D = \dfrac{F_D}{\tfrac{1}{2}\rho V^2 A} \quad \rho = 0.07489\,lbm/ft^3$

$C_{D_1} = \dfrac{7\,lbf}{0.5(0.07484\,lbm/ft^3)(29.34\,ft/s)^2(0.184\,ft^2)} \cdot \dfrac{32.2\,lbm\,ft/s^2}{lbf} = 38.0 \quad \boxed{C_{D_1} = 38.0}$

$C_{D_2} = \dfrac{7\,lbf}{0.5(0.07484\,lbm/ft^3)(29.34\,ft/s)^2(0.303\,ft^2)} \cdot \dfrac{32.2\,lbm\,ft/s^2}{lbf} = 23.1 \quad \boxed{C_{D_2} = 23.1}$

$C_{D_3} = \dfrac{7\,lbf}{0.5(0.07484\,lbm/ft^3)(29.34\,ft/s)^2(0.0902\,ft^2)} \cdot \dfrac{32.2\,lbm\,ft/s^2}{lbf} = 77.5 \quad \boxed{C_{D_3} = 77.5}$

CONVERSIONS

$26.5\,in^2 \rightarrow \dfrac{1\,ft^2}{12^2\,in^2} \rightarrow 0.184\,ft^2$

$43.57\,in^2 \rightarrow 0.303\,ft^2$

$13\,in^2 \rightarrow 0.0902\,ft^2$

$20\,mph \rightarrow \dfrac{1.467\,ft/s}{1\,mph} \rightarrow 29.34\,ft/s$

Appendix A-12 – Analysis 12: Transmission Cover Fastener Shear

Please view the following green sheet detailing the analysis over the shear stress present in the fasteners to be used to secure the two pieces of the transmission cover together:

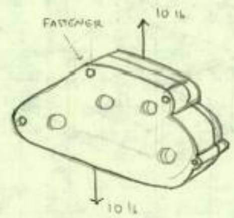
JEFFREY HARN
~~22 OCT 2020~~
6 NOV 2020

MET 489A | ~~ANALYSIS 8~~ | TRASMISSION COVER ~~DISTRIBUTED LOAD STRESS ANALYSIS~~ | 1/

ANALYSIS 12 FASTENER SHEAR

GIVEN: 10 lb SHEAR FORCE, SCREW MATERIAL OF STEEL GRADE 4.6 → 240 MPa YIELD (TABLE 19-3 MOTT)

FIND: REQUIRED SCREW SIZE (DIAMETER)



ASSUMPTIONS: DIRECT SHEAR FORCE
MATERIAL AROUND SCREW IS RIGID AND INFINITELY STRONG
HOMOGENOUS SCREW MATERIAL

METHOD: DEFINE SCREW MATERIAL PROPERTIES
SHEAR EQUATION V/A
SOLVE FOR DIAMETER

MATERIAL PROPERTIES
METRIC STEEL FASTENER GRADE 4.6
YIELD STRENGTH OF APPROXIMATELY 240 MPa (TABLE 19-3 MOTT)

$\tau = \frac{V}{A}$ $A = \pi r^2$

$\tau = \frac{V}{\pi r^2}$ → SOLVE FOR r → $r = \sqrt{\frac{V}{\pi \tau}}$

$10\,lb \to N \to 10\,lb \cdot \frac{4.448\,N}{1\,lbf} = 44.48\,N$

$r = \sqrt{\frac{44.48\,N}{240{,}00{,}000\,Pa\,(\pi)}} = 5.899 \cdot 10^{-8}\,m \to 0.00000005899 \to 58.99\,nm$

DIAMETER PARAMETER: 118 nm

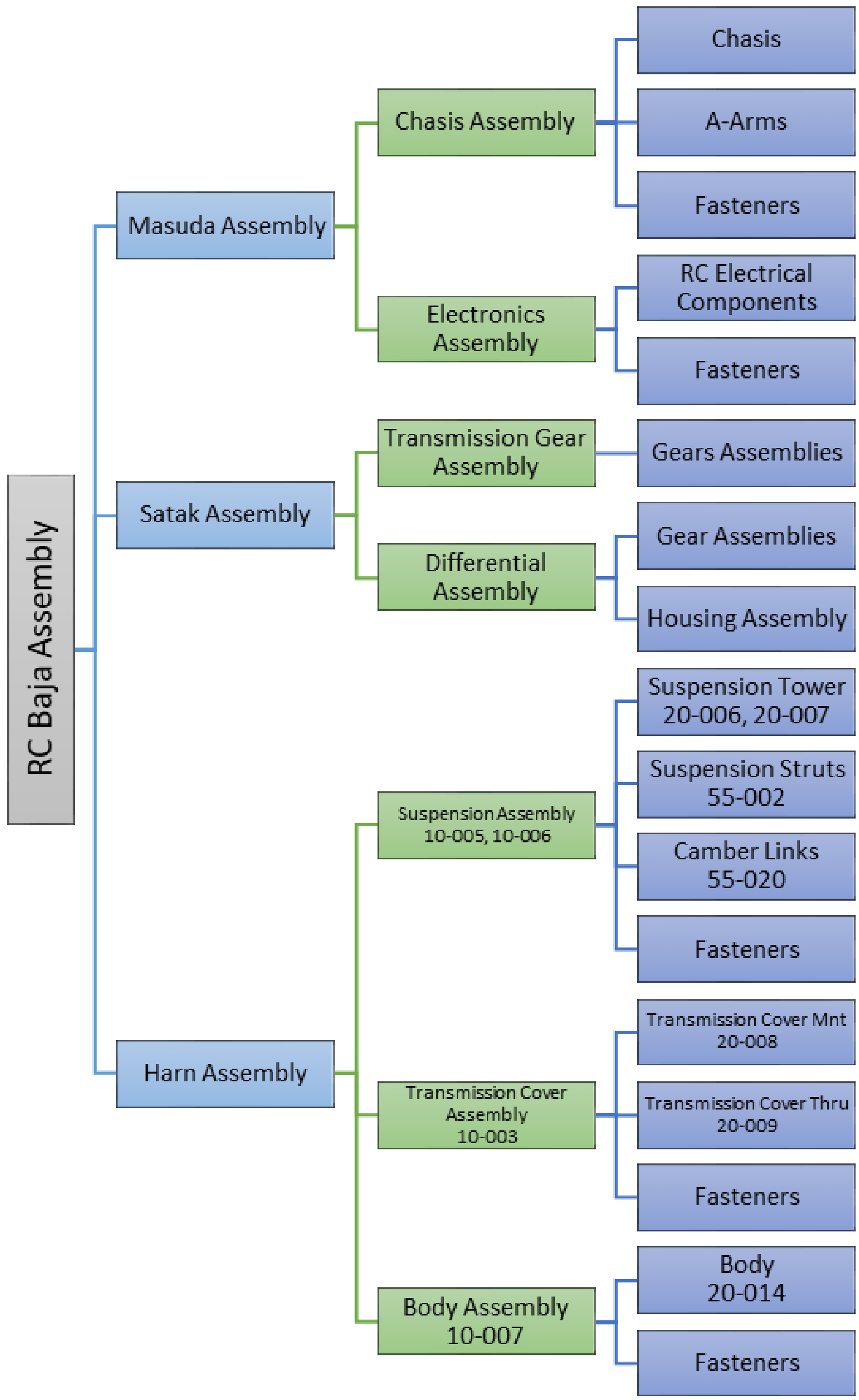
SMALLEST DIAMETER AVAILABLE: 1.6 mm (M1.6) (TABLE 19-5 MOTT)

$SF = \frac{1.6\,mm}{0.000118\,mm} = 13560$!!!

APPENDIX B - Drawings

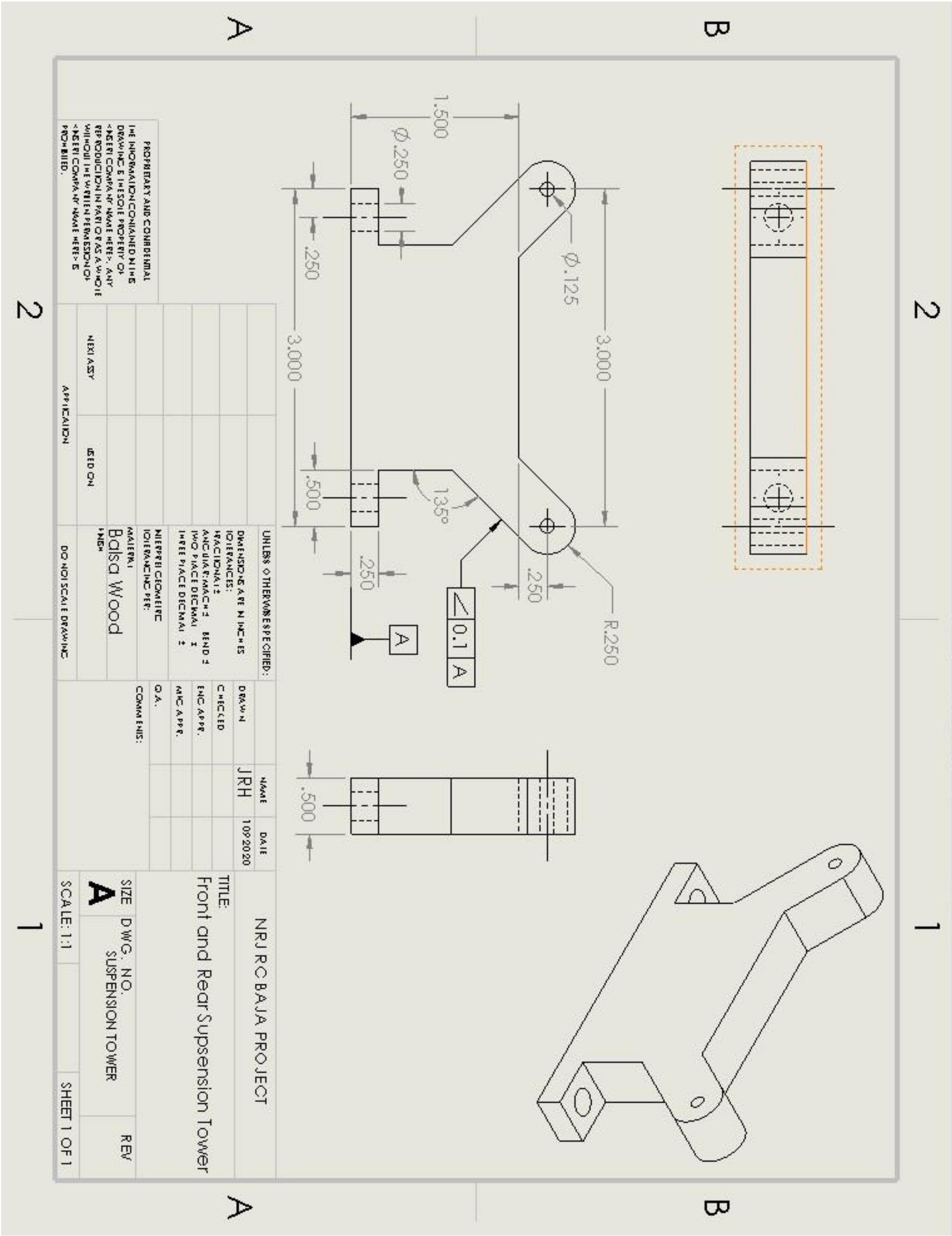
Appendix B-1 – Drawing Tree

Please see the below drawing tree detailing the hierarchy of the various part and assembly drawings for the project.



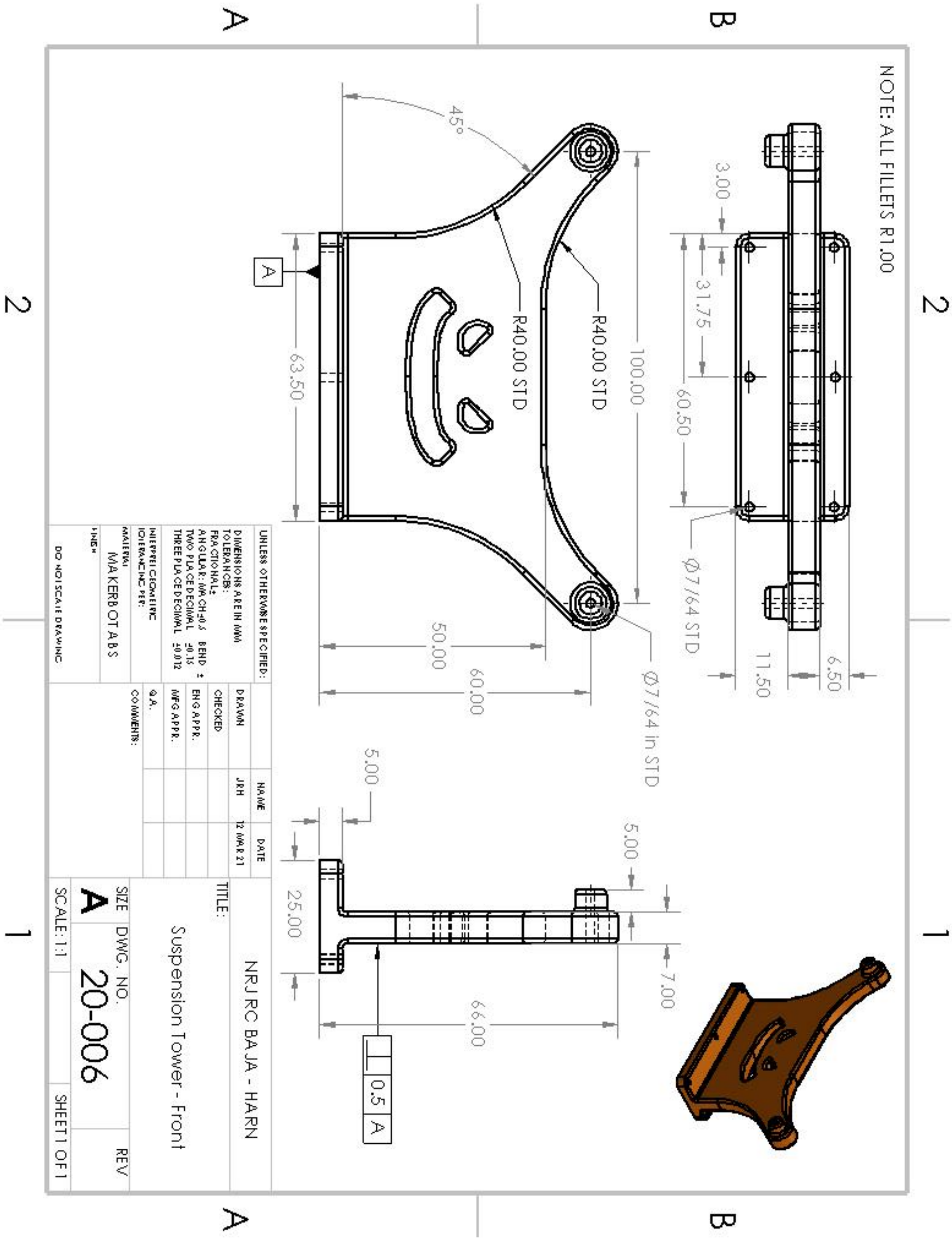
Appendix B-2 – Suspension Tower Mk. I Drawing

Please see the below drawing of the device that will allow suspension struts to mount to the chassis.



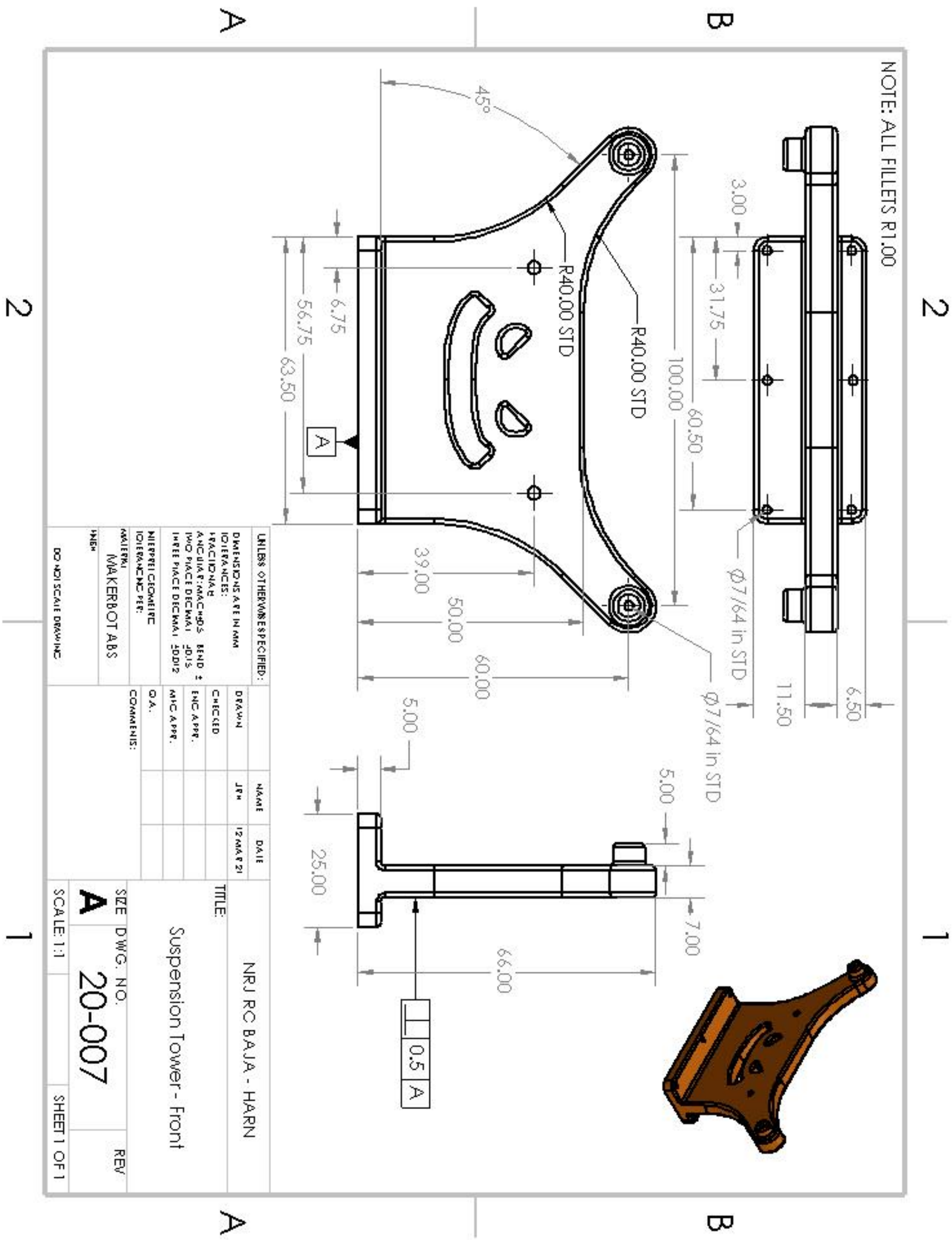
Appendix B-3 – Front Suspension Tower Mk. II Drawing

Please see the below drawing of the device that will allow suspension struts to mount to the front of the chassis, redesigned.



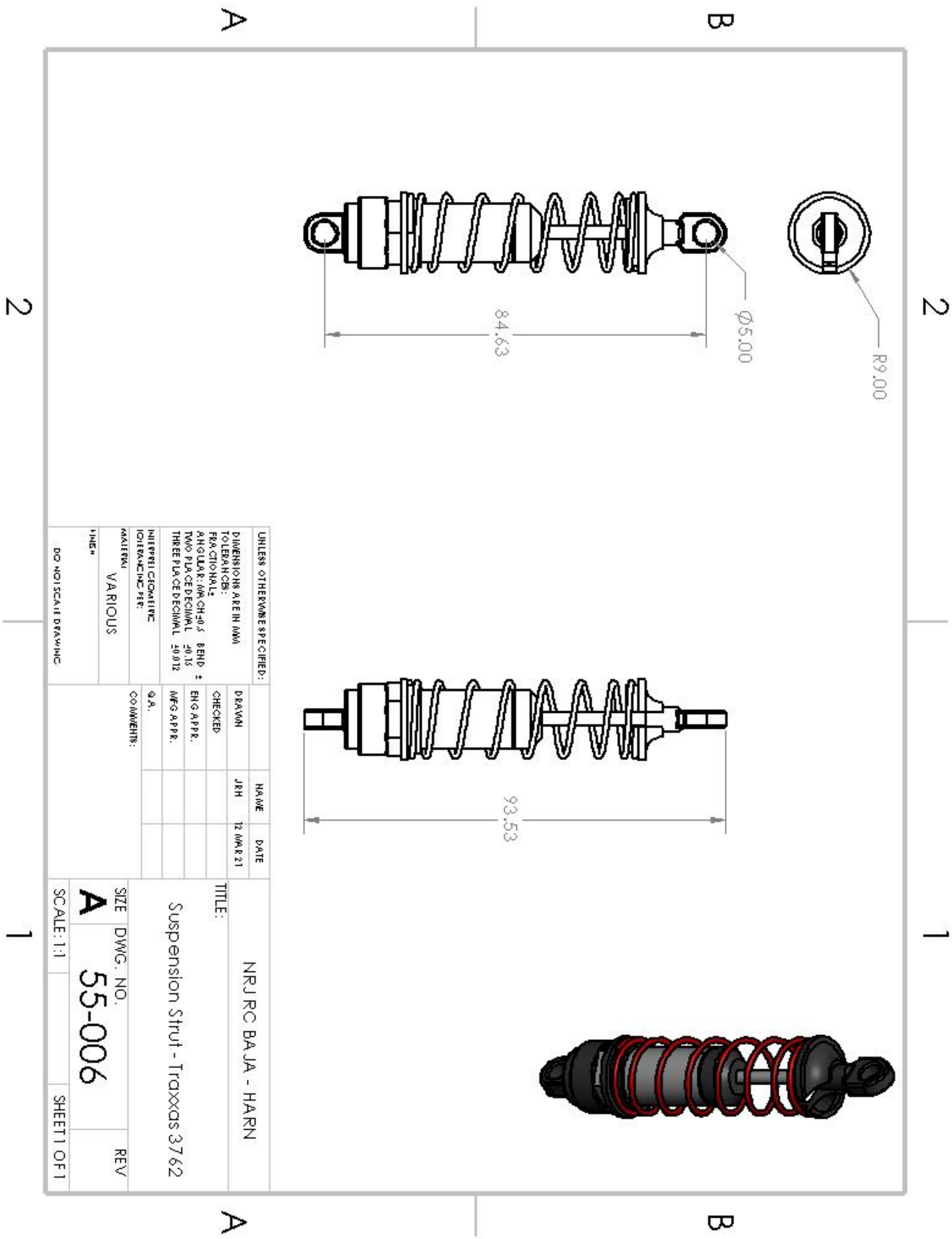
Appendix B-4 – Rear Suspension Tower Mk. II Drawing

Please see the below drawing of the device that will allow suspension struts to mount to the rear of the chassis, redesigned.



