SINGAPORE POLYTECHNIC

SCHOOL OF MECHANICAL AND AERONAUTICAL

DIPLOMA IN MECHATRONICS AND ROBOTICS

Office Transporter

Project Code: 20518

Internship Equivalent
IE5001

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ABSTRACT

This project is a take on the Autonomous Office Transporter with minor changes to its design. The purpose of this project is to improve the first batch's Office Transporter with better components used in the previous batch's transporter. The office transporter required a program upgrade to better achieve smoother transition and traveling, to accomplish its task of functioning in an office environment with the goal of transporting documents from one waypoint to another more efficiently.

The Office Transporter would allow office workers to be able to call upon the Transporter to travel to their location, The user can set a new location to enable the transporter to deliver the items required, to the desired location. The Transporter would be capable of avoiding both obstacles and people while moving. The transporter has the ability to dock and charge itself.

The purpose of this report is to showcase the improvements in not only the design and layout of the components, but also the changes in the codings of our Office Transporter Project.

ACKNOWLEDGEMENT

Our team would like to give our thanks to our supervisor Mr Tan Tuan Kiat for supervising us, guiding and helping us in our time of need despite his packed schedule throughout our project. He has taught us many valuable lessons and skills that are useful for our future. The accomplishments we have thus far in recreating the robot could not have been possible without his guidance and support.

We would also like to thank the previous team who partook in the Office Transporter Project for assisting us. They guided, assisted and motivated us when we were stuck and didn’t know how to move forward. We would like to thank Jowell and Ryan for their support. They came back to help us to better understand the project better. Ryan took the extra mile to teach us how to program, and taught us how the formula works.

Lastly, we would like to thank our classmates and peers for supporting us and coordinating with us in order to achieve a wonderful experience.

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1.Introduction

1.1 Project Background

SICK Sensor Intelligence has commissioned Singapore Polytechnic to build an office transporter that can navigate around the office environment in their company. This office transporter will essentially function as an office boy/delivery system within the office building to deliver documents and objects around the office.

1.2 Project Objective

We are the third batch of students to work on this FYP project. This means that most of the designs have already been established by the previous groups. Our goal will be to upgrade the existing transporter, starting mostly with replicating on what the previous group had done, but also implementing changes that can help resolve certain issues faced by the previous group.

1.3 Project Scope

Build a new transporter with the new features
To fine tune the transporter making it more reliable when navigating through obstacles.
Create a document box that can help store important documents.

2. Gantt Chart

Table 1: Gantt Chart

No	Description of Activities	Term	Vacation						Work From Home					Semester										
		Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	Preliminary discussions on proposed project topics																							
2	Research and information gathering																							
3	Design Study a.3D part and assembly drawing b.Part and material listing c.Part fabrication procedure																							
4	a. Preliminary / conceptual design with a few alternatives b. Final design selection																							
5	Feasibility study: a.Design concept b.Cost c.Design calculation d.Material selection e.Fabrication and assembly																							
6	Part / material purchase and fabrication																							
7	Assembly / installation																							
8	Learning the program																							
9	Testing and commissioning																							
10	Modification																							
11	Report writing																							
12	Set up project for exhibition Project exhibition																							
13	Project viva																							

3. Design Changes

The construction of the Transporter was already established by the previous group. Our group objective requires us to use the transporter created from the 1st batch that worked on this project, and improve it to the standard of the previous group. We have decided to reuse the design of the previous group and make improvements from where they left off.

One of the problems faced by the previous group was the overheating of the motors. To prevent it from overheating, we have decided to change the position of the fan to allow better ventilation.

Another problem observed was the size and position of the screen, how it was tedious for the programmer to modify the program. To tackle this, we replaced it with a bigger sized monitor for ease of programming as well as changing the position of the screen to the top of the transporter.

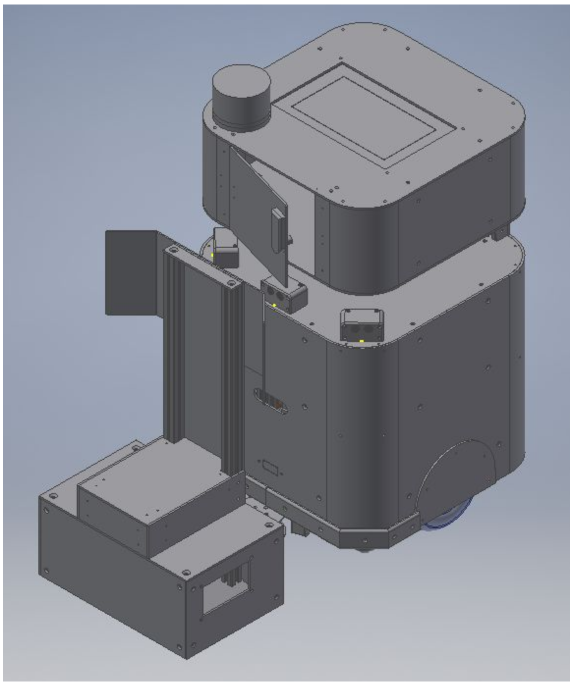


Figure 3-1 Full rendering of Transporter

3.1 Mechanical changes (Base plate)

Majority of the mechanical changes were made to the underside of the base plate. The base plate has gone through multiple design changes to achieve a baseplate that is able to accommodate the needs of the transporter. Most changes of the base plate were made on the underside of the robot.

