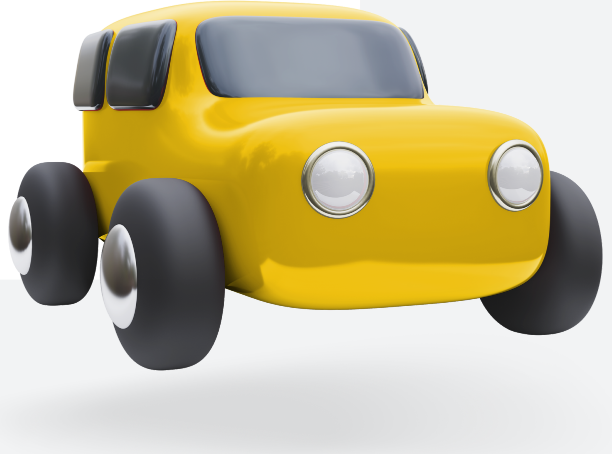
IAM3D
National Institute of Technology Silchar

ASME
SETTING THE STANDARD
NIT SILCHAR
STUDENT CHAPTER

Design Report

Team Godspeed

ASME e-fest IAM3D 2022



NIT SILCHAR

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Points for discussion

Design Journey

DEFINE 01

Defining and understanding the problem statement.

RESEARCH 02

Both Qualitative & Quantitative Research are carried along thoroughly

IDEATE 03

Bringing all sketch designs to 3D models using softwares like solidworks & fusion360

PROTOTYPE 04

Bringing 3D model designs into real life through additive manufacturing

TEST 05

The prototype is tested along obstacle course in different tracks - indoor & outdoor respectively

Problem Statement -

The objective is to design, test, and manufacture a “D.I.R.T.”-GBRCV (Design, Integration, Research, and Test – Ground Based Remote Controlled Vehicle) using additive manufacturing and an iterative design process that will demonstrate your teams design and testing skills! Be creative! It doesn’t just have to just drive.

Solution -

The idea is to make a Remote Control Car having adjustable shock absorbers that would be able to move through relentless obstacles in both indoor & outdoor track course.

CAD Assembly

Team Godspeed

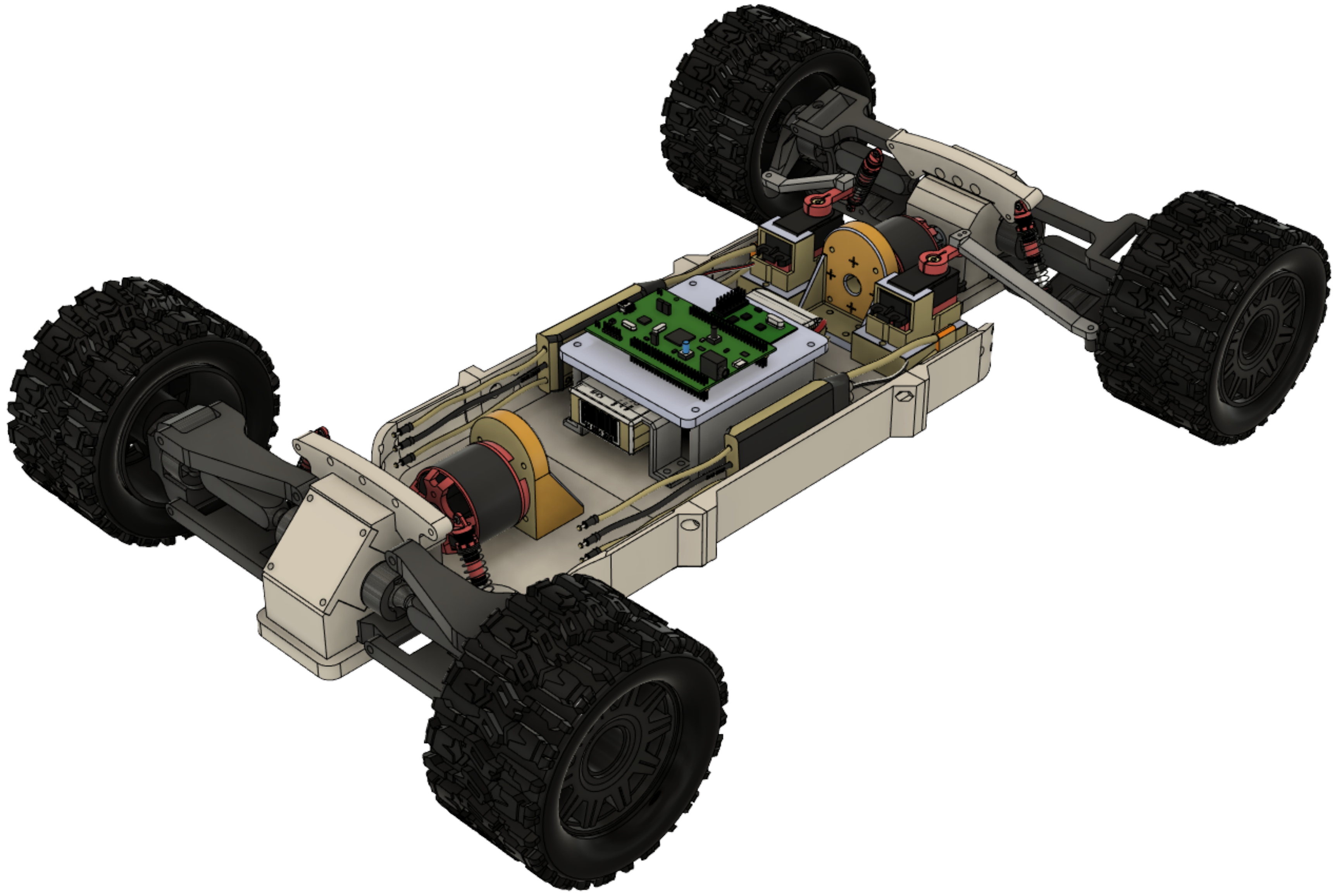
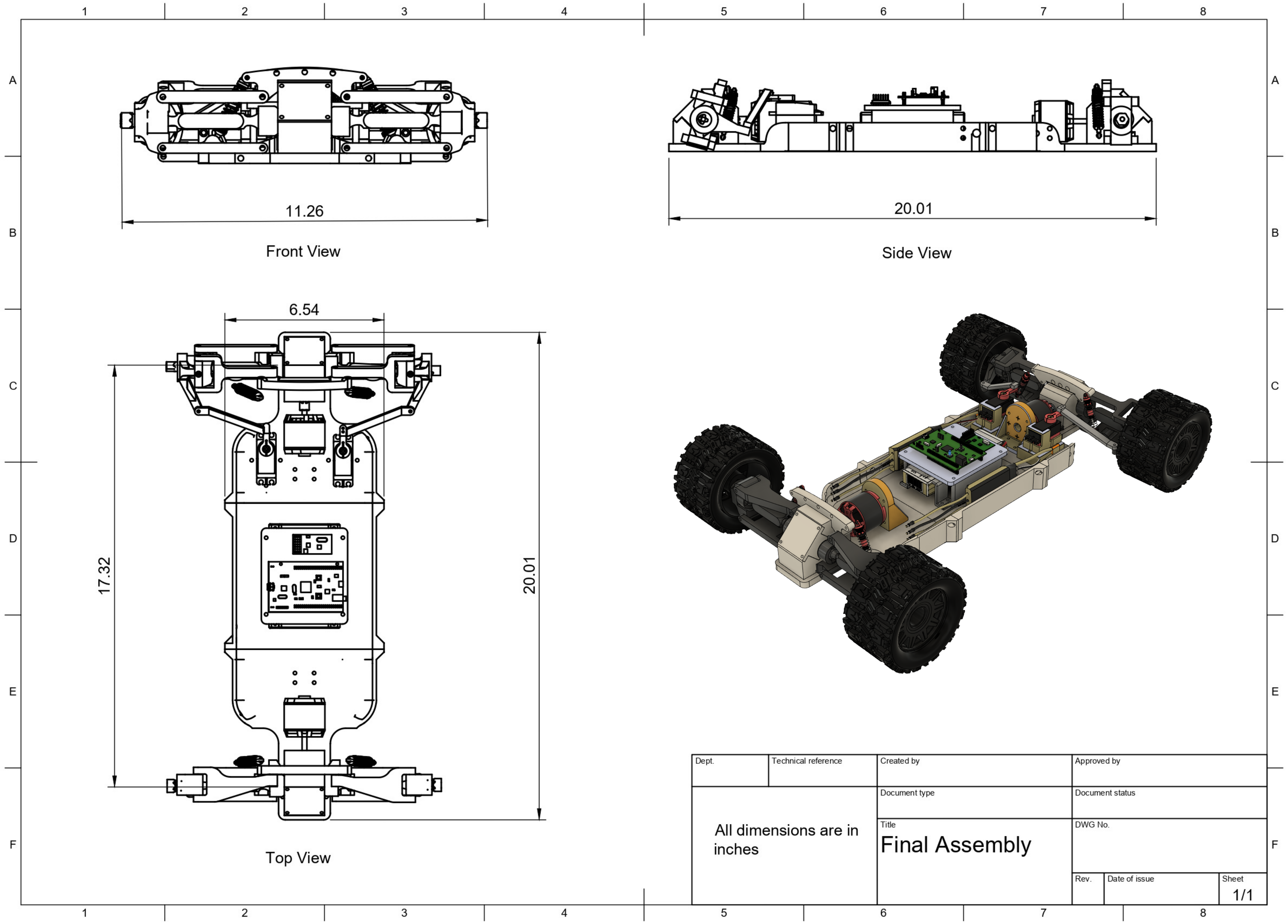


Fig. - CAD Model

Fig. - Prototype Model



Final Assembly Drawing

The GBRCV comprised of the following dimensions :

- 17.32 inches in length from centre to centre
- 20.01 inches in length from Top end to Bottom end of the vehicle
- 11.26 inches in width from centre to centre

Power Transmission

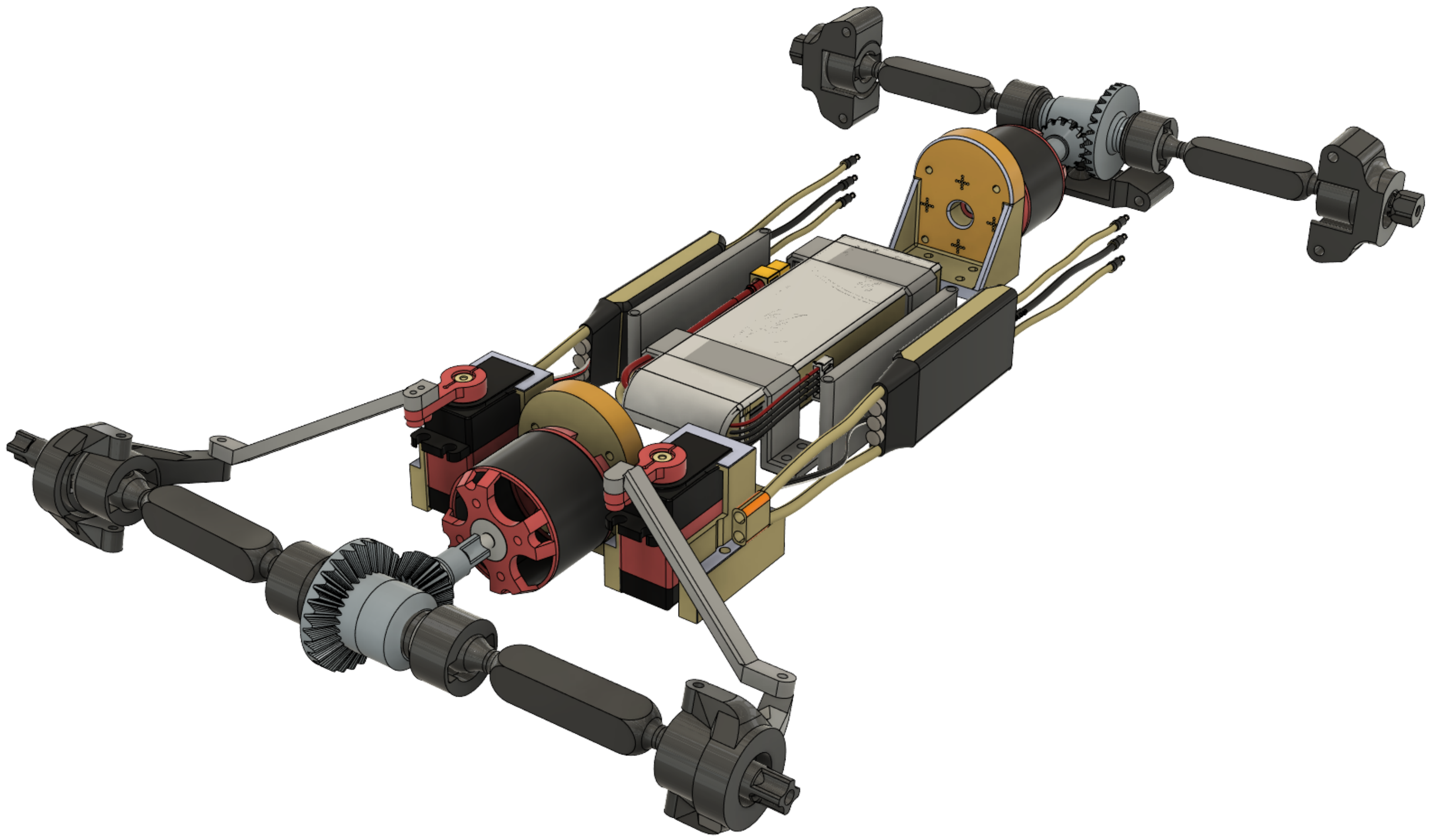
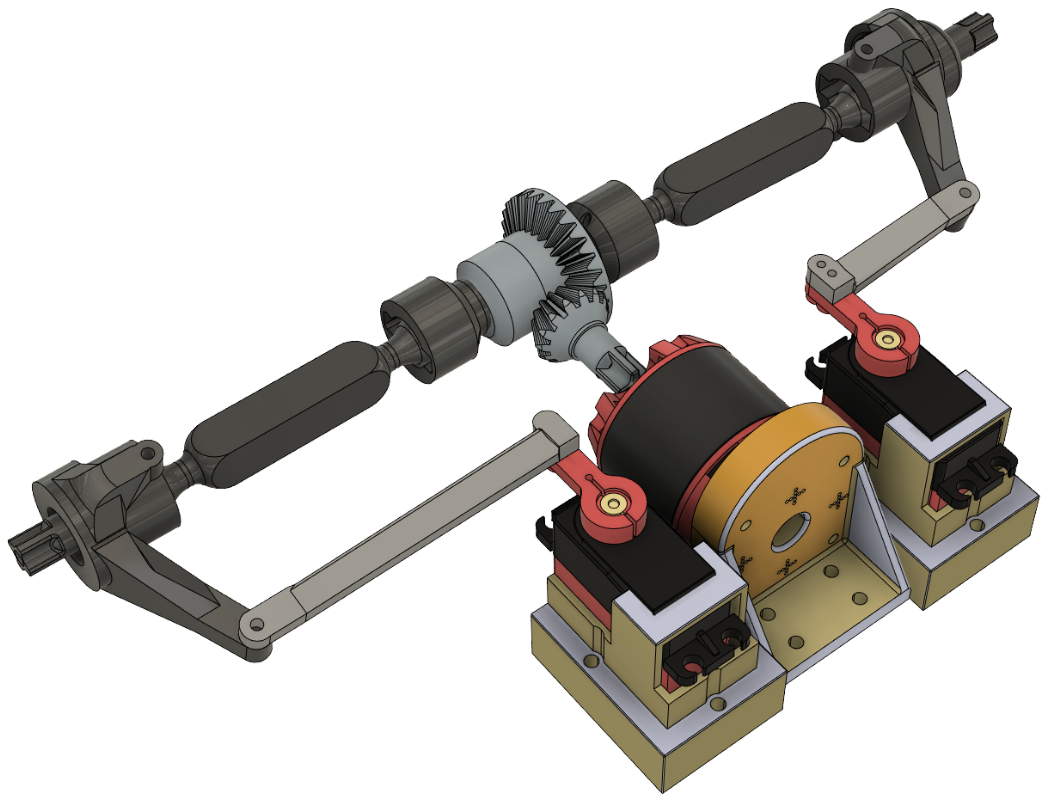
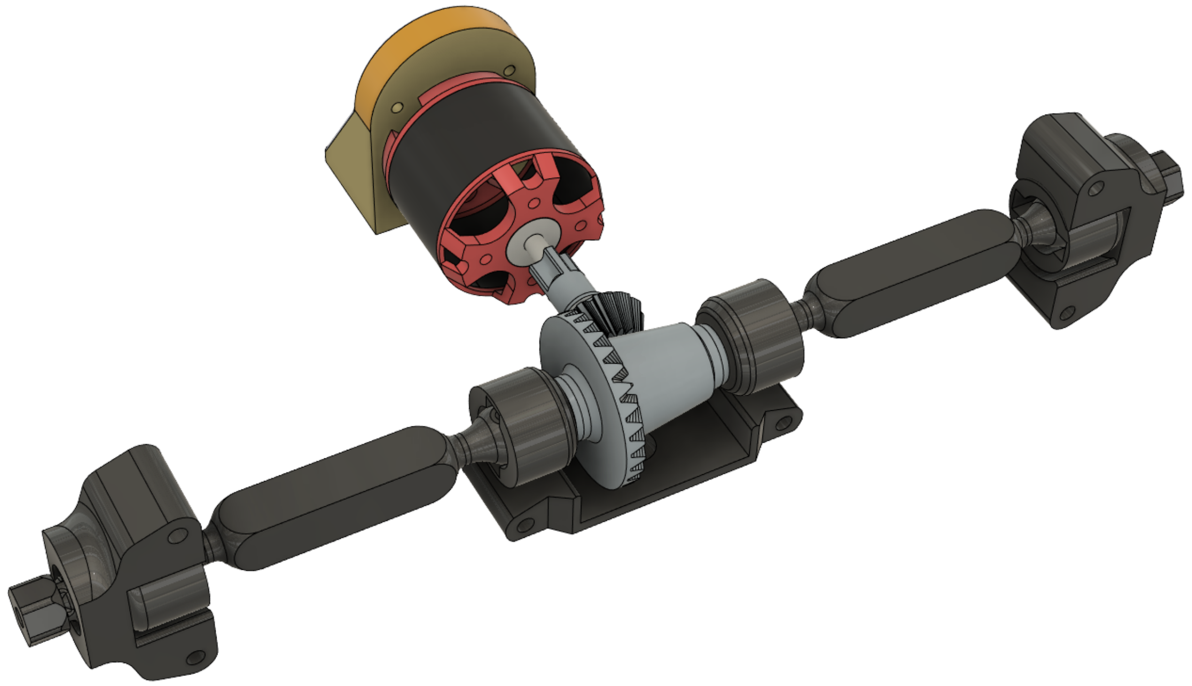


Fig. - Isometric View

The power source of this rc car is a “Spec” Li-Po Battery. This battery powers the two BLDC motors for front and rear wheels respectively through two separate ESCs. The motor is connected to the input bevel gear of the Differential Gear System which then rotates the output bevel gears. The output bevel gear is connected to the driving axles through the bell housing. Finally the driving axle rotates the wheels and moves the rc car.

Steering System





The steering system is illustrated in the figure. Two separate servo motors have been used for the steering. This was done to make the steering system less cumbersome with too many links. The servo is connected to the Steering Linkage which in turn is connected to Steering Knuckle which moves the Wheels.

Gear System

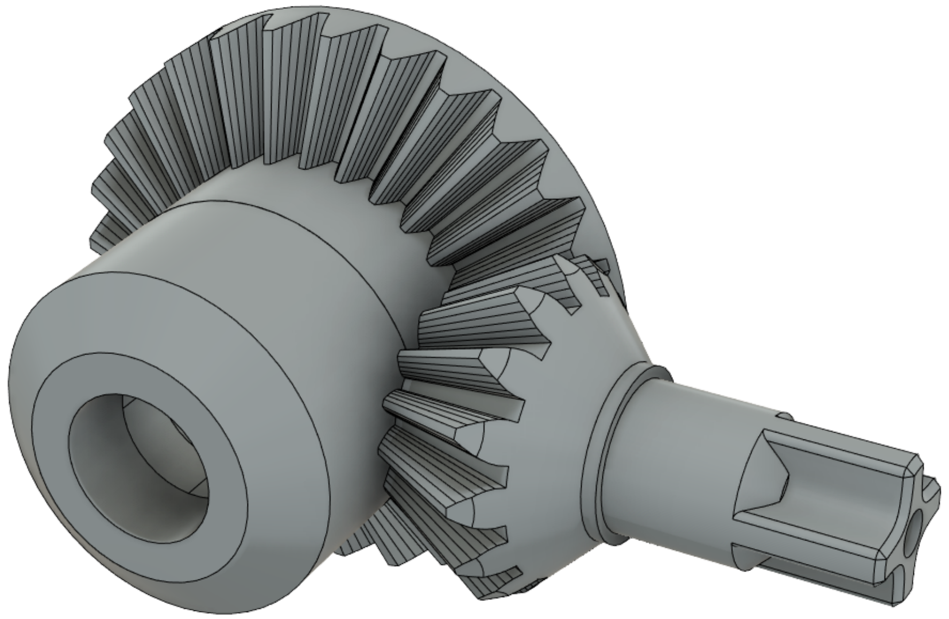


Fig. - Isometric View

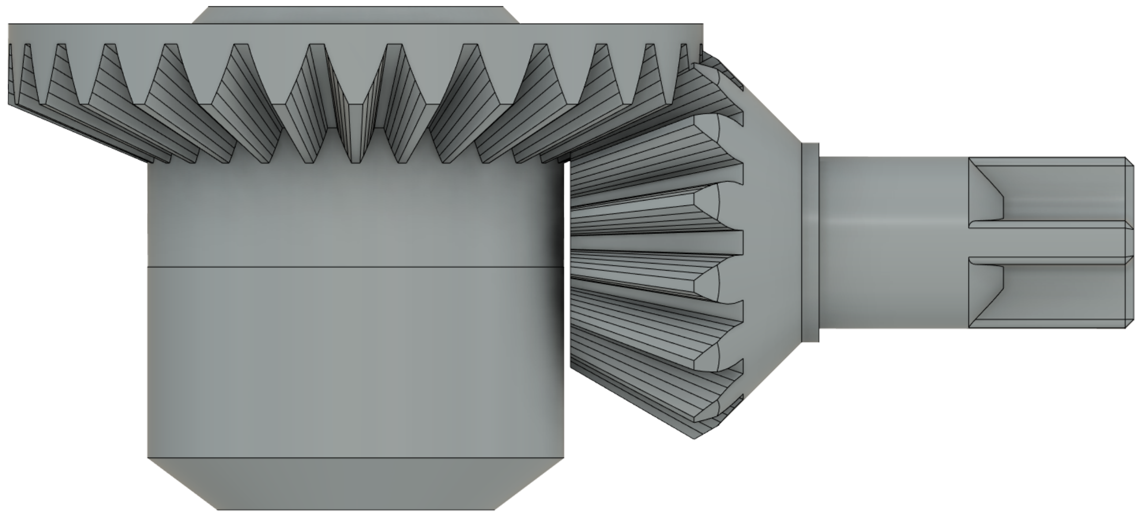


Fig. - Isometric View

The gear arrangement is as shown in figure. The rc car has a bevel gear arrangement in the differential. The gear ratio is kept at 1:2. This was done after deciding that optimum speed that we wanted the rc car to achieve. The calculation has been shown.