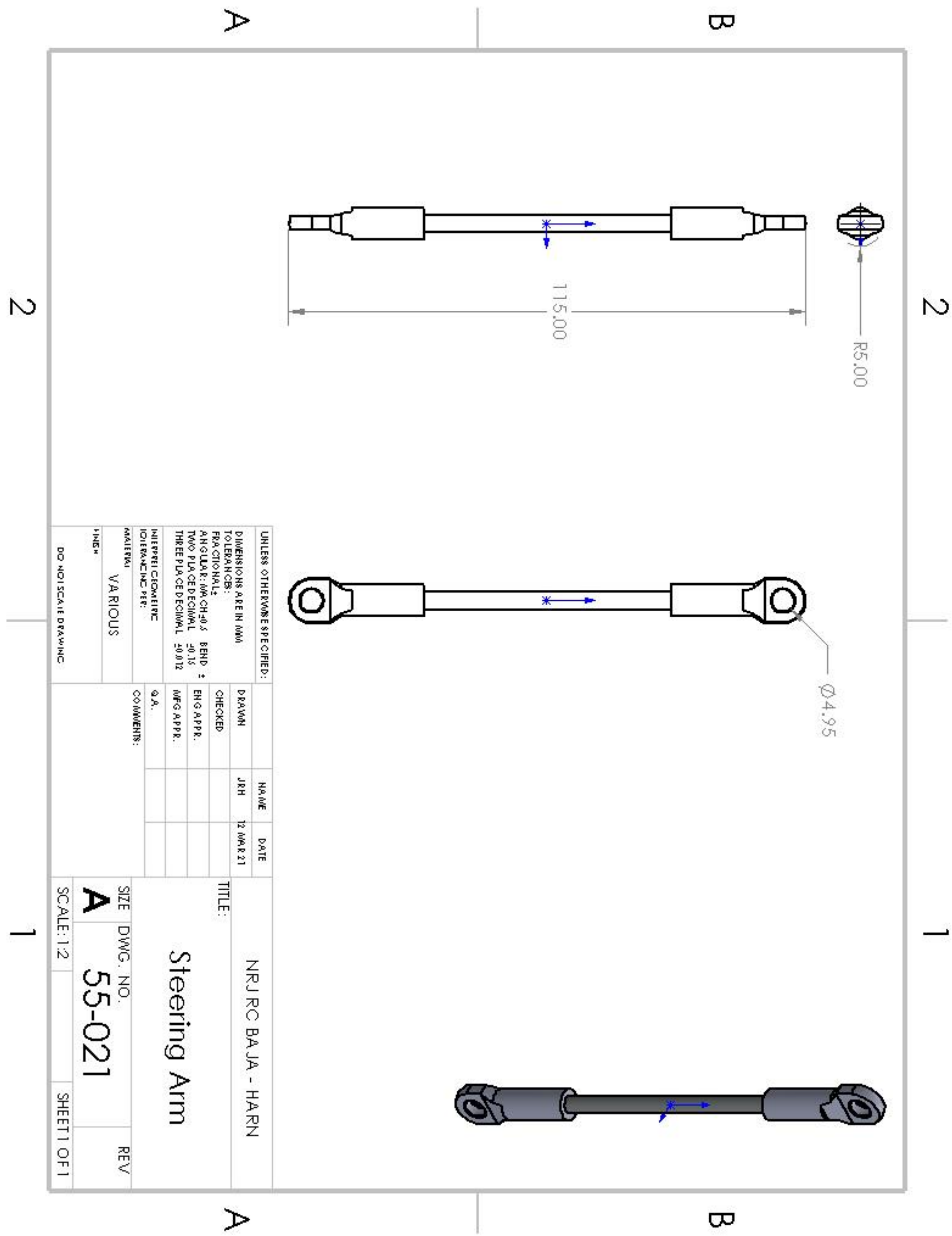
Appendix B-5 – Suspension Strut Drawing

Please see the below drawing of the strut and spring assembly for the RC suspension. This model was downloaded from GrabCAD and is the Traxxas #3764A Model.



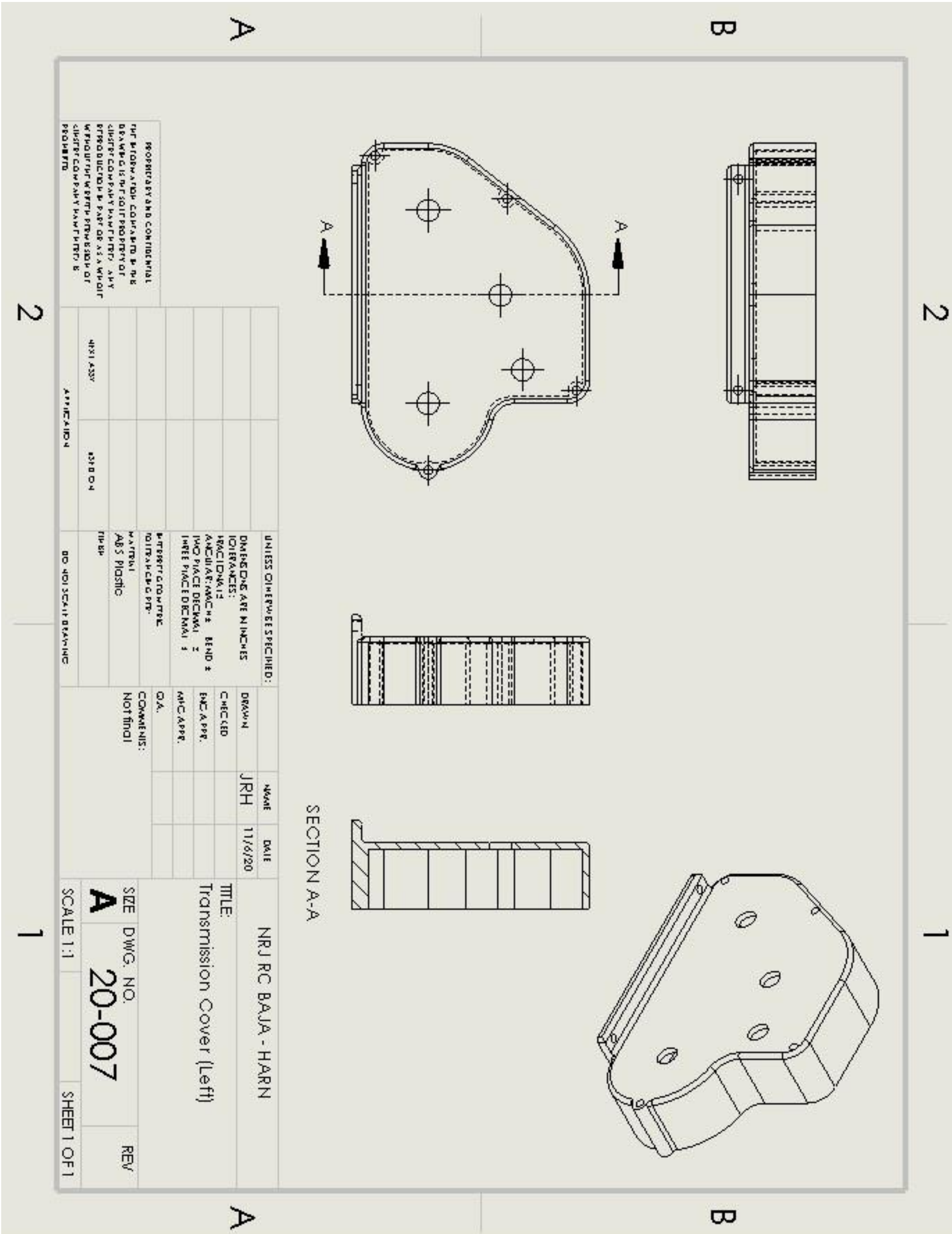
Appendix B-6 – Steering Arm Drawing

Please see the below drawing of the steering arm for the RC suspension. This model was downloaded from GrabCAD and is the Traxxas #3644 Model.



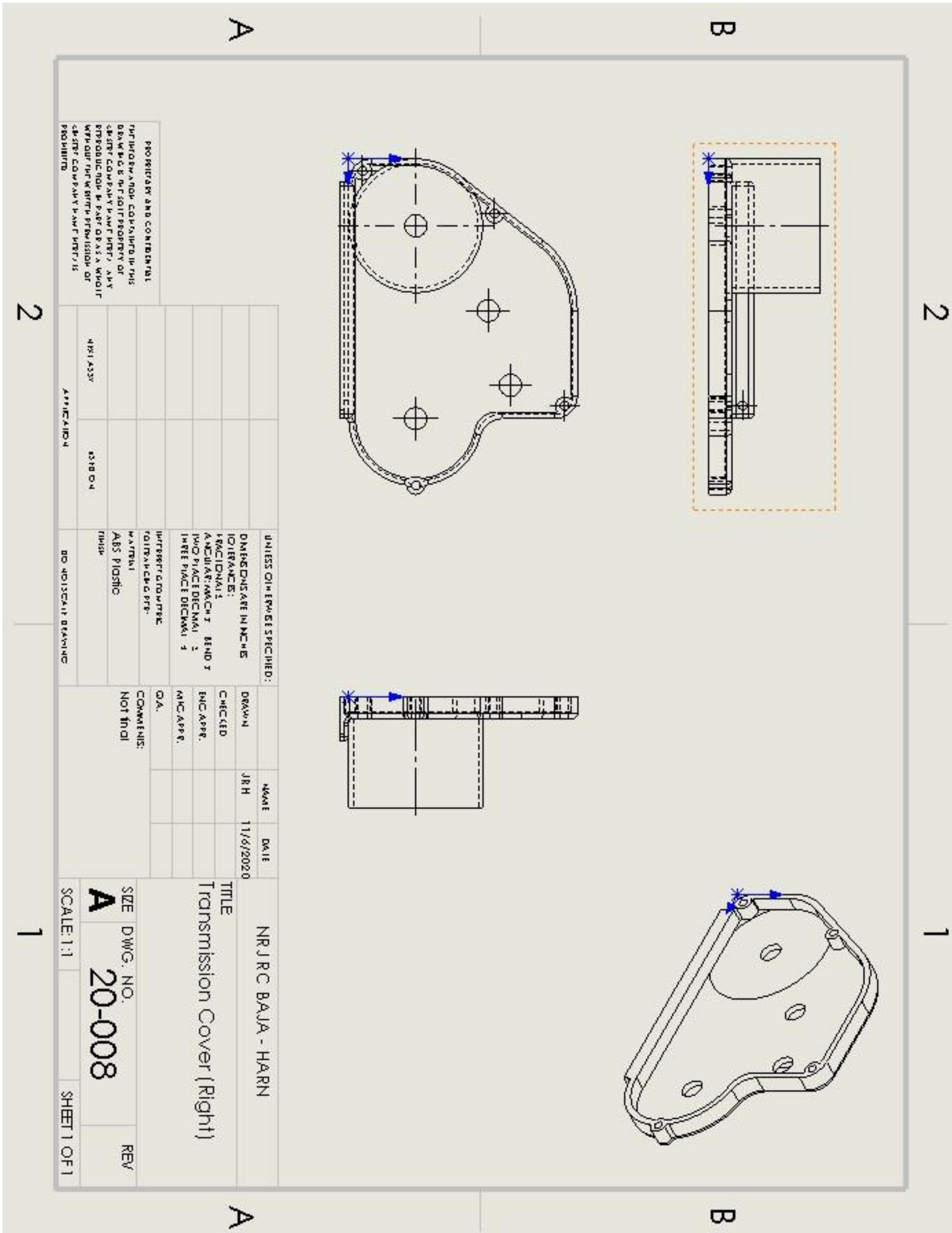
Appendix B-7 – Transmission Cover Motor Mount Mk. I

Please see the below drawing of the left side of the transmission cover assembly:



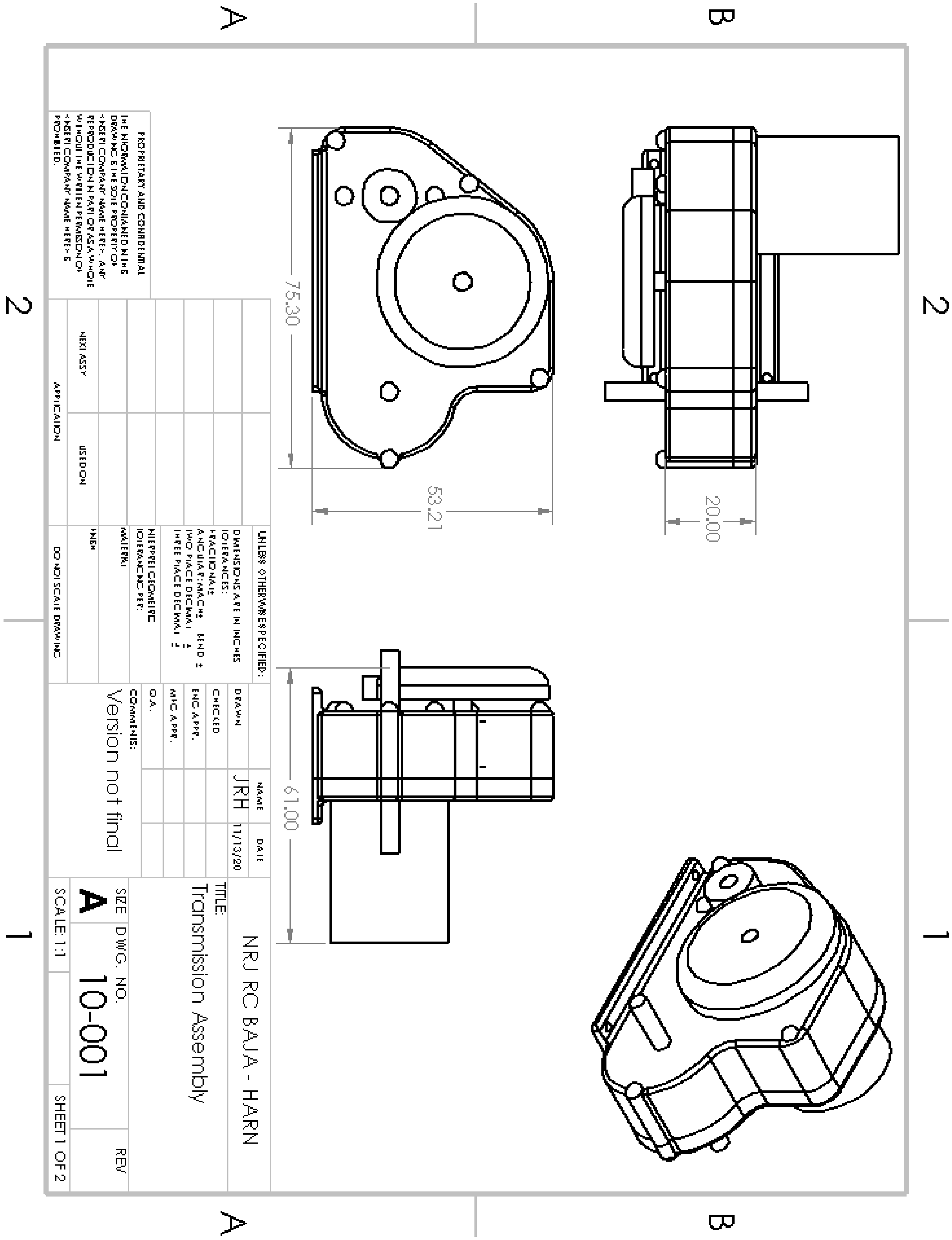
Appendix B-8 – Transmission Cover Motor Throught Mk. I

Please see the below drawing of the right side of the transmission cover assembly:

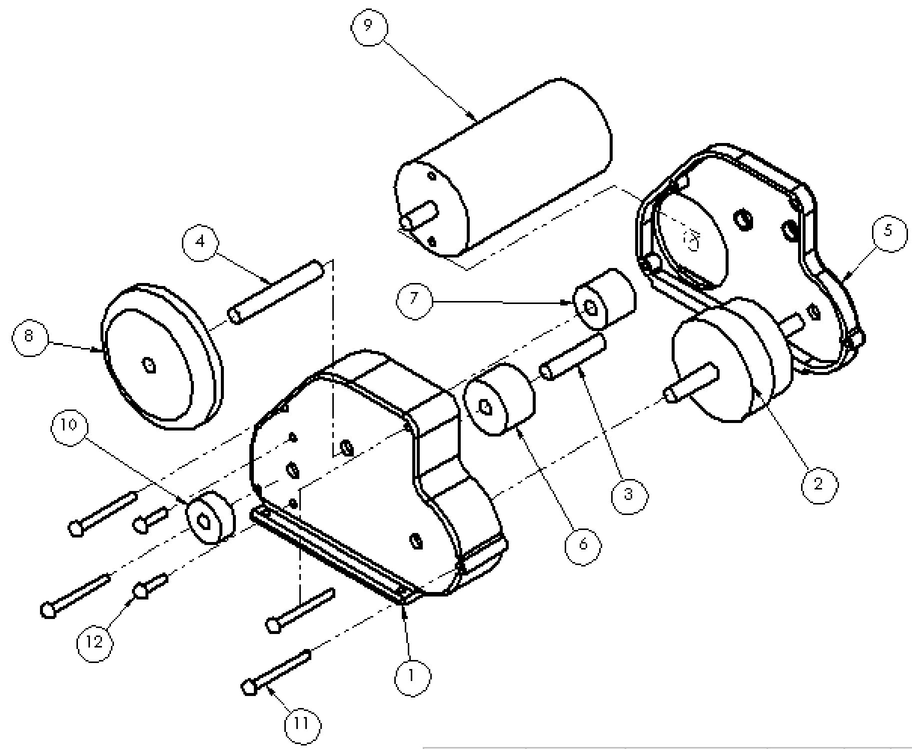


Appendix B-9 – Transmission Assembly Mk. I

Please see the below assembly drawings (two pages) of the transmission assembly:



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	20-007	Transmission Cover (Left)	1
2	20-005	Differential Assembly	1
3	55-012	Traxxas Part 3691A	1
4	55-013	Traxxas Part 3793	1
5	20-008	Transmission Cover (Right)	1
6	55-009	Traxxas Part 3696	1
7	55-010	Traxxas Part 3195	1
8	55-011	Traxxas Part 4690	1
9	55-016	Traxxas Part 3785	1
10	55-008	Traxxas Part 2743	1
11	55--014	Traxxas 3x23BCS	4
12	55-015	Traxxas 3x8FCS	2