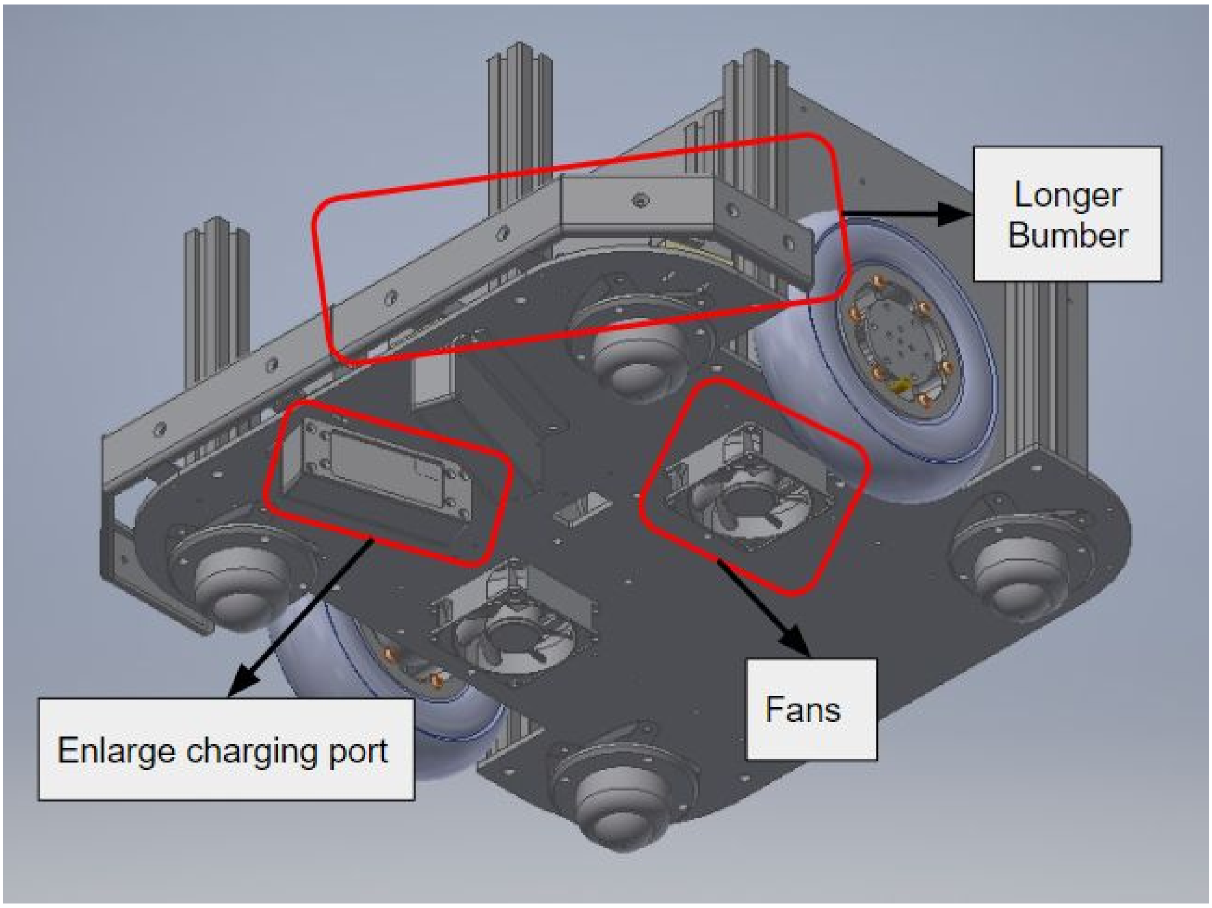


Figure 3-2 Changes made on the Base Plate

3.1.1 Mechanical changes (Addition of 80mm fans)

One of the problems faced by the previous team was the issue of the motor turning hot over time. The old design has the fans mounted on the back of the battery enclosure. The wiring and components were preventing the air from circulation
.
Therefore the team has decided to place the fans at the bottom of the design, without affecting the transporter's movement.