Analysis

Mathematical

Gear ratio taken as 1:2

RPM of the motor	=	790KV x 11.1V
	=	8769 RPM
Circumference of the wheel	=	2 πr
	=	12.36 inches
Revolution per minute	=	63360 / 12.36
	=	5126.2
Vehicle speed	=	82.6 kmph
	=	51.33 miles per hour
Wheel rpm	=	(51.33 x 5126.2)/60
	=	4385 rpm
Gear Ratio	=	4385 / 8769
	=	1:2

Hence the gear ratio is 1:2

Drawings of the Individual Parts

Points for discussion

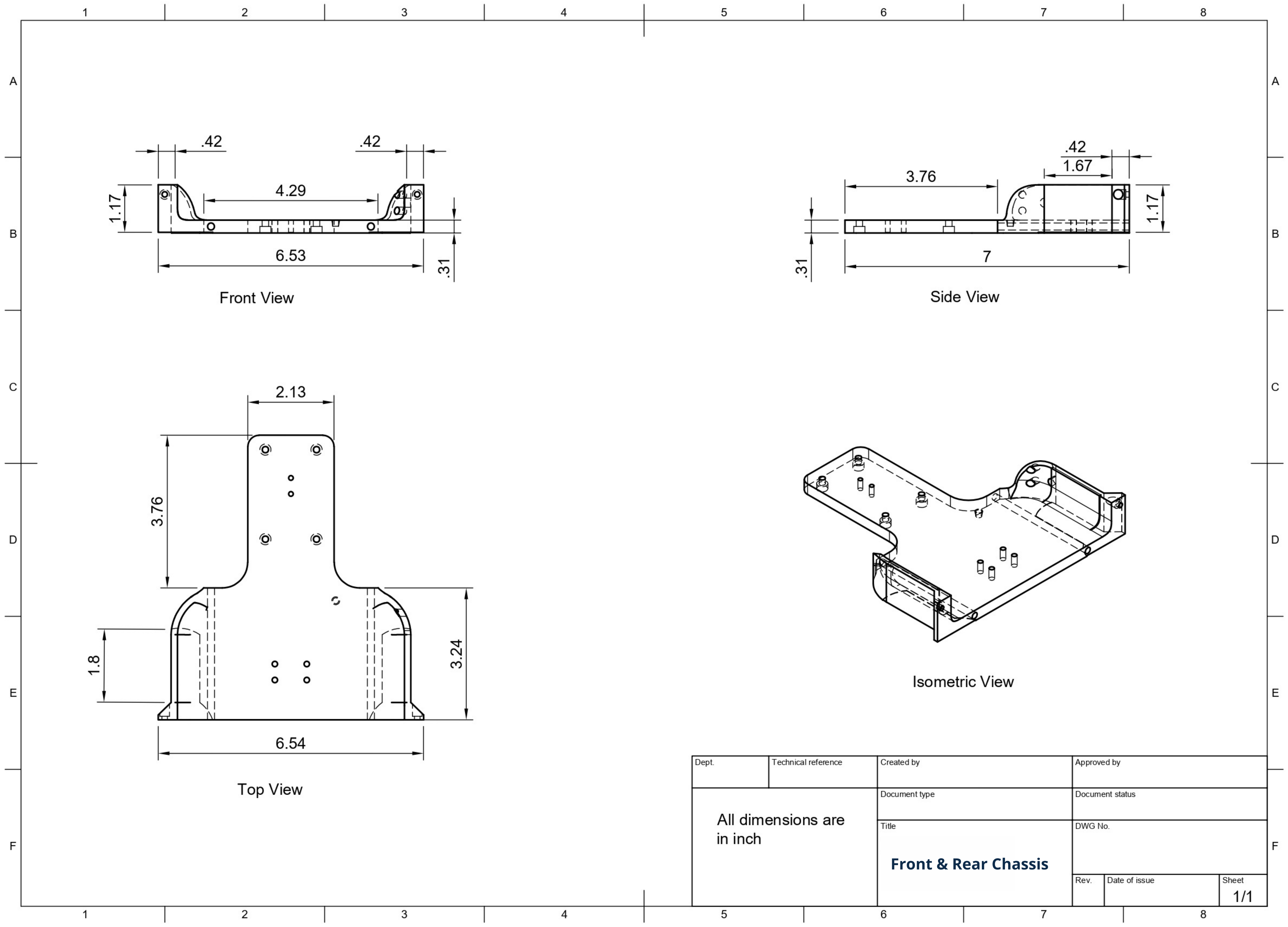
- Front & Rear Chassis
- Centre Chassis
- Bell Housing
- Axle
- Lower Control Arm
- Differential Gearbox

- Steering Knuckle
- Suspension Mount
- Bevel Gear - Output
- Bevel Gear - Input
- Servo Mount
- BLDC Motor Mount

- Wheel Hub
- Upper Control Arm
- Arduino Plate
- Knuckle Mount
- Battery Mount
- Wheel Adaptor

- Steering Arm
- Battery Stand

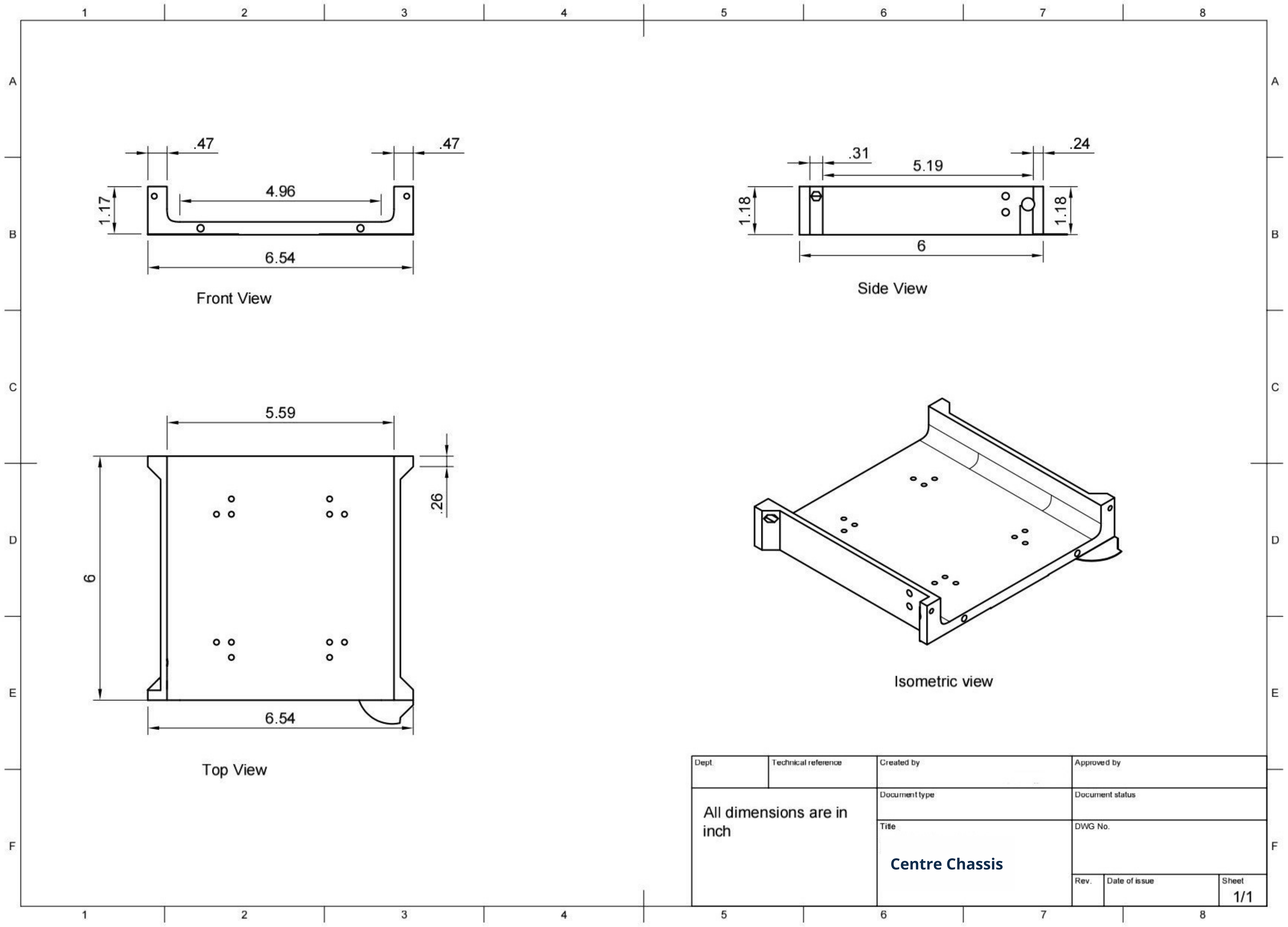
Front & Rear Chassis



The front chassis handles the weight of the servo motor giving it ease of assembly and alignment. It connects the front post of the RC car with the central chassis and provides bridging support between the chassis. It balances the weight of the front post and gives the steering linkages enough area for its moments.

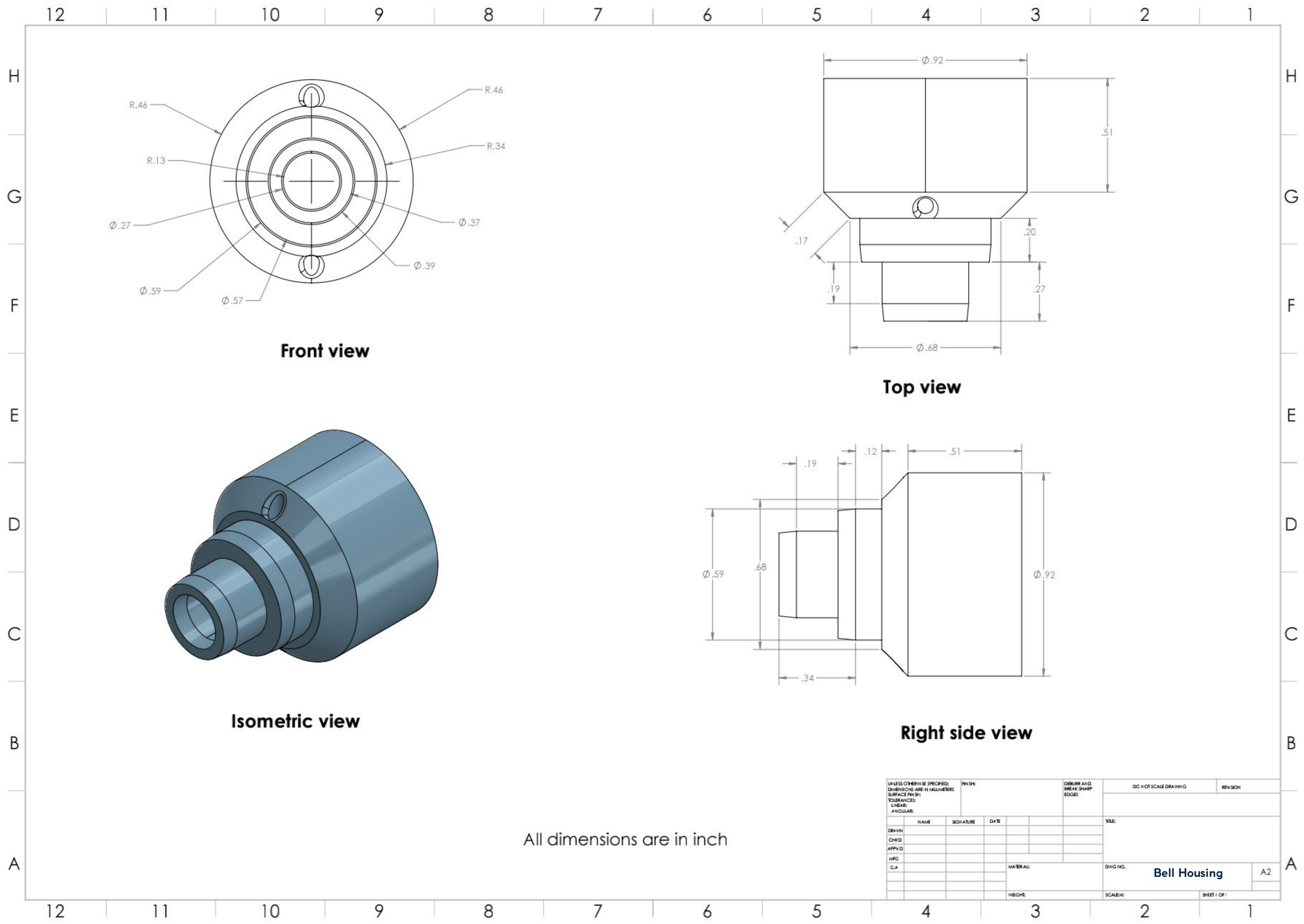
The rear chassis supports the mount made for the BLDC motor and balance its weight. This would remain undisturbed of the vibrations aroused by the BLDC motor during the run of the RC car. It provides balancing support to the respective components. 7x6.54x1.17 inches of both front & rear chassis provides strength to the RC car.

Centre Chassis



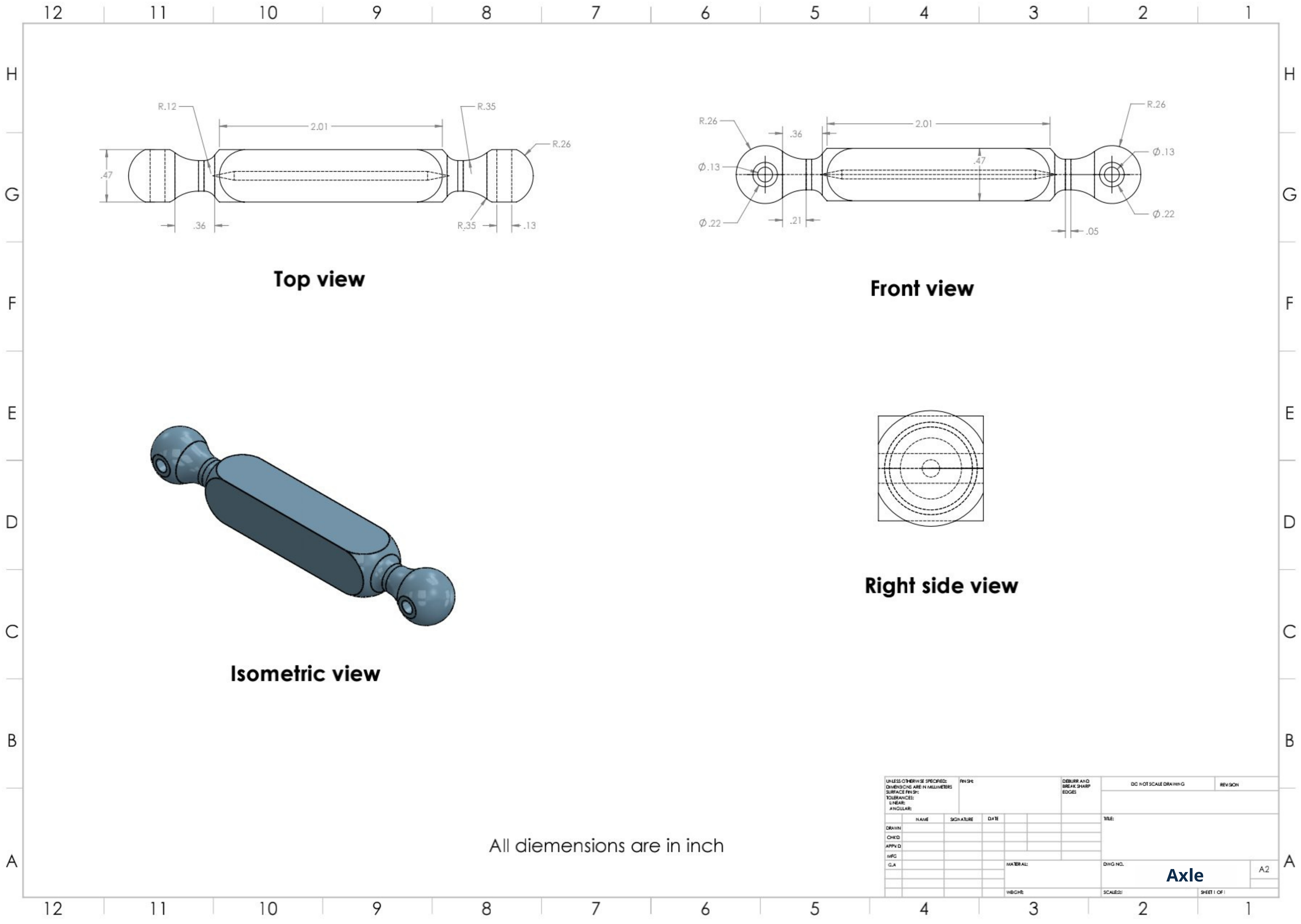
The central chassis acts as a supporting bridge between the front and rear chassis providing the battery - occupancy area and providing a good strength to the center of the RC car . It handles the weight of the battery and the Arduino board placed upon it and gives some space for the receiver as well. 6x6.54x1.18 inches is the provided dimensions for the central chassis by observing the strength of the part.

Bell Housing



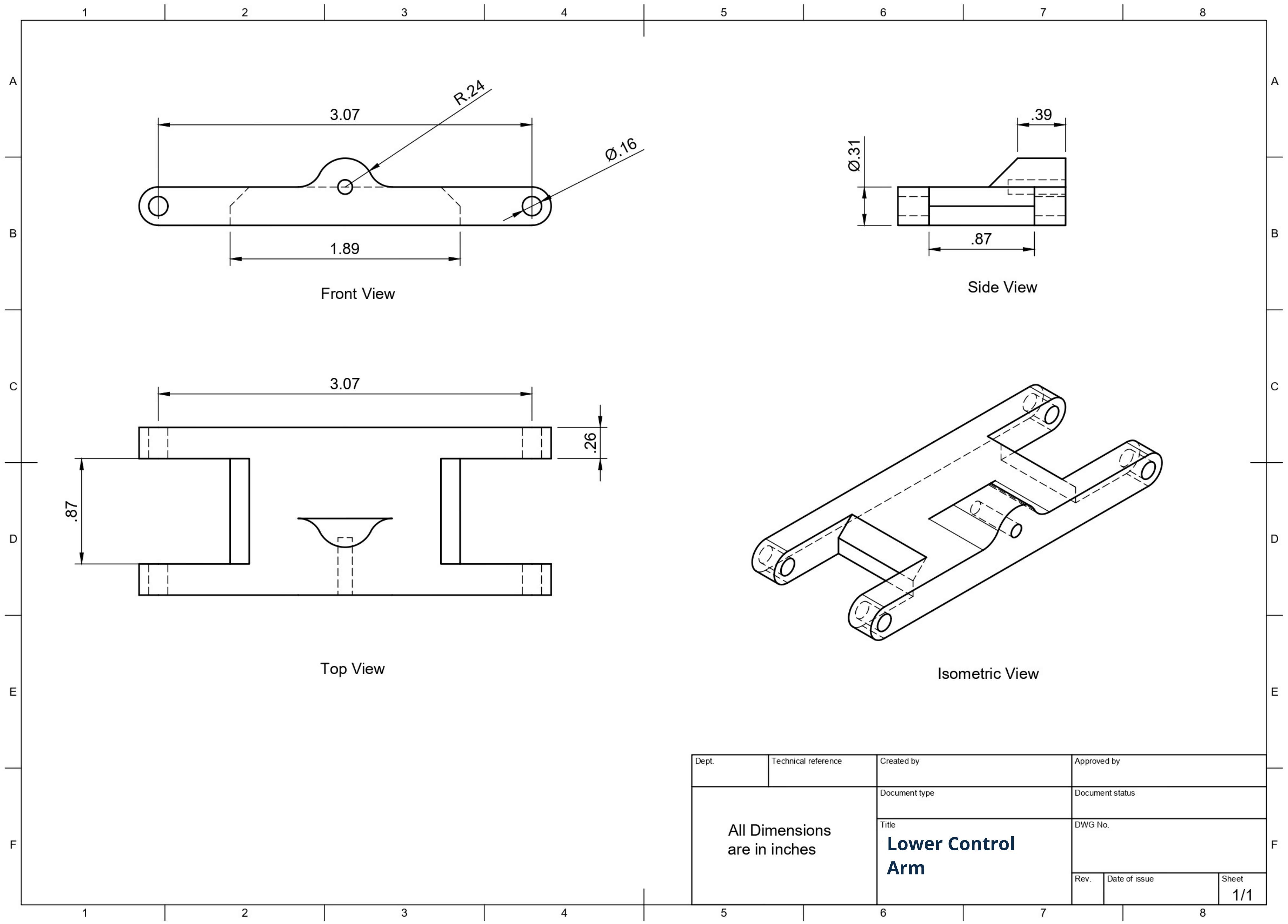
Bell housing is used with the bevel gear acting as a torque converter of the transmission on the RC car powdered by the BLDC motors and the battery. It provides a linkage between the bevel gear, the ball bearing, and the axles that transmit the rotation motion to the wheels. It also provides a balancing force to the ball bearings to stabilize the all-over motion of the RC car. A gear perpendicular to it helps it to execute the rotation in the linkages of the front post and rear post. Its length of 1.01 and larger diameter of 0.92 inches gives it a good space to fix itself efficiently with the axle and the bevel gear.

Axle



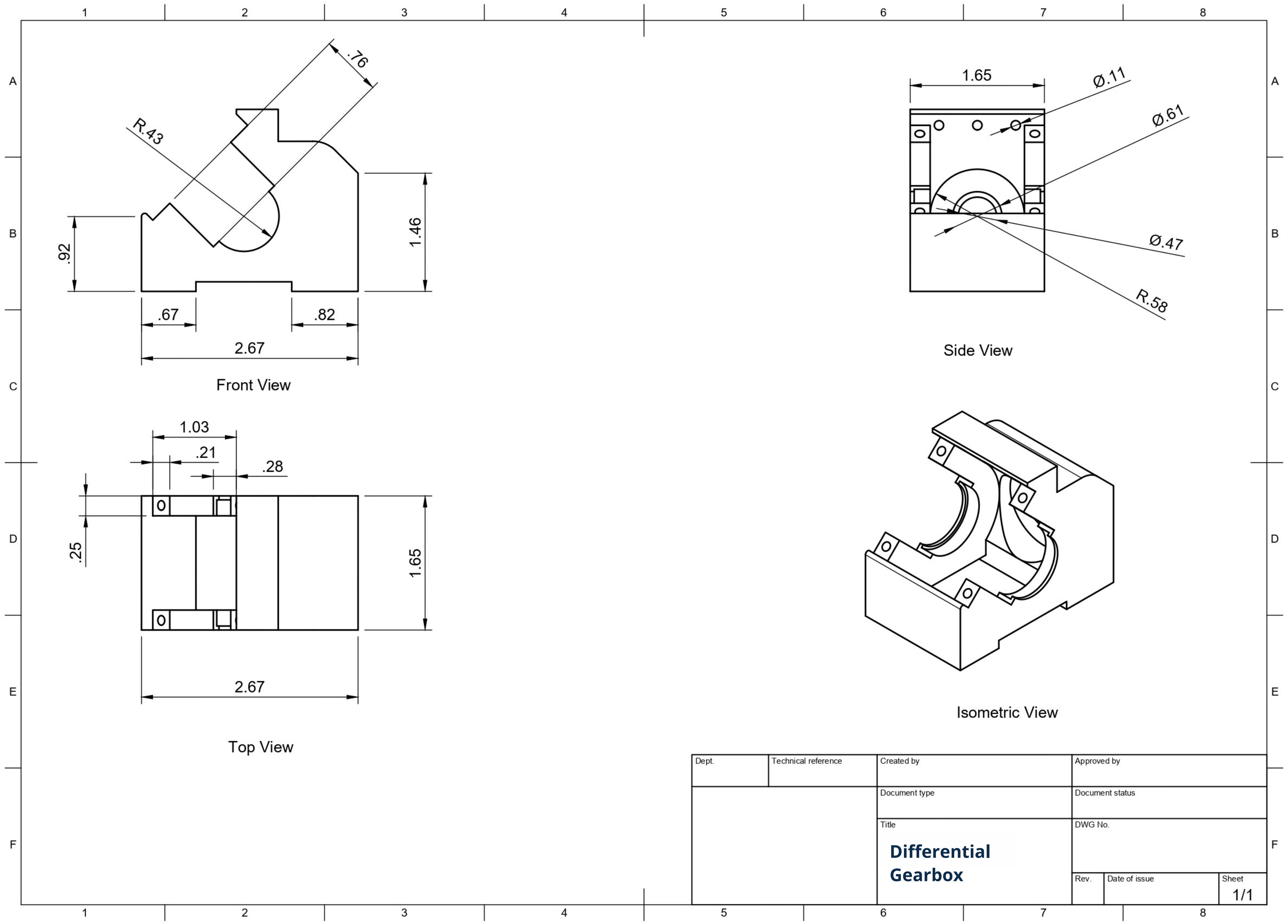
The figure shows the driving axle in different views for better understanding. It does the power transmission from the differential to the wheels. The mid-portion dimension is 2.01in. The front and rear portions are rounded to be fitted to the knuckle with radius of 0.26 in. The dimensions were reached upon keeping in mind the torsional force that it has to withstand. While printing 80% infill was used to get the desired strength.

Lower Control Arm



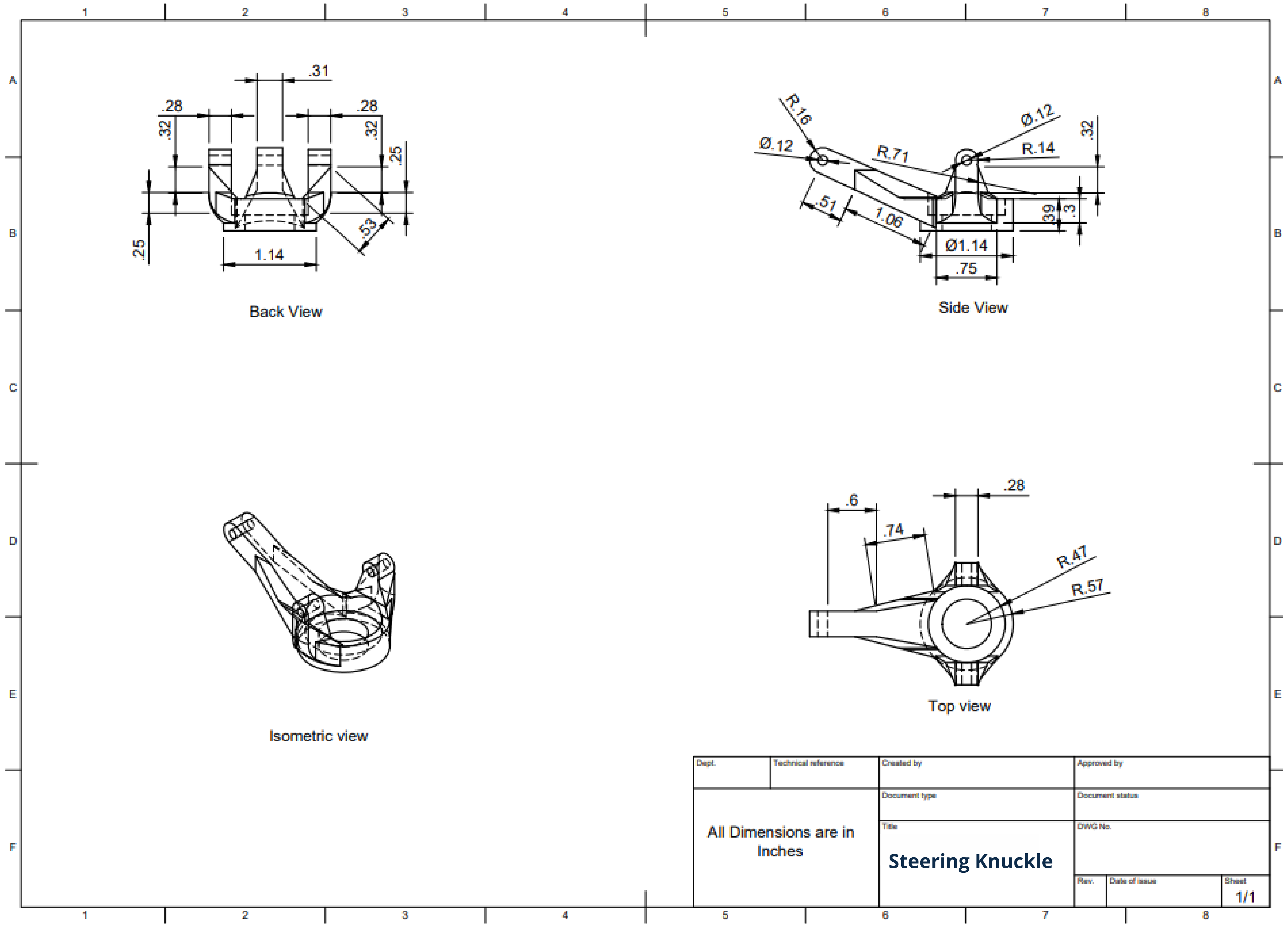
The four lower control arms are implemented to give flexibility to the assembly part of the front post and the rear post. The shocks are paired with the lower control arms to provide the suspension to the RC car and help the wheels in balancing the RC car over the uneven surface of the track. The flexibility of the lower control arm provides an easy moment to the front and rear post giving the wheels an unhindered attachment with the posts. 3.07x1.39x0.31 inches of the dimensions provides the four lower control arms a pretty good strength to uphold the shocks of the suspension.