NRJ RC BAJA - HARN

TITLE: Transmission Assembly

DRAWN: JRH 11/13/20

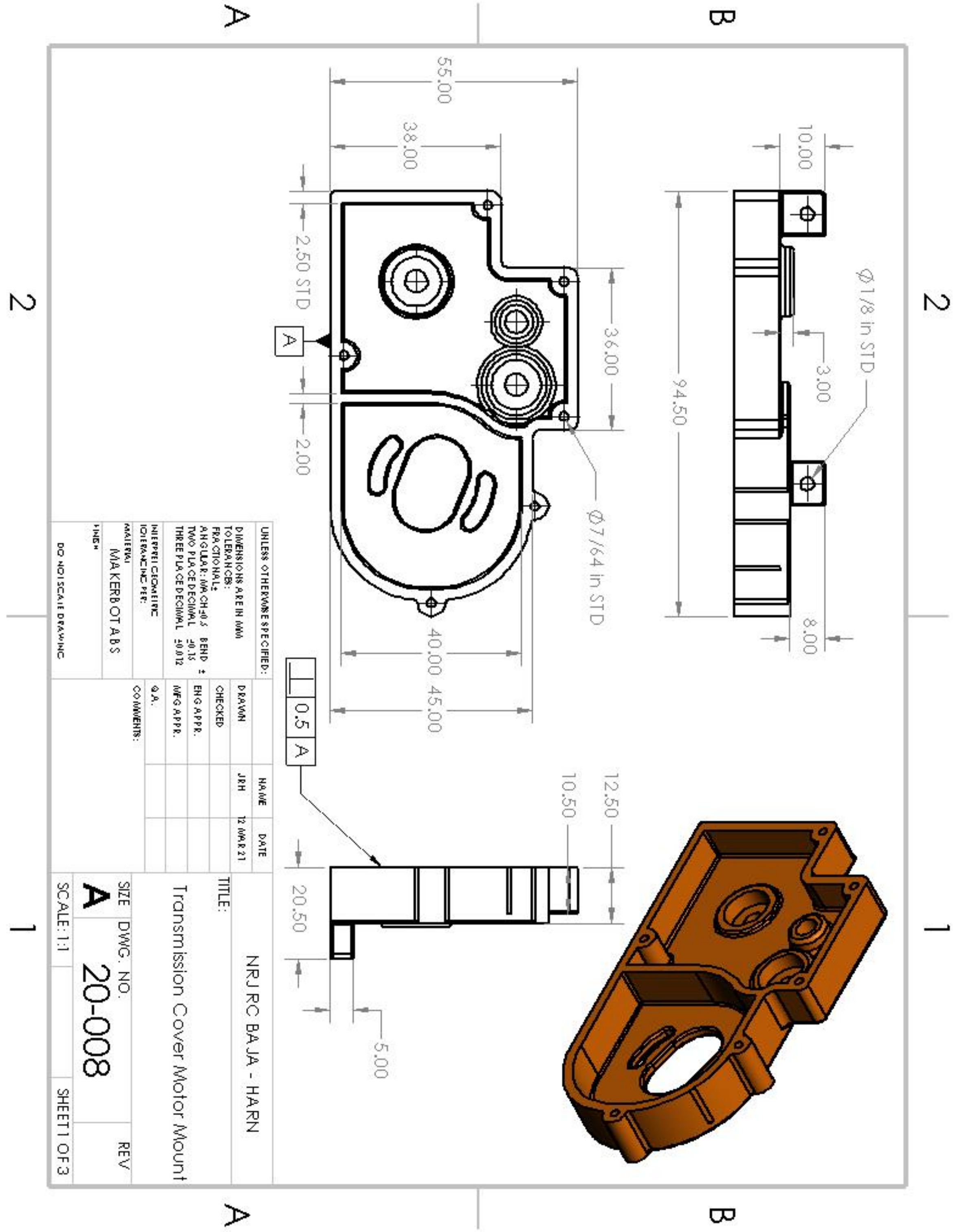
COMMENTS: Version not final

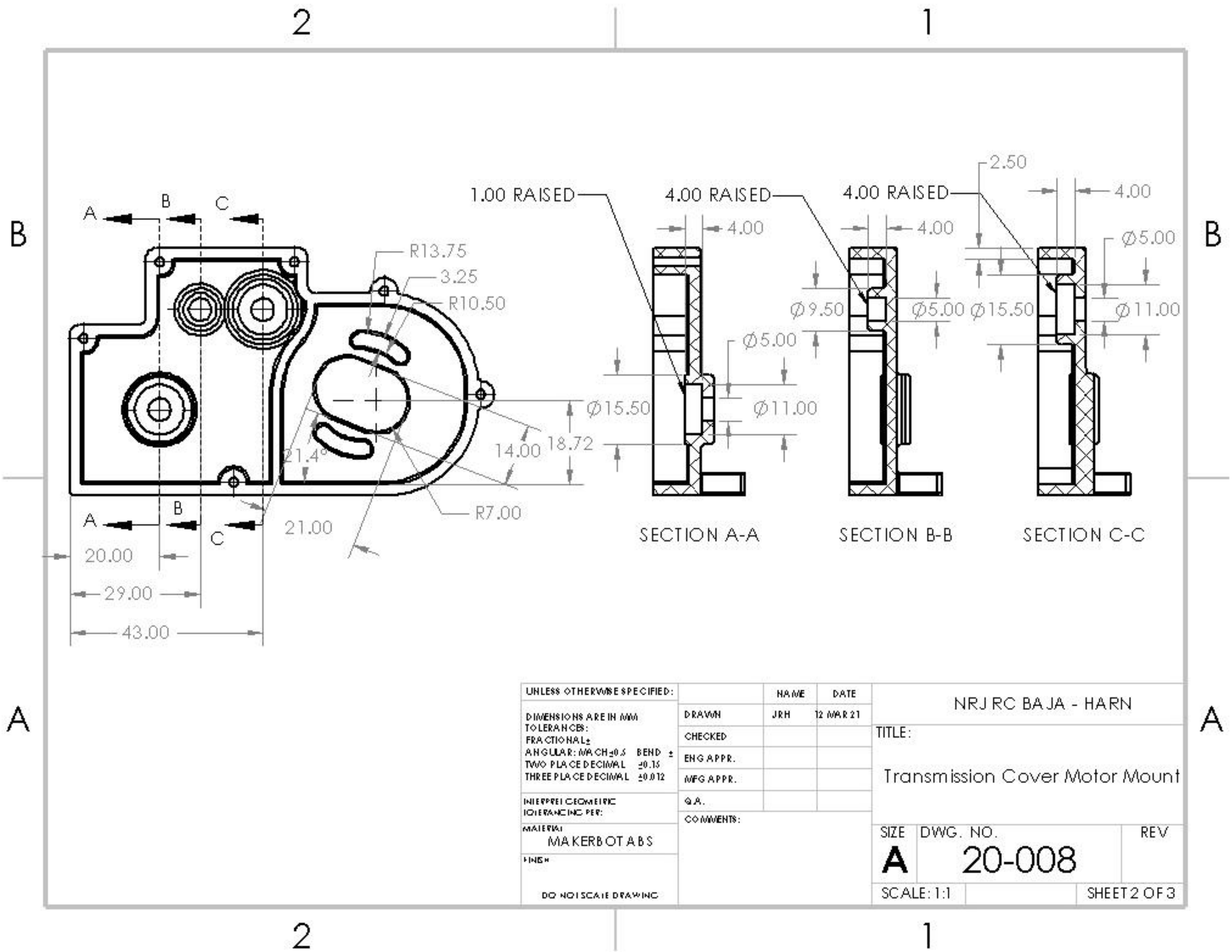
SIZE: B DWG. NO. 10-001 REV

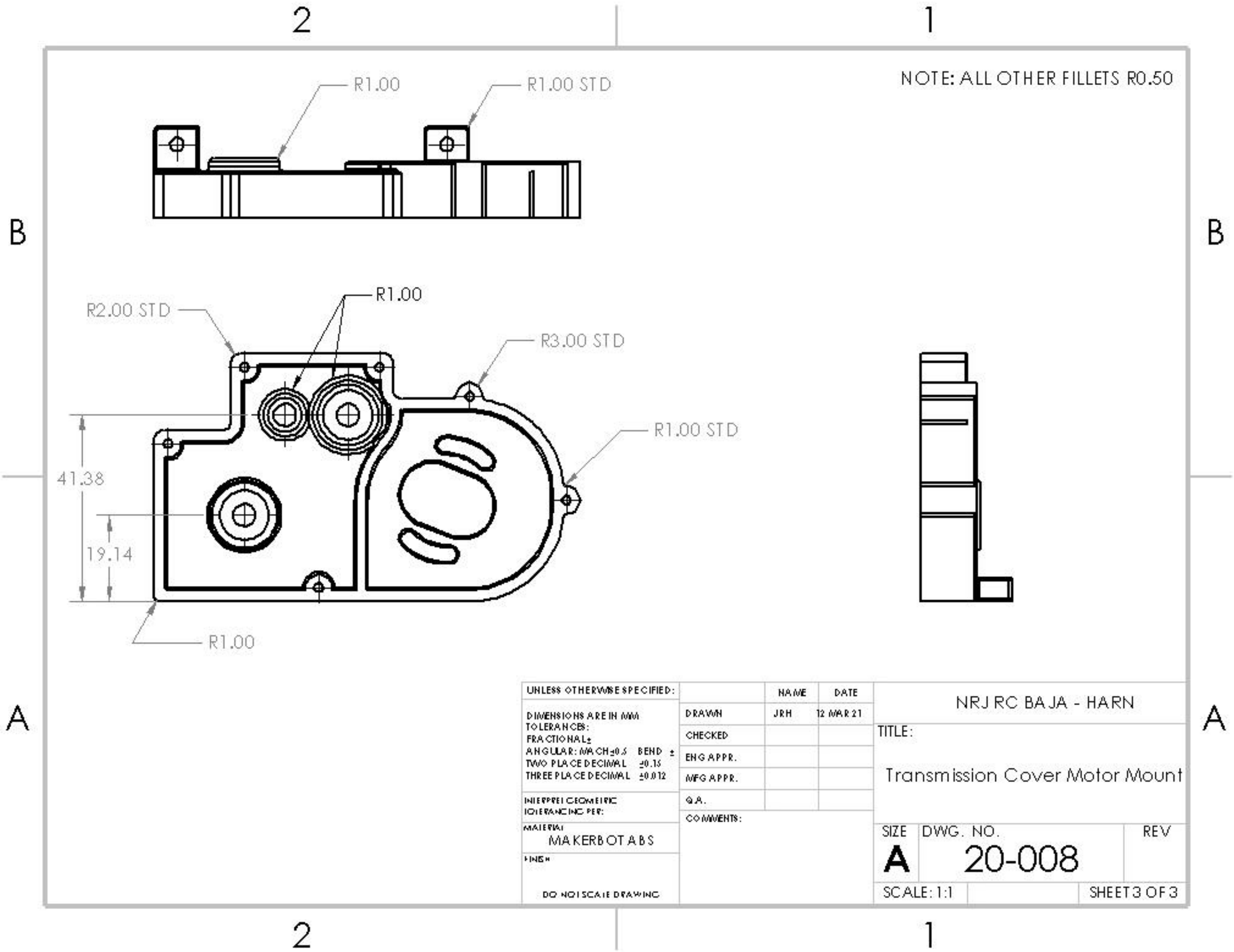
SCALE: 1:1 WEIGHT: SHEET 2 OF 2

Appendix B-10 – Transmission Cover Motor Mount Mk. II

Please see the below drawing of the side of the transmission cover the motor mounts to, redesigned:

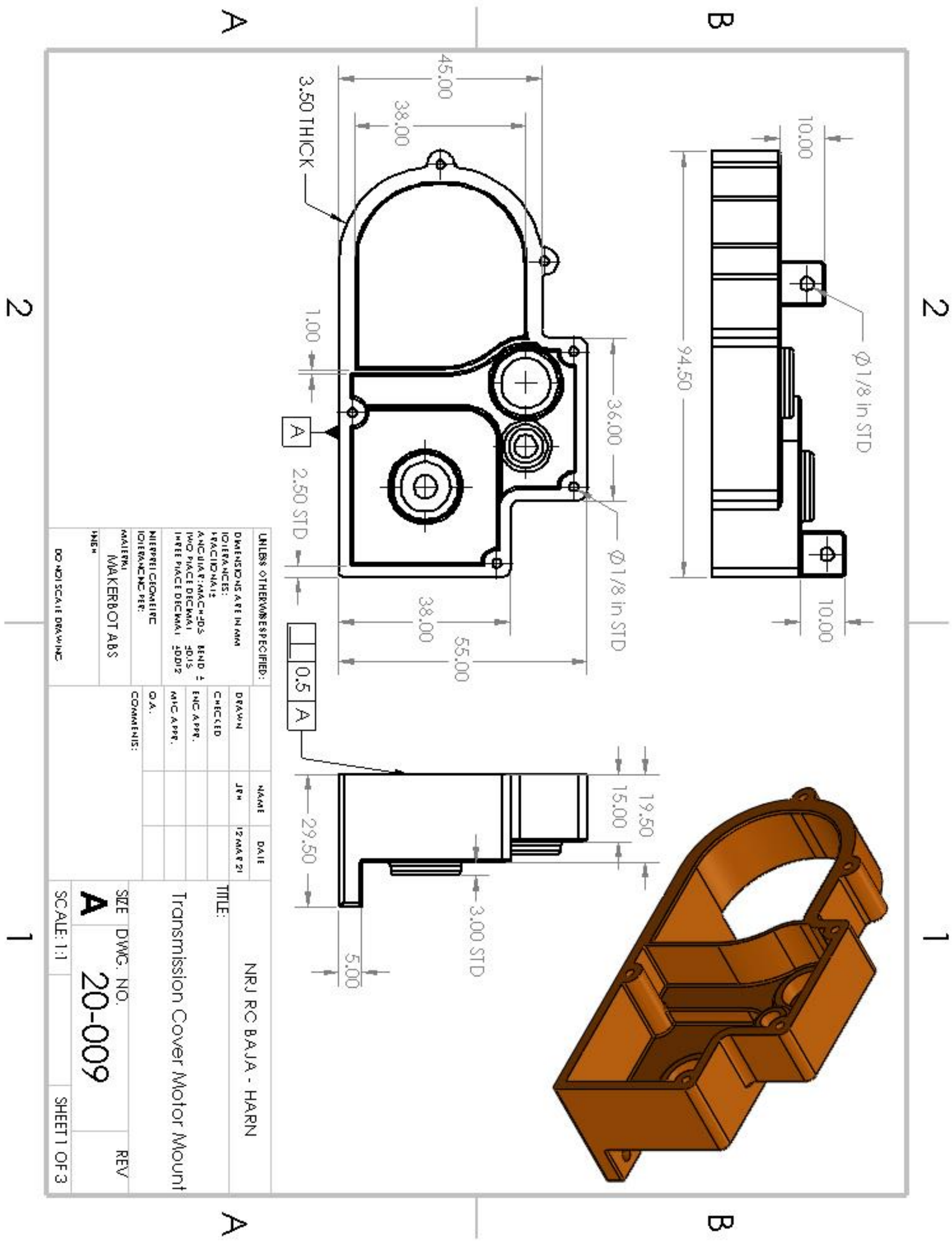


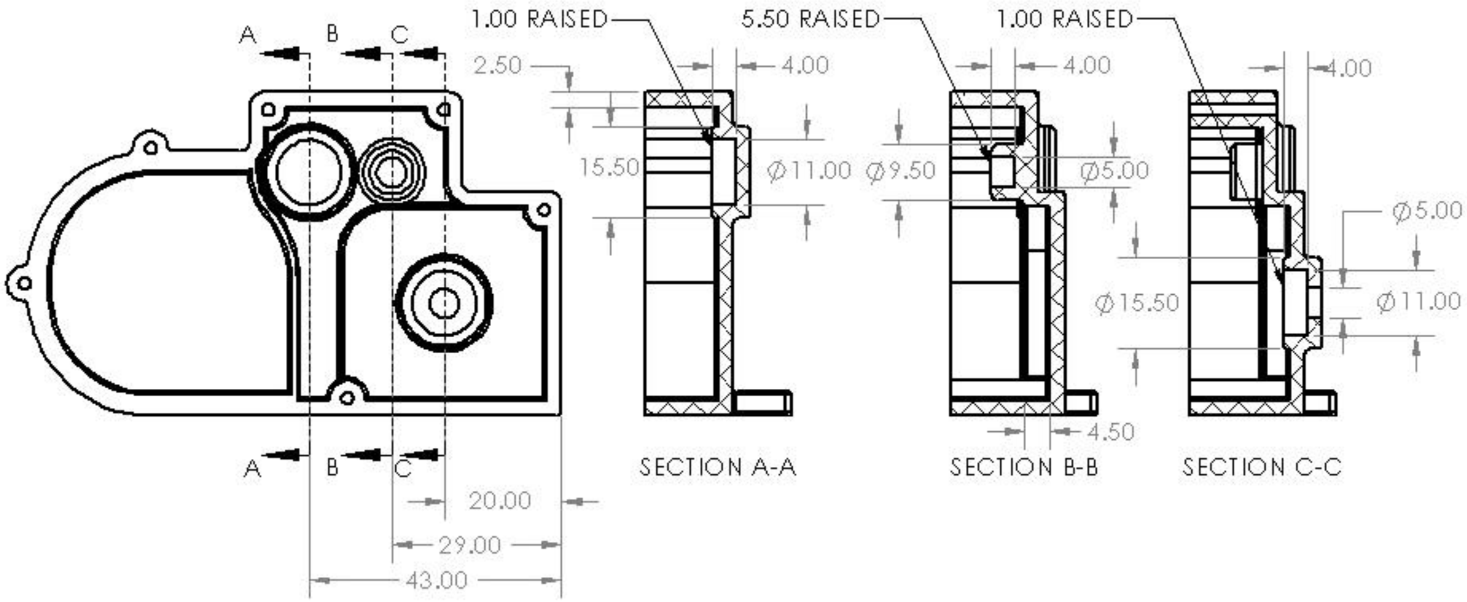

A
B
C
R13.75
3.25
R10.50
R7.00
21.4°
14.00
18.72
21.00
20.00
29.00
43.00
1.00 RAISED
4.00 RAISED
4.00 RAISED
4.00
4.00
4.00
2.50
Ø15.50
Ø5.00
Ø11.00
Ø9.50
Ø5.00
Ø15.50
Ø5.00
Ø11.00
SECTION A-A
SECTION B-B
SECTION C-C
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MM
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH±0.5 BEND ±
TWO PLACE DECIMAL ±0.15
THREE PLACE DECIMAL ±0.012
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
MAKERBOT ABS
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
JRH
12 MAR 21
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
NRJ RC BAJA - HARN
TITLE:
Transmission Cover Motor Mount
SIZE
A
DWG. NO.
20-008
REV
SCALE: 1:1
SHEET 2 OF 3


NOTE: ALL OTHER FILLETS R0.50
R1.00
R1.00 STD
R2.00 STD
R1.00
R3.00 STD
R1.00 STD
41.38
19.14
R1.00
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MM
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH±0.5 BEND ±
TWO PLACE DECIMAL ±0.15
THREE PLACE DECIMAL ±0.012
INTERPRET GEOMETRIC
TOLERANCING PER:
MATERIAL
MAKERBOT ABS
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
JRH
12 MAR 21
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
NRJ RC BAJA - HARN
TITLE:
Transmission Cover Motor Mount
SIZE
A
DWG. NO.
20-008
REV
SCALE: 1:1
SHEET 3 OF 3

Appendix B-11 – Transmission Cover Motor Through Mk. II

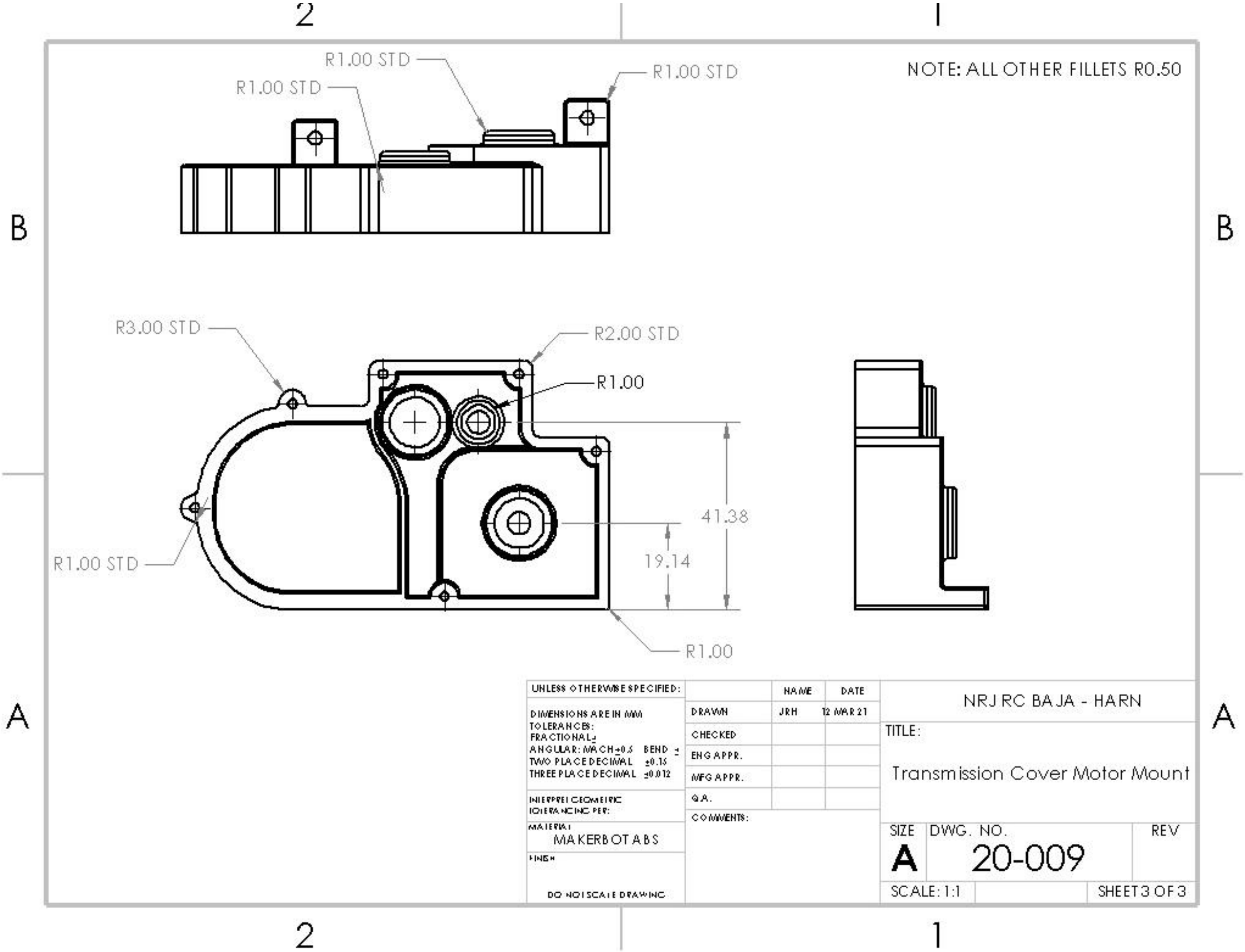
Please see the below drawing of the side of the transmission cover the motor passes through, redesigned:





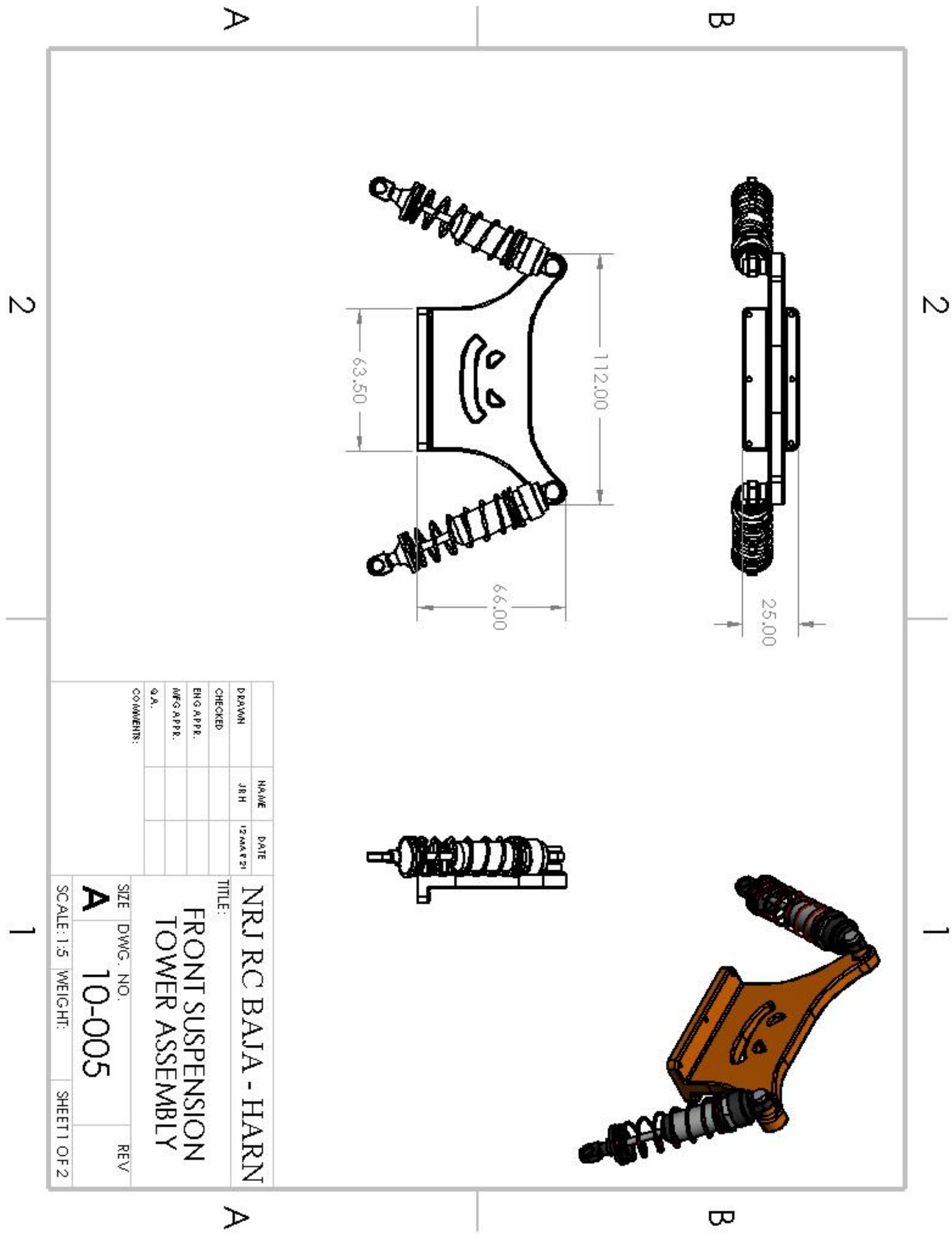
UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN MM TOLERANCES: FRACTIONAL± ANGULAR: MACH±0.5 BEND ± TWO PLACE DECIMAL ±0.15 THREE PLACE DECIMAL ±0.012	DRAWN	JRH	12 MAR 21
	CHECKED		
	ENG APPR.		
	MFG APPR.		
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
MATERIAL MAKERBOT ABS	COMMENTS:		
FINISH			
DO NOT SCALE DRAWING			