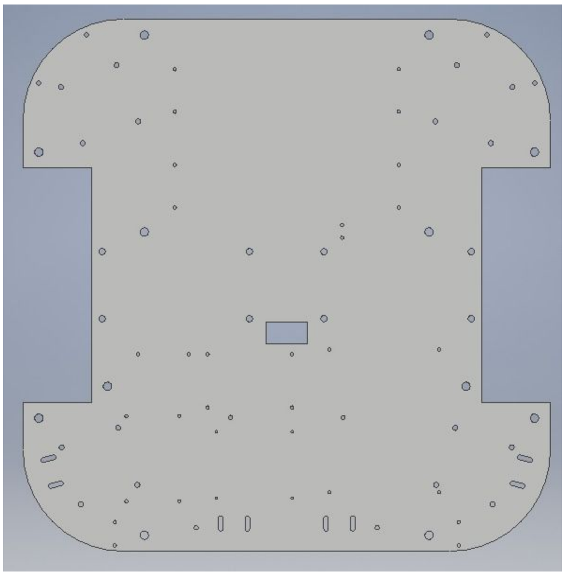


Figure 3-3 Old Base Plate

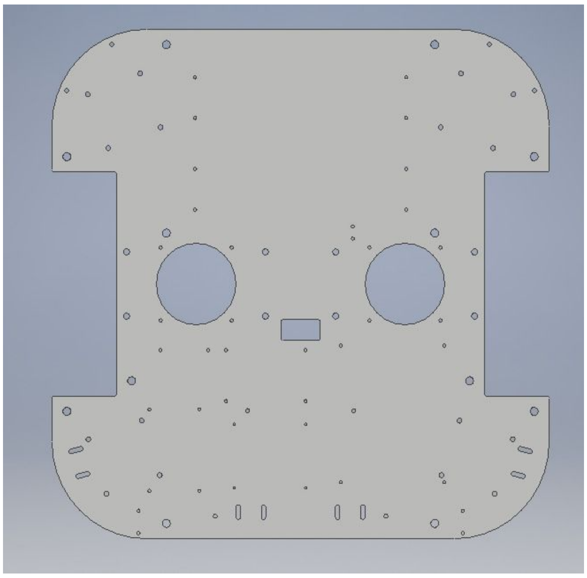


Figure 3-4 New Base Plate

We had to choose a fan that is not thicker than 47mm so that it will not hit the ground. We also chose to use a fan that runs on 24V, this will allow us to reduce the amount of step-down and regulator needed in this transporter.

The team decided to go with a 80mm 24V DC fan with a thickness of 25mm.

3.1.2 Mechanical changes (Enlarged charging ports)

The team decided to modify the charging port. When the transporter is trying to dock, at times the copper prongs might be missed aligned. This will prevent the transporter from receiving power. Our team has decided to increase the height of the copper plate as shown in FigX. This allows the copper prongs to easily come in contact with the transporter.

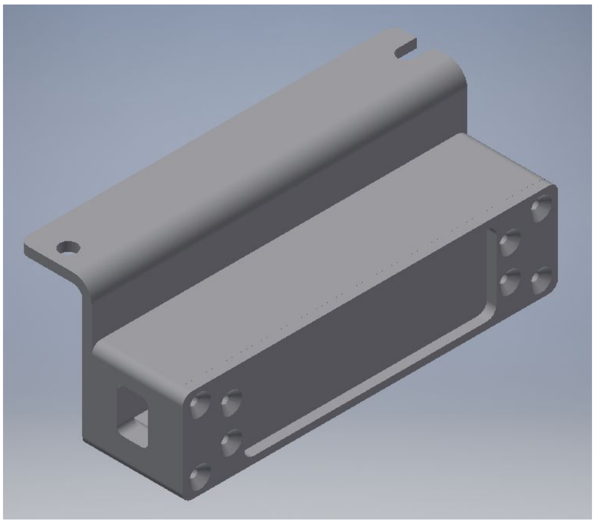


Figure 3-5 Old Charger

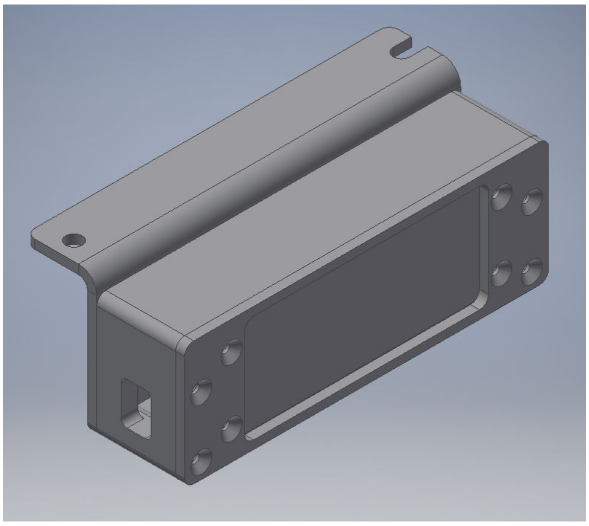


Figure 3-6 New Charger

3.1.3 Mechanical