Differential Gearbox



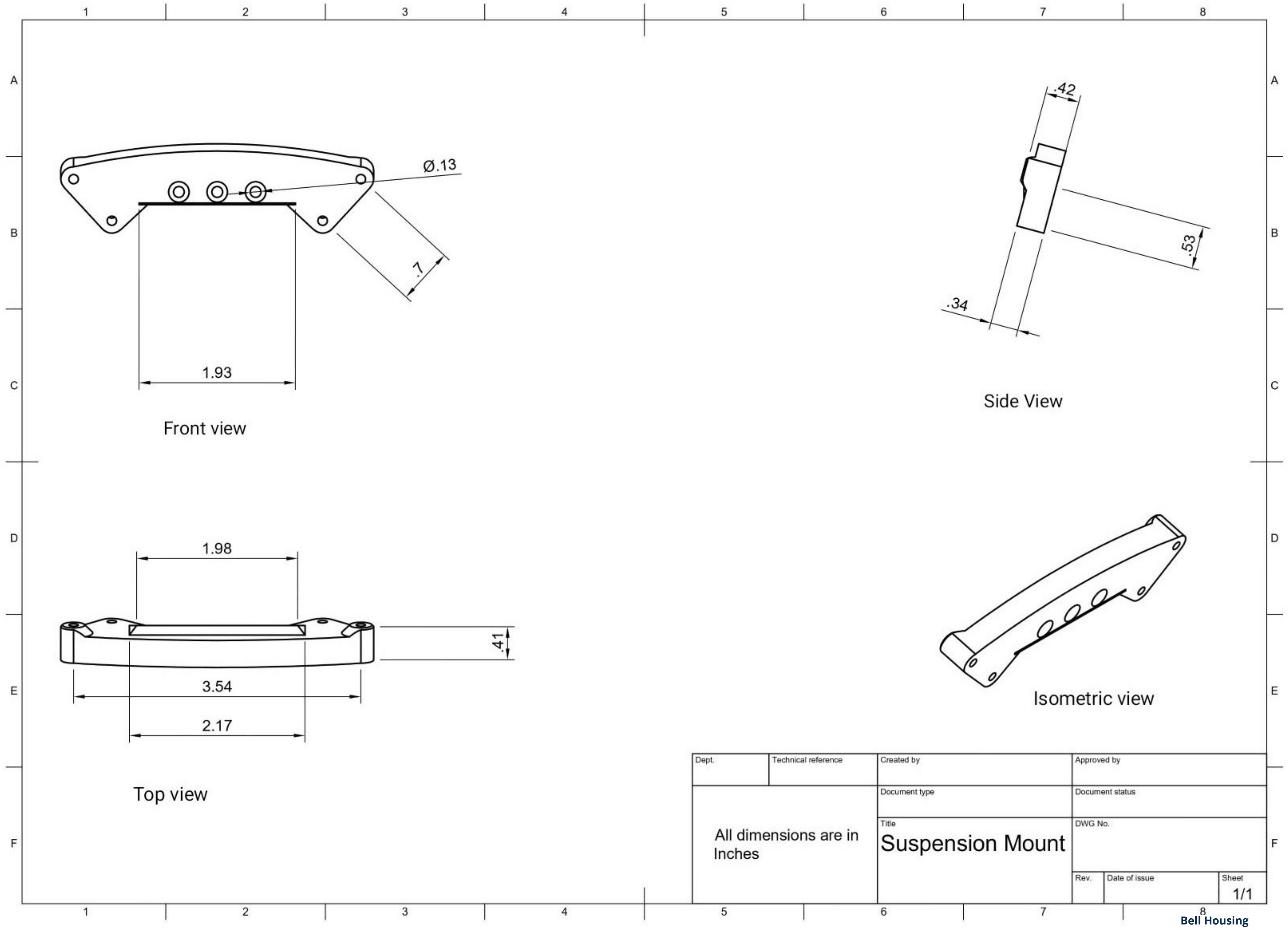
The figure shows the differential gear box in different views for better understanding. The differential gear box houses the main driving bevel gear arrangement. It has a opening to hold the 12x24x6 mm bearing for the motor link and two openings respectively for the right and left axle bearing of dimension 15x28x7mm. It also acts as the support for the upper control arm. While printing 60% infill was used to achieve desired strength and finish.

Steering Knuckle



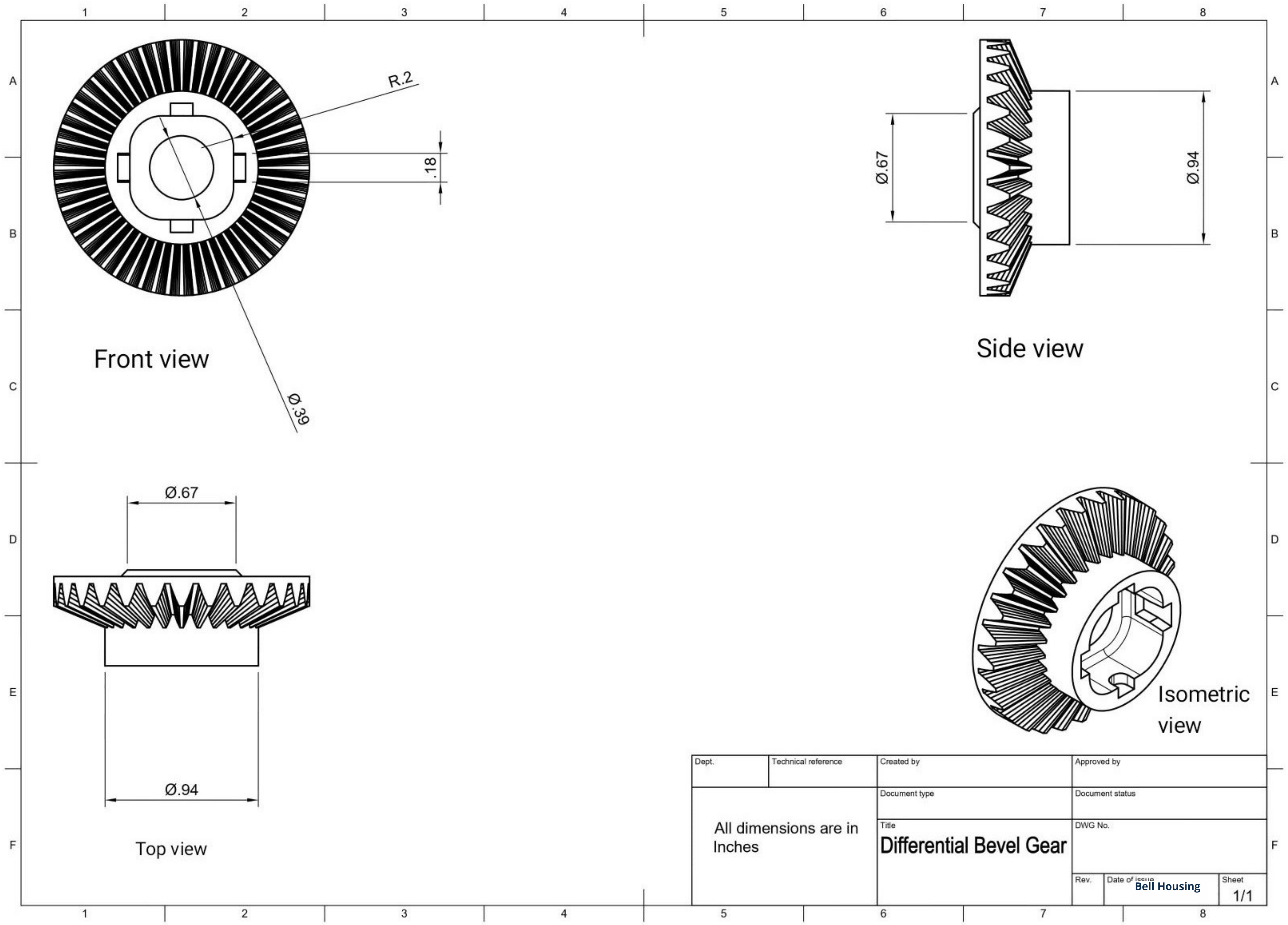
The figure shows the steering knuckle in different views for better understanding. The knuckle has provision to house the wheel hub with an opening of dimension 0.606in. The knuckle has links to the steering arms at the front. The infill was kept at 60% to have desired strength to handle impact.

Suspension Mount



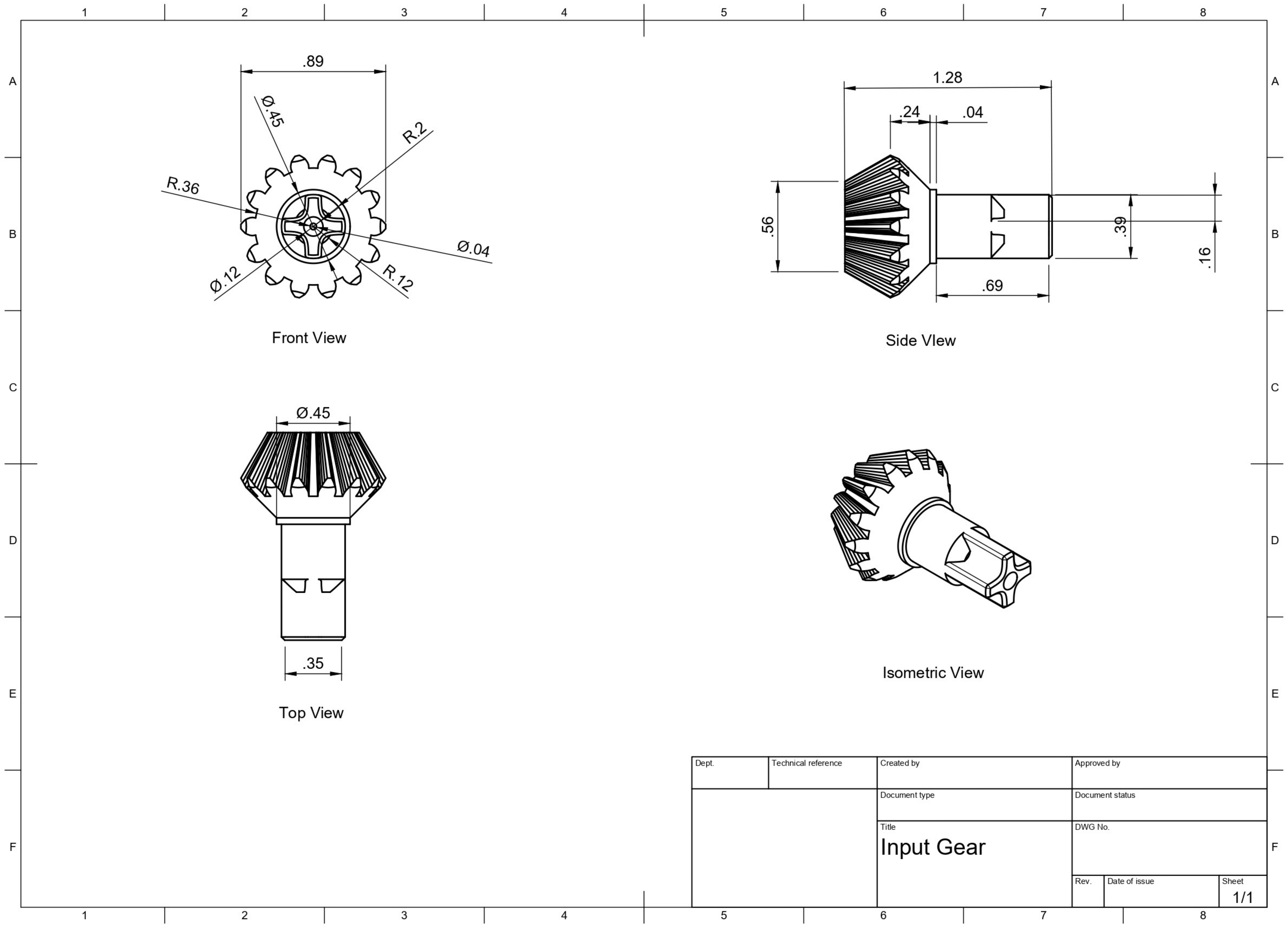
The shock mount provides the suspension a pair which further creates a link between the suspension mount and the lower control arm in itself. It is mounted over the bevel gear which lives the axles and gear undisturbed. 3.54x1.93x0.41 inches, dimensions of the suspension mount provide the shock a better alignment area and efficient free path for the moments of the shock. The suspension mount absorbs the shocks given by the shock linkage during the run of the RC car and provides firm support to the shock by not bothering the chassis of the RC car.

Bevel Gear - Output



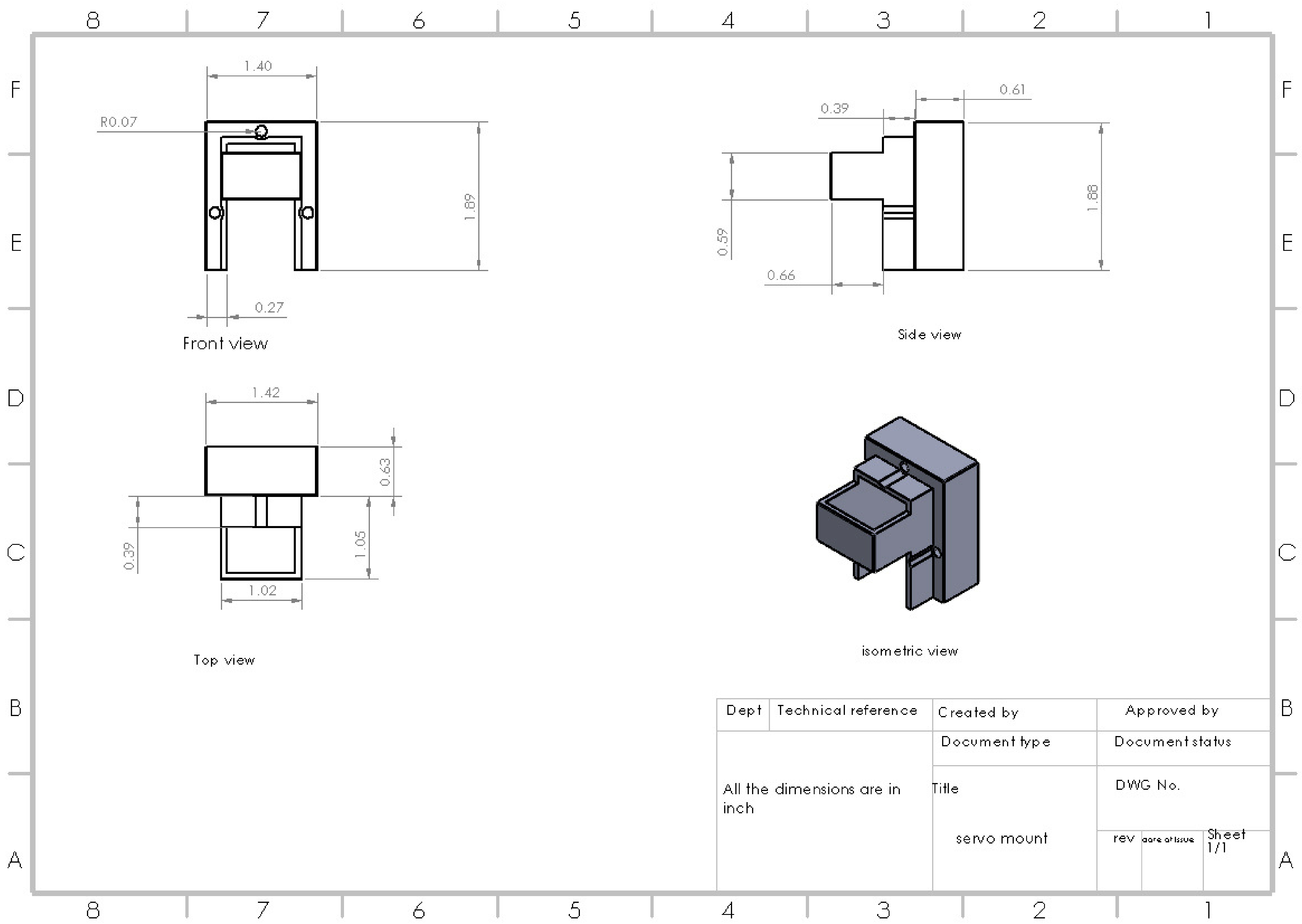
The figure shows the output gear in different views for better understanding. This gear has 28 teeth in accordance to 14 teeth in the input gear so as to achieve 1:2 transmission ratio. The internal diameter of the gear in 0.39in with provision to lock the bell housing of desired dimension. The infill was kept at 80% to have good strength and avoid lags in transmission.

Bevel Gear - Input



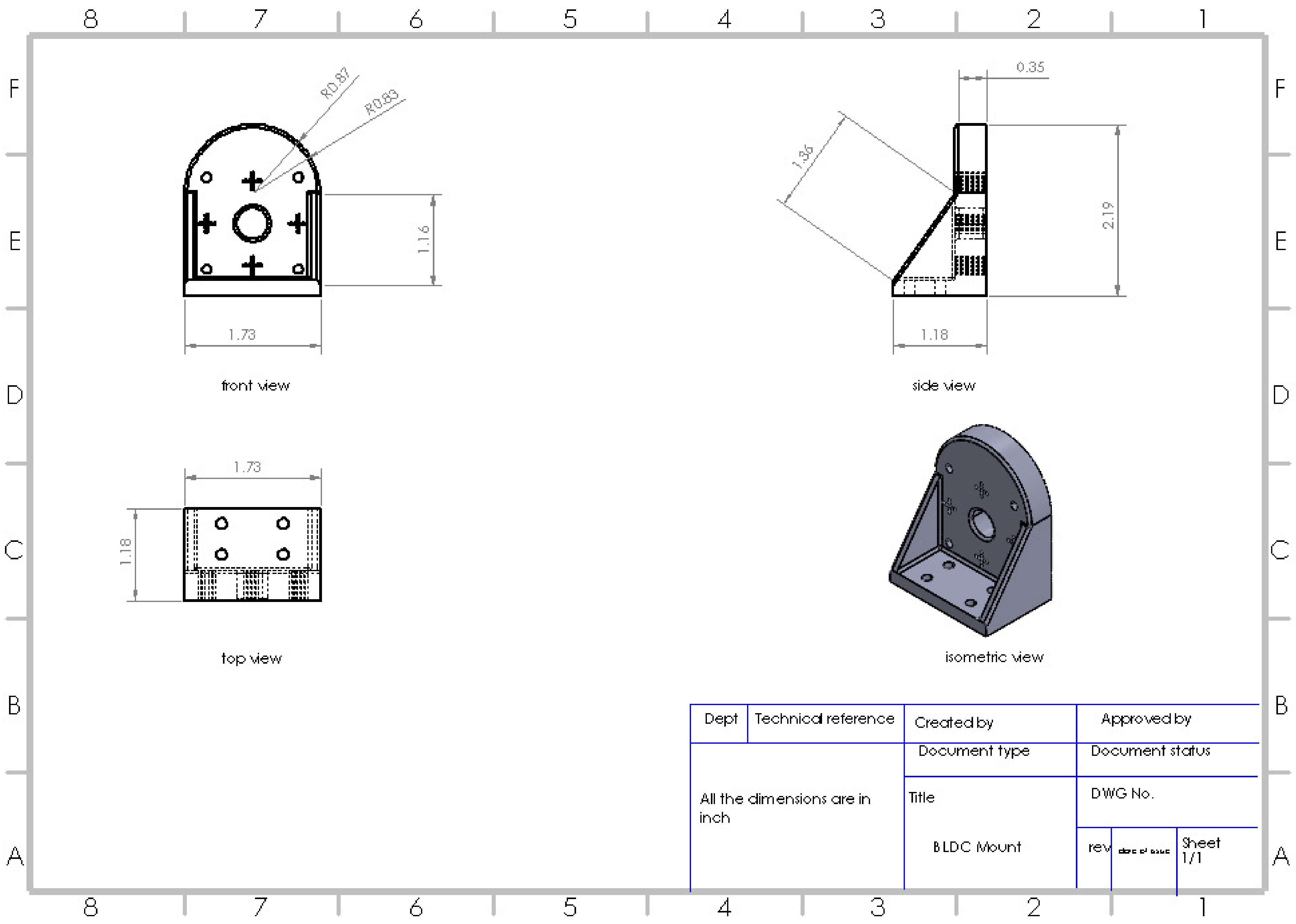
The figure shows the output gear in different views for better understanding. This gear has 14 teeth in accordance to 18 teeth in the output gear so as to achieve 1:2 transmission ratio. The internal diameter of the gear is 0.66in with provision to lock the motor shaft of 5mm dimension. The infill was kept at 80% to have good strength and avoid lags in transmission.

Servo Mount



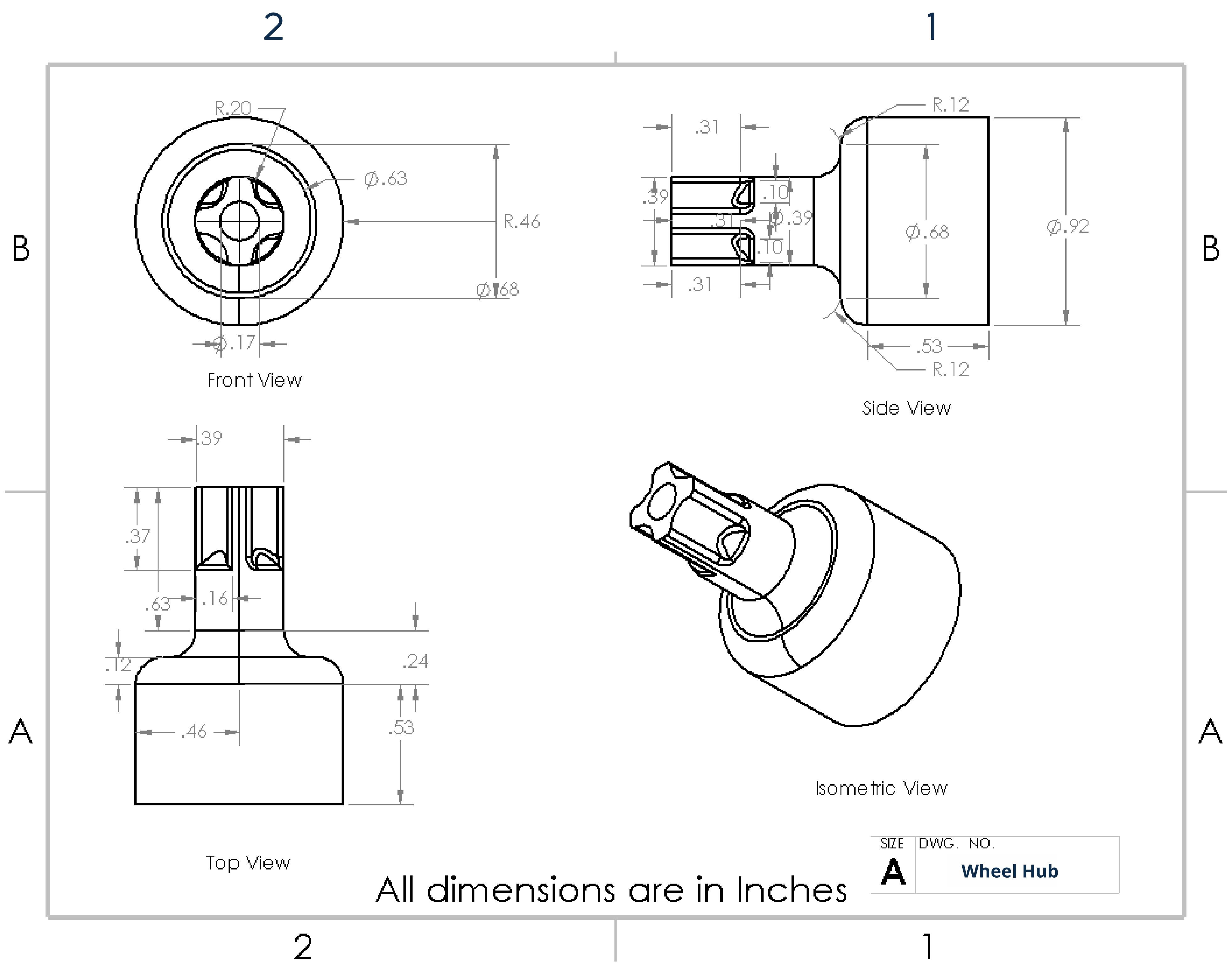
The two **1.88x1.66x0.27** inches servo mount provides firm support to the positions of the servo motors. Allows easy connections of the servo motor to the steering linkages and the Arduino UNO R3 broad without its movement during the run of the RC car.

BLDC Motor Mount



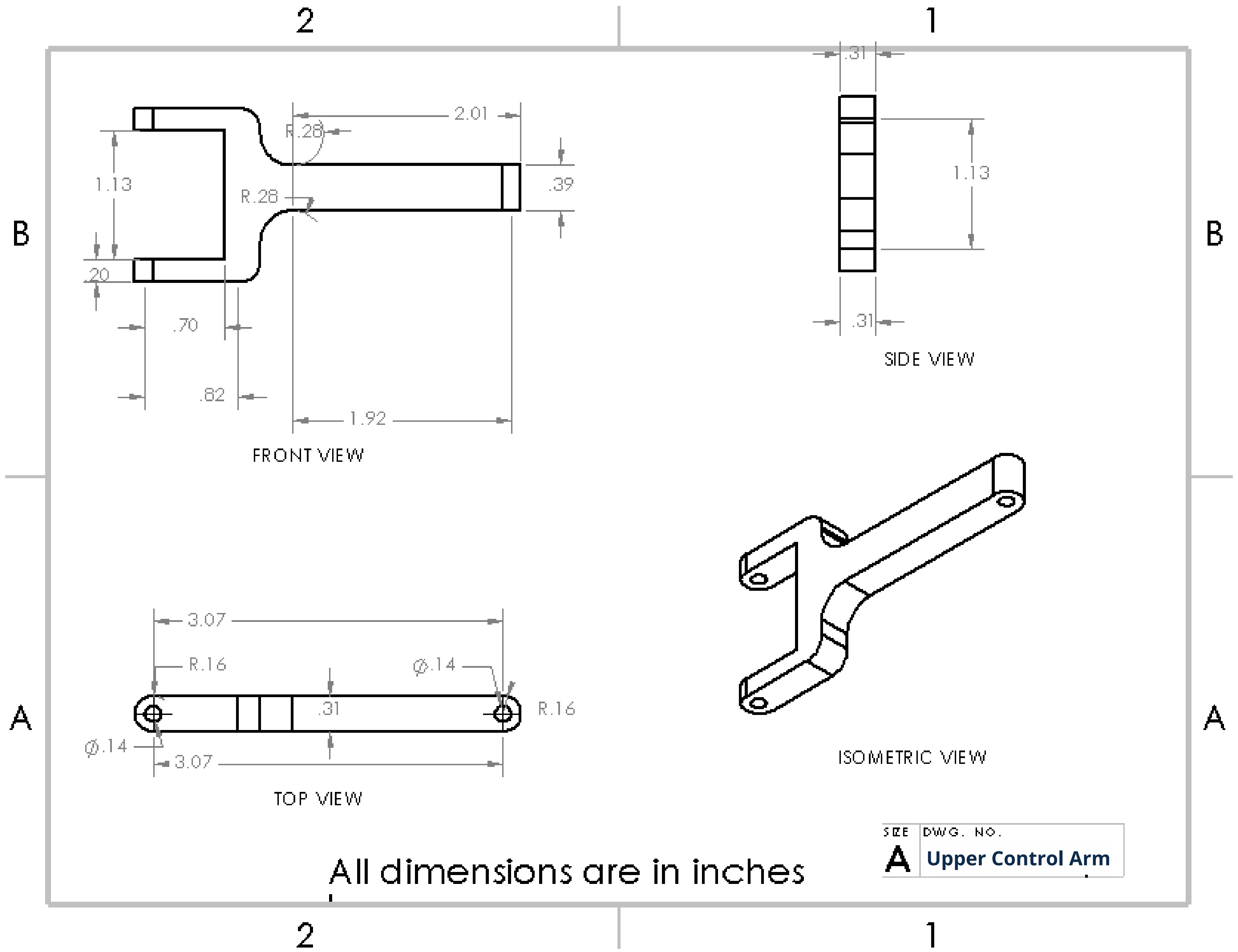
The 2.19x1.18x0.35 inches BLDC motor mount is placed over the front and rear chassis giving the BLDC motor a fixed position in the RC car. The 0.2-inch hole allows the motor shaft to connect the gear perpendicular to the bell housing and 0.06 inch small holes allow the motor to fix itself firmly with the mount. This mount absorbs the vibrations created by the BLDC motor and allows the RC car to run efficiently.