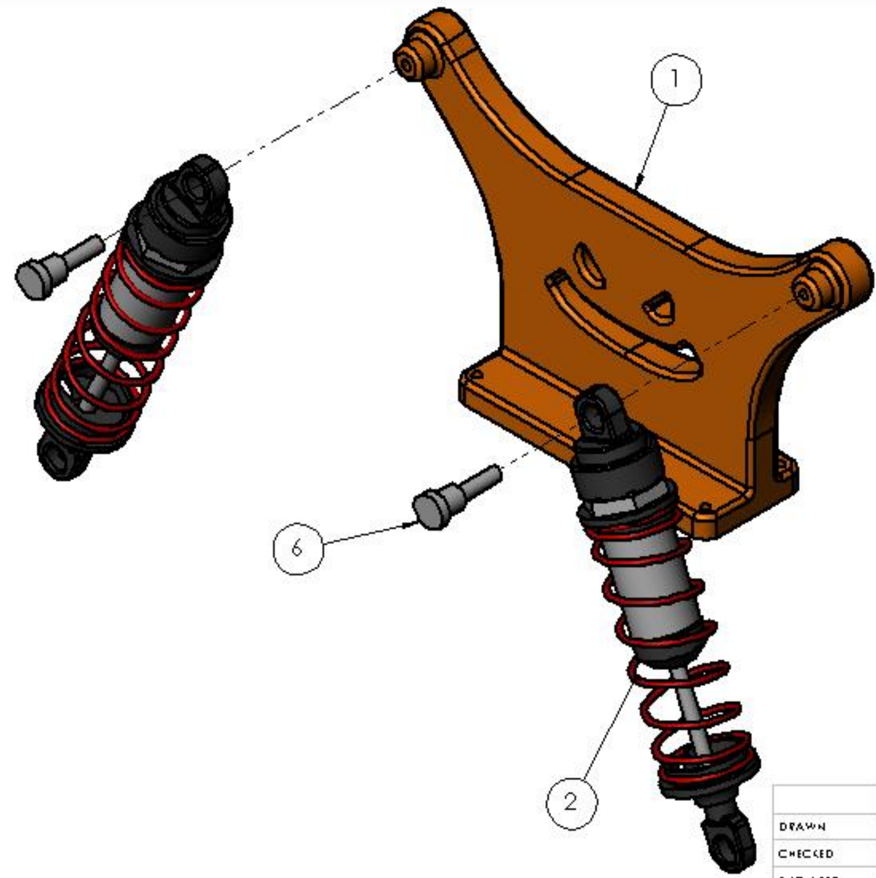
NRJ RC BAJA - HARN		
TITLE: Transmission Cover Motor Mount		
SIZE A	DWG. NO. 20-009	REV
SCALE: 1:1		SHEET 2 OF 3


NOTE: ALL OTHER FILLETS R0.50
R1.00 STD
R1.00 STD
R1.00 STD
R3.00 STD
R2.00 STD
R1.00
R1.00 STD
41.38
19.14
R1.00
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MM
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH±0.5 BEND ±
TWO PLACE DECIMAL ±0.15
THREE PLACE DECIMAL ±0.012
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
MAKERBOT ABS
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
JRH
12 MAR 21
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
NRJ RC BAJA - HARN
TITLE:
Transmission Cover Motor Mount
SIZE
A
DWG. NO.
20-009
REV
SCALE: 1:1
SHEET 3 OF 3

Appendix B-12 – Front Suspension Tower Mk.II Assembly

Please see the below assembly drawing of the front suspension tower Mk. II assembly:





ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	20-006	Suspension Tower Front	1
2	55-006	Suspension Strut 3762	2
6	50-004	Suspension Strut Fastener	2

	NAME	DATE
DRAWN	JRH	12MAR21
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		
COMMENTS:		

NRJ RC BAJA - HARN

TITLE:

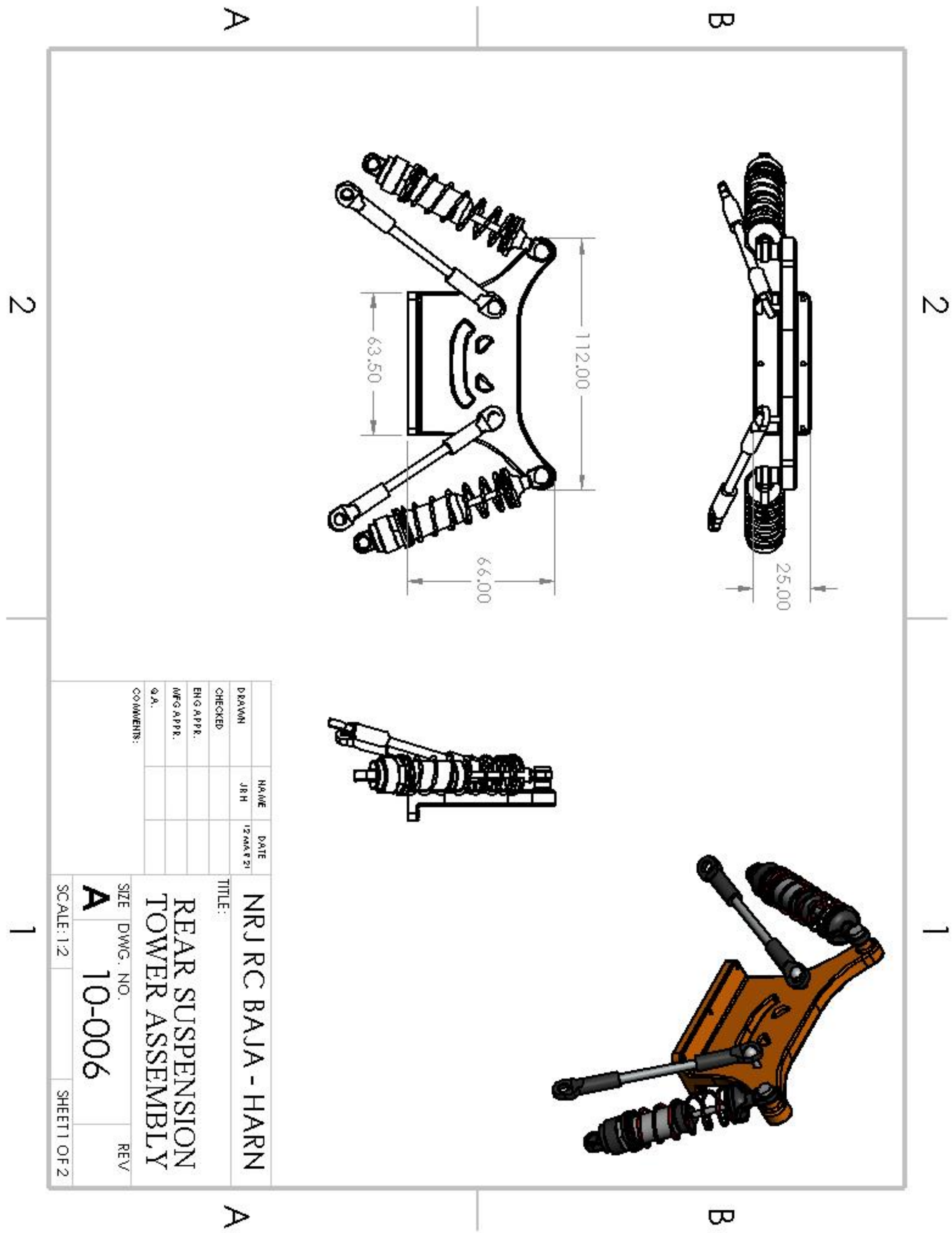
FRONT SUSPENSION TOWER ASSEMBLY

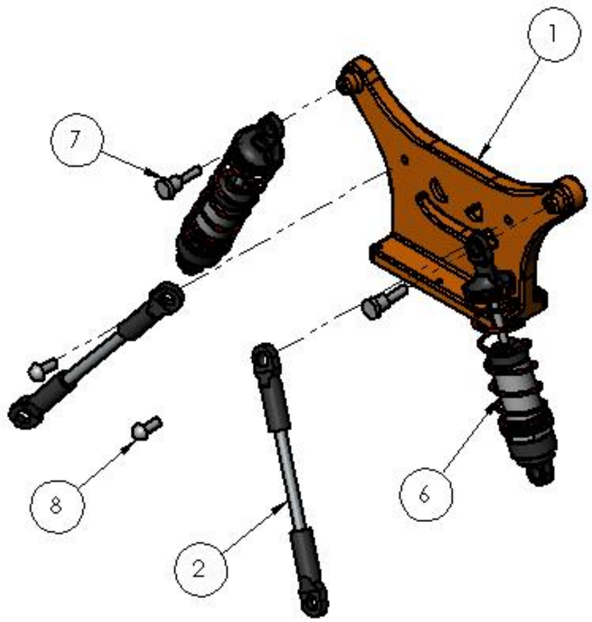
SIZE A | DWG. NO. 10-005 | REV

SCALE: 1:5 | WEIGHT: | SHEET 2 OF 2

Appendix B-13 – Rear Suspension Tower Mk.II Assembly

Please see the below assembly drawing of the rear suspension tower Mk. II assembly:





ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	20-007	Suspension Tower Rear	1
2	55-020	Control Arm	2
3	55-006	Spuspension Strut 3762	2
7	50-004	Suspension Strut Fastener	2
8	50-005	Traxxas M3 Fastener	2

	NAME	DATE
DRAWN	JRH	12MAR21
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

NRJ RC BAJA - HARN

TITLE:

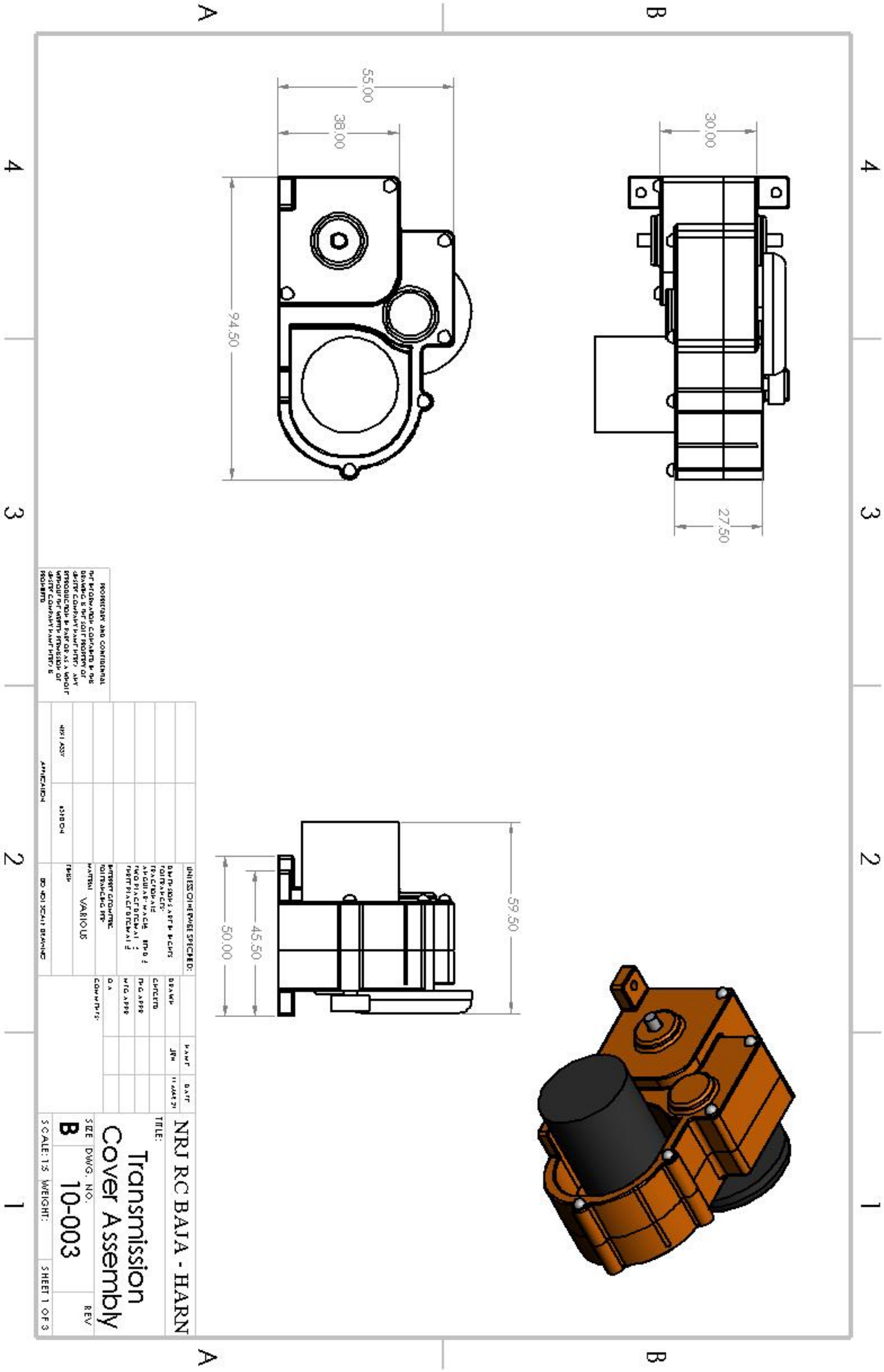
REAR SUSPENSION TOWER ASSEMBLY

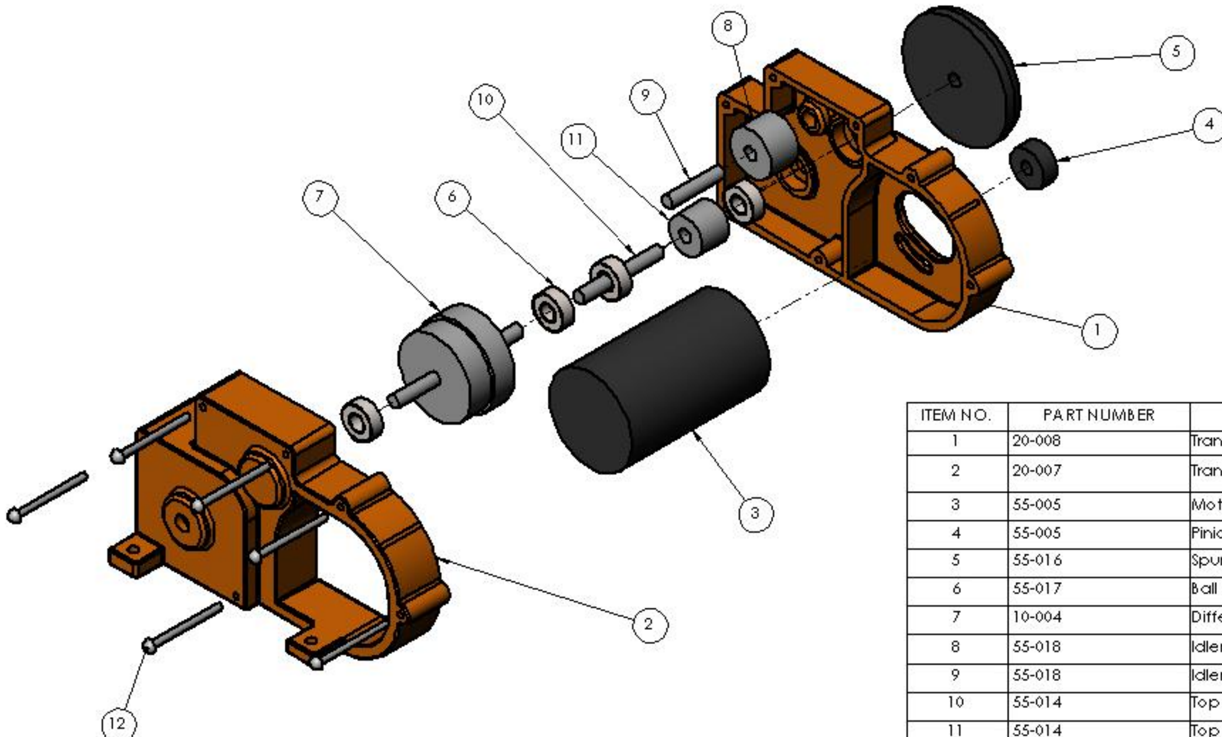
SIZE A DWG. NO. 10-006 REV

SCALE: 1:2 SHEET 2 OF 2

Appendix B-14 – Transmission Mk.II Assembly

Please see the below assembly drawing of the transmission Mk. II assembly:





ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	20-008	Transmission Cover Motor Mount	1
2	20-007	Transmission Cover Motor Through	1
3	55-005	Motor	1
4	55-005	Pinion Gear	1
5	55-016	Spur Gear Slipper Clutch	1
6	55-017	Ball Bearing 5X11X4	4
7	10-004	Differential Assembly	1
8	55-018	Idler Gear	1
9	55-018	Idler Gear Shaft	1
10	55-014	Top Drive Gear Shaft	1
11	55-014	Top Drive Gear Shaft	1
12	50-001	M3x25 Screw	6

NRJ RC BAJA - HARN

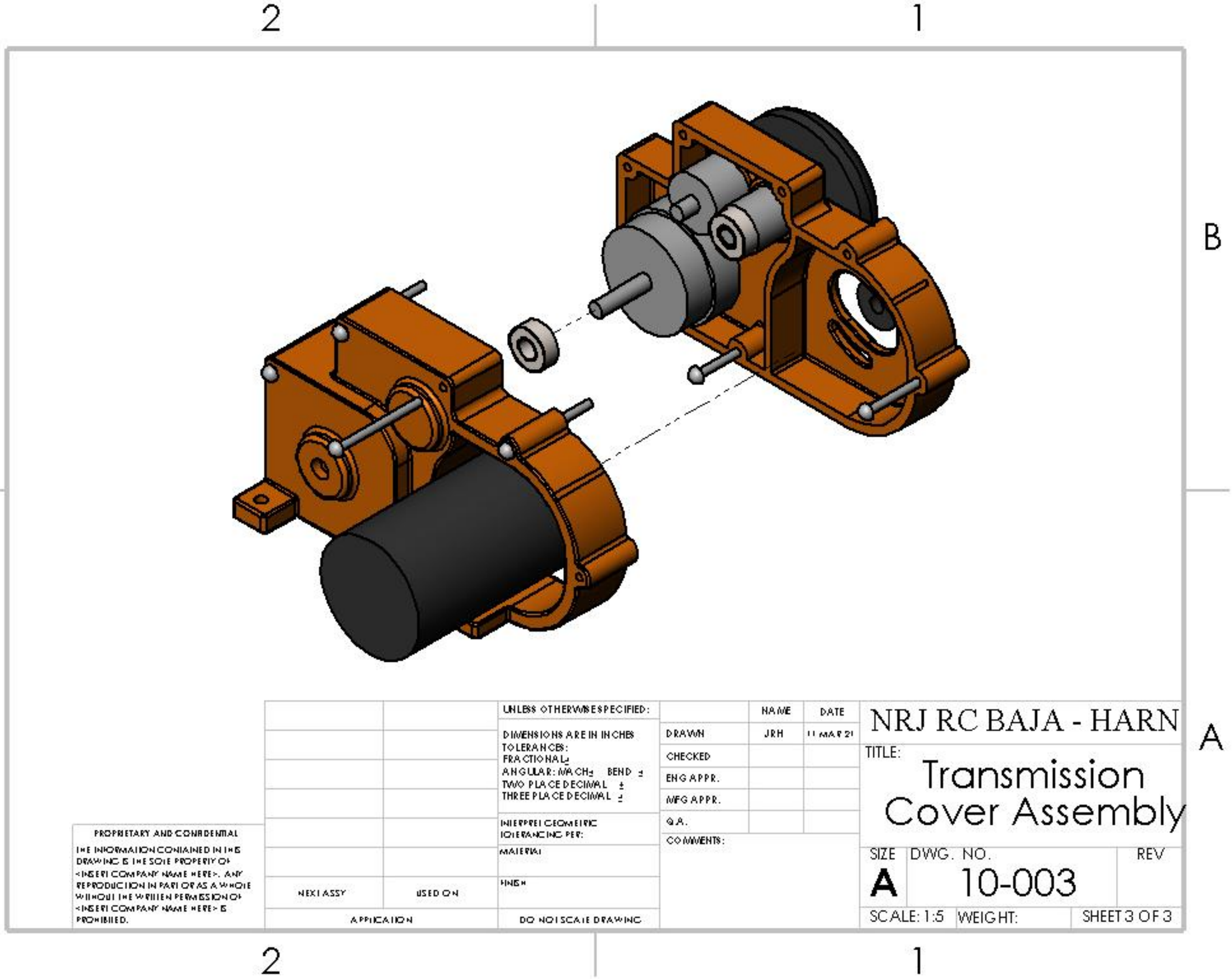
DRAWN JEH 11 MAR 21

MATERIAL VARIOUS

TITLE: Transmission Cover Assembly

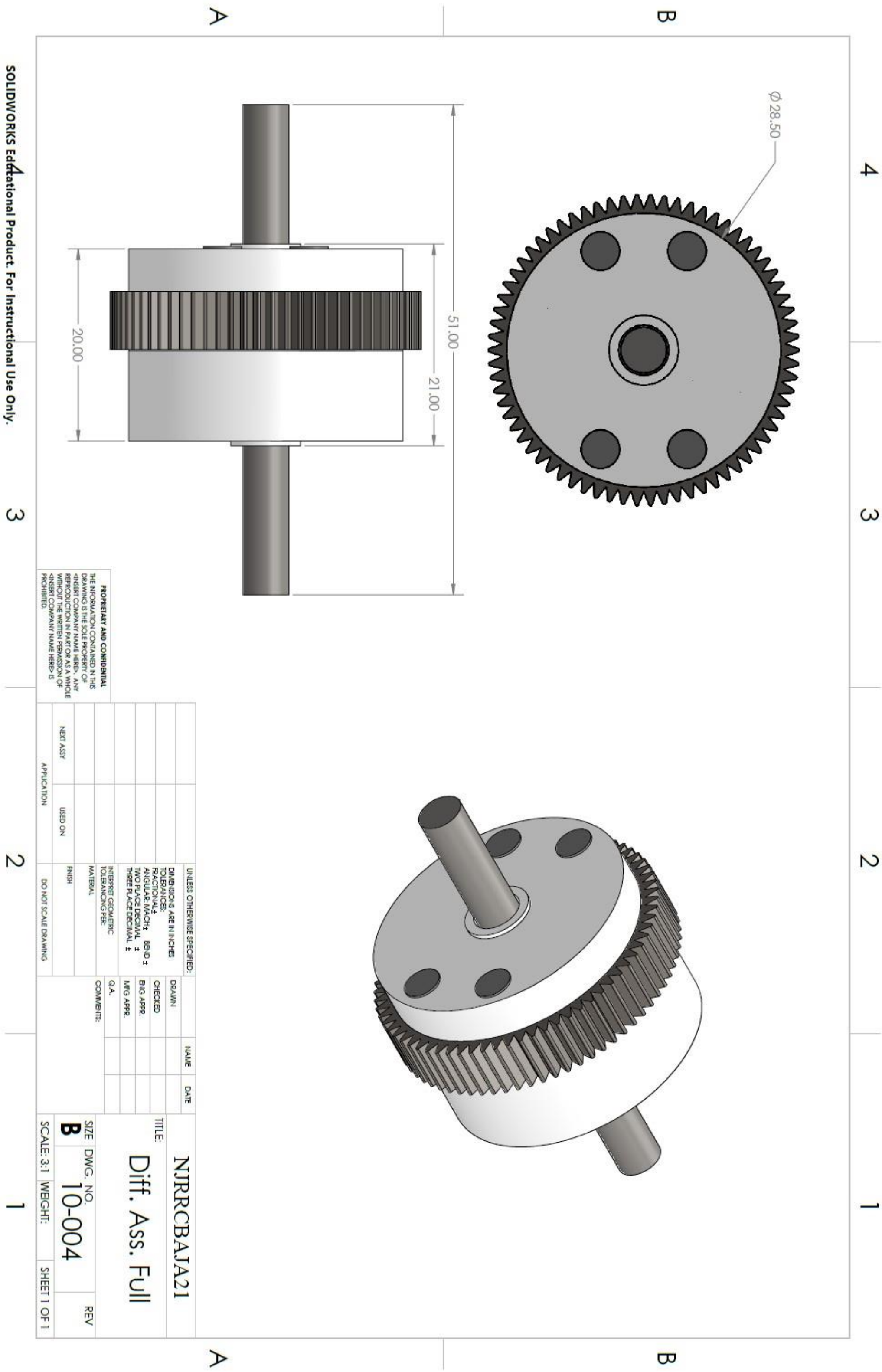
SIZE B DWG. NO. 10-003 REV

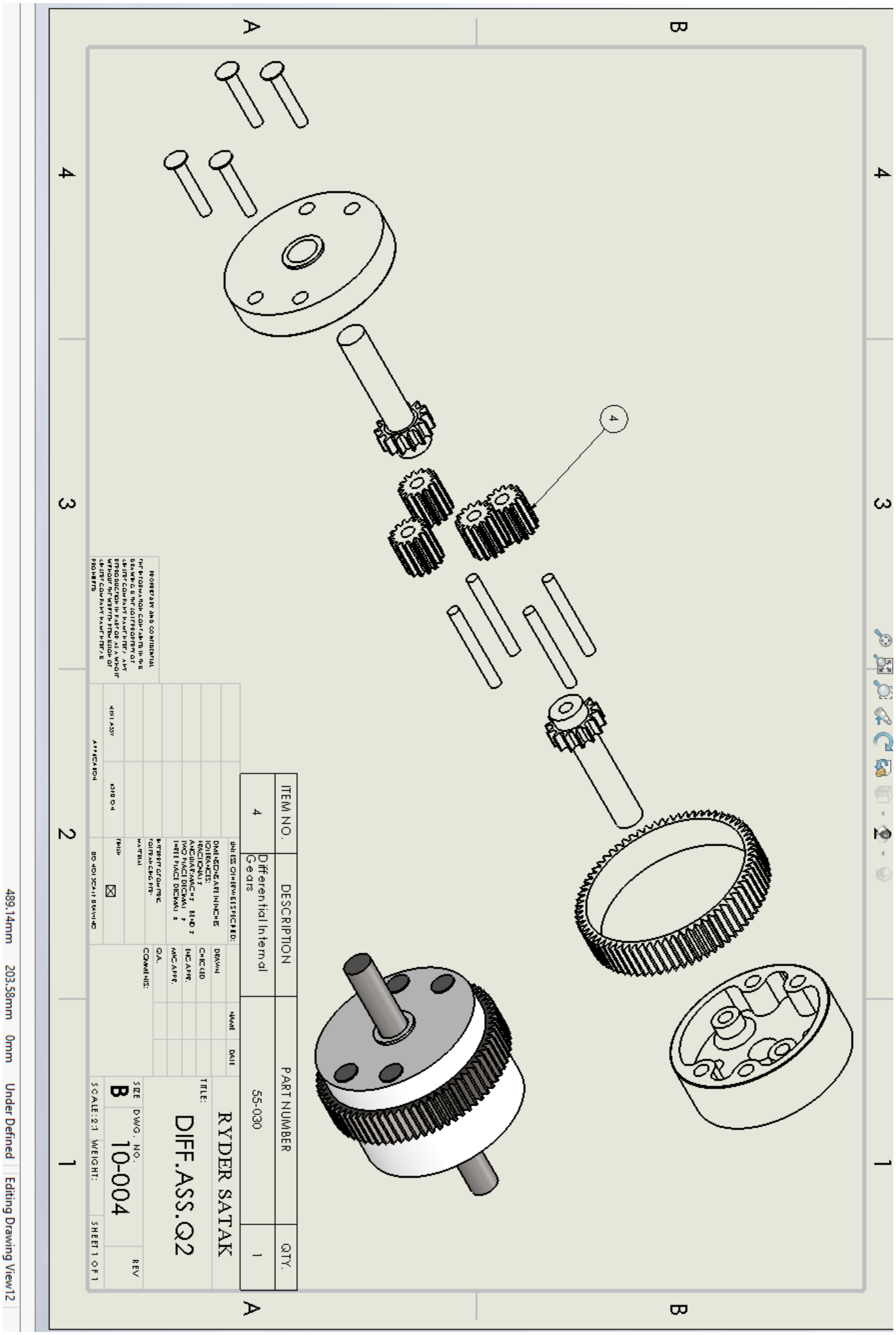
SCALE: 1:5 WEIGHT: SHEET 2 OF 2


2
1
B
A
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN
JRH
11 MAR 21
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
NRJ RC BAJA - HARN
TITLE:
Transmission Cover Assembly
SIZE
A
DWG. NO.
10-003
REV
SCALE: 1:5
WEIGHT:
SHEET 3 OF 3
PROPRIETARY AND CONFIDENTIAL
THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF <INSERT COMPANY NAME HERE>. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF <INSERT COMPANY NAME HERE> IS PROHIBITED.

Appendix B-15 – Differential Assembly - Satak

Please see the below assembly drawing of Ryder Satak's differential assembly:

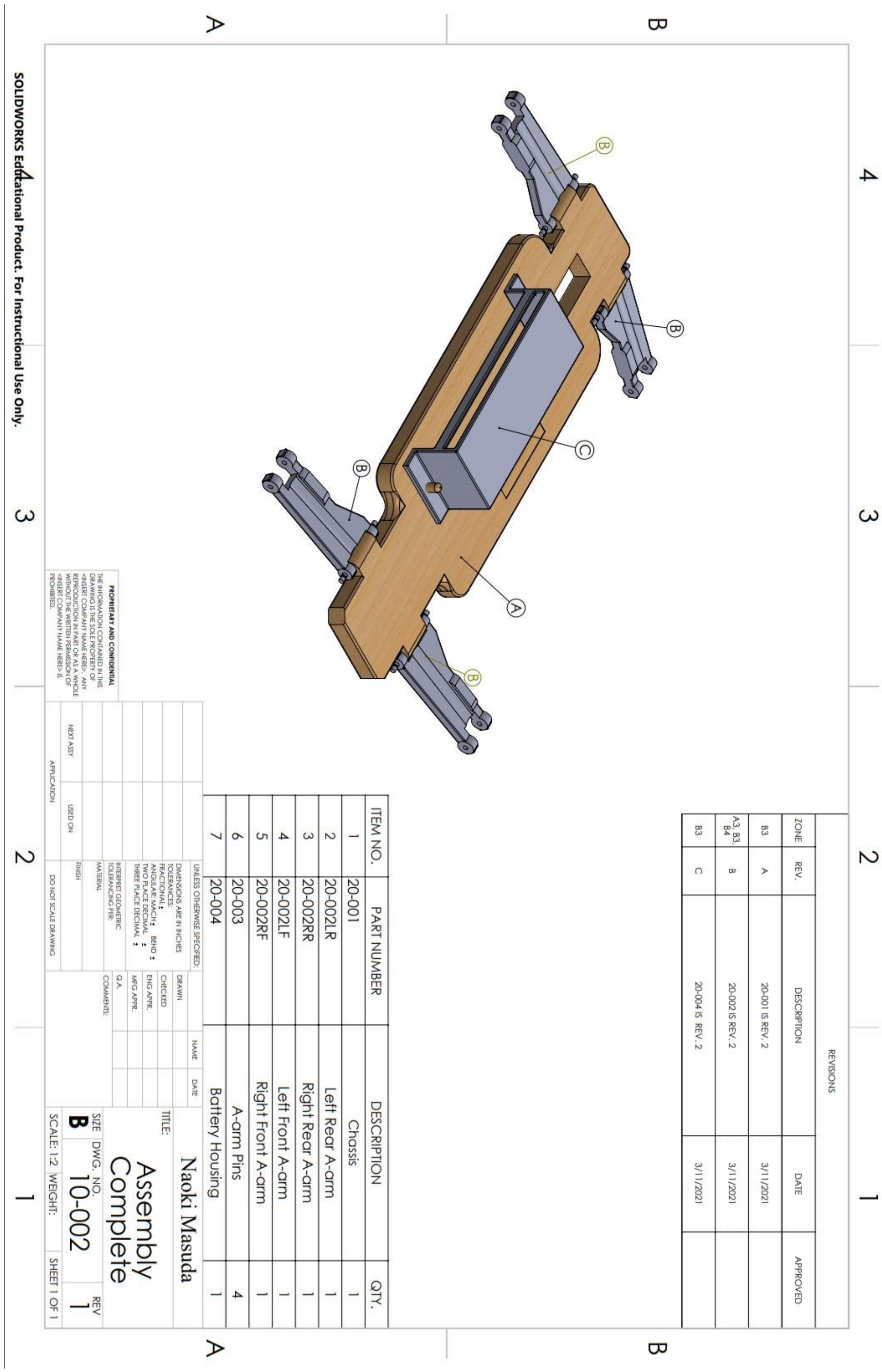


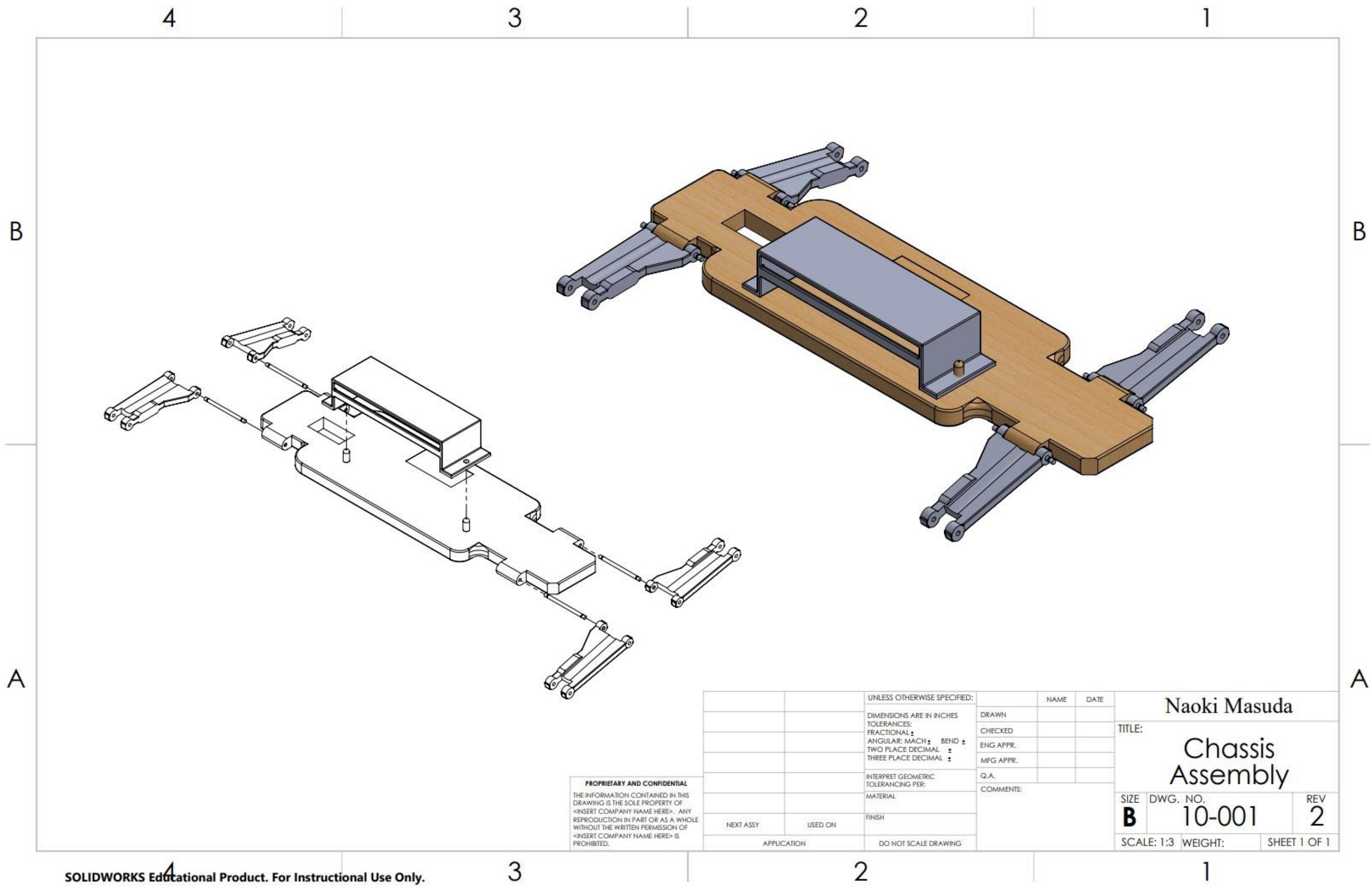


ITEM NO.
DESCRIPTION
PART NUMBER
QTY.
4
Differential Internal Gears
55-030
1
RYDER SATAK
TITLE:
DIFF.ASS.Q2
SIZE
B
DWG. NO.
10-004
REV
SCALE: 2:1
WEIGHT:
SHEET 1 OF 1
489.14mm
203.58mm
0mm
Under Defined
Editing Drawing View12

Appendix B-16 – Chassis Assembly - Masuda

Please see the below assembly drawing of the Naoki Masuda's differential assembly:




Naoki Masuda
TITLE:
Chassis Assembly
SIZE B
DWG. NO. 10-001
REV 2
SCALE: 1:3
WEIGHT:
SHEET 1 OF 1
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
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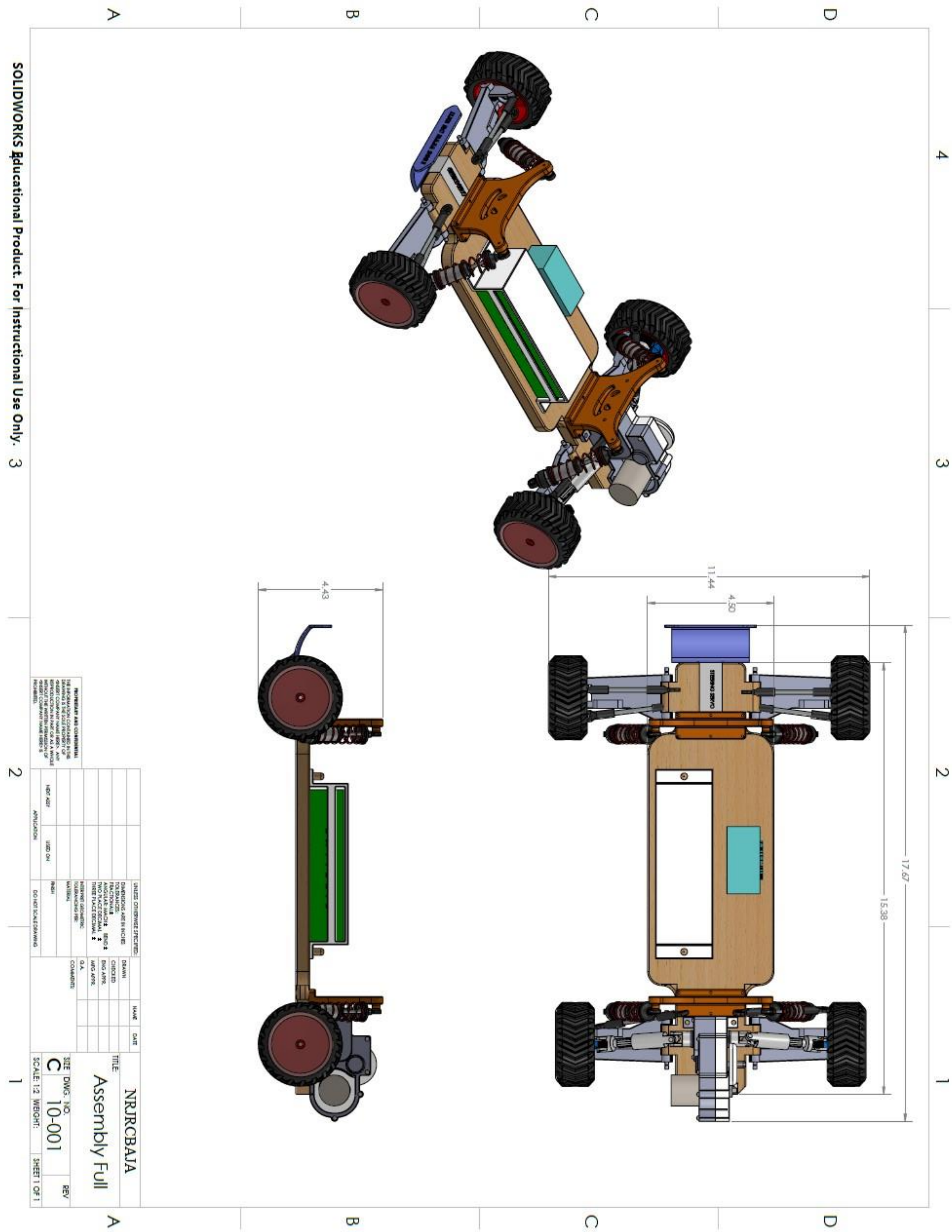
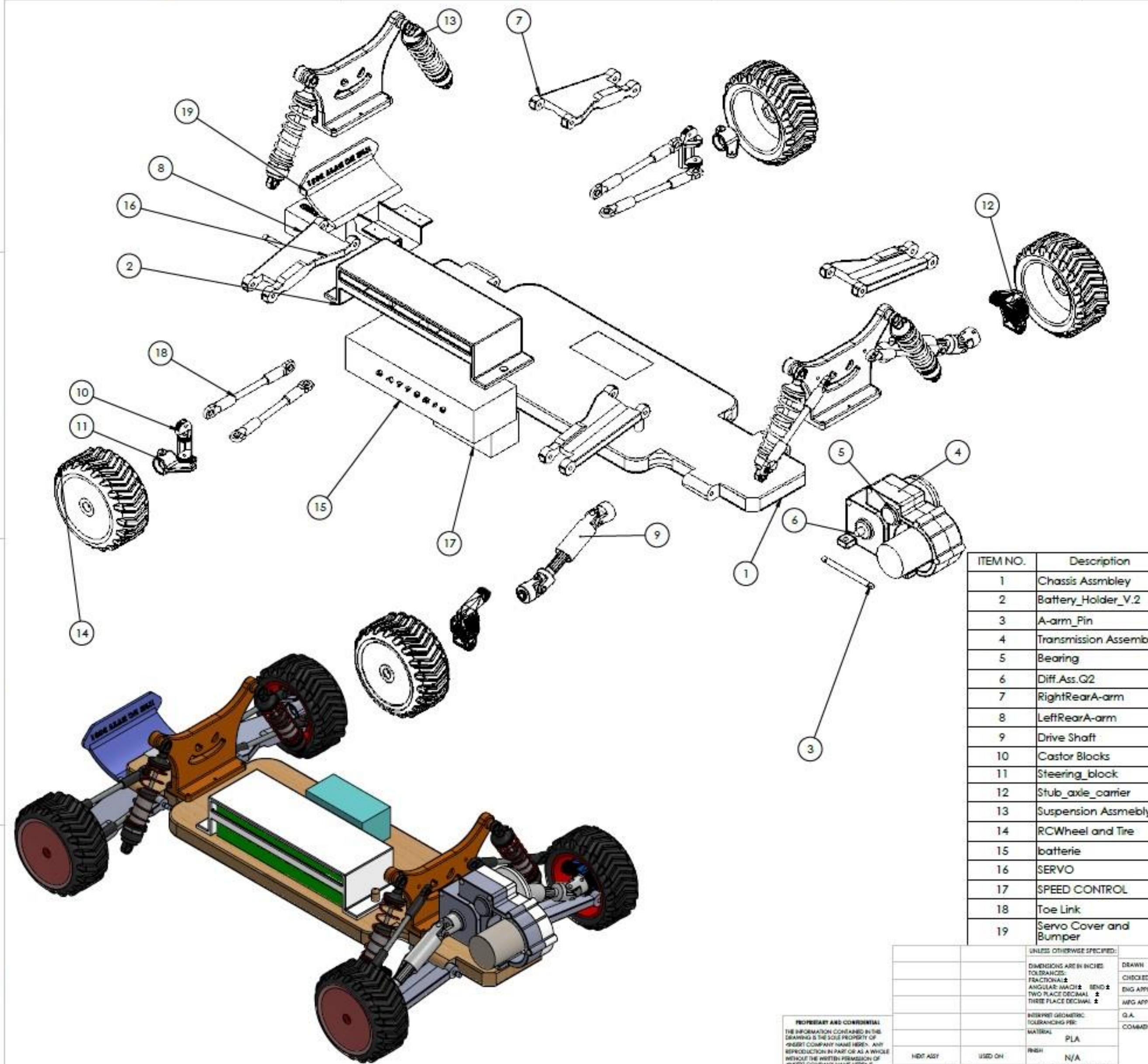
Appendix B-17 – Full RC Assembly

Please see the below assembly drawing of the full RC assembly:





ITEM NO.	Description	Part Number	QTY.
1	Chassis Assmbley	10-002	1
2	Battery_Holder_V.2	20-004	1
3	A-arm_Pin	20-003	4
4	Transmission Assembly	10-003	1
5	Bearing	55-017	12
6	Diff.Ass.Q2	10-004	1
7	RightRearA-arm	20-002RR	2
8	LeftRearA-arm	20-003LR	2
9	Drive Shaft	55-032	2
10	Castor Blocks	55-026	1
11	Steering_block	55-027	2
12	Stub_axle_carrier	55-028	2
13	Suspension Assmebly	10-005/10-006	1
14	RCWheel and Tire	55-011	4
15	batterie	55-002	1
16	SERVO	55-004	1
17	SPEED CONTROL	55-001	1
18	Toe Link	55-021	4
19	Servo Cover and Bumper	20-012	1

RYDER SATAK

TITLE: RCBAJAASSQ2

SIZE C | DWG. NO. 10-001 | REV

SCALE: 1:5 | WEIGHT: 5.0LBS | SHEET 1 OF 1

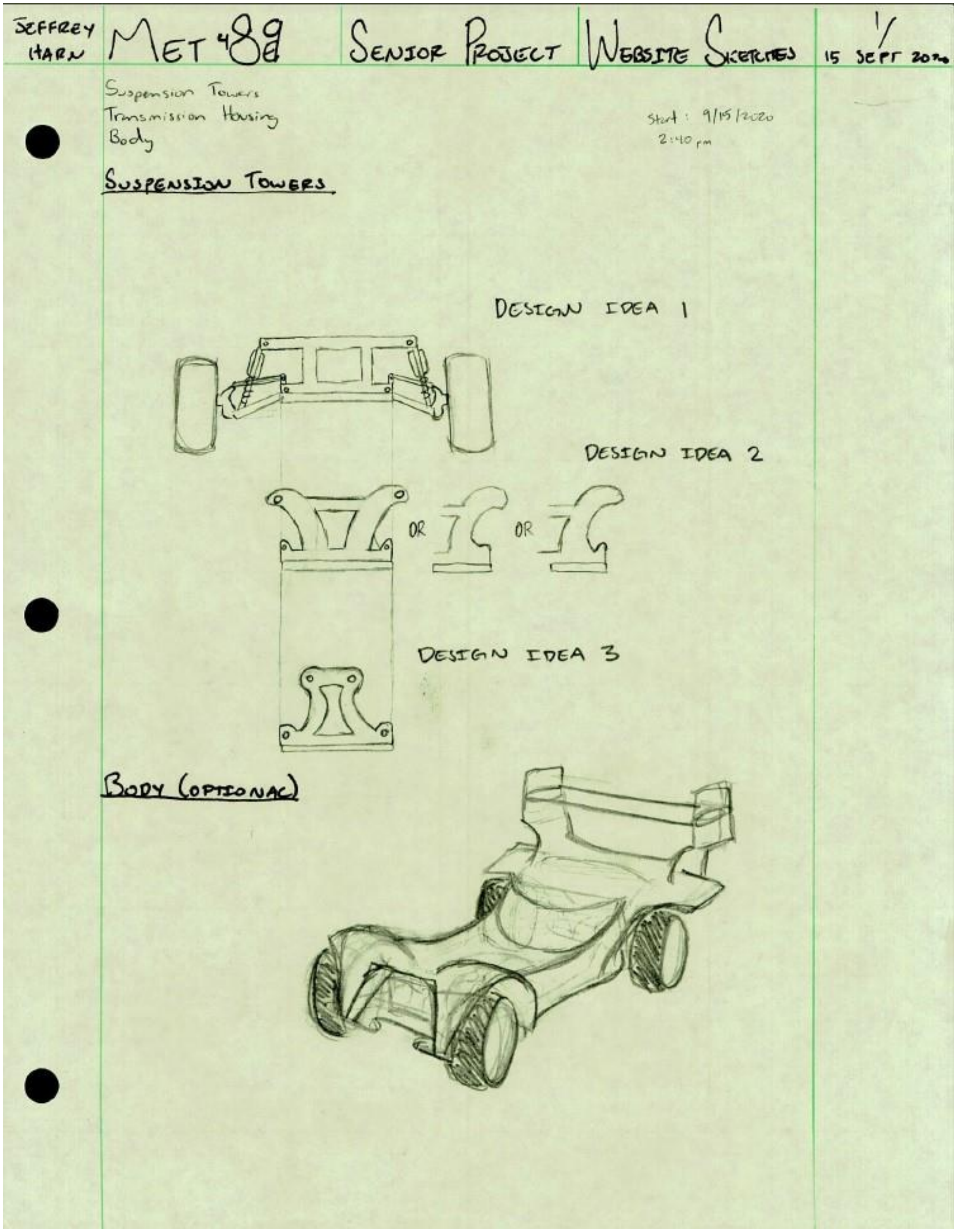
MATERIAL: PLA

FINISH: N/A

DO NOT SCALE DRAWING

Appendix B-18 – Initial Suspension Shower Desing Sketches

Please see the below scanned image of the initial design sketches for the suspension tower.



APPENDIX C – Parts List and Costs

Appendix C-1 – Fall 2020 Design Quarter Parts List and Costs

Please see the below spreadsheet detailing the parts to be used, manufactured, and purchased for this project:

Part Number	Qty	Part Description	Source	Cost	Disposition
10-001	1	Complete RC Assembly	Mfg	TBD	Team
10-002	1	Chassis Assembly (Chassis, A-arms, dowels)	Mfg	--	Masuda
10-003	1	Transmission Cover Assembly	Mfg	--	Harn
10-004	1	Differential Assembly	Mfg	--	Satak
10-005	1	Front Suspension Tower Assembly	Mfg	--	Harn
10-006	1	Rear Suspension Tower Assembly	Mfg	--	Harn
10-007	1	Body Assembly	Mfg	--	Harn
20-001	1	RC Chassis	Mfg	--	Masuda
20-002LR	1	Left Rear A-Arm	Mfg	--	Masuda
20-002RR	1	Right Rear A-Arm	Mfg	--	Masuda
20-002LF	1	Left Front A-Arm	Mfg	--	Masuda
20-002RF	1	Right Front A-Arm	Mfg	--	Masuda
20-003	4	A-Arm Pin	Mfg	--	Masuda
20-004	1	Battery Cover	Mfg	--	Satak, Masuda
20-005	2	Control Arm Dowel	Mfg	--	Satak, Harn
20-006	1	Front Suspension Tower	Mfg	--	Harn
20-007	1	Rear Suspension Tower	Mfg	--	Harn
20-008	1	Transmission Cover - Motor Mount	Mfg	--	Harn
20-009	1	Transmission Cover - Motor Through	Mfg	--	Harn
20-010	1	Differential Housing	Mfg	--	Satak
20-011	1	Differential Top Cover	Mfg	--	Satak
20-012	1	Front Bumper	Mfg	--	Satak
20-013	1	Rear Bumper	Mfg	--	Satak
20-014	1	Body Cover	Mfg	--	Harn
50-001	16	M3X25 Fastener Screw	Ace Hardware	0.33	Purchased 24 FEB 21
50-002	32	Washer 3mm	Ace Hardware	0.17	Purchased 24 FEB 21
50-003	16	M3 Nut	Ace Hardware	0.18	Purchased 24 FEB 21
50-004	4	Suspension Strut Fastener	Previously Owned	--	Satak Donation
50-005	TBD	Traxxas M3 Screw	Previously Owned	--	Satak Donation
55-001	1	Speed Controller	TBD	TBD	Purchased 17 FEB 21
55-002	1	Battery	Previously Owned	--	Satak Donation
55-003	1	Receiver Pack	TBD	TBD	Purchased 17 FEB 21
55-004	1	Steering Servo	Previously Owned	--	Harn Donation
55-005	1	Motor and Pinion	Previously Owned	--	Satak Donation
55-006	4	Suspension Strut	Previously Owned	--	Satak Donation
55-007	2	Steering Block	Previously Owned	--	Satak Donation
55-008	4	Camber Block Front/Rear	Previously Owned	--	Satak Donation
55-009	1	Clutch Assembly	Previously Owned	--	Satak Donation
55-010	1	Gear-Up Assembly	Previously Owned	--	Satak Donation
55-011	4	Wheels	Previously Owned	--	Satak Donation
55-012	1	Battery Connector	Jerrols	TBD	Purchased 2 MAR 21
55-013	1	Shaft Slipper Clutch Roll Pin	Jerrols	3.00	Purchased 2 FEB 21
55-014	1	Top Drive Gear Steel 22-Tooth	Jerrols	3.00	Purchased 2 FEB 21
55-015	1	Slipper Pressure Plate Aluminum	Jerrols	8.00	Purchased 2 FEB 21
55-016	1	Spur Gear 86-T 48-P Slipper Clutch	Jerrols	3.00	Purchased 2 FEB 21
55-017	12	Ball Bearing 5X11X4	Jerrols	3.50	Purchased 2 FEB 21
55-018	1	Idler Gear 30-Tooth Steel	Jerrols	3.00	Purchased 2 FEB 21
55-019	2	Camber Links 49mm Rear	Jerrols	7.50	Purchased 2 FEB 21
55-020	4	Toe Links 59mm	Jerrols	8.75	Purchased 2 FEB 21
55-021	4	Toe Links 61mm	Jerrols	8.50	Purchased 2 MAR 21
55-022	2	Hex Hubs and Axle Pins	Jerrols	2.00	Purchased 2 FEB 21
55-023	2	Wheel Hub Hex	Jerrols	3.00	Purchased 2 FEB 21
55-024	2	Suspension Pins 44mm	Jerrols	2.50	Purchased 2 FEB 21
55-025	1	Screw Pin Set Suspension	Jerrols	4.50	Purchased 2 FEB 21
55-026	2	Caster Block	Jerrols	4.00	Purchased 2 FEB 21
55-027	2	Steering Block	Jerrols	3.00	Purchased 2 FEB 21
55-028	2	Stub Axle Carrier	Jerrols	3.00	Purchased 2 FEB 21
55-029	2	Front Axle	Jerrols	3.00	Purchased 2 FEB 21
55-030	1	Differential Gears	RC Hobbies Lacey	38.23	Purchased 20 JAN 21
55-031	1	Differential Ring Gear	Ebay	31.52	Purchased 11 JAN 21
55-032	2	Drive Shaft Assembly	Previously Owned	--	Satak Donation

APPENDIX D – Budget

Appendix D-1 – Fall 2020 Design Quarter Budget

Please see the below spreadsheet detailing the parts and other materials to be purchased and their total costs:

Item	Qty	Part Description	Unit Cost	Total Cost	
55-001	1	Speed Controller	85	85.00	Purchased 17 FEB 21
55-003	1	Receiver Pack	30	30.00	Purchased 17 FEB 21
55-012	1	Battery Connector	8	8.00	Purchased 2 MAR 21
55-013	1	Shaft Slipper Clutch Roll Pin	3.00	3.00	Purchased 2 FEB 21
55-014	1	Top Drive Gear Steel 22-Tooth	3.00	3.00	Purchased 2 FEB 21
55-015	1	Slipper Pressure Plate Aluminum	8.00	8.00	Purchased 2 FEB 21
55-016	1	Spur Gear 86-T 48-P Slipper Clutch	3.00	3.00	Purchased 2 FEB 21
55-017	5	Ball Bearing 5X11X4 (2x)	3.50	17.50	Purchased 2 FEB 21
55-018	1	Idler Gear 30-Tooth Steel	3.00	3.00	Purchased 2 FEB 21
55-019	2	Camber Links 49mm Rear	7.50	15.00	Purchased 2 FEB 21
55-020	2	Toe Links 59mm (2x)	8.75	17.50	Purchased 2 FEB 21
55-021	2	Toe Links 61mm (2x)	8.50	17.00	Purchased 2 MAR 21
55-022	2	Hex Hubs and Axle Pins	2.00	4.00	Purchased 2 FEB 21
55-023	2	Wheel Hub Hex	3.00	6.00	Purchased 2 FEB 21
55-024	2	Suspension Pins 44mm	2.50	5.00	Purchased 2 FEB 21
55-025	1	Screw Pin Set Suspension	4.50	4.50	Purchased 2 FEB 21
55-026	1	Caster Blocks	4.00	4.00	Purchased 2 FEB 21
55-027	1	Steering Blocks	3.00	3.00	Purchased 2 FEB 21
55-028	2	Stub Axle Carrier	3.00	6.00	Purchased 2 FEB 21
55-029	2	Front Axle	3.00	6.00	Purchased 2 FEB 21
55-030	1	Differential Gears	38.23	38.23	Purchased 20 JAN 21
55-031	1	Differential Ring Gear	31.52	31.52	Purchased 11 JAN 21
50-001	16	M3X25 Fastener Screw	0.33	5.28	Purchased 24 FEB 21
50-002	32	Washer 3mm	0.17	5.44	Purchased 24 FEB 21
50-003	16	M3 Nut	0.18	2.88	Purchased 24 FEB 21
1		Solder Service for Battery Connector	30	30	
2		Discounts		-10.00	
3		Balsa Wood		--	
4		3D Printing Polymer Material		--	
5		Taxes		20.00	
6		Parts Contingency Cushion		--	
7		Emergency Fund		--	
			TOTAL:	371.85	
			ACTUAL TOTAL:	340.74	
			HARN INDIVIDUAL PAYMENT:	100	

APPENDIX E – Schedule

Appendix E-1 – Project Gant Chart

Below is the work-in-progress Gant Chart for the RC Baja Project.

PROJECT TITLE.:RC Baja Project Team #3														
Principal Investigator.:Jeffrey Harn														
		Duration												
TASK: ID	Description	Est. (hrs)	Actual (hrs)	%Comp.	Septembe	October	November	Dec	January	February	March	April	May	June
1	Proposal/Report													
1a	Revisions	2	5.25	90										X
1b	Intro	4	4	98										
1bb	Table of Contents	0.5	0.5	100										X
1bc	Title Page	0.5	0.5	100										X
1c	Methods	5	6.25	98										
1d	Analysis	20	14	98										X
1e	Discussion	5	1.75	98										
1f	Parts and Budget	5	9.75	98										X
1g	Drawings	5	1.5	98										
1h	Schedule	2	1.5	98										X
1i	Conclusion	5	0.75	98										X
1j	Testing	5	1.5	98										X
1k	Abstract	2	1.25	100										
1l	Testing Report	5	8.25	100										X
1m	Appendix	10	3	100										
1n	Gantt Chart Work	20	19	99										X
	subtotal:	96	78.75											
					Septembe	October	November	Dec	January	February	March	April	May	June
2	Project Website													
2a	Startup	4	2	100	X									
2b	General Maintenance	5	5.25	90										
2c	Homepage Startup	2	1	100	X									
2d	Budget Startup	1	0.5	100										
2e	Testing Startup	0.5	0.25	100										
2f	Photography	1	1	100									X	
	subtotal:	13.5	10											
					Septembe	October	November	Dec	January	February	March	April	May	June
3	Analyses													
3a	A1 Motor Power	0.5	3	100	X									
3b	A2 Suspension Arm Forces	0.5	1.75	100									X	
3c	A3 Sus Arm Bending Stress	0.5	0.75	100									X	
3d	A4 Sus Arm Shear Stress	0.5	0.75	100									X	
3e	A5 Sus Twr Bending Stress	0.5	0.75	100									X	
3f	A6 Sus Twr Bolt Shear	0.5	1	100		X								
3g	A7 Sus Twr Strut Hole	0.5	1.75	100									X	
3h	A8 Sus Twr Camber Hole	0.5	1.25	100									X	
3i	A9 Sus Twr Strut Hole Shear	0.5	0.75	100									X	
3j	A10 Sus Twr Camber Shear	0.5	0.75	100									X	
3k	A11 Car Body Drag	0.5	1.5	100			X							
3l	A12 Trans Cover Shear	0.5	0.5	100			X							
3m	A13 SP1 Trans Cvr Spprt	1	1.75	100						X				
3n	A14 SP2 Sus Twr Stress	1	1.75	100							X			
	subtotal:	8	18											
					Septembe	October	November	Dec	January	February	March	April	May	June
4	Drawings and Models													
4a	Suspension Tower	1	6.5	100							X			
4b	Suspension Strut	1	0.75	100							X			
4c	Camber Link	1	0.75	100							X			
4d	Transmission Cover (Mnt)	2	17	100							X			
4e	Transmission Cover (Thru)	2	8.25	100							X			
4f	Trans Cover Assembly	2	4.5	100							X			
4g	M3x25 Screw	0.5	0.25	100							X			
	subtotal:	9.5	38											
					Septembe	October	November	Dec	January	February	March	April	May	June
5	Group Meetings													
5a	Team Meeting	20	7	N/A										
5f	Mentor Meeting	8.5	4.75	N/A										
	subtotal:	28.5	11.75											
					Septembe	October	November	Dec	January	February	March	April	May	June
6	Presentations													
6a	MDR	2	2	100					X					
6b	SOURCE Presentation	3	2.5	100								X		
6c	Final Presentation Prep	1	1	100									X	
6d	Final Presentation	1	2.25	100									X	
6e	Presentations Comments	2	2	100									X	
	subtotal:	9	9.75											
					Septembe	October	November	Dec	January	February	March	April	May	June
7	Part Construction													
7a	Machine Trans Cover Drvr	2	3	100						X				
7b	Machine Trans Cover Psngr	2	2.75	100						X				
7c	Machine Suspension Tower	1	0.75	100							X			
7d	Purchase Parts	2	0.75	100							X			
7e	Assembly	5	0.5	100							X			
7f	Part Modification	1	0.5	100							X			
	subtotal:	13	8.25											
					Septembe	October	November	Dec	January	February	March	April	May	June
8	Device Evaluation													
8a	Test Procedures	3	3.5	100										X
8b	Dis/assembly Test	1	0.5	100								X		
8c	Operation Integrity Test	2	1.25	100								X		
8d	Sus Twr Load Test	1	0.75	100									X	
8e	Other Tests	2	1	100										X
8f	Team Testing Support	5	2.75	100									X	
8g	TDR Presentation	2	4.25	100								X		
	subtotal:	16	14											
					Septembe	October	November	Dec	January	February	March	April	May	June
9	Professional													
9a	LinkedIn Profile	3	1.75	80										
9b	Willdcat Career Network	1	1.25	50										
9c	Resume	1	0.75	100	X									
	subtotal:	5	3.75											
	Grand Totals:	198.5	192.3		Septembe	October	November	Dec	January	February	March	April	May	June

APPENDIX F – Expertise and Resources

Appendix F-1 – Component Material Decision Matrix

Please find below the decision matrix that aided in the decision between the use of balsa wood or printed ABS plastic as the material for the components being designed.

Criterion	Weight	Best Possible	Balsa Wood		Printed ABS Plastic		
	1 to 3	3	1	Score x Wt	2	Score x Wt	
Mass	1	3	3	3	1	1	
Cost	3	9	3	9	2	6	
Manufacturing Ease	2	6	1	2	2	4	
Fastener Compatability	2	6	1	2	3	6	
Reusability	3	9	2	6	3	9	
Compactabilty	1	3	2	2	3	3	
Strength	3	9	1	3	3	9	
Total	15	45		27		38	
NORMALIZE THE DATA (muliply by fraction, N)		2.22		60.00		84.44	
MatWeb used as reference	Weighting/Scoring Scale					84.44	Percent
	1	Worst (too costly, low confidence, too big, etc.)				48.89	Average
	2	Median Values, or Unsure of actual value				42.22	Std Dev.
	3	Best (Low Cost, high confidence, etc.)					Good Bias
	Criterion						
	Mass	More mass is more cost					
	Cost	More cost takes up more project budget					
	Manufacturing Ease	Less required machining is prefered					
	Fastener Compatability	Ability to insert and remove fasteners without damage					
	Reusability	Ability to insert and remove part from assembly without damage					
	Compactabilty	Ability to be manufactured small while maintaining suitable strength					
	Strength	A high tensile, and bending strength is prefered					

Appendix F-2 – Body Design Style Decision Matrix

Please find below the decision matrix that aided in the decision between the three proposed body design styles.

Criterion	Weight	Best Possible	Design #		Design #		Design #		
	1 to 3	3	1	Score x Wt	2	Score x Wt	2	Score x Wt	
Mass	1	3	2	2	1	1	3	3	
Aesthetic	3	9	3	9	2	6	1	3	
Drag Coefficient	2	6	2	4	1	2	3	6	
Total	6	18		15		9		12	
NORMALIZE THE DATA (muliply by fraction, N)		5.56		83.33		50.00		66.67	Percent
								66.67	Average
	Weighting/Scoring Scale							16.67	Std Dev.
	1	Worst (too costly, low confidence, too big, etc.)							Good Bias
	2	Median Values, or Unsure of actual value							
	3	Best (Low Cost, high confidence, etc.)							
	Criterion								
	Mass	More mass is more cost							
	Aesthetic	A visually appealing body attracts buyers							
	Drag Coefficient	Less drag leads to greater efficiency							

APPENDIX G – Testing Report

TESTING REPORT

NRJ RC BAJA VEHICLE TESTING

A Full Report of the Requirements, Testing, and Results of the Transmission and Suspension Systems

Jeffrey Harn

10 May 2021 – 4 June 2021

TRANSMISSION: ASSEMBLY TEST

Introduction

The test detailed below addresses the following requirements detailed in the engineering report for the transmission cover assembly:

- Must require no greater than two tools to assemble and disassemble.
- Must be assembled and disassembled in no longer than ten minutes (five minutes per process).

Parameters of interest for this test include tool number count in number of pieces, assembly time in seconds, and disassembly time in seconds. It is predicted that the transmission cover will require three tools to disassemble as there are only three fastener-head types used in the assembly of the transmission cover. Also, no prying or forcing is expected to be required as the transmission covers have no sealing or latching incorporated into their design, so no prying or forcing equipment will be required.

Data acquisition will be conducted using visual inspection and a temporal measurement device. Data will be recorded on a data sheet. The data sheet may be found in **APPENDIX G2**.

This test is the first conducted of all tests for the transmission and suspension systems. Please refer to the project Gantt chart for details over actual time taken and date conducted in **APPENDIX G5**.

Method

This test requires one individual, a set of instructions, a video-recording device, and a datasheet. The test will involve a timed disassembly of the transmission cover while following directions, then a timed assembly of the transmission cover while following directions. This test requires the possession of a full transmission cover assembly and a specific tool set to complete and may be completed at any time of day indoors or outdoors. Data will be stored in video .mp4 file format and on an excel datasheet and will be presented in the same manners. With the use of a stopwatch, this test is accurate to ±2 seconds and has a precision of one centisecond.

Summary

This procedure overviews the following test known as the “transmission assembly and disassembly test.” The transmission cover assembly of the NRJ RC Baja vehicle will be subjected to a timed assembly and disassembly, and the required tools will be evaluated. The transmission cover must be assembled in less than five minutes and must be disassembled in less than five minutes. The transmission cover must be assembled and disassembled using less than three tools. Please see **FIG 1** and **FIG 2** for images of the disassembly set-up, and the assembly set up, respectively.

FIG 1 – Disassembly set-up. **FIG 2** – Assembly set-up.

Time:
This test was conducted on 11 April 2021 at 1720 hours at a residential unit. The test required less than one hour to conduct from set up to take down.