Wheel Hub



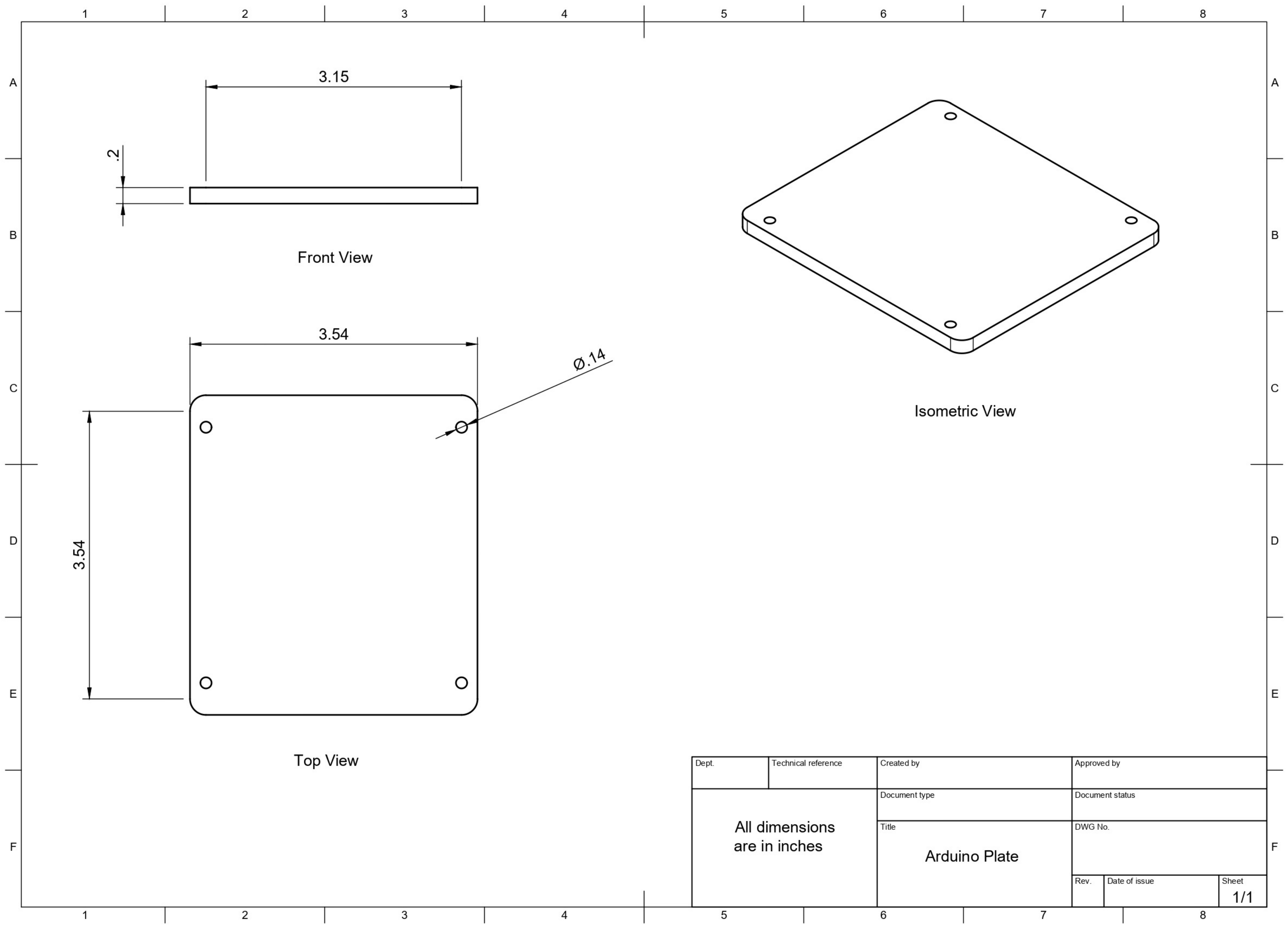
The figure shows the wheel hub in different views for better understanding. The wheel hub connects the axle to the wheels and helps run the wheels. The base length of the hub is 0.53in and exterior length is 0.63in. The base diameter is 0.92in and in exterior part the outer diameter is 0.40in and inner diameter is 0.17in. The infill was given at 80% to achieve required strength to handle impacts in the course.

Upper Control Arm



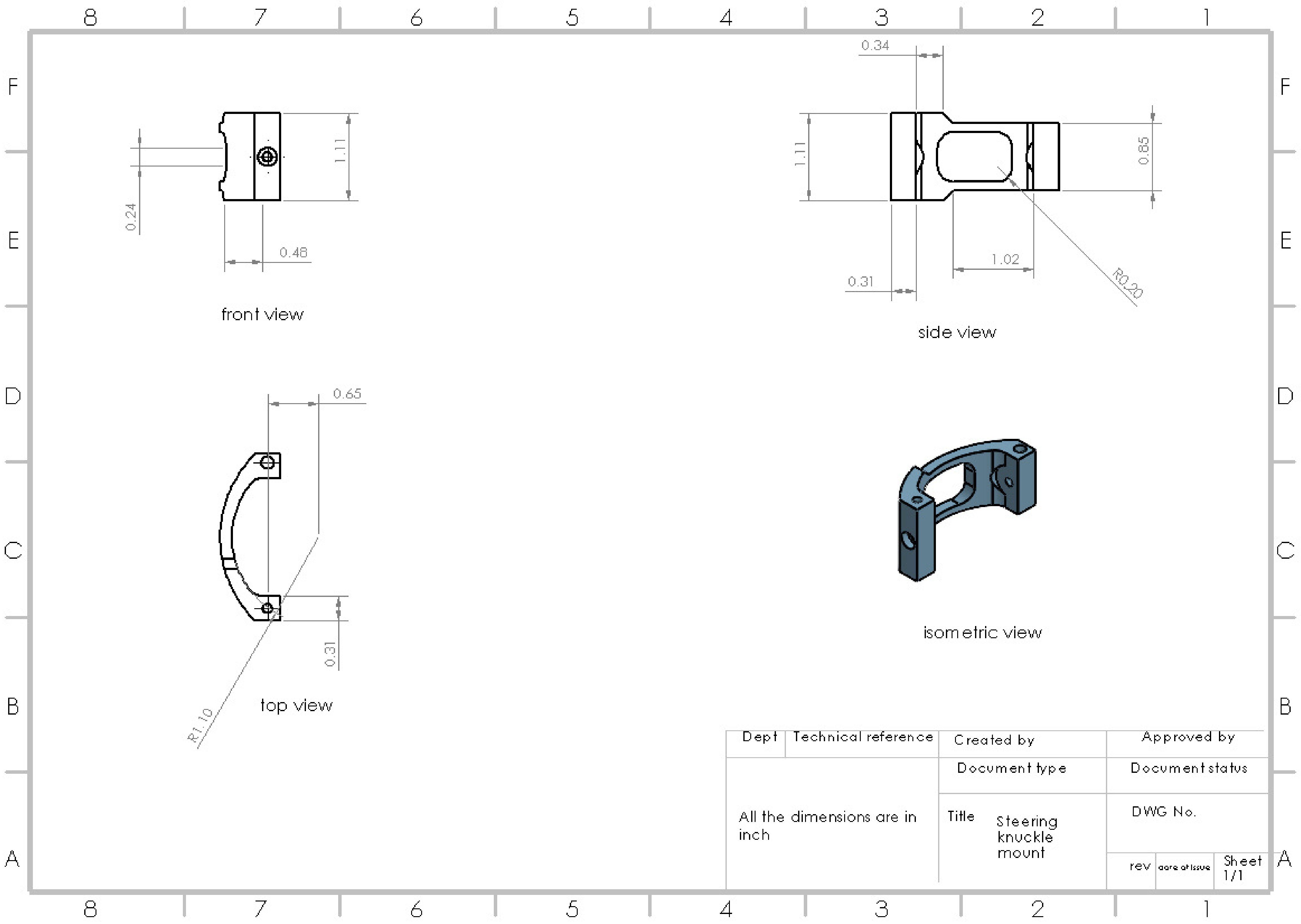
The four upper control arms are implemented in the RC car to give flexibility to the assembly part of the front post and the rear post giving the wheels an unhindered attachment with the posts. These act as a connecting bridge between the suspension mount and the steering knuckle mount in the front post. It holds the steering knuckle mount firmly during the run of the RC car providing it the strength and support to absorb the vibrations generated by the movements of the wheels.

Arduino Plate



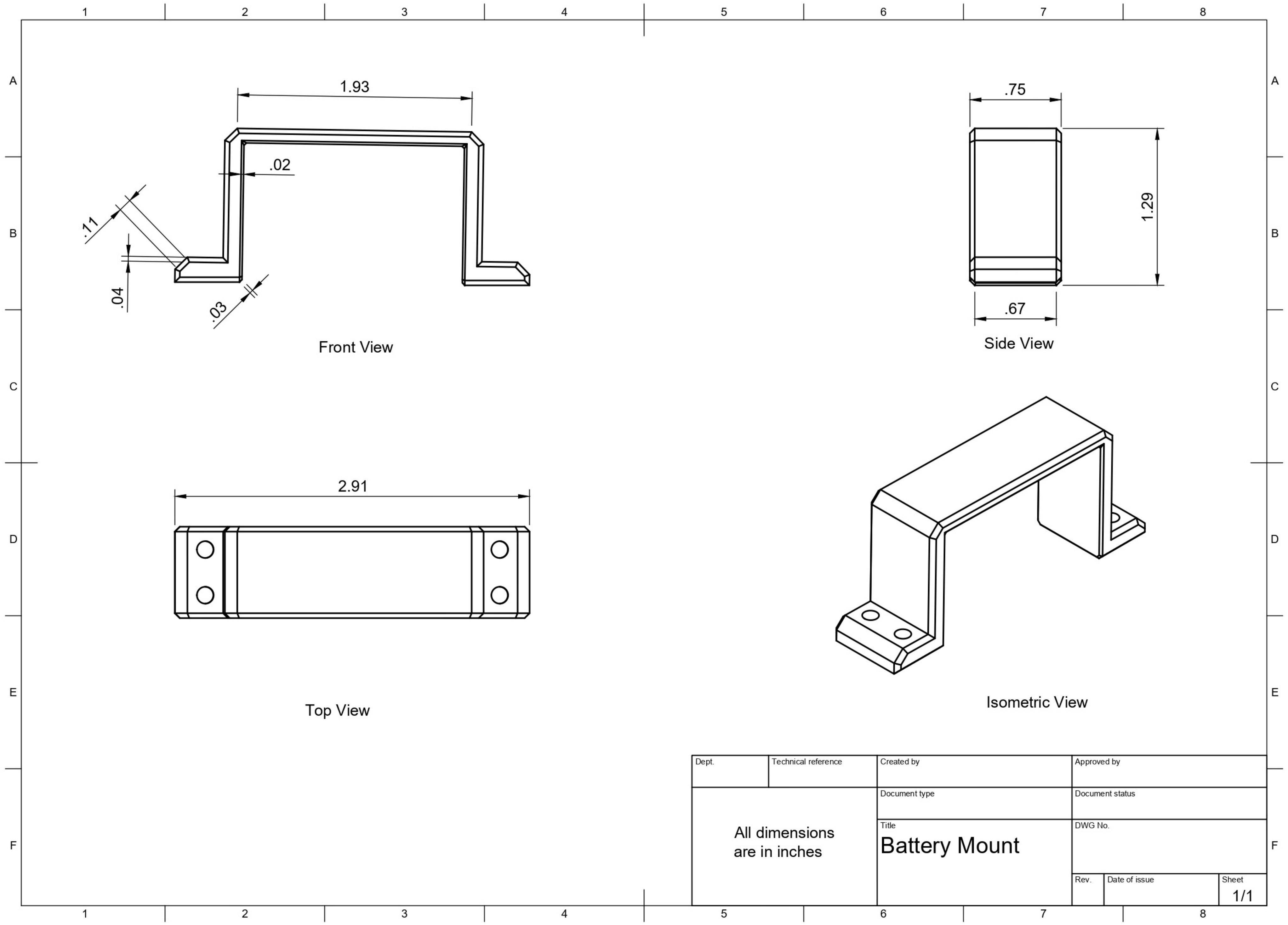
The 3.54x3.54 inches Arduino plate provides a static current free platform to the Arduino UNO R3 board though it is mounted near to the Lippo battery. This plate gives an easily available space to the Arduino board for its connections to the ESCs, receiver, servo motors. It offers a safety mount to the delicate analog, power, and digital pin ranges, microchips, USB jack of the Arduino UNO R3 board.

Steering Knuckle Mount



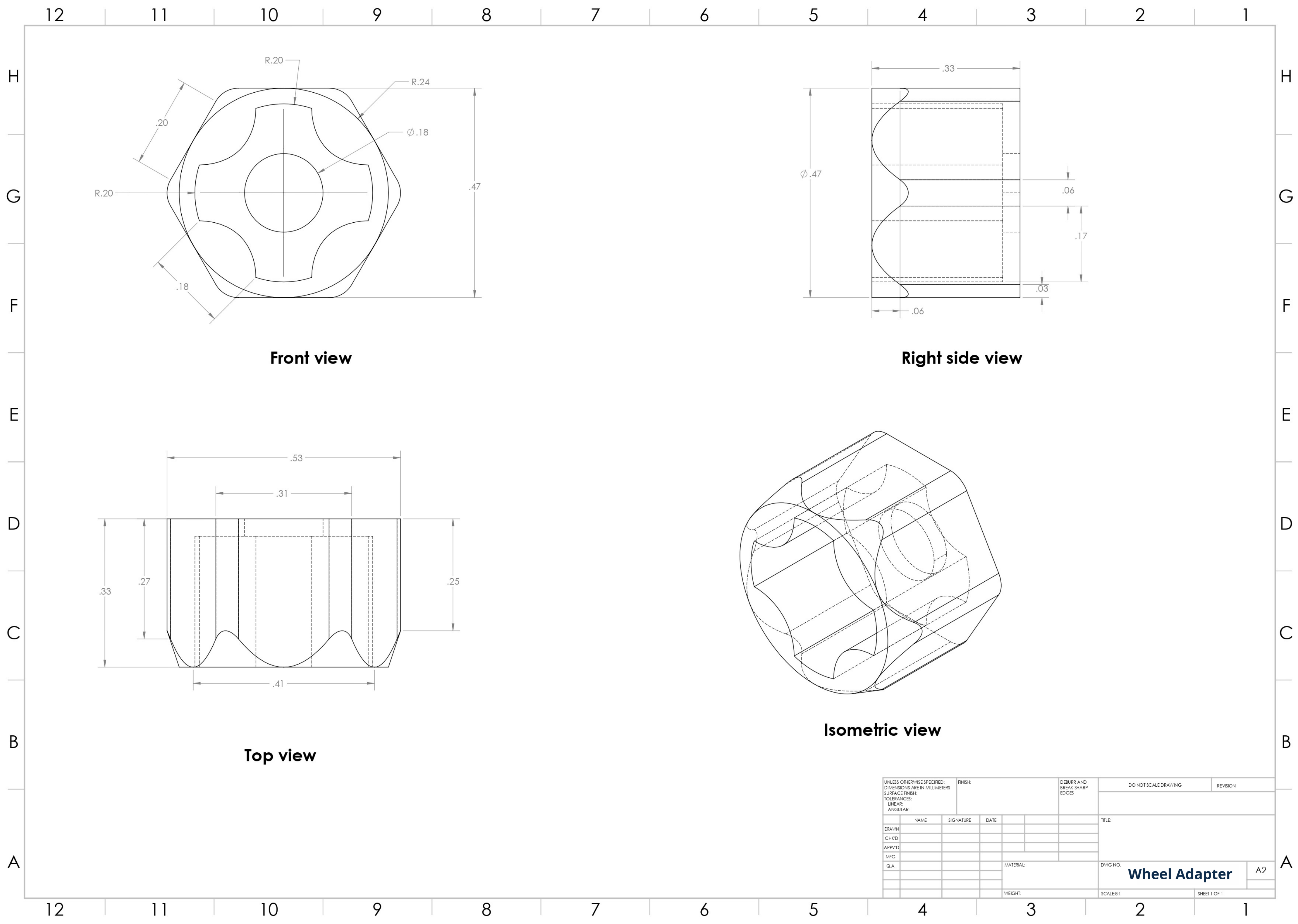
The steering knuckle mount connects the steering linkages and the axles efficiently by providing the wheels an unbothered degree of freedom. These mounts give a wide extension to the steering linkages for their vivid and smooth movements. These mounts are attached between the upper control arm and the lower control arm providing a helping extend to the smooth and stable performance of the ball bearing as well.

Battery Mount



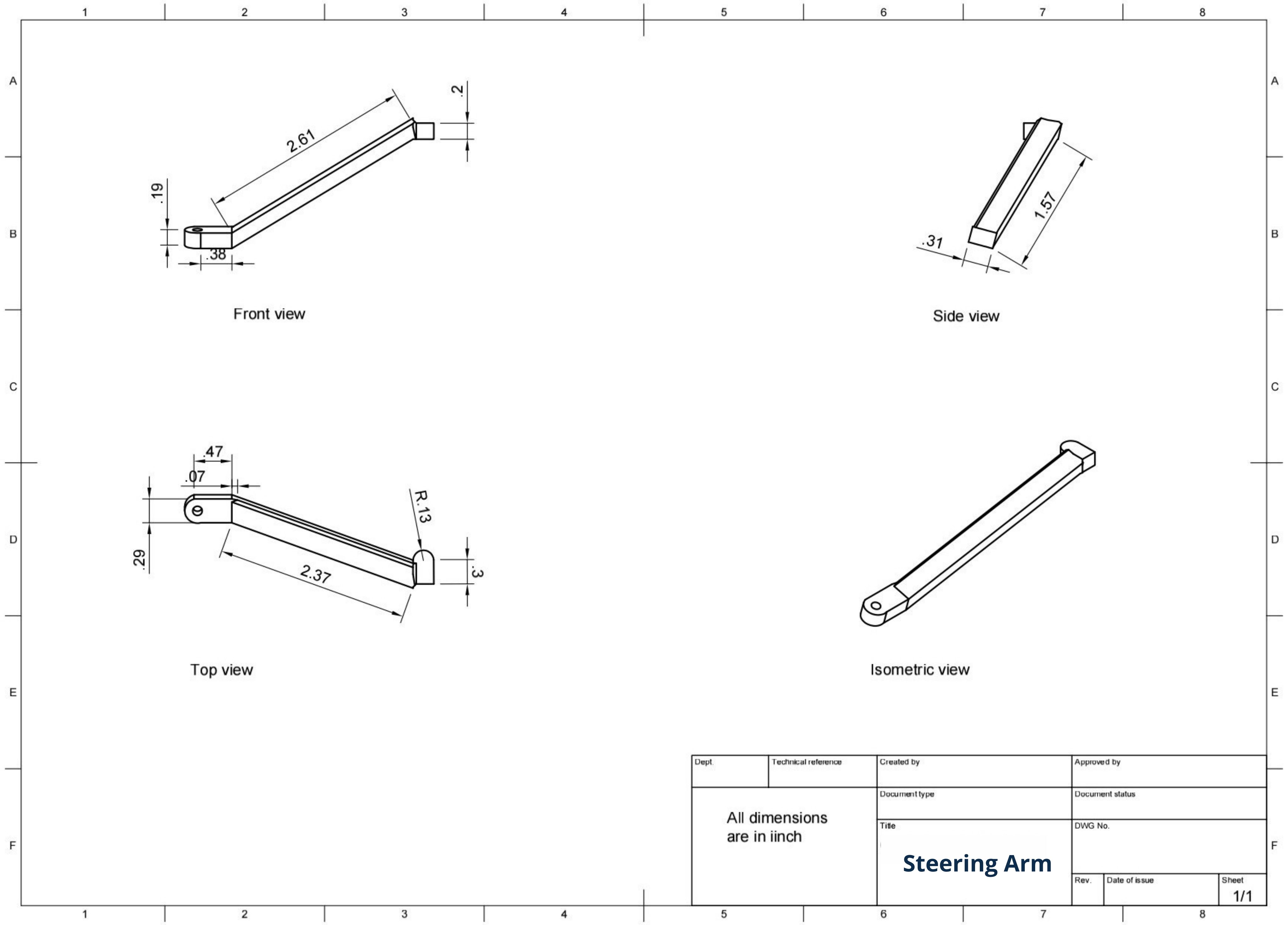
The battery mount was used to provide a firm fixed support for the battery. This helps the battery to be stable during the run of the RC car . This battery mount also provides a flat surface for arduino plate keeping it safe from static current. The battery mount is mounted in the central of the RC car over the central chassis.

Wheel Adapter



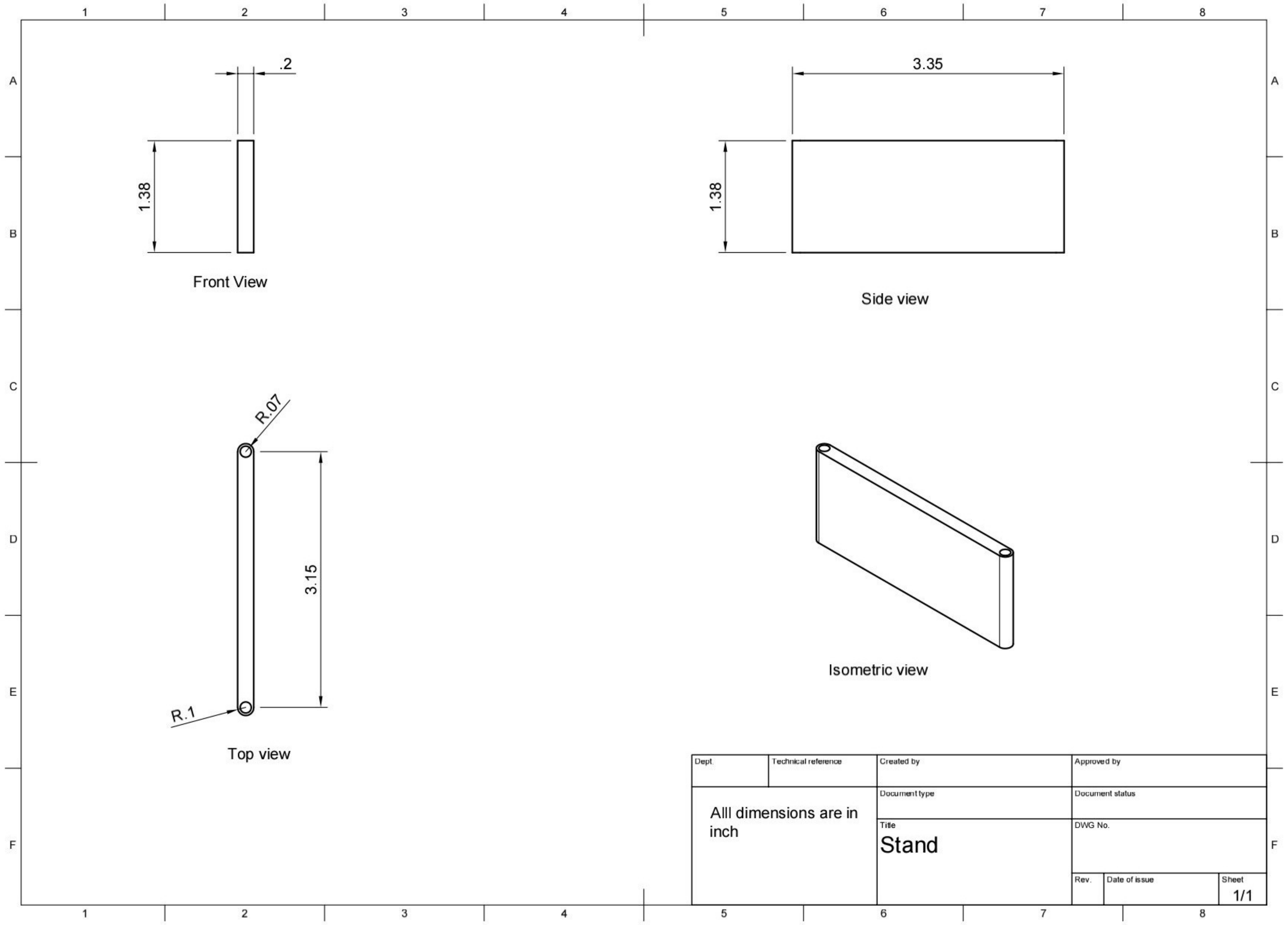
The Wheel Adapter widens the wheelbase and makes the driving more stable.

Steering Arm



The steering arm provides linkage between the servo motor and steering knuckle so as to change the directions of the RC car according to our needs.

Battery Stand



The battery stand is mounted over the central chassis, this provides a fixed position to the Lipo battery. It also gives an undisturbed alignment and connection to the ESCs. The battery stand helps the central chassis in upholding the weight of the Lippo battery in a well distributive manner.

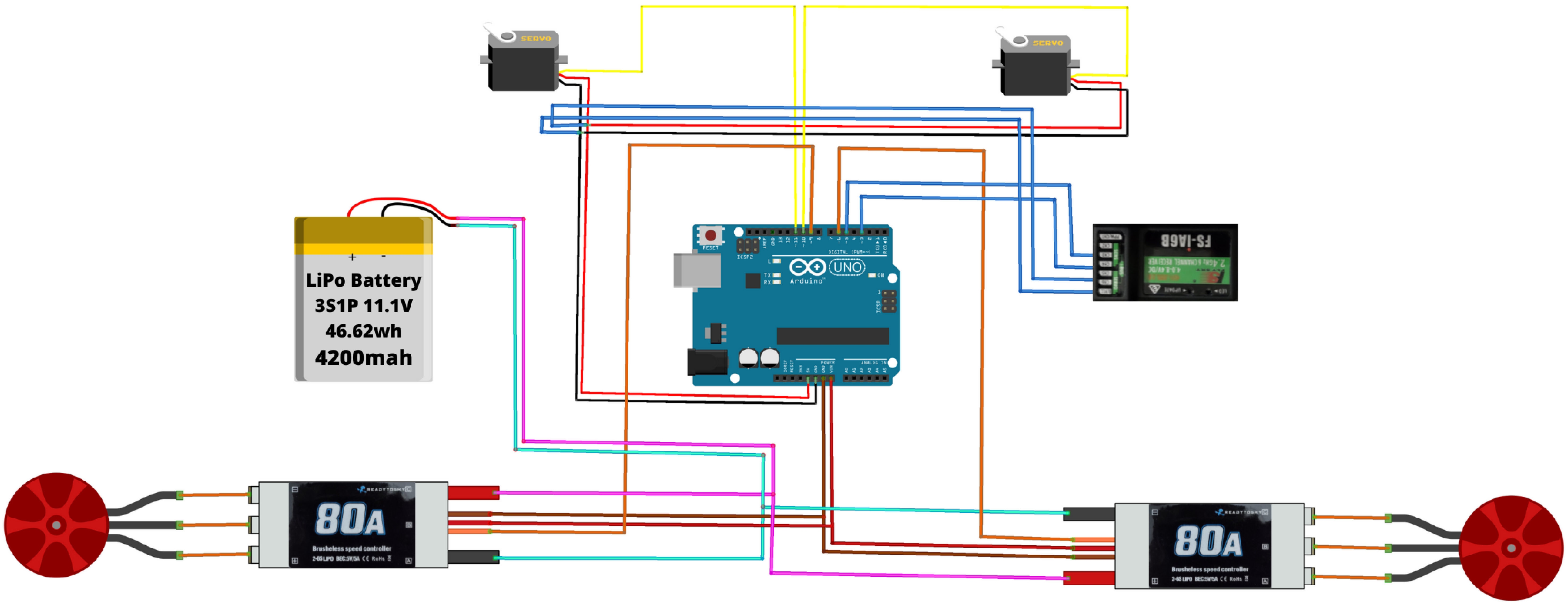
Construction of the Device

The drivetrain is made up of three major sub-assemblies :

- The first sub assembly consists of mounts, motors. Mounts keeps the brushless DC motor, Servo motor battery Arduino board stationary inside the body of the car.
- The second sub-assembly is the front differential. The differential contains bevel gears , knuckle joints. The steering is being controlled by servo motor, that can turn the car wheels in either of the directions.
- The third sub-assembly is the rear differential. The rear differential is very similar to the front differential.

Constructing this device was not an easy task. This project has many moving parts and sub-assemblies; all of which have to work together to make a running/driving car. Therefore, not only does each individual part have to be accurate, where each part is located is just as important. All the above assembly parts were designed in Fusion 360 and Solid works and then 3D printed.

Electronic System



Electronic System

An FS controller consisting of FS-iA6B receiver having maximum frequency range of 2.475 GHz coupled with Wp-1625-Brushed ESCs were used to control the stability and agility of the RC car by carefully controlling the 790KV BLDC motor providing the necessary thrust of 1650 g . Tower-Pro MG995 Sem-Metal Gear Servo Motors are highspeed servo motors with a mighty torque of 10 kg/cm were used in the RC car , these High-Speed Digital Servo motor equips sophisticated internal circuitry that provides holding power, and faster updates in response to external forces using Arduino UNO R3 board having Microcontroller Chip - ATmega328 . Power source used was the 4200mAh Bonka Lithium Polymer battery having a voltage of 11.1V which is designed to have a Max Continuous Discharge of 35C and Max Burst Discharge of 70C.

Electronic System

Selection of Electronic Components

PART NAME	QUANTITY	DIMENSIONS (in cm)
BLDC MOTORS	2	8 × 5 × 5
ELECTRONIC SPEED CONTROLLER	2	13 × 9 × 2
TRANSMITTER	1	17.4 x 8.9 x 19
RECEIVER	1	4.7 x 2.62 x 1.5
SERVO MOTORS	2	4.05 x 2 x 4.4
LI-POLYMER BATTERY	1	13 x 4 x 2
ARDUINO UNO R3	1	7.5 x 5.4 x 1.2

BLDC Motor

Brushless DC Motors are used as they are more efficient and more power-dense than brushed motors. Here, the DYS High-Quality **D3548-6 790 KV brushless outrunner motor** is specifically made to power Multirotors. It is a 790kV motor. It provides high performance, superpower, and brilliant efficiency. The motor comes with 3mm banana male connector attached which can be directly connected with 80A ESC without any soldering requirement. This is a low price and excellent quality Brushless Motor. It comes with Bullet Connectors already soldered.

Specifications :

- Battery: 3~5 Cell /11.1~18.5V
- RPM: 790kv
- Max current: 40A
- No load current: 1.8A
- Max power: 715W
- Internal resistance: 0.040 ohm
- Diameter of shaft: 5mm
- Dimensions: 8×5×5 cm
- Weight: 159g (including connectors)

Features :

- The steel design is capable of withstanding competitive conditions.
- Offers great performance and value for money.
- Lightweight design makes them suitable for a wide range of Multirotor Frames.

Servo Motors

Servo Motor are used to steer and operate the throttle on the RC car. They are very accurate in following the directions from the transmitter thus making the servo very precise in controlling the motion. We have fitted two servos on the RC car. One will be for the throttle and the other one will be for steering. The performance of a servo is based on the control signal called pulsed signals that tell the motor where to go. Its plug has three wires- power supply, ground and control signals usually following colour codes: RED – Positive, Brown – Negative & Orange – Signal. While the power supply wires provide voltage to the plug and the ground does what is supposed to do, the control signal is the wire that communicates the messages to motor and tells it where to go.

Specifications :

- Model: MG995
- Weight: 55 gm
- Gear Type: Semi-Metal
- Operating Speed @6.6V - 0.16sec/60°
- Operating voltage: 4.8V~ 7.2V
- Dimensions (mm) - 40.5 x 20 x 44

Features :

- The TowerPro MG995 High-Speed Digital Servo Motor rotates 90° in each direction making it 180° servo motor. It is a Digital Servo Motor that receives and processes PWM signal faster and better. It equips sophisticated internal circuitry that provides good torque, holding power, and faster updates in response to external forces. These TowerPro MG995 Sem-Metal Gear Servo Motors are highspeed servo motors with a mighty torque of 10 kg/cm.

Electronic Speed Controller (ESC)

The RC cars' servo motors contain electronic circuits. The ESC's purpose is to adjust or alter the speed, control, and so operate as the dynamic brake. The first wire is plugged or connected to the main battery of your RC car. The second wire consists of a servo wire that connects with the receiver's throttle channel and for operating the motor, the third wire is used.

Specifications :

- Model: Readytosky 80A ESC Brushless
- BEC: 5A/5V (Linear Mode)
- Voltage Range: 2-6S LiPoly
- Constant Current: 80A
- Burst Current: 100A
- Throttle signal refresh rate (Hz): 50 - 432

Features :

- Water-proof and dust-proof, suitable for all-weather condition races.
- Great current endurance capability.
- Water-proof and dust-proof, suitable for all-weather condition races.

Lithium-Polymer Battery

LiPo batteries are used having the advantages of small and light, high capacity and high discharge rate.

Specifications :

- Model: BONKA 4200/3S1P-35C
- Max Burst Discharge: 70C(154A)
- Max. Continuous Discharge: 35C
- Charge Rate: 1-3C
- Balance Plug: JST-XH balance plug
- Dimensions(in mm) : 130x40x20 (LxWxH)

Features :

- The 4200mAh Bonka Lithium Polymer battery has a voltage of 11.1V.
- The Bonka LiPo battery is integrated with a JST-XH balance plug and T discharge plug
- It is designed to have a Max Continuous Discharge of 35C and Max Burst Discharge of 70C.
- The 11.1V 4200mAh Bonka LiPo battery packs are equipped with heavy duty discharge leads that is highly essential to minimize the resistance and sustain high current loads

Arduino Uno R3

We have used the latest third version of an Arduino board – the Arduino UNO R3. It is used as the main advantage of this board is if we make a mistake, we can change the microcontroller on the board.

Specifications :

- Microcontroller Chip - ATmega328
- Input Voltage (limit) - 6-20V
- Operating Voltage (VDC) - 5
- Flash Memory - 32 KB
- Weight (gm) - 28 (without cable), 54 (with cable)
- Dimensions in mm (LxWxH) - 75 x 54 x 12

Connections to Arduino:

- ESC 1 (BEC): Signal lead - 6 (PWM) Digital pin; Voltage lead - Vin, Power pin; Ground lead - GND, Power pin
- ESC 2 (BEC): Signal lead - 9 (PWM) Digital pin; Voltage lead - Vin, Power pin; Ground lead - GND, Power pin
- Servo 1: Signal lead - 10 (PWM) DP; Voltage lead - 5V Power pin; Ground lead - GND, Power pin
- Servo 2: Signal lead - 11 (PWM) DP; Voltage lead - 5V Power pin; Ground lead - GND, Power pin.

Transmitter - Receiver

The RC Transmitter is used here to send data to the RC Receiver by generating a modulated radio frequency carrier, while the Receiver is tuned to detect the Transmitter's carrier frequency. The accuracy of sending and receiving frequencies are usually achieved by the use of crystals. The Receiver detects data from the modulated carrier, decodes and deliveries it to the respective Servo. The model is controlled by a radio link, which means by using electromagnetic radiation.

Specifications of Transmitter :

- Band: 142
- 2.4ghz System: AFHDS 2A and AFHDS
- ANT length: 26x2 mm(dual antenna)
- Channel Order: Aileron-CH1, Elevator-CH2, Throttle-CH3, RudderCH4, Ch 5 & 6 open to assignment to other functions.

Specifications of Receiver :

- Model: FS-iA6B
- Channel: 6
- Frequency Range: 2.4055–2.475 GHz
- Band Width Number: 140
- Transmitting Power: ≤ 20 dBm.
- RF Receiver Sensitivity: 105 dBm.
- Antenna Length: 2x26 mm (dual antenna).
- Dimension: 47 x 26.2 x 15 mm
- Weight: 14.9 gm.

Features of the Transmitter :

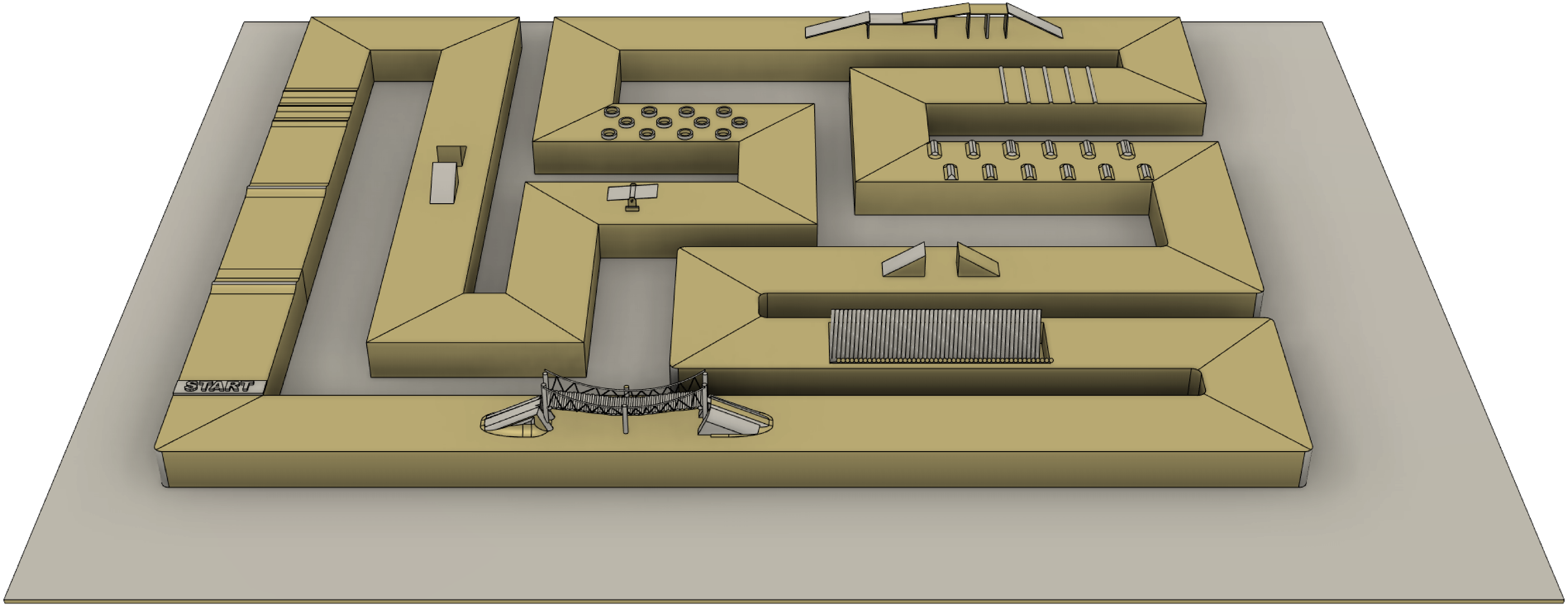
- Entry-level 6 channel 2.4GHz radio with telemetry capability.
- 20 Model Memory.
- The backlight LCD screen displays real-time transmitter and receiver voltage.

Features of the Receiver :

- This compact 6 channel receiver is great for any model using up to 6 channels and, with a range exceeding 500 meters, it can be considered to be the full range for all but the most demanding of application. The receiver has end-on connectors to enable a neat installation in tight spaces.
- This has FLY SKY FS IA6B RF 2.4GHz 6ch PPM output with iBus port receiver built in connectors which allows you to use any of the optional FlySky telemetry sensors. Dual antennas give the FS-iA6B excellent reception and interference rejection capability. With easy binding, compact dimensions, optional telemetry, and dual antennas.
- Each transmitter has a unique ID and so when binding; the receiver remembers this ID and accepts data from that transmitter only. This avoids picking up other transmitter signals and dramatically decreases inference and increases safety.

Obstacle Course

Outdoor Track



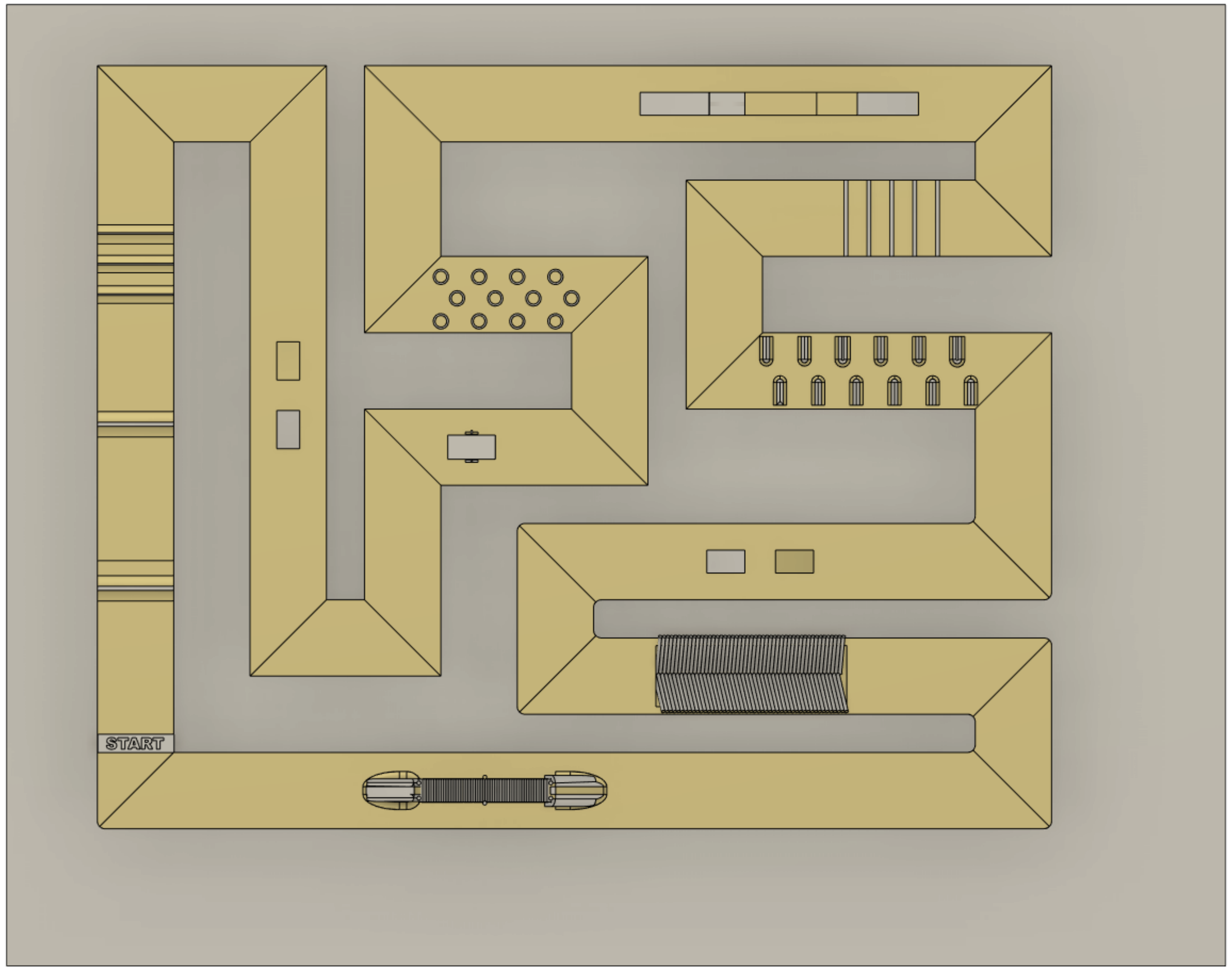


Fig. : Top View

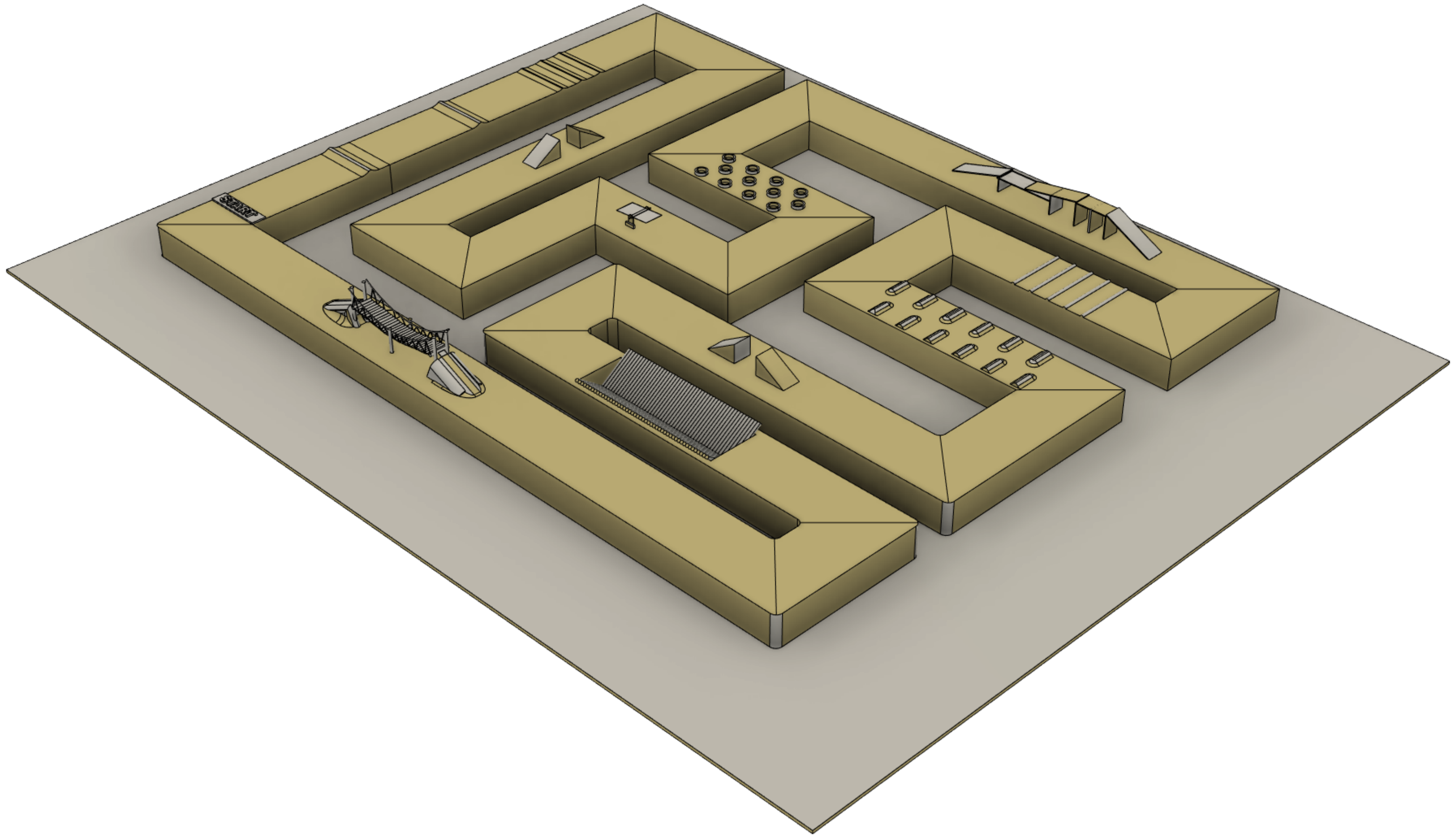


Fig. : Isometric View

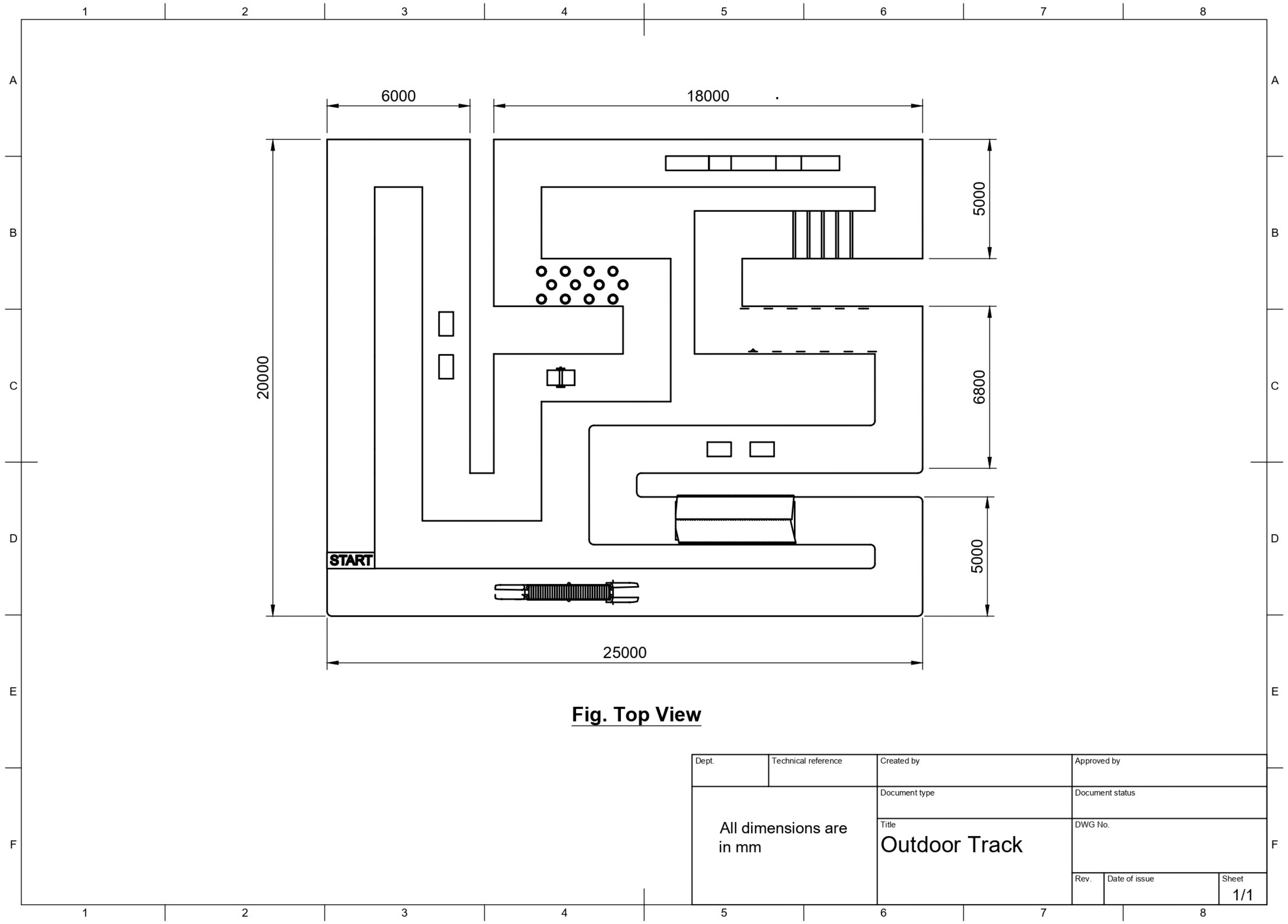


Fig. : Top View Drawing

The Outdoor Track is of the dimension 20 x 25 (m)

The entire track is based on sand - ground.

It consists of the following components :

- Suspension Bridge
- V-Bridge
- Ramp (x2)
- See-Saw Bridge
- Table-Top Bridge
- Bamboo logs speedbreakers
- Damaged Car Tires Obstacles

Suspension Bridge

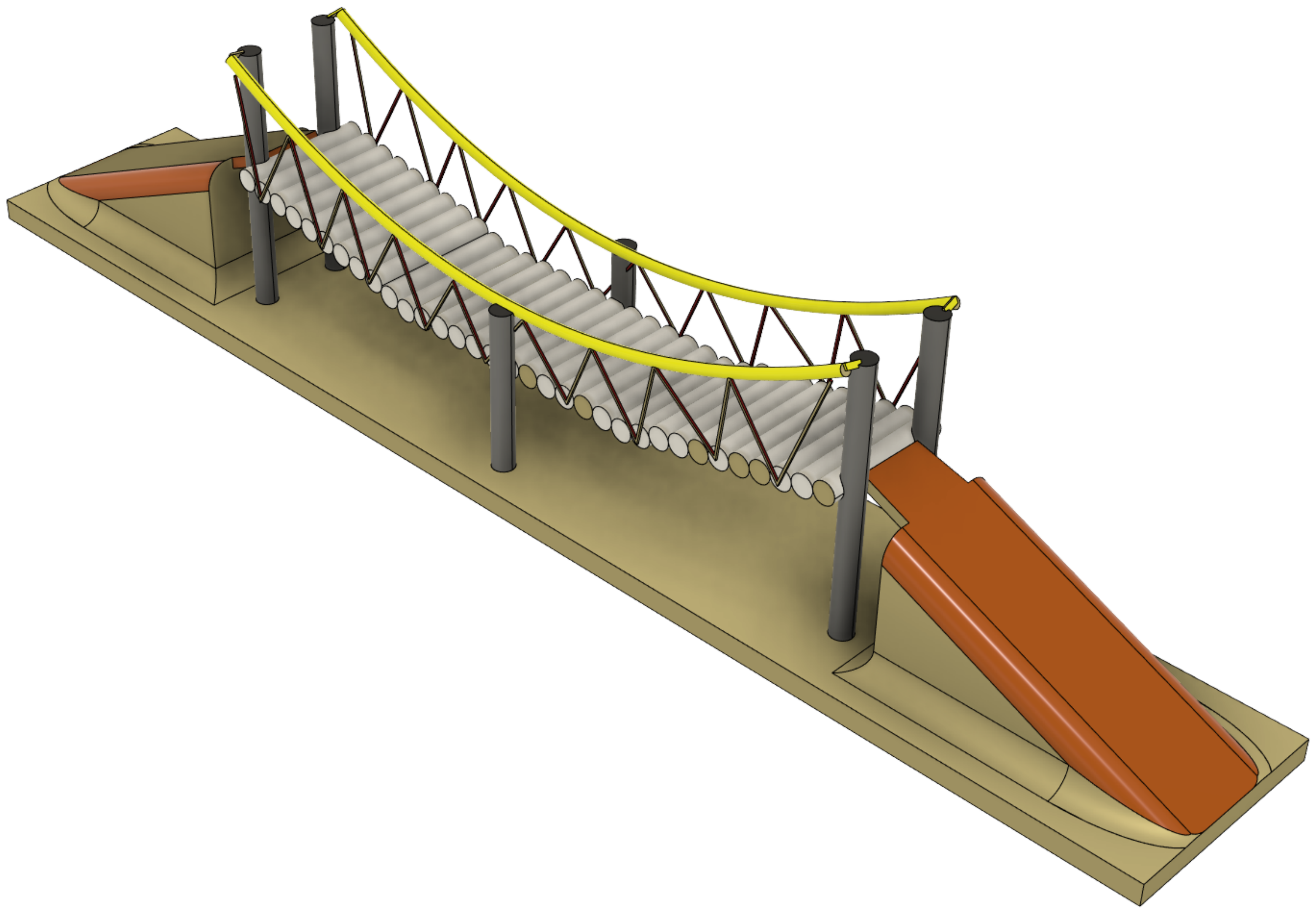


Fig. : Isometric View

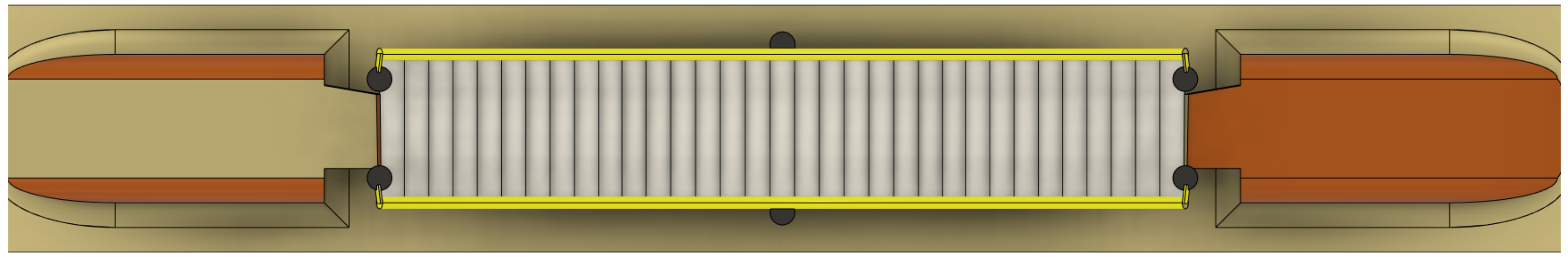


Fig. : Top View

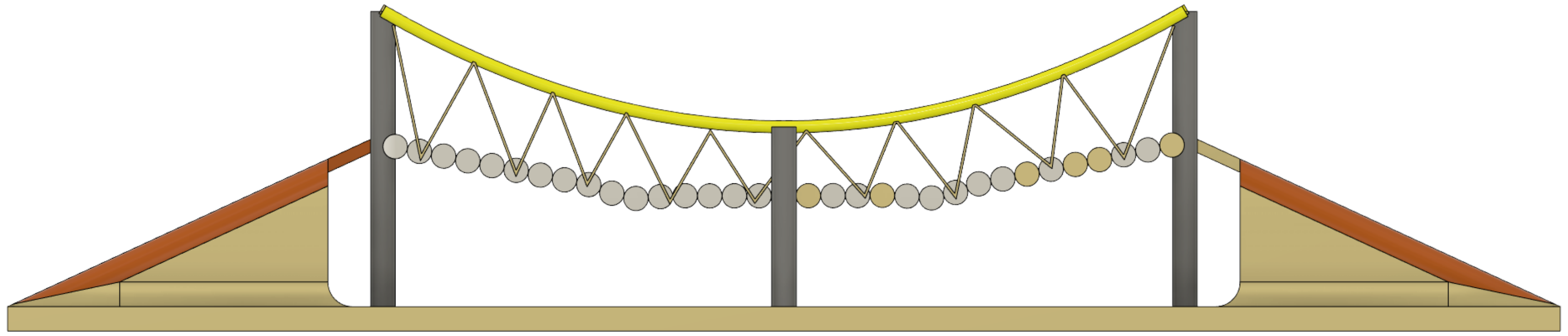


Fig. : Side View

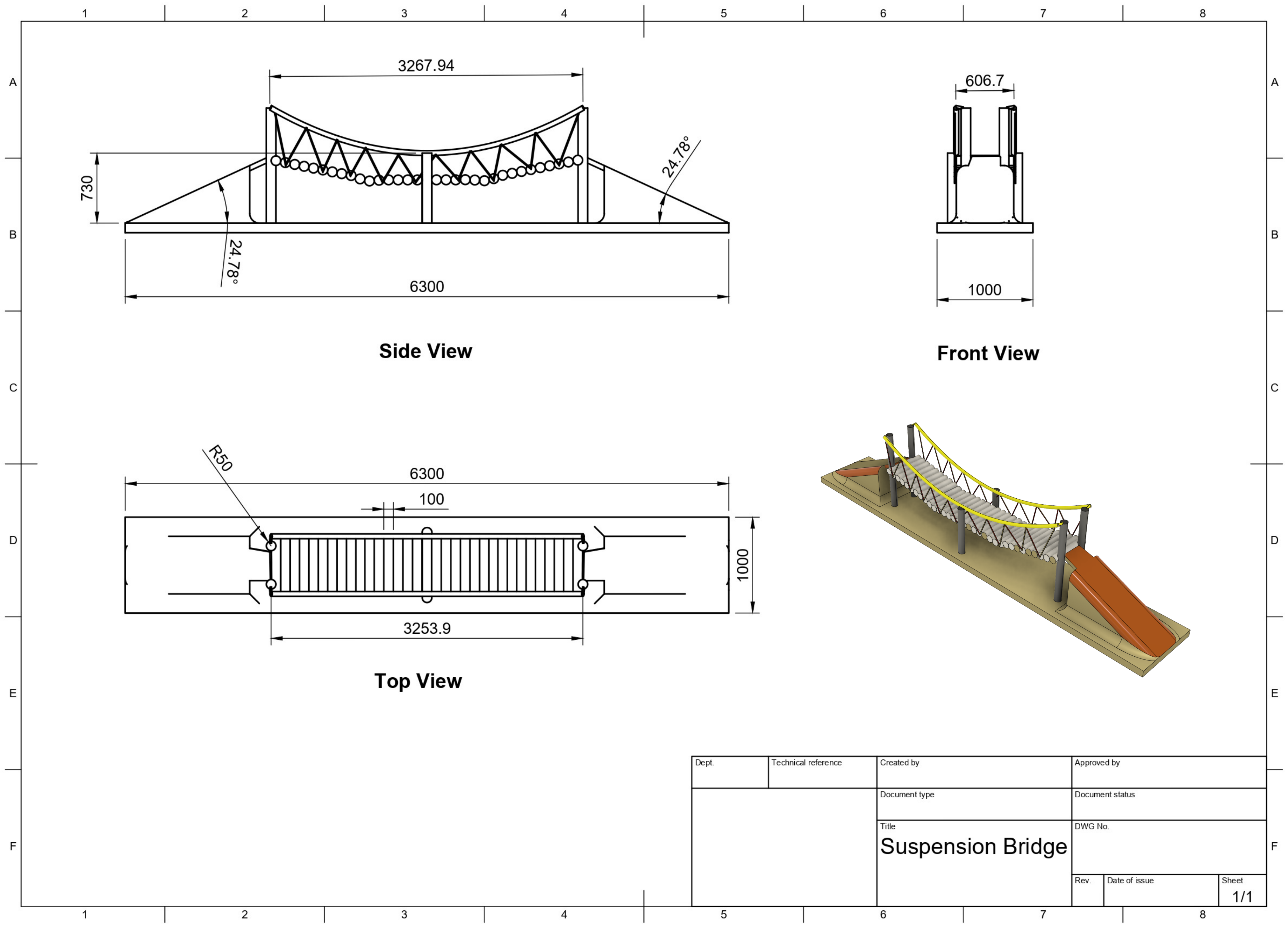


Fig. : Top View Drawing

The Suspension Bridge is made up of a pile of bamboo logs tied up by Nylon Ropes and is attached freely from one support to another just like a hanging bridge. Two inclination ramps are attached at the start & end with an angle of elevation of 24.78°. The hanging part can carry weight less than 10 kg without creating depression in the middle of the bridge.

But a support truss is added in the middle for avoiding any subsequent circumstances making the RC car move smoothly without any difficulty.

The entire length of the bridge is 6.3 metre.

SeeSaw Bridge

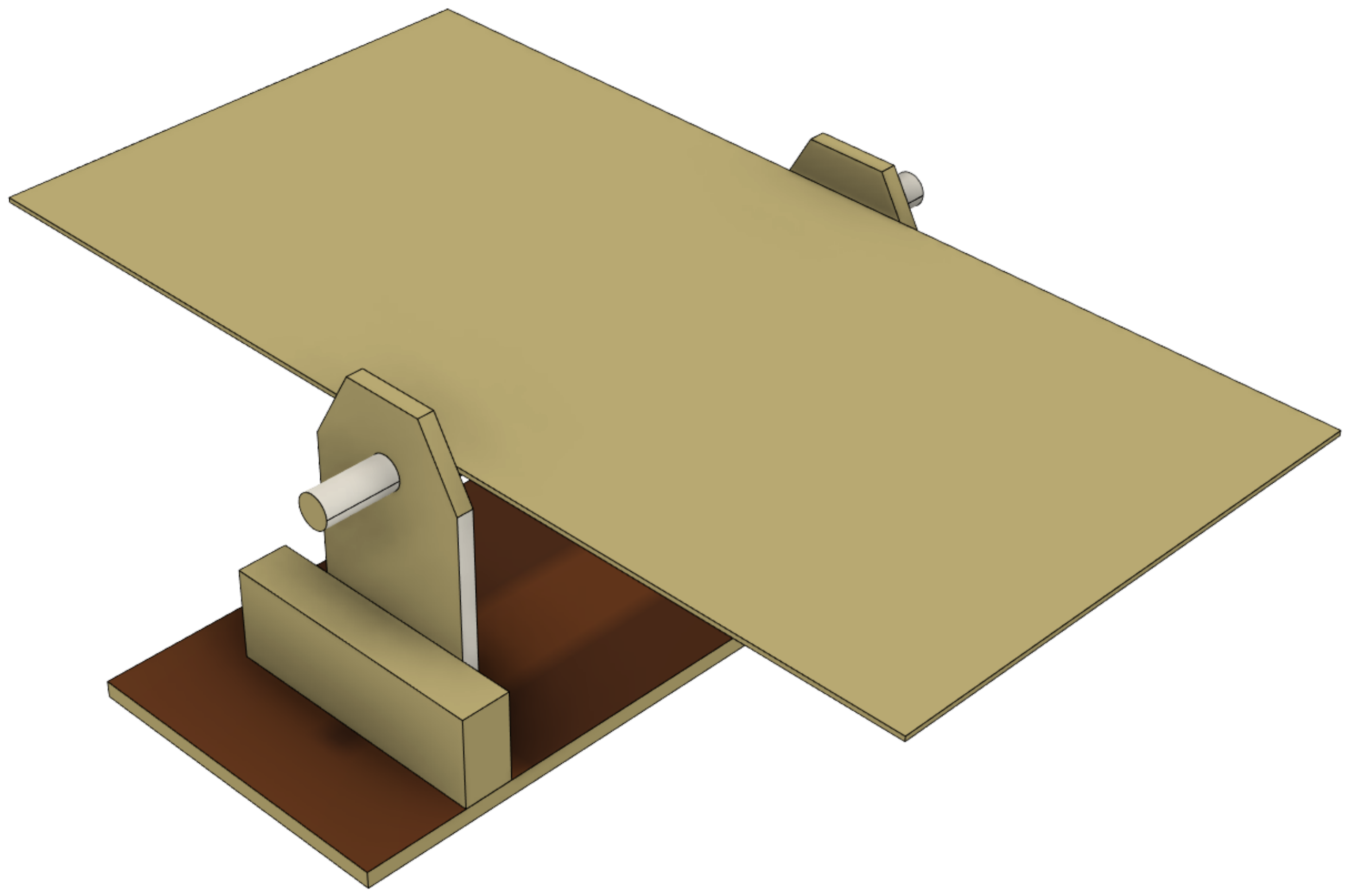


Fig. : Isometric View

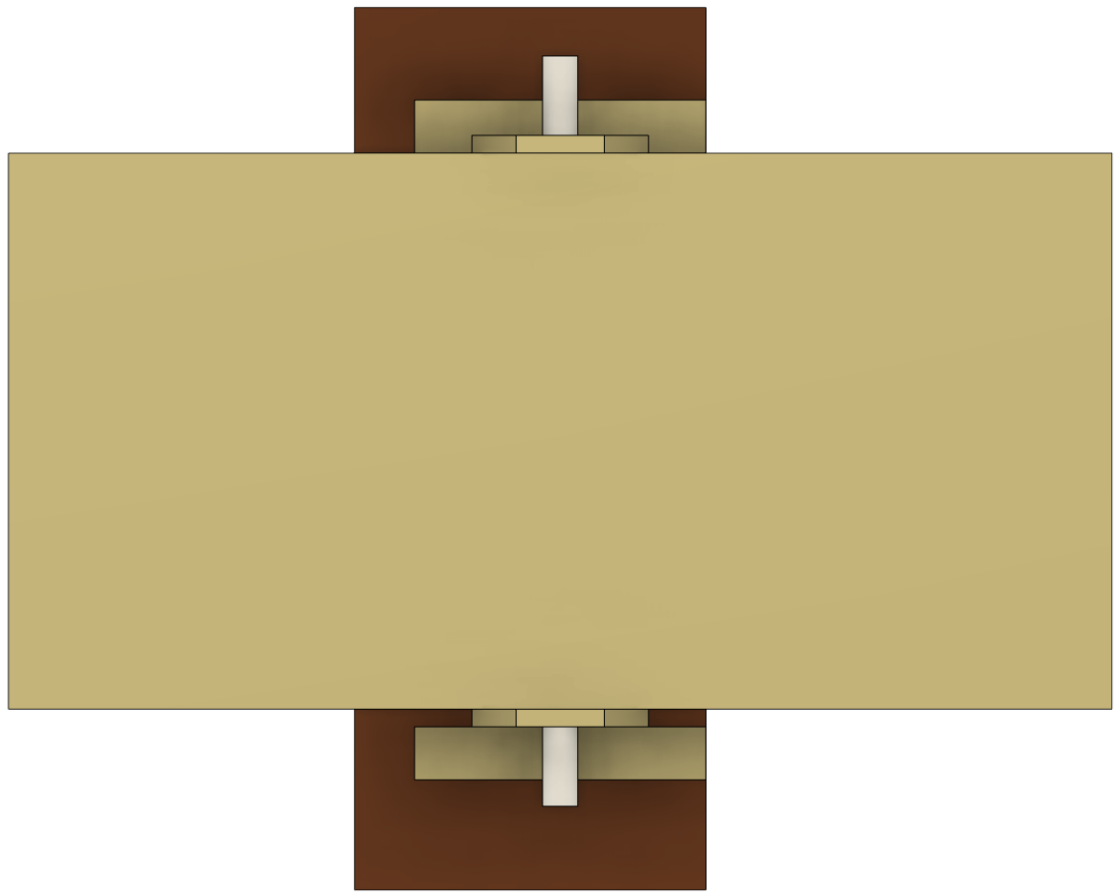


Fig. : Top View

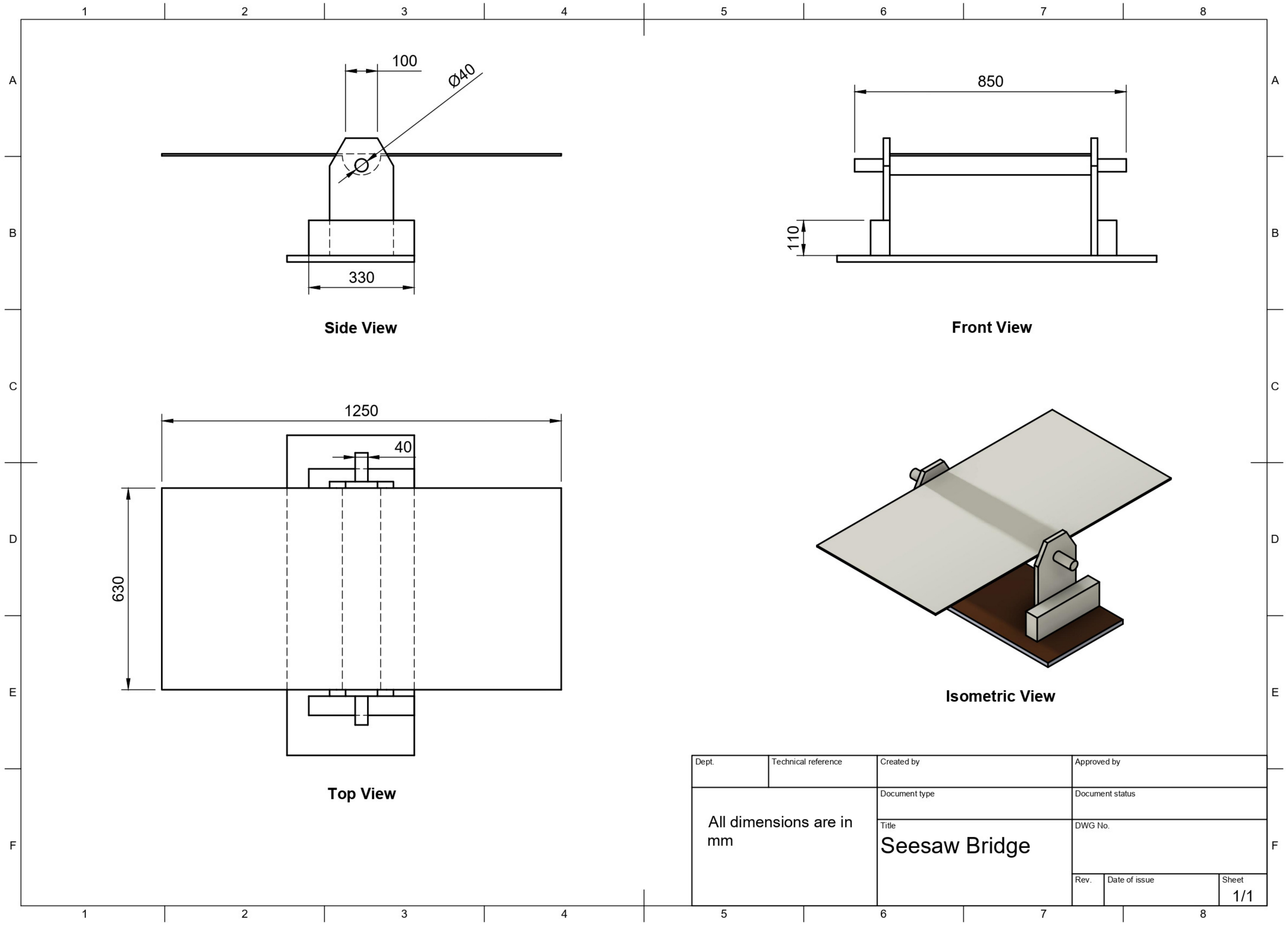


Fig. : Isometric View

The See-Saw Bridge is made with plywood which works on the same mechanism as that of a see-saw. The dimensions are shown in the fig. The centre of balance is chosen such that the lever gets sufficient torque for it to rotate as long as the car moves around it.

Table-Top Bridge

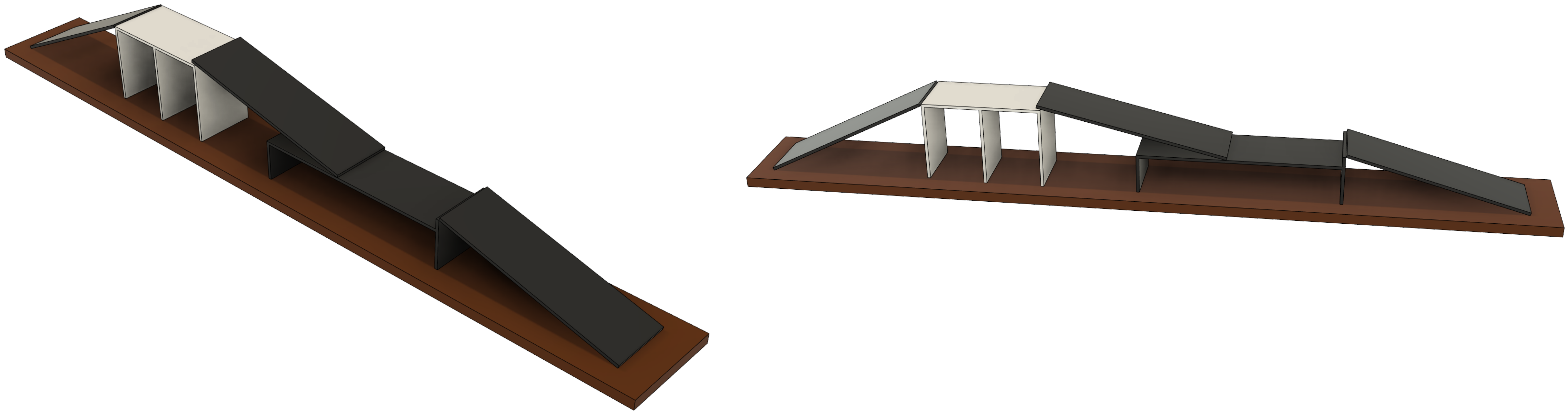


Fig. : Isometric View

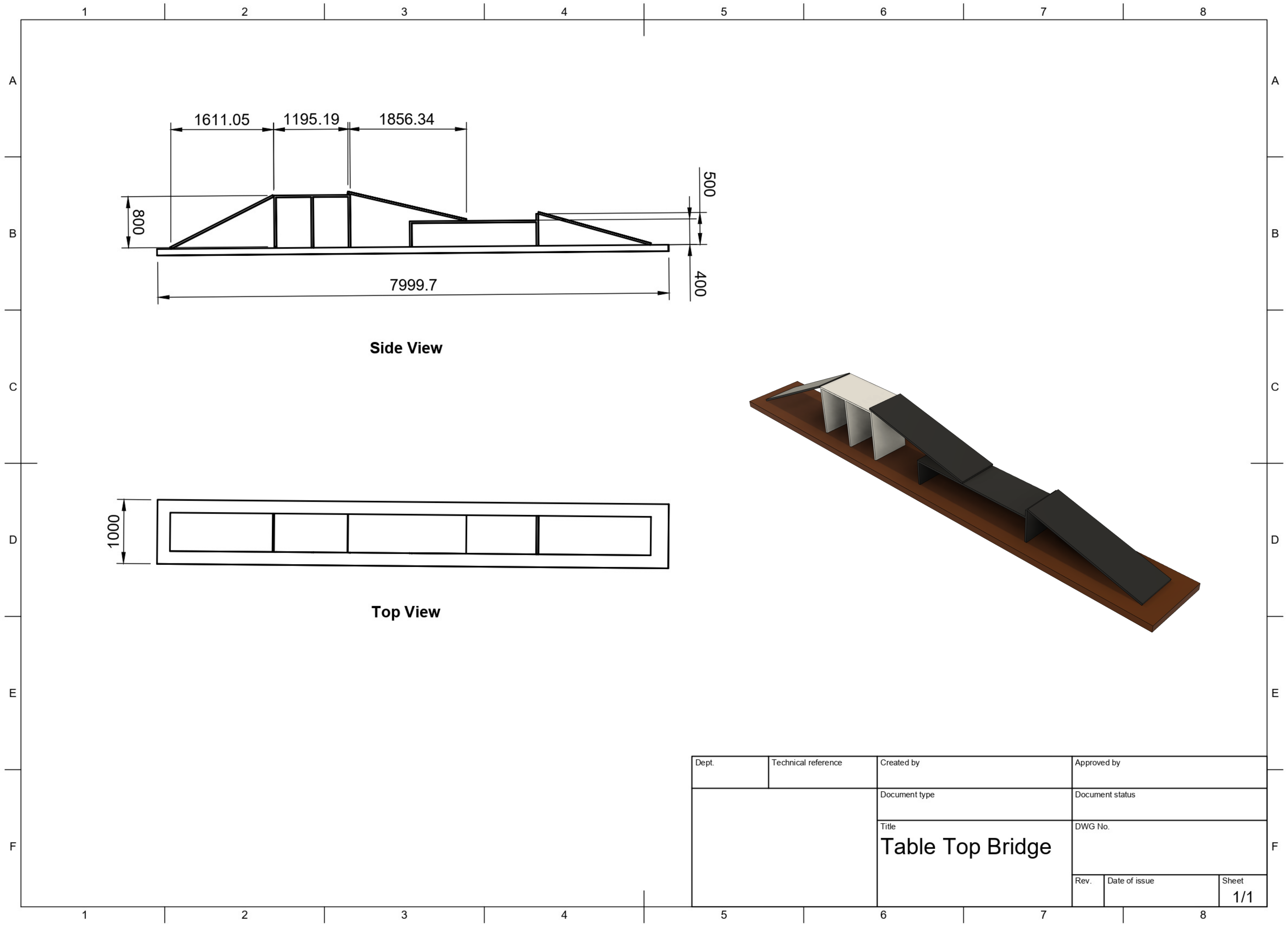


Fig. : Top View Drawing

The Table Top Bridge is made with the concept of achieving a maximum height with layers of objects placed upon one another and the RC car when coming downward could control the impact of the sudden downward inclination with minimal speed.

V- Bridge

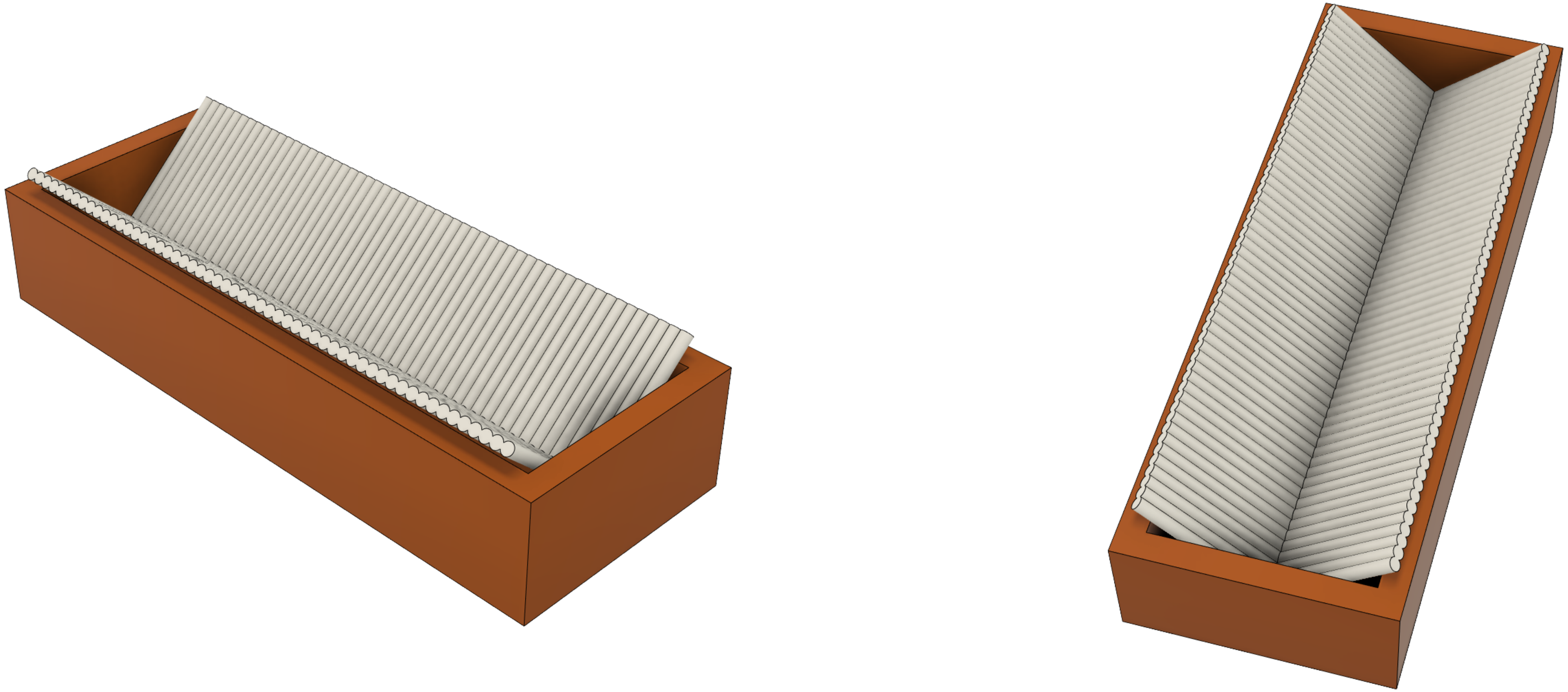


Fig. : Isometric View

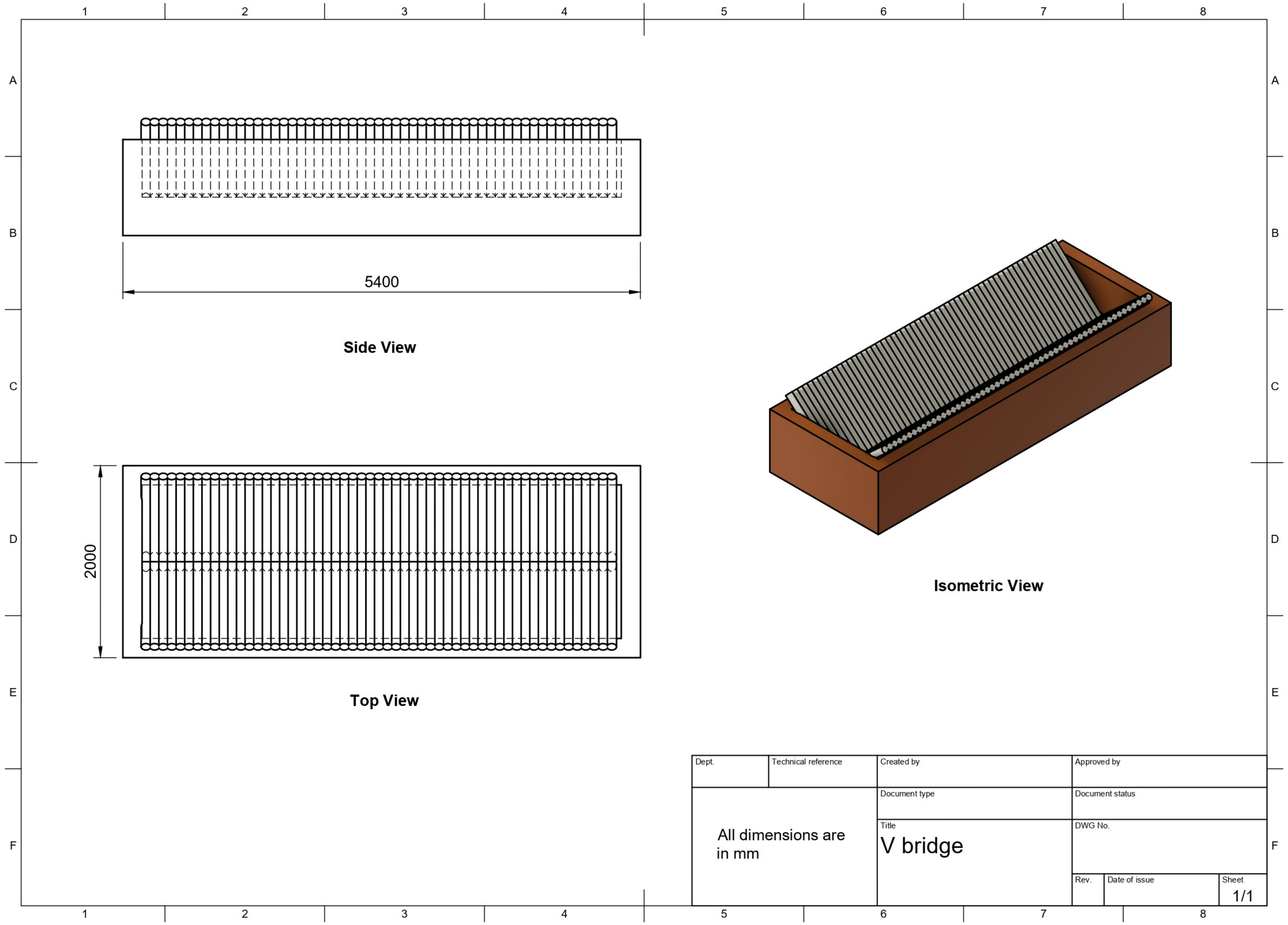
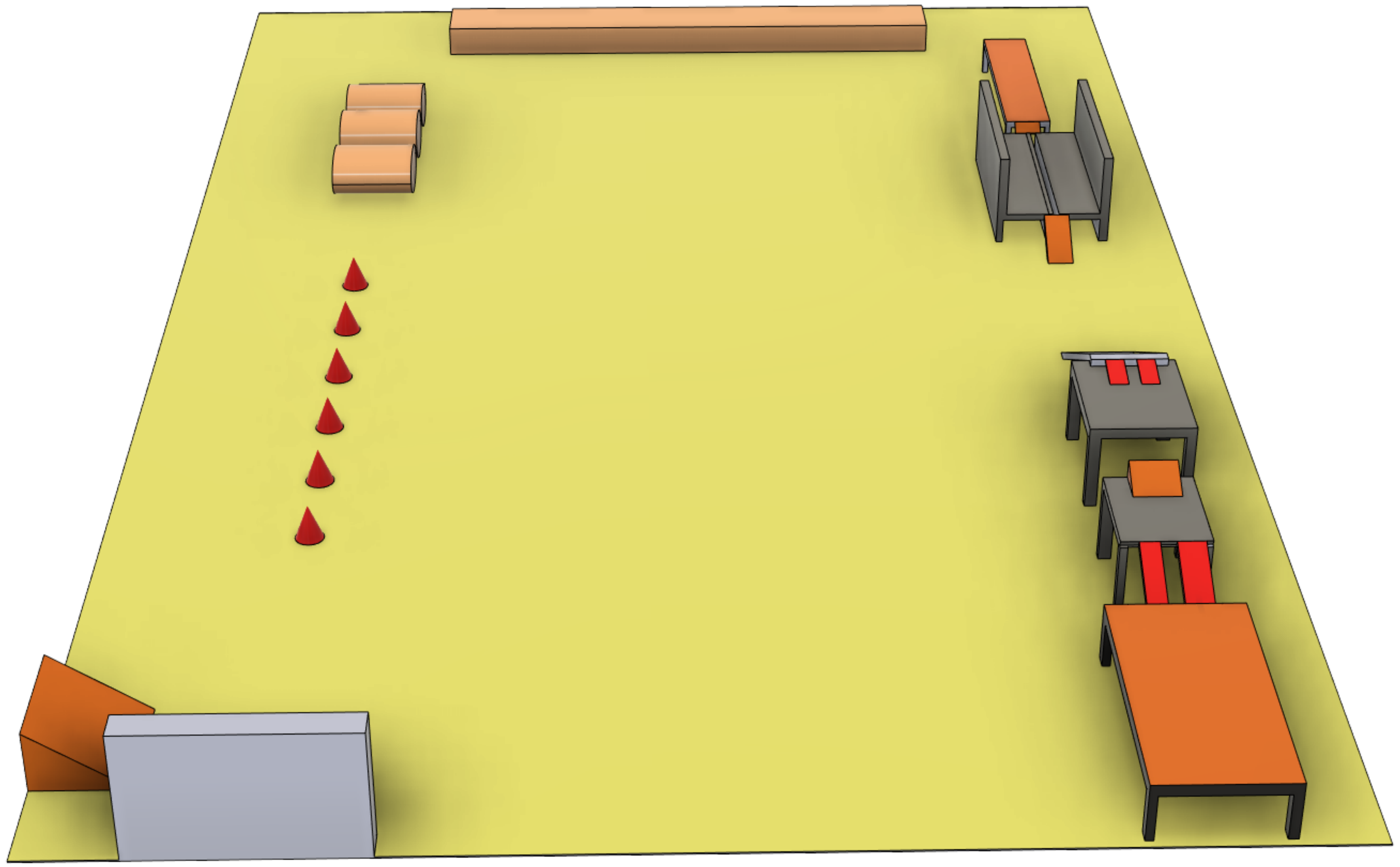


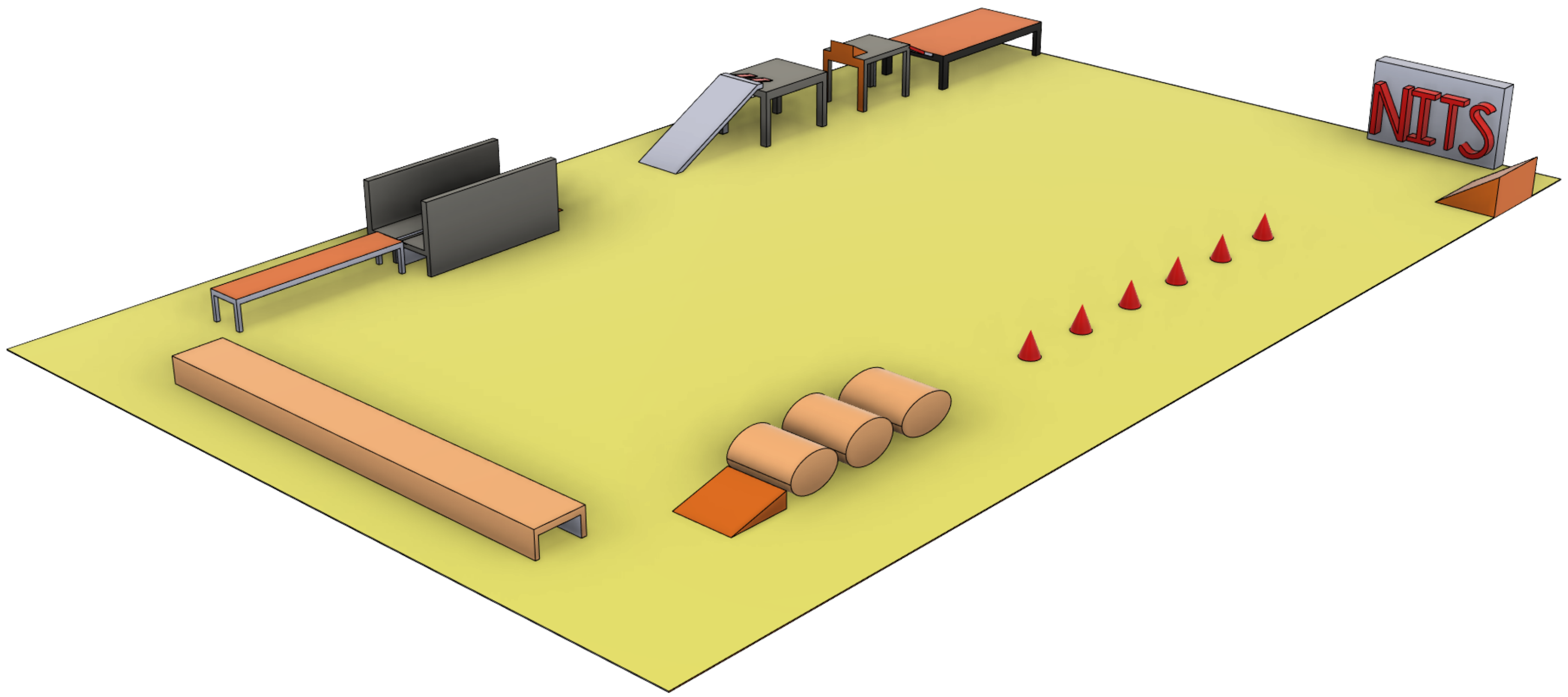
Fig. : Isometric View

The V-Bridge consists of 100 bamboo logs that are inclined at an angle of 45° . Each log is placed very closely to each other and are tied by Nylon ropes which are having high elastic property & breaking point. There are 50 bamboos on each alternative sides.

Obstacle Course

Indoor Track





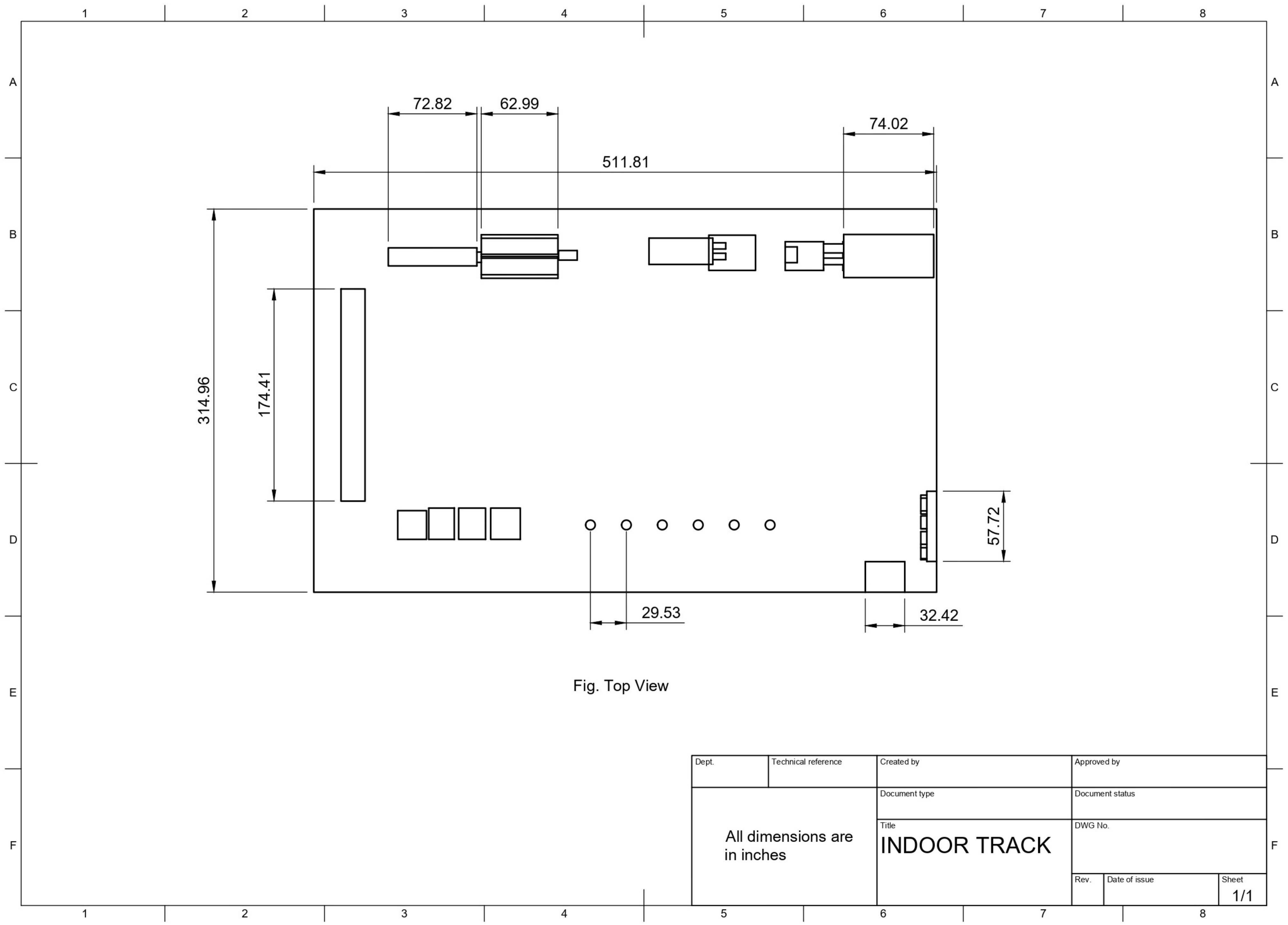


Fig. : Top View Drawing

The Indoor Track is of the dimension 314.96 x 511.81 inches .The entire track is based on concrete floor

It consists of the following components :

- Cement Bags
- Tiles
- Tables
- Duct Tapes
- LED strip wires
- Cones
- Ramp

The entire track was proposed with components that are easily available & free. Most of the items are taken from hostel of the institute and has almost none money spend.

DESIGN FOR MANUFACTURING AND ASSEMBLY

DFMA

This study will be using the integration of Design for Manufacturing Assembly (DFMA) and Sustainable Design approach. DFMA methodology has to include DFA which analyzes manual handling and manual insertion and DFM to evaluate the comparison of material and the entire cost of the process to ensure the potential materials can be used to the next stage which is manufacturing process.

In the development of a product, DFMA impacts in the following ways :

- Reduction of no of parts
- Reduction of cost
- Reduction of labor and energy to build the product
- Reduction of complexity
- Simpler Assembly

Part Count Reduction :

The RC Car has been designed so as to minimize the number of parts and assembly operations.

- The Arduino uno has been mounted over the battery.
- The complex steering system has been simplified by using two servos and two links respectively in place of the five links required for a single servo steering system.
- The ESCs were conveniently placed beside the battery mounts on both sides.

Reduction of track making cost:

Indoor Track:

- The idea was to build the track with items available in a college hostel.
- Dinning tables, beds, benches, floor tiles, sand bags, cardboard boxes were few of the items that were used to build the track.

Outdoor Track:

- The outdoor track was built in the college sports complex.
- Bamboo and wood was used in place of steel or iron to build various wedges, bridges and other obstacles.

3D printing time reduction :

- To reduce the printing time the smaller parts were exported to the slicer in groups of two or three and printing was done.
- The infill and layer heights were selected according to the strength and finish needed for that particular part.
- Orientations were selected conveniently so that the support does not eat up too much time.
- The infill pattern was kept gyroid for the parts that needed to be stronger. The rest were printed with cubic pattern to reduce the time.

Iteration 1 Analysis

The parts used in the first iteration are:

- Bottom Chassis Front
- Bottom Chassis Middle
- Bottom Chassis Rear
- Driving Axle **(4 Nos)**
- Wheel hub **(4 Nos)**
- Upper Control Arm Front **(2 Nos)**
- Upper Control Arm Rear **(2 Nos)**
- Lower Control Arm Front **(2 Nos)**
- Lower Control Arm Rear **(2Nos)**
- Differential Input Gear **(2 Nos)**
- Differential Output Gear **(2 Nos)**
- Steering Links **(6 Nos)**
- Bell housing **(4 Nos)**
- Open Differential Gears **(2 Nos)**
- Drive shaft **(2 Nos)**
- Steering Knuckle **(2 Nos)**
- Steering Knuckle Mounts **(2nos)**
- Knuckle Rear **(2Nos)**
- Shock Mounts **(2 Nos)**
- Battery Mount **(1 Nos)**
- Motor Mount **(1 Nos)**

Joints

- 3 Bottom Chassis assembled using **4 M4 Screws** and **2 M3 Rods**
- 2 Differential Gear Boxes attached to chassis using **4 M4 Screws** each
- 4 Upper control arms attached to the differential gear box using **2 M4 Screws** each and to the steering knuckle mount using **2 M4 Screws** each
- 4 Lower control arms attached to the front and rear chassis using **2 M4 Screws** each and to the steering knuckle mount using **2 M4 Screws** each
- Open differential box is attached to the bottom chassis with **8 M4 Screws**
- The battery mount is attached above the open differential box with **4 M4 Screws**
- The motor mount is attached to the bottom chassis with **3 M4 Screws**
- The 4 steering knuckles are attached to knuckle mounts using **2 M4 Screws** each
- The 2 Shock mounts are attached to the differential gear box using **3 M4 Screws** each

Iteration 1

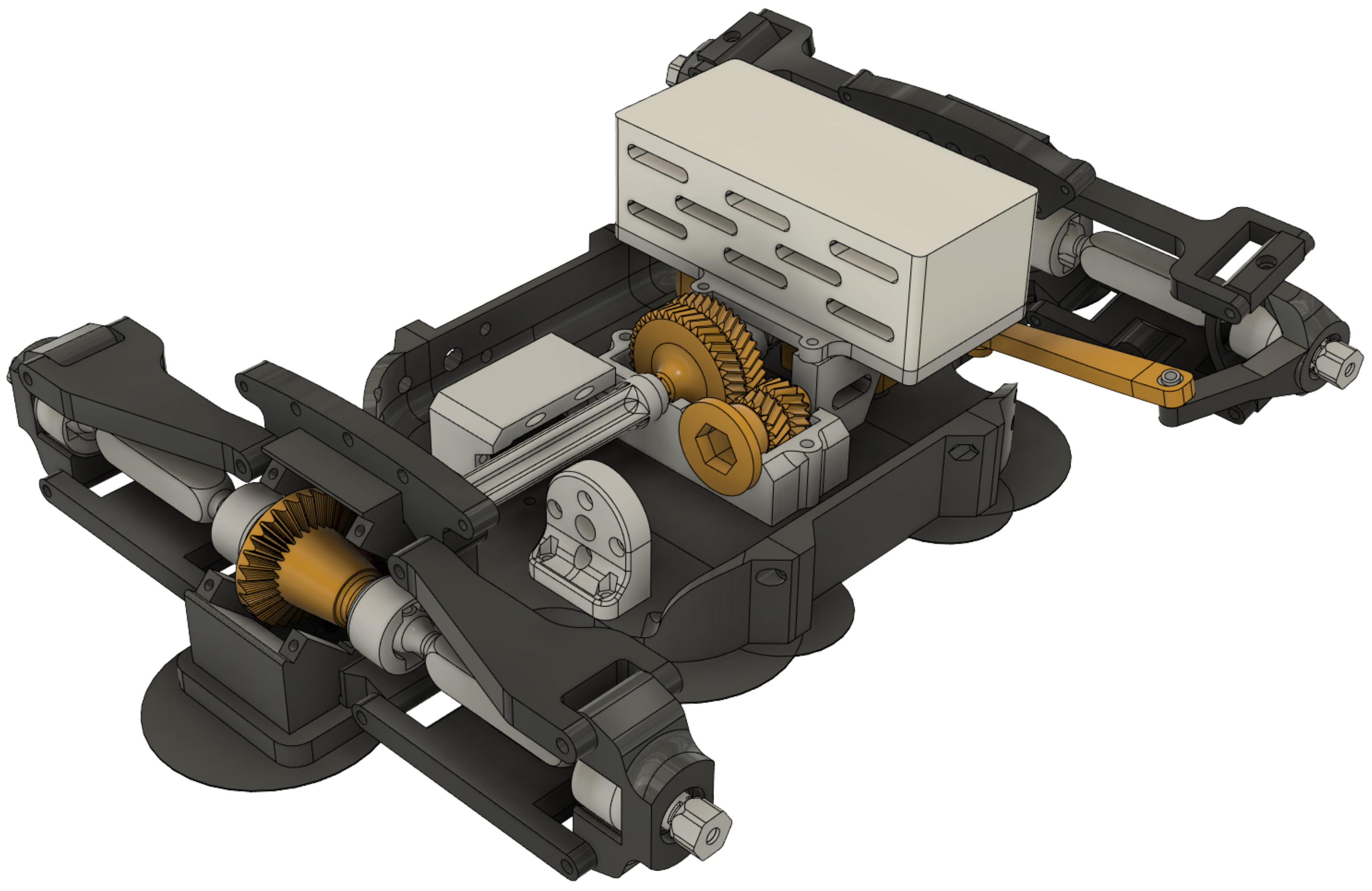


Fig. - Isometric View

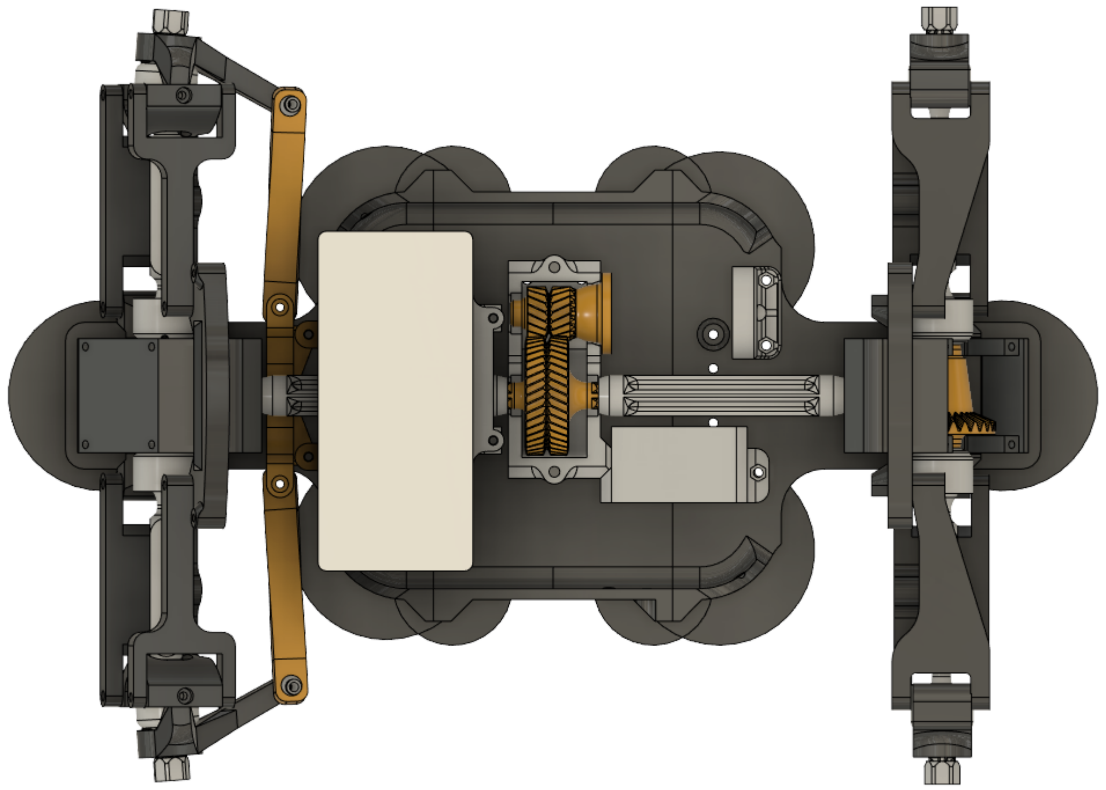


Fig. - Top View

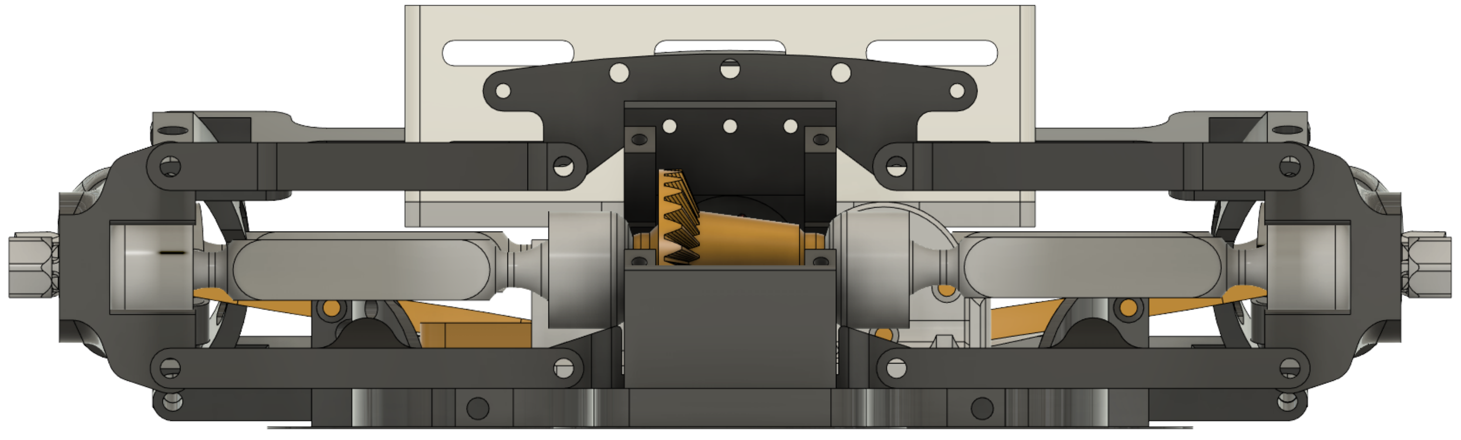


Fig. - Front View

Iteration 2 Analysis

The parts used in the second iteration are:

- Bottom Chassis Front
- Bottom Chassis Middle
- Bottom Chassis Rear
- Driving Axle **(4 Nos)**
- Wheel hub **(4 Nos)**
- Upper Control Arm Front **(2 Nos)**
- Upper Control Arm Rear **(2 Nos)**
- Lower Control Arm Front **(2 Nos)**
- Lower Control Arm Rear **(2 Nos)**
- Differential Input Gear **(2 Nos)**
- Differential Output Gear **(2 Nos)**
- Steering Links **(4 Nos)**
- Bell housing **(4 Nos)**
- Steering Knuckle **(2 Nos)**
- Steering Knuckle Mounts **(2 Nos)**
- Knuckle Rear **(2 Nos)**
- Shock Mounts **(2 Nos)**
- Battery Mount **(1 Nos)**
- Motor Mount **(2 Nos)**
- Servo mounts **(2 Nos)**
- Suspension shock absorber **(4 Nos)**
- Arduino plate
- Wheels **(4 Nos)**

Joints

- 3 Bottom Chassis assembled using **4 M4 Screws** and **2 M3 Rods**
- 2 differential gear boxes attached to chassis using **4 M4 Screws** each
- 4 Upper control arms attached to the differential gear box using **2 M4 Screws** each and to the steering knuckle mount using **2 M4 Screws** each
- 4 Lower control arms attached to the front and rear chassis using **2 M4 Screws** each and to the steering knuckle mount using **2 M4 Screws** each
- 2 battery mounts is attached on the middle chassis with **4 M4 Screws**
- The Arduino plate is placed above the battery and attached to the middle chassis using **4 M4 Screws**.
- 2 motor mounts are attached to front and rear chassis using **4 M4 Screws** each
- 2 Shock mounts are attached to the differential gear box using **3 M4 Screws** each
- 2 servo mounts are attached to the front chassis using **4 M4 Screws** each
- 4 suspension shock absorbers are attached to the lower control arm using **2 M4 Screws** and to the shock mounts using **2 M4 Screws**

Iteration 2 Final

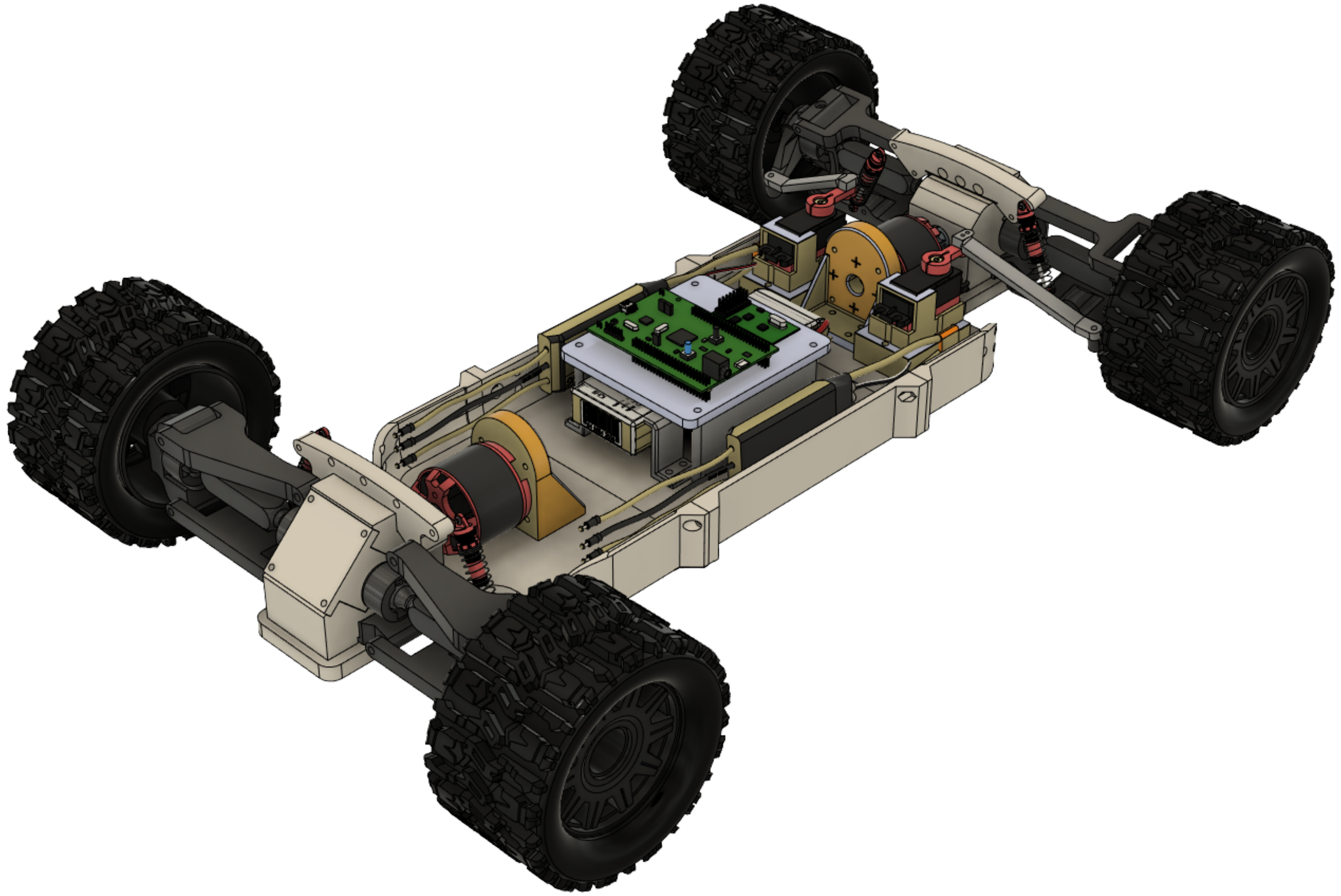


Fig. - Isometric View

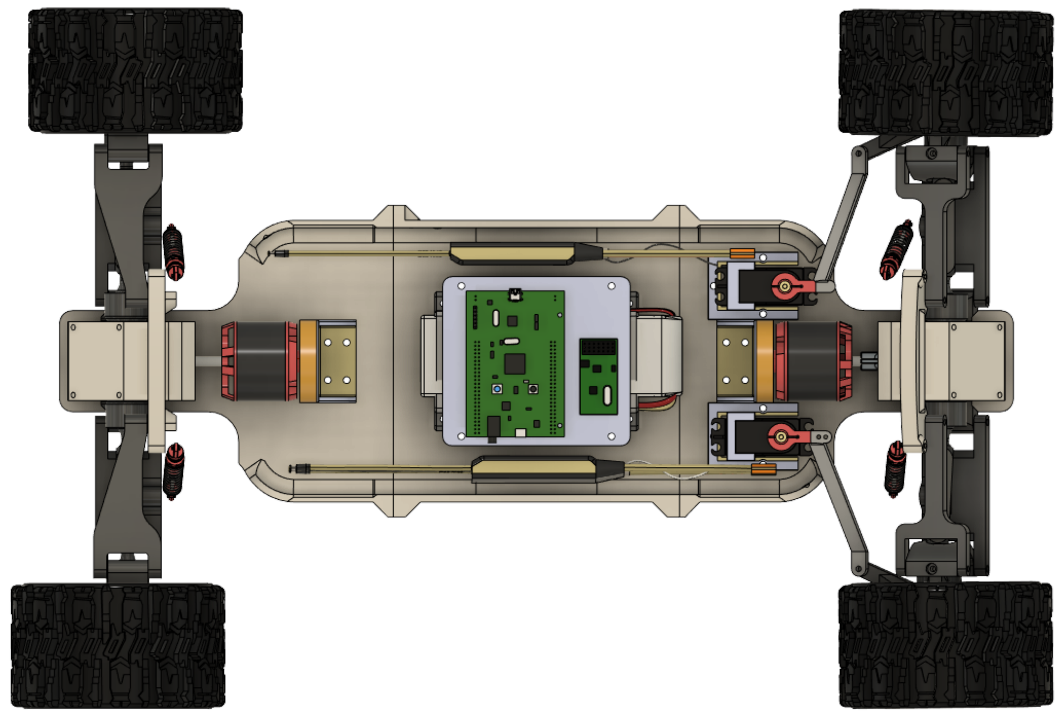


Fig. - Top View

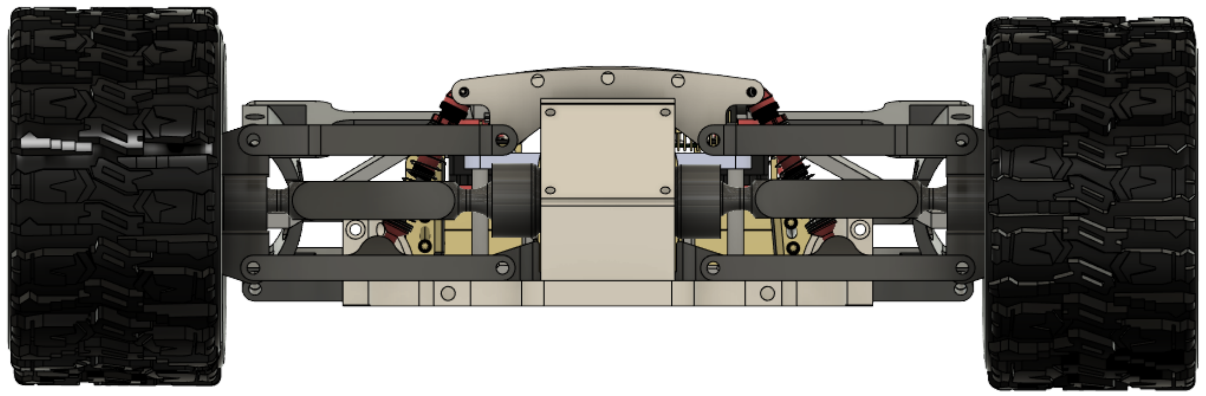
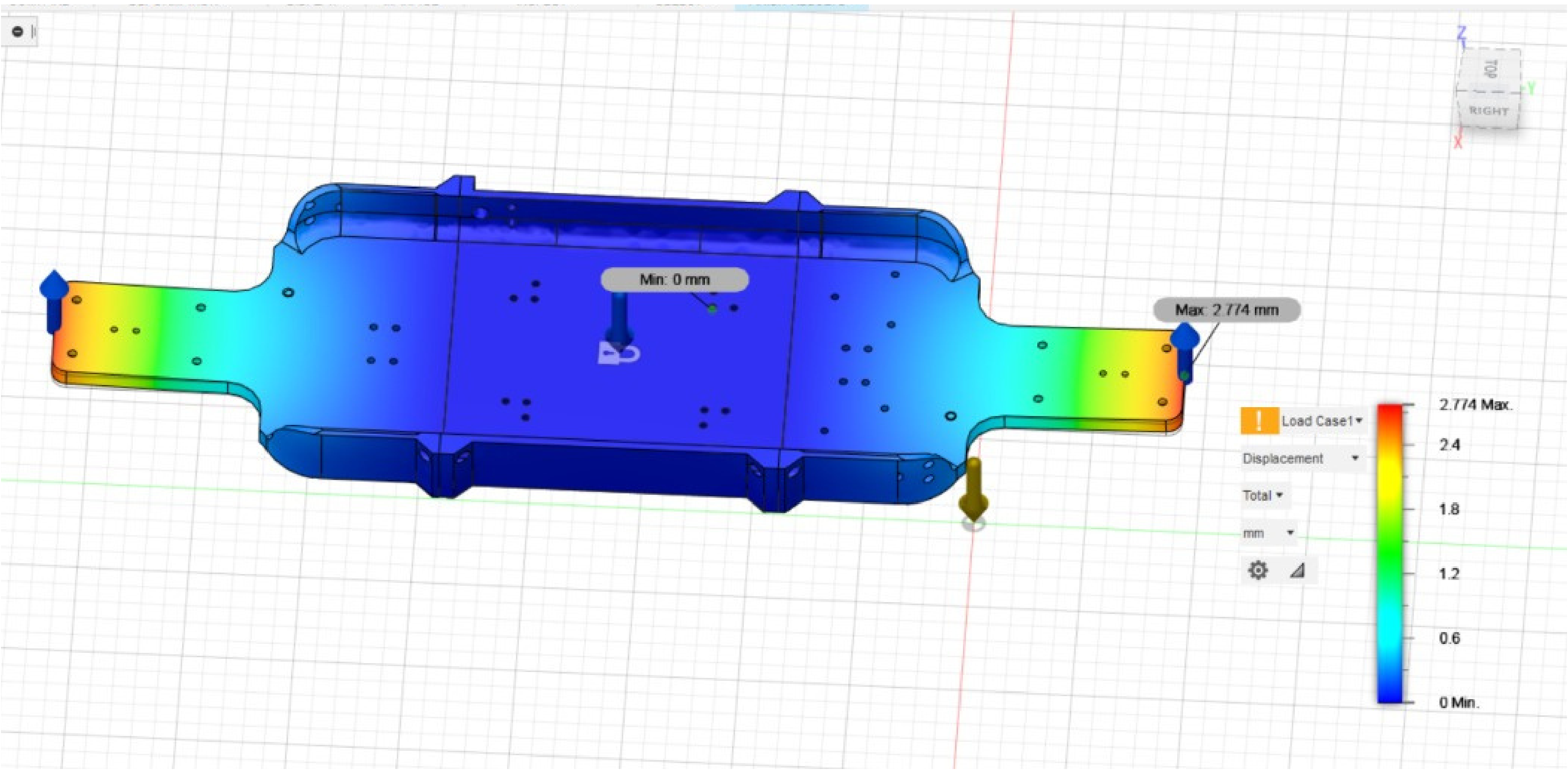
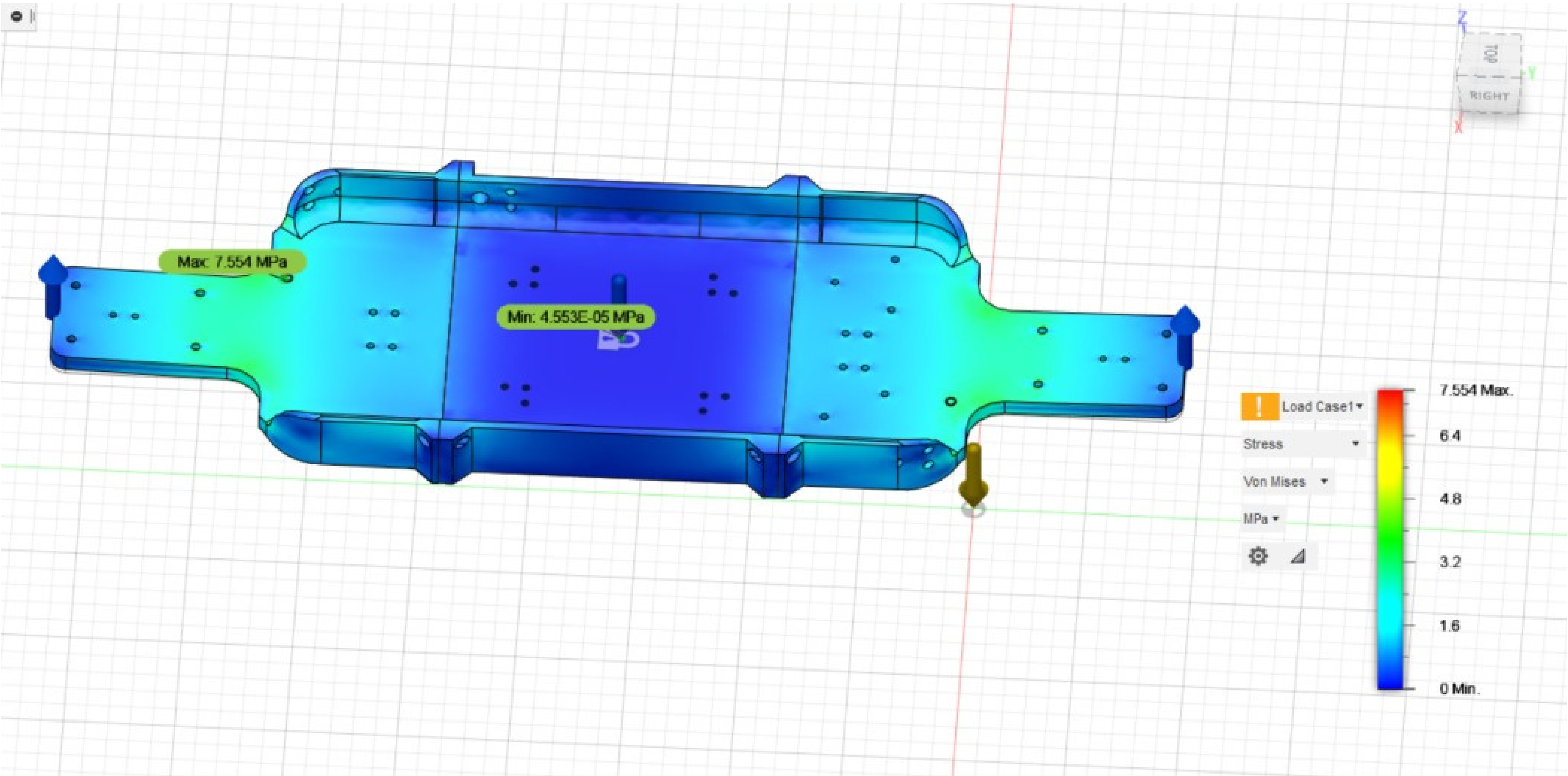


Fig. - Front View

Simulations

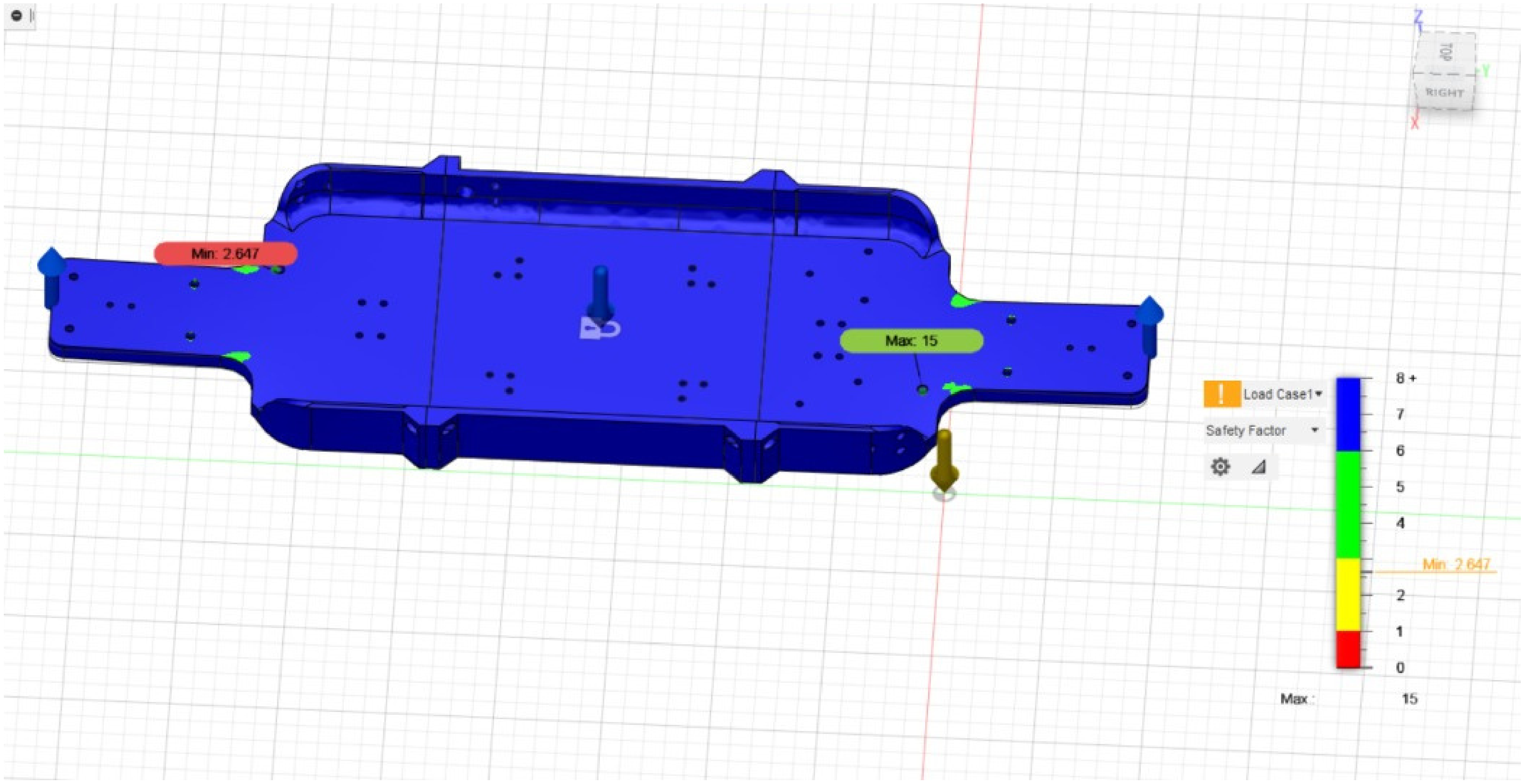
Parameter	Values
Displacement	2.744 mm
Stress	7.554 MPa

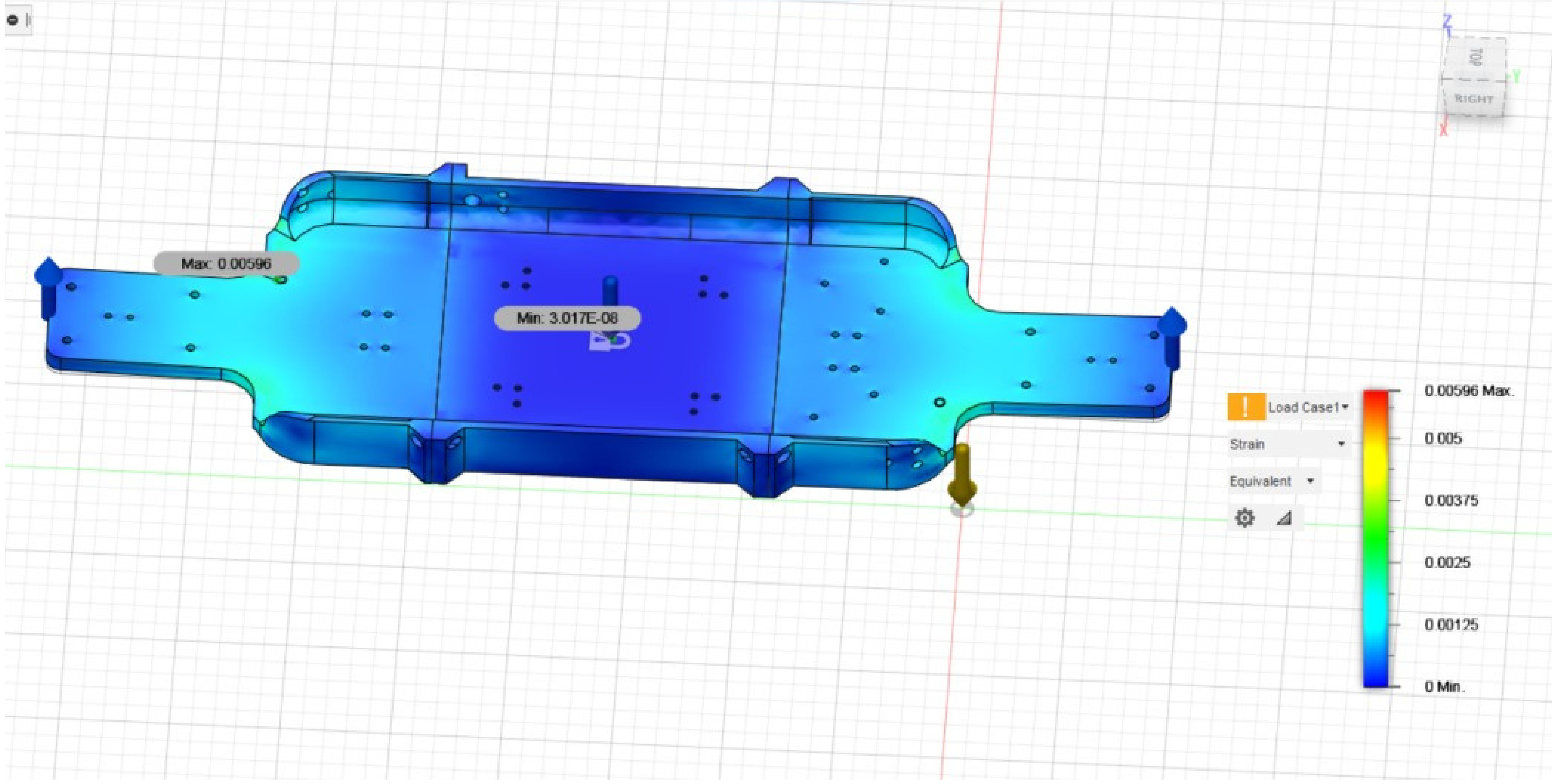




Simulations

Parameter	Values
Safety Factor	15
Strain	0.00596





DESIGN FOR ADDITIVE MANUFACTURING

DFAM

Infill Percentage :

The infill percentage was varied for different parts on the basis of required strength. The parts that needed to handle the impacts were given 80% infill and the rest parts were printed with 60% or 70% infill. For instance, the shock mounts and control arms were printed with 80% infill whereas the bottom chassis and the mounts were printed with 60% infill. This resulted I reduction of printing time and also reduction of weight of the vehicle.

Infill Pattern :

The infill pattern was also varied in accordance to the requirement. Gyroid pattern was used for the parts that needed extra strength. For the rest of the parts cubic pattern was used. For example, the differential gear box which also works as the mount for the shock mount was printed with gyroid structure whereas the steering links and knuckle were printed with cubic structure.

Layer Height :

The layer height was kept at an optimum 0.2mm. This height was because on increasing the layer height the adhesion would have been more and structure strength would have decrease whereas on decreasing the layer height, the printing time would increase excessively.

Print Orientation for Strength :

The control arms and the differential gear box were printed in such a way so that the loads on it would be perpendicular to the printing pattern (gyroid in this case). This was done due to the fact that the structure can withstand more loads when the load is perpendicular to the printing structure.

Print Orientation for Minimal Support Structures :

In the slicer, the parts were oriented in such a way so as to minimise the support structure. This helped in reducing the printing time.

Multiple Parts Printed Simultaneously :

There were a lot of small parts that needed to be printed. These small parts were exported to the slicer in groups of two or three and theprinted simultaneously. This helped in reduction of time in exporting and setting up the printer.

Physical Testing

PETG was chosen for 3D printing due to its high toughness, impact strength, and ease of printing.

Following are some of the features of PETG because of which it was chosen:

- PETG’s strength and impact resistance means it is ideal for glazing and high-strength display units
- Extremely low warping tendency
- Not sensitive to outdoor weather conditions such as change in temperature and humidity
- Fatigue resistant

Conclusion End

The “D.I.R.T.”-GBRCV design solution for the ASME E-fests IAM3D competition 2022 was reached via an iterative design process and constant improvements in the design. Several problems were encountered during the designing and prototyping phase - one of which is the clogging of the nozzle of the 3D Printer. The sudden emergence of Omicron had its adverse affect of the availability of the respective components in online market. Managing all the calamities in the line of action, we were finally able to manufacture the required GBRCV with additive manufacturing.

Regards,

Team Godspeed