Location and Resources
This test was conducted on a desk at a residential unit in Ellensburg. Please see the below list of the required equipment:

- Table or desk surface to work on.
- Camcorder or some device capable of recording video.
- Tripod or other standing device to hold the video capturing device.
- Transmission cover assembly.
- Stopwatch or a stopwatch application for recording time.
- Tooling:
    - 2mm hex wrench.
    - 3mm hex wrench.
    - 10mm socket.
- Transmission cover assembly and disassembly testing datasheet found in **APPENDIX G2**.

Risks
This test runs the risk of losing or damaging components of the transmission cover assembly during assembly or disassembly. This test does not involve any safety risks or concerns.

Procedure
Please see the below procedure detailing how this test may be replicated.

1. Obtain the transmission cover assembly and place it atop a table or desk in a one square foot of empty tabletop or desktop area.
2. Obtain a 2mm and 3mm hex wrench and a 10mm socket and place them neatly beside the transmission cover
3. Set up a camera and tripod such that the camera records the assembler/disassembler's hands and the transmission cover in full frame.
4. Obtain a stopwatch or stopwatch application.
5. Obtain a transmission cover assembly and disassembly test blank datasheet and a pencil.
6. Start the recording of the camera.
7. The disassembly will now begin, ready yourself and press start on the timer and disassemble the transmission cover according to the directions found in **APPENDIX G4**.

8. Stop the timer when the transmission cover is fully disassembled. Record time elapsed during disassembly on the appropriate location on the datasheet in seconds (time evaluated is from first touch to last touch). Reset the timer.
9. The assembly will now begin, ready yourself and press start on the timer and assemble the transmission cover according to the directions found in **APPENDIX G4**.
10. Stop the timer when the transmission cover is fully assembled. Record time elapsed during assembly on the appropriate location on the datasheet in seconds (time evaluated is from first touch to last touch).
11. Stop the recording of the camera and save the file.
12. Evaluate the results on the datasheet and determine whether the test passed or failed.

Deliverables

This test returns temporal data of the time taken to disassemble the transmission cover assembly, time taken to assemble the transmission cover assembly, numerical data of the number of tools used during the disassembly and assembly, and Boolean data of a pass or failure of the test. No calculations are required for this test.

ALL SYSTEMS: OPERATION TEST

Introduction

The test detailed below addresses the following requirements detailed in the engineering report for the transmission cover assembly (TC) and the suspension tower assemblies (ST):

- (TC) Must be able to prevent all amounts of dust, water, and mud from entering the transmission housing interior.
- (TC) Must not self-disassemble or be damaged crucially in any fashion after one hour of straight operation
- (ST) Must not self-disassemble or be damaged crucially in any fashion after one hour of straight operation

Parameters of interest for this test include operation time in minutes, component successes in Boolean units of pass/fail for disassembly avoidance, and Boolean units of pass/fail for component structural survivability. It is predicted that the transmission cover and suspension towers will not disassemble due to any vibration, shock, or other related causes. Also, it was predicted that the suspension tower will structurally survive across all degrees of use as the arms were designed with a factor of safety to withstand a ten-pound load from the suspension struts. It was predicted that the transmission cover will structurally survive due to its small size and compactness.

Data acquisition will be conducted using visual inspection of the components during and after the test, and through the use of time-tracking on a notebook. Data will be recorded on a data sheet. The data sheet may be found in **APPENDIX G2**.

This test is the second conducted of all tests for the transmission and suspension systems, behind the assembly test. Please refer to the project Gantt chart for details such as actual time taken and date conducted in **APPENDIX G5**.

Method

This test requires one individual (two individuals are preferred), a set of instructions, a video-recording device, and a datasheet. The test will involve the operation of the entire NRJ RC Baja vehicle assembly outdoors. This test requires the possession of the full RC vehicle assembly, access to a clock, and may be completed during the day outdoors, and anytime indoors. Data will be stored in video .mp4 file format and on an Excel datasheet and will be presented in the same manners. This test is accurate to the visual extent of the human eye for perceiving damage and ±2.5 minutes for time recording with a precision of one minute.

The following definitions regarding the three degrees of RC operation follow. Light use – RC operation of speeds under 10 [mph] on flat, smooth surfaces with no collisions. Medium use – RC operation of speeds between 10 to 15 [mph] and/or on rough, bumpy surfaces (bark, gravel, dirt, etc) with lateral changes no more than half a foot. Minor collisions and flipping (under 5 [mph]). Heavy use – RC operations of speeds greater than 15 [mph] and/or on very rough, bumpy surfaces with lateral changes greater than half a foot, RC airtime, and major collisions (over 5 [mph]).

The following limits are defined for the different degrees of usage. In total, the RC must be operated for one battery life (approximately one hour). At least 50% of the total operation time must be classified as medium use. Another 25% of the total operation time must be classified as heavy use. Lastly, at least 15% of the total operation time must be classified as light use. The remaining 10% is used as a window for flexibility and error.

Summary
This procedure overviews the following test known as the “RC operation test.” A fully assembled RC Baja vehicle is driven in different conditions and environments for one battery life (about one hour). The RC Baja vehicle must withstand the environments and withstand the forces it will undergo during operation and must not show any signs of disassembly or damage. Please see **FIG 3** for an image of the RC set-up before a day of operation testing.

FIG 3 – Testing day set-up.

Time:
This test was conducted over the course of three days. The days include 12 April, 23 April, and 27 April 2021. The test required two hours in total to conduct.

Location and Resources
This test was conducted on a street in a residential neighborhood area, and on the patio and garden areas surrounding the Hogue technology building at Central Washington University. Please see the below list of the required equipment:

- A fully assembled RC Baja vehicle.
- Radio remote for controlling the Baja vehicle.
- Clock or another time-indicating device.
- Camcorder or some device capable of recording video.
- RC Baja vehicle operation test data sheet found in **APPENDIX G2**.

Risks
This test runs the risk of delivering substantial damage to an RC Baja vehicle. Also, due to possible substantial damage, fragments of broken components may become airborne. The RC vehicle may at times be moving at high speeds across rough terrain and control may be lost. Danger of RC collision with the operator or kicking up of natural debris is a possibility.

Procedure
Please see the below procedure detailing how this may be replicated:

1. Select an area of flat concrete or asphalt for light use and medium use testing.
2. Select an area of fairly flat, natural ground for medium use and heavy use testing.
3. Select an area of rough, bumpy, natural ground for heavy use testing.

4. Obtain the fully assembled RC vehicle. Ensure the battery has a full charge. If the battery does not have full charge, delay the test until a full charge is obtained.
5. Activate the RC and operate the RC, driving the RC around on the three different areas selected.
6. Pay attention to the time every five minutes. The test will last for one battery life or one hour, whichever comes last. Switch degrees of usage when necessary according to the limits discussed in the **Method** section above.
7. When switching between the three selected areas, or switching between degrees of usage, document the time elapsed for the degree of usage up to that point.
8. When switching between the three selected areas, or switching between degrees of usage, inspect the RC for any damage or unusual behavior. If either exists, document the abnormality and under which usage the abnormality occurred.
9. Operate the RC until both the battery life has been exhausted and an hour of operation has passed.
10. Note the total time elapsed and total up the elapsed times under each degree of use. Record these on the data sheet.
11. Inspect the transmission cover assembly and evaluate the first requirement listed in the **Introduction** section. Record results in appropriate location on data sheet.
12. Complete a final inspection of the RC vehicle and note any abnormalities and evaluate pass/fail criteria for each component based on any disassembly or damage. Record findings on data sheet. Document any comments in the appropriate section.

Deliverables

This test returns temporal data of the total time elapsed, and the time elapsed in each degree of use of operation. Visual inspection comments, and Boolean data of pass or fail for each component is also delivered. No calculations are required for this test.

SUSPENSION: LOAD TEST

Introduction

The test detailed below addresses the following requirements detailed in the engineering report for suspension tower assemblies:

- Must withstand a maximum 10 lbs of force from suspension arm actuation.
- Must vertically hold up to 5 lbs when inverted.
- Must secure body/fuselage and resist up to 5 lbs of force.

Parameters of interest for this test include Boolean units of pass/fail for component structural survivability, and visual inspection data of any abnormalities or defects exposed due to the testing, or failures caused by the testing. Deflection and strain are measured if applicable. It is predicted that the suspension towers will not fail under a 10-pound vertical load as analyses were conducted that allowed the suspension towers to withstand a 10-pound load with a factor of safety of two.

Data acquisition will be conducted using visual inspection of the components during and after the test. Weight will be applied and failure will be documented if it occurs during the test. If no discrete failure occurs during the test, the component will be thoroughly inspected afterwards for any damage. Data will be recorded on a data sheet. The data sheet may be found in **APPENDIX G2**.

This test is the third conducted of all tests for the transmission and suspension systems, behind the operation test. Please refer to the project Gantt chart for details such as actual time taken and date conducted in **APPENDIX G5**.

Method

This test requires one individual, weights, a scale, a set of instructions, and a datasheet. The test will involve the loading of the suspension tower to evaluate structural integrity. Data will be store in an Excel datasheet. This test is accurate to the visual extent of the human eye for perceiving damage and yielding. The precision of the scale is ±0.1 pound, and the accuracy of the scale is unknown.

Summary

This procedure overviews the following test known as the “suspension tower vertical loading test.” A disassembled (body only) suspension tower component will be placed on a table and a vertical load of 10 pounds will be applied across both of the arms. The suspension tower must withstand this vertical loading and not present any mechanical failure, new abnormalities, or defects during or after the testing occurs. Please see **FIG 4** for an image of the suspension tower set-up during testing.

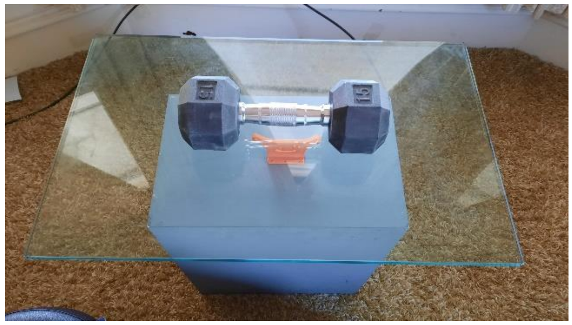


FIG 4 – Suspension tower with vertical load applied.

Time:

This test was conducted on 11 May 2021 at 1245 hours. The test required one hour to conduct, with 45 minutes dedicated to set-up and take-down.

Location and Resources

This test was conducted at-home, indoors, on private property. Please see the below list of the required equipment:

- Disassembled suspension tower body.
- Flat surface to serve as the testing floor. A sturdy table, or hard house floor.
- A flat plane to act as the applied-load holder and balancer (glass table-top shown in **FIG 4**)
- A weight to serve as the applied load. This weight must be greater than 10 pounds.
- A scale or other mass/weight-measuring device.
- Suspension tower vertical load test data sheet found in **APPENDIX G2**.

Risks

This test runs the risk of failing a plastic component which may send shards or other debris airborne. Because this test requires careful balancing, there is a risk of dropping, falling, and damage of items used when balancing. This presents the risk of injury from crushing. Lastly, because this test deals with weights, risks of crushing of limbs or fingers must be made aware.

Procedure

Please see the below procedure detailing how this may be replicated:

1. Obtain the weight and applied-load holder (ALH) and measure their individual weights with a mass/weight measuring device. Record their values in the appropriate section on the datasheet.
2. Place the suspension tower component upright on the flat testing-floor surface selected.
3. Place the ALH atop the suspension tower such that it spans the tops of each arm. Balance the ALH so that it requires no assistance to sit atop the suspension tower.
4. Observe the suspension tower. Look for any major deflection or yielding. If none found, continue the test.
5. Place the applied load atop the ALH and maintain the balance of the hole set-up.
6. Maintain the system for at least 15 seconds.
7. Observe the suspension tower for any yielding or complete failure.
8. Remove the applied load and the ALH carefully.

9. Inspect the suspension tower closely for any signs of damage, yielding, or failure.
10. Record the results in the appropriate section on the data sheet.
11. Record any comments in the appropriate section on the data sheet.

Deliverables

This test returns numerical data of the total load applied to the suspension tower and Boolean data of pass or fail based on the structural survivability of the suspension tower during the vertical load test. Visual inspection comments are also recorded. No calculations are required for this test.

Appendix G-1 – Procedure Checklists

Below are found the material and procedure checklists for the three mainline tests performed in this project. Each checklist is located on one full page for printability.

Appendix G-1.1 – Transmission Cover Dis/Assembly Test

N R J   R C   B A J A

Transmission Cover Assembly and Disassembly Test Checklist

Required Materials

Please gather the required materials listed below and check off each box when complete.

- ☐ Table or desk surface to work on.
- ☐ Camcorder or some device capable of recording video.
- ☐ Tripod or another standing device to hold the video capturing device.
- ☐ Transmission cover assembly.
- ☐ Stopwatch or a stopwatch application for recording time.
- ☐ Tooling:
    - ☐ 2mm hex wrench.
    - ☐ 3mm hex wrench.
    - ☐ 10mm socket.
- ☐ Transmission cover assembly and disassembly testing datasheet found in **APPENDIX G2**.

Procedure

Please see the below procedure for this test. Check off each step as it is completed.

- ☐ Obtain the transmission cover assembly and place it atop a table or desk in a one square foot of empty tabletop or desktop area.
- ☐ Obtain a 2mm and 3mm hex wrench and a 10mm socket and place them neatly beside the transmission cover
- ☐ Set up a camera and tripod such that the camera records the assembler/disassembler's hands and the transmission cover in full frame.
- ☐ Obtain a stopwatch or stopwatch application.
- ☐ Obtain a transmission cover assembly and disassembly test blank datasheet and a pencil.
- ☐ Start the recording of the camera.
- ☐ The disassembly will now begin, ready yourself and press start on the timer and disassemble the transmission cover according to the directions found in **APPENDIX G4**.
- ☐ Stop the timer when the transmission cover is fully disassembled. Record time elapsed during disassembly on the appropriate location on the datasheet in seconds (time evaluated is from first touch to last touch). Reset the timer.
- ☐ The assembly will now begin, ready yourself and press start on the timer and assemble the transmission cover according to the directions found in **APPENDIX G4**.
- ☐ Stop the timer when the transmission cover is fully assembled. Record time elapsed during assembly on the appropriate location on the datasheet in seconds (time evaluated is from first touch to last touch).
- ☐ Stop the recording of the camera and save the file.
- ☐ Evaluate the results on the datasheet and determine whether the test passed or failed.

Appendix G-1.2 – RC Operation Test

N R J R C B A J A

Full RC Assembly Operation Degree of Use Test Checklist

Required Materials

Please gather the required materials listed below and check off each box when complete.

- ☐ A fully assembled RC Baja vehicle.
- ☐ Radio remote for controlling the Baja vehicle.
- ☐ Clock or another time-indicating device.
- ☐ Camcorder or some device capable of recording video.
- ☐ RC Baja vehicle operation test data sheet found in **APPENDIX G2**.

Procedure

Please see the below procedure for this test. Check off each step as it is completed.

- ☐ Select an area of flat concrete or asphalt for light use and medium use testing.
- ☐ Select an area of fairly flat, natural ground for medium use and heavy use testing.
- ☐ Select an area of rough, bumpy natural ground for heavy use testing.
- ☐ Obtain the fully assembled RC vehicle. Ensure the battery has a full charge. If the battery does not have full charge, delay the test until a full charge is obtained.
- ☐ Activate the RC and operate the RC, driving the RC around on the three different areas selected.
- ☐ Pay attention to the time every five minutes. The test will last for one battery life or one hour, whichever comes last. Switch degrees of usage when necessary according to the limits discussed in the **Method** section above.
- ☐ When switching between the three selected areas, or switching between degrees of usage, document the time elapsed for the degree of usage up to that point.
- ☐ When switching between the three selected areas, or switching between degrees of usage, inspect the RC for any damage or unusual behavior. If either exists, document the abnormality and under which usage the abnormality occurred.
- ☐ Operate the RC until both the battery life has been exhausted and an hour of operation has passed.
- ☐ Note the total time elapsed and total up the elapsed times under each degree of use. Record these on the data sheet.
- ☐ Inspect the transmission cover assembly and evaluate the first requirement listed in the **Introduction** section. Record results in appropriate location on data sheet.
- ☐ Complete a final inspection of the RC vehicle and note any abnormalities and evaluate pass/fail criteria for each component based on any disassembly or damage. Record findings on data sheet. Document any comments in the appropriate section.

Appendix G-1.3 – Suspension Tower Vertical Load Test

N R J R C B A J A

Suspension Tower Vertical Load Test Checklist

Required Materials

Please gather the required materials listed below and check off each box when complete.

- ☐ Disassembled suspension tower body.
- ☐ Flat surface to serve as the testing floor. A sturdy table, or hard house floor.
- ☐ A flat plane to act as the applied-load holder and balancer (glass table-top shown in **FIG 4**)
- ☐ A weight to serve as the applied load. This weight must be greater than 10 pounds.
- ☐ A scale or other mass/weight-measuring device.
- ☐ Suspension tower vertical load test data sheet found in **APPENDIX G2**.

Procedure

Please see the below procedure for this test. Check off each step as it is completed.

- ☐ Obtain the weight and applied-load holder (ALH) and measure their individual weights with a mass/weight measuring device. Record their values in the appropriate section on the datasheet.
- ☐ Place the suspension tower component upright on the flat testing-floor surface selected.
- ☐ Place the ALH atop the suspension tower such that it spans the tops of each arm. Balance the ALH so that it requires no assistance to sit atop the suspension tower.
- ☐ Observe the suspension tower. Look for any major deflection or yielding. If none found, continue the test.
- ☐ Place the applied load atop the ALH and maintain the balance of the hole set-up.
- ☐ Maintain the system for at least 15 seconds.
- ☐ Observe the suspension tower for any yielding or complete failure.
- ☐ Remove the applied load and the ALH carefully.
- ☐ Inspect the suspension tower closely for any signs of damage, yielding, or failure.
- ☐ Record the results in the appropriate section on the data sheet.
- ☐ Record any comments in the appropriate section on the data sheet.

Appendix G-2 – Blank Data Sheets

Below are found the blank data sheets for the three mainline tests performed in this project. Each checklist is located on one full page for printability.

Appendix G-2.1 – Transmission Cover Dis/Assembly Test

N R J   R C   B A J A

Transmission Cover Assembly and Disassembly Test Data Sheet

Time

Test conducted, date and time: ___________________.
This test was conducted by: ____.

Procedure

Below is the procedure for this report. Please see the testing report for full definitions and details.

1. Obtain the transmission cover assembly and place it atop a table or desk in a one square foot of empty tabletop or desktop area.
2. Obtain a 2mm and 3mm hex wrench and a 10mm socket and place them neatly beside the transmission cover
3. Set up a camera and tripod such that the camera records the assembler/disassembler's hands and the transmission cover in full frame.
4. Obtain a stopwatch or stopwatch application.
5. Obtain a transmission cover assembly and disassembly test blank datasheet and a pencil.
6. Start the recording of the camera.
7. The disassembly will now begin, ready yourself and press start on the timer and disassemble the transmission cover according to the directions found in **APPENDIX G4**.
8. Stop the timer when the transmission cover is fully disassembled. Record time elapsed during disassembly on the appropriate location on the datasheet in seconds (time evaluated is from first touch to last touch). Reset the timer.
9. The assembly will now begin, ready yourself and press start on the timer and assemble the transmission cover according to the directions found in **APPENDIX G4**.
10. Stop the timer when the transmission cover is fully assembled. Record time elapsed during assembly on the appropriate location on the datasheet in seconds (time evaluated is from first touch to last touch).
11. Stop the recording of the camera and save the file.
12. Evaluate the results on the datasheet and determine whether the test passed or failed.

Raw Data Collection

Please utilize the below table to record the data collected in this test.

Test Type	Required Time (s)	Predicted Time	Actual Time	Tools Used	Pass/Fail
Disassembly	< 300				
Assembly	< 300				

Comments

Please use the below space to record any comments, concerns, or issues regarding this test.

Appendix G-2.2 – RC Operation Test

N R J R C B A J A

Full RC Assembly Operation Degree of Use Test Data Sheet

Time

Test conducted, date and time: ___________________.
This test was conducted by: ____.

Procedure

Below is the procedure for this report. Please see the testing report for full definitions and details.

1. Select an area of flat concrete or asphalt for light use and medium use testing.
2. Select an area of fairly flat, natural ground for medium use and heavy use testing.
3. Select an area of rough, bumpy natural ground for heavy use testing.
4. Obtain the fully assembled RC vehicle. Ensure the battery has a full charge. If the battery does not have full charge, delay the test until a full charge is obtained.
5. Activate the RC and operate the RC, driving the RC around on the three different areas selected.
6. Pay attention to the time every five minutes. The test will last for one battery life or one hour, whichever comes last. Switch degrees of usage when necessary according to the limits discussed in the **Method** section above.
7. When switching between the three selected areas, or switching between degrees of usage, document the time elapsed for the degree of usage up to that point.
8. When switching between the three selected areas, or switching between degrees of usage, inspect the RC for any damage or unusual behavior. If either exists, document the abnormality and under which usage the abnormality occurred.
9. Operate the RC until both the battery life has been exhausted and an hour of operation has passed.
10. Note the total time elapsed and total up the elapsed times under each degree of use. Record these on the data sheet.
11. Inspect the transmission cover assembly and evaluate the first requirement listed in the **Introduction** section. Record results in appropriate location on data sheet.
12. Complete a final inspection of the RC vehicle and note any abnormalities and evaluate pass/fail criteria for each component based on any disassembly or damage. Record findings on data sheet. Document any comments in the appropriate section.

Raw Data Collection

Please utilize the below table to record the data collected in this test.

		Light use	**Medium use**	**Heavy use**
	Results	Pass / Fail		
	Suspension Towers			
	Transmission Cover			
Total Time				
Percent Time	100%			

Comments

Please use the below space to record any comments, concerns, or issues regarding this test.

Appendix G-2.3 – Suspension Tower Vertical Load Test

N R J   R C   B A J A

Suspension Tower Vertical Load Test Data Sheet

Time

Test conducted, date and time: ___________________.
This test was conducted by: ____.

Procedure

Below is the procedure for this report. Please see the testing report for full definitions and details.

1. Obtain the weight and applied-load holder (ALH) and measure their individual weights with a mass/weight measuring device. Record their values in the appropriate section on the datasheet.
2. Place the suspension tower component upright on the flat testing-floor surface selected.
3. Place the ALH atop the suspension tower such that it spans the tops of each arm. Balance the ALH so that it requires no assistance to sit atop the suspension tower.
4. Observe the suspension tower. Look for any major deflection or yielding. If none found, continue the test.
5. Place the applied load atop the ALH and maintain the balance of the hole set-up.
6. Maintain the system for at least 15 seconds.
7. Observe the suspension tower for any yielding or complete failure.
8. Remove the applied load and the ALH carefully.
9. Inspect the suspension tower closely for any signs of damage, yielding, or failure.
10. Record the results in the appropriate section on the data sheet.
11. Record any comments in the appropriate section on the data sheet.

Raw Data Collection

Please utilize the below table to record the data collected in this test.

		Suspension Tower	
Weights (lbs)		Pass / Fail	
ALH Weight			
Applied Load			
Total Weight			

Comments

Please use the below space to record any comments, concerns, or issues regarding this test.

Appendix G-3 – Completed Data Sheets and Images

Below are found the completed data sheets for the three mainline tests performed in this project. Each checklist is located on one full page for printability. Attached, if available, are images of the testing and results.

Appendix G-3.1 – Transmission Cover Dis/Assembly Test

N R J R C B A J A

Transmission Cover Assembly and Disassembly Test Data Sheet

Time

Test conducted, date and time: 11 April 2021 1720 hours.
This test was conducted by: Jeffrey Harn.

Procedure

Below is the procedure for this report. Please see the testing report for full definitions and details.

1. Obtain the transmission cover assembly and place it atop a table or desk in a one square foot of empty tabletop or desktop area.
2. Obtain a 2mm and 3mm hex wrench and a 10mm socket and place them neatly beside the transmission cover
3. Set up a camera and tripod such that the camera records the assembler/disassembler's hands and the transmission cover in full frame.
4. Obtain a stopwatch or stopwatch application.
5. Obtain a transmission cover assembly and disassembly test blank datasheet and a pencil.
6. Start the recording of the camera.
7. The disassembly will now begin, ready yourself and press start on the timer and disassemble the transmission cover according to the directions found in **APPENDIX G4**.
8. Stop the timer when the transmission cover is fully disassembled. Record time elapsed during disassembly on the appropriate location on the datasheet in seconds (time evaluated is from first touch to last touch). Reset the timer.
9. The assembly will now begin, ready yourself and press start on the timer and assemble the transmission cover according to the directions found in **APPENDIX G4**.
10. Stop the timer when the transmission cover is fully assembled. Record time elapsed during assembly on the appropriate location on the datasheet in seconds (time evaluated is from first touch to last touch).
11. Stop the recording of the camera and save the file.
12. Evaluate the results on the datasheet and determine whether the test passed or failed.

Raw Data Collection

Please utilize the below table to record the data collected in this test.

Test Type	Required Time (s)	Predicted Time	Actual Time	Tools Used	Pass/Fail
Disassembly	< 300	180	165	3	Pass
Assembly	< 300	180	243	3	Pass

Comments

Please use the below space to record any comments, concerns, or issues regarding this test.

This test was completed by Jeffrey Harn, the designer and manufacturer of the transmission cover. It is important to note that because of his knowledge of the transmission cover assembly, Harn may have been able to assemble and disassemble this component faster than a person ignorant of the transmission cover. This point was made by several peers.

Images

Below is a collection of images taken before, during, or after this test.

Appendix G-3.2 – RC Operation Test

N R J R C B A J A

Full RC Assembly Operation Degree of Use Test Data Sheet

Time

Test conducted, date and time: 12 April 2021, 23 April 2021, and 27 April 2021.
This test was conducted by: Jeffrey Harn, Ryder Satak, Naoki Masuda.

Procedure

Below is the procedure for this report. Please see the testing report for full definitions and details.

1. Select an area of flat concrete or asphalt for light use and medium use testing.
2. Select an area of fairly flat, natural ground for medium use and heavy use testing.
3. Select an area of rough, bumpy natural ground for heavy use testing.
4. Obtain the fully assembled RC vehicle. Ensure the battery has a full charge. If the battery does not have full charge, delay the test until a full charge is obtained.
5. Activate the RC and operate the RC, driving the RC around on the three different areas selected.
6. Pay attention to the time every five minutes. The test will last for one battery life or one hour, whichever comes last. Switch degrees of usage when necessary according to the limits discussed in the **Method** section above.
7. When switching between the three selected areas, or switching between degrees of usage, document the time elapsed for the degree of usage up to that point.
8. When switching between the three selected areas, or switching between degrees of usage, inspect the RC for any damage or unusual behavior. If either exists, document the abnormality and under which usage the abnormality occurred.
9. Operate the RC until both the battery life has been exhausted and an hour of operation has passed.
10. Note the total time elapsed and total up the elapsed times under each degree of use. Record these on the data sheet.
11. Inspect the transmission cover assembly and evaluate the first requirement listed in the **Introduction** section. Record results in appropriate location on data sheet.
12. Complete a final inspection of the RC vehicle and note any abnormalities and evaluate pass/fail criteria for each component based on any disassembly or damage. Record findings on data sheet. Document any comments in the appropriate section.

Raw Data Collection

Please utilize the below table to record the data collected in this test.

		Light use	Medium use	Heavy use
	Results	Pass / Fail		
	Suspension Towers	Pass	Fail	Fail
	Transmission Cover	Pass	Pass	Pass
Total Time	58 minutes	10 minutes	32 minutes	16 minutes
Percent Time	100%	17%	55%	28%

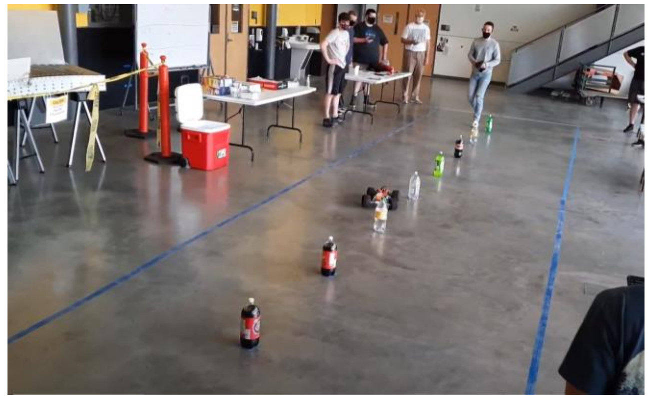
Comments

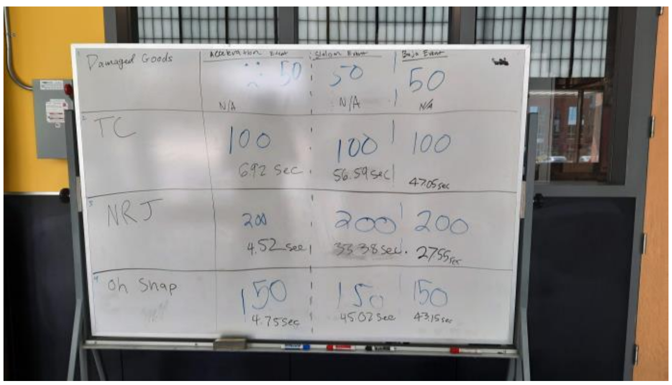
Please use the below space to record any comments, concerns, or issues regarding this test.

Under medium use, a control arm attached to the rear suspension tower came unassembled. This is considered a disassembly of the suspension tower and thus is a failure of the test. Under heavy use, the screw bosses for the mounting of the suspension struts of the rear suspension tower sheared off. This is considered a mechanical failure and a disassembly and thus is a failure of the test.

Images

Below is a collection of images taken before, during, or after this test.





Appendix G-3.3 – Suspension Tower Vertical Load Test

N R J R C B A J A

Suspension Tower Vertical Load Test Data Sheet

Time

Test conducted, date and time: 11 May 2021 1245 hours.
This test was conducted by: Jeffrey Harn.

Procedure

Below is the procedure for this report. Please see the testing report for full definitions and details.

1. Obtain the weight and applied-load holder (ALH) and measure their individual weights with a mass/weight measuring device. Record their values in the appropriate section on the datasheet.
2. Place the suspension tower component upright on the flat testing-floor surface selected.
3. Place the ALH atop the suspension tower such that it spans the tops of each arm. Balance the ALH so that it requires no assistance to sit atop the suspension tower.
4. Observe the suspension tower. Look for any major deflection or yielding. If none found, continue the test.
5. Place the applied load atop the ALH and maintain the balance of the hole set-up.
6. Maintain the system for at least 15 seconds.
7. Observe the suspension tower for any yielding or complete failure.
8. Remove the applied load and the ALH carefully.
9. Inspect the suspension tower closely for any signs of damage, yielding, or failure.
10. Record the results in the appropriate section on the data sheet.
11. Record any comments in the appropriate section on the data sheet.

Raw Data Collection

Please utilize the below table to record the data collected in this test.

		Suspension Tower	
Weights (lbs)		Pass / Fail	
ALH Weight	18	Pass	
Applied Load	15	Not tested alone	
Total Weight	33	Pass	

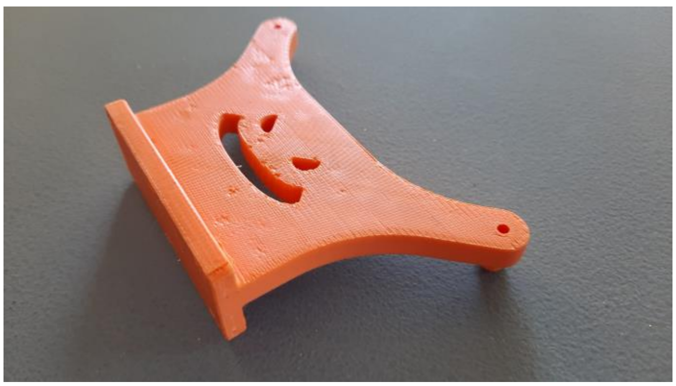
Comments

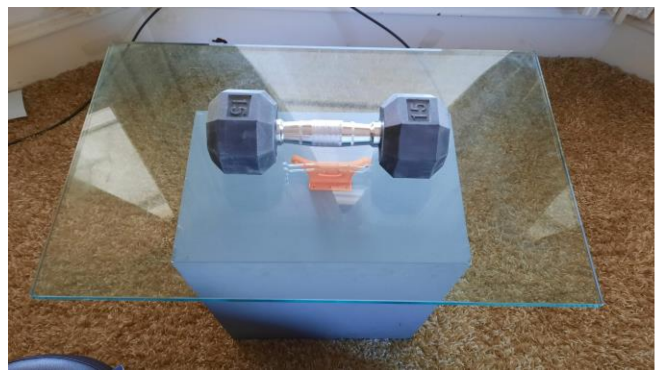
Please use the below space to record any comments, concerns, or issues regarding this test.

The Hogue laboratory equipment was not utilized so an at-home test was conducted. There was no object at hand that was ten pounds and able to be easily utilized. A 15 pound dumbbell was used for the applied load and a glass tabletop was used for the ALH. The glass tabletop weighed 18 pounds. The suspension tower showed absolutely no signs of yielding, defects, or failure. The suspension tower exhibited little to no deflection noticeable to the naked eye. This test was a clear pass.

Images

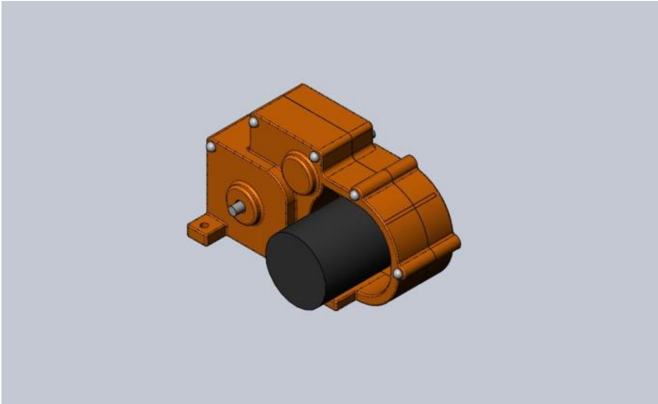
Below is a collection of images taken before, during, or after this test.





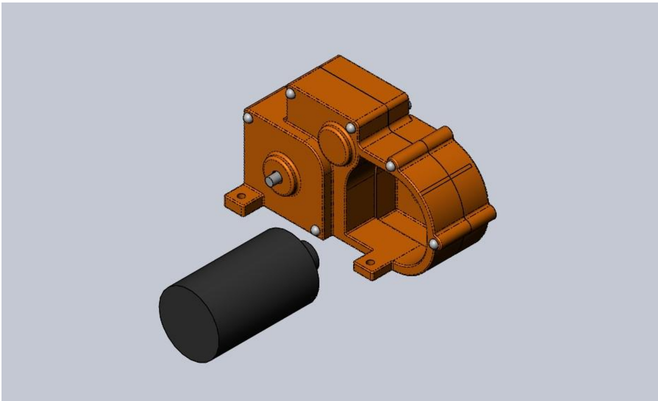
Appendix G-4 – Transmission Cover Assembly Instructions

Contained in this appendix is the assembly and disassembly instructions that are used in the completion of the transmission assembly and disassembly test.



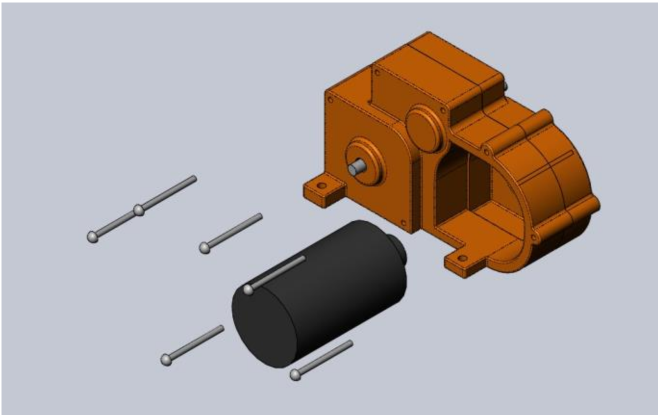
Step 1

Remove the two screws that secure the motor with the 3mm hex wrench.



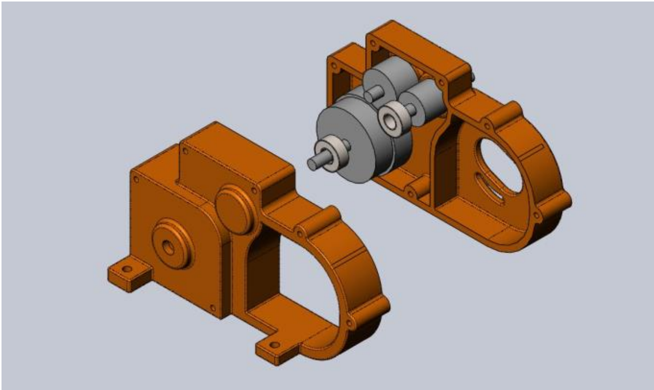
Step 2

Remove the motor from the assembly.

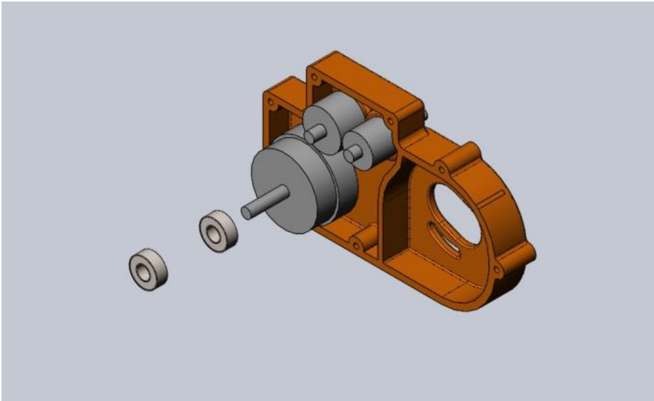


Step 3

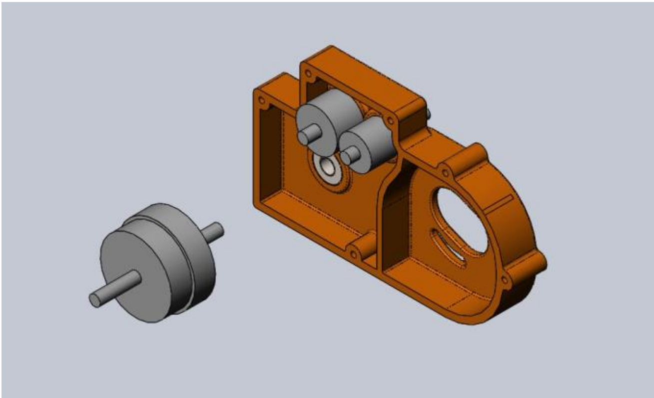
Unscrew the six “bolts” that secure the two pieces of the transmission cover together using both the 2mm hex screw and the 3mm hex screw.



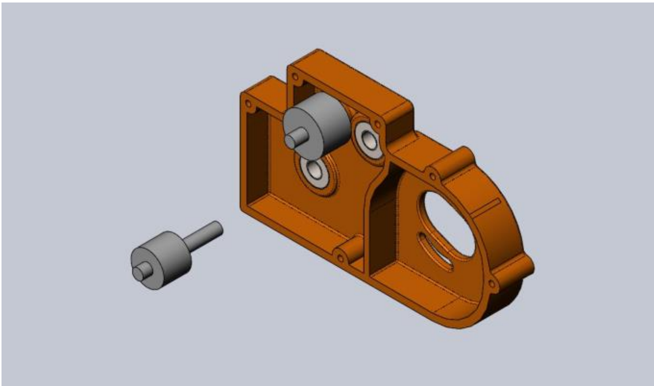
Step 4
Carefully separate the two sides of the transmission cover assembly.



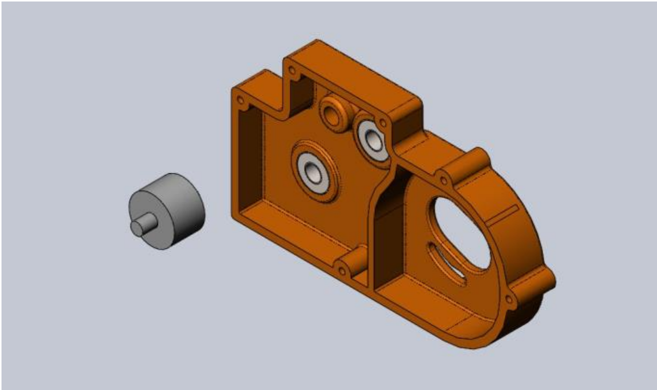
Step 5
Remove the two bearings shown.



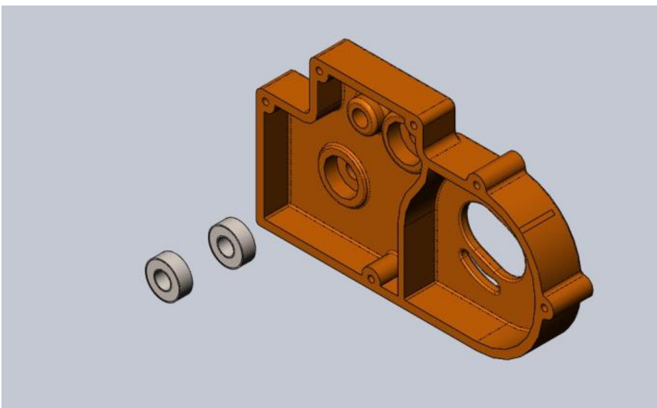
Step 6
Remove the differential assembly.



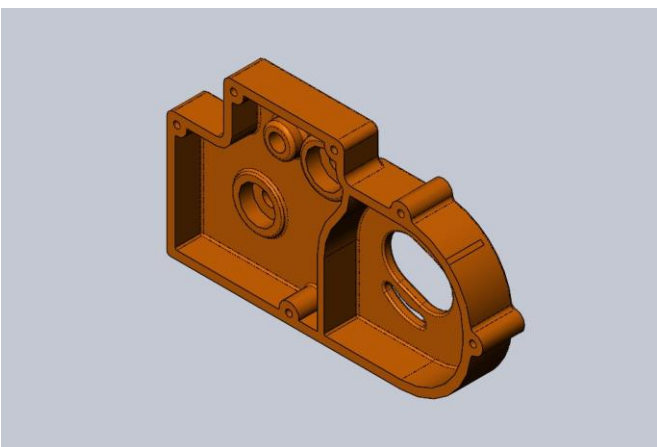
Step 7
Remove the drive gear and its shaft.



Step 8
Remove the idler gear and its shaft.



Step 9
Remove the two bearings shown.



Step 10
The transmission cover is disassembled. Reverse through the above process to reassemble the transmission cover.

Appendix G-5 – Gantt Chart Testing Schedule

See the below Gantt chart section for details over testing time, duration, and date conducted.

PROJECT TITLE:RC Baja Project Team #3														
Principal Investigator.:Jeffrey Harn														
		Duration												
TASK: ID	Description	Est. (hrs)	Actual (hrs)	%Com	Septembe	October	November	Dec	January	February	March	April	May	June
8	Device Evaluation													
8a	Test Procedures	3	3.5											X
8b	Dis/assembly Test	1	0.5									X		
8c	Operation Integrity Test	2	1.25									X		
8d	Sus Twr Load Test	1	0.75										X	
8e	Other Tests	2	1											X
8f	Team Testing Support	5	2.75										X	
8g	TDR Presentation	2	4.25									X		
	subtotal:	16	14											

APPENDIX H – Resume

J E F F R E Y   H A R N

ADDRESS: 4001 Lemon RD NE, Olympia, WA 98506
PHONE: Mobile: (360) 701-4402 Home: (360) 357-3008
EMAIL: Jeffreyharn37@gmail.com

Professional Summary
Current mechanical engineering student with experience in drafting, 3D modeling, and practical experience obtained from working in engineering labs and warehouse environments.

Characteristics and Skills
Please see the following list of Jeffrey Harn's notable characteristics and labor-related skills:

- Detailed	- SolidWorks Proficiency (certified)
- Organized	- AutoCAD Proficiency
- Independent	- Computer Proficiency
- Trustworthy	- Power Tool/Machine Operation
- Hardworking	- Basic Maintenance Knowledge

Work History
Please see the below job history information for Jeffrey Harn:

Warehouse Associate – Stackdown
Fred Meyer Distribution Center – Chehalis, WA 07/2020 to 09/2020
222 Maurin Rd, Chehalis, WA 98532 (360) 740-6600

CAD/GIS Technician
Central Washington University – Ellensburg, WA 06/2019 to 09/2019
205 East 11th Avenue Ellensburg, WA 98926-7523 (509) 963-3000

Mover/Packer
Olympic Moving and Storage – Olympia, WA 07/2018 to 09/2018
935 Poplar St SE, Olympia, WA 98501 (360) 753-2344

Lifeguard
Tanglewilde Recreation Center – Olympia, WA 06/2017 to 09/2017
414 Wildcat St. SE Olympia, WA 98503 (360) 701-0182

Education
Please see the below education history for Jeffrey Harn:

BA, Mechanical Engineering Technology
Central Washington University – Ellensburg, WA To Graduate in 2021

Associate of Arts
South Puget Sound Community College – Olympia, WA 2018

High School Diploma
North Thurston High School – Lacey, WA 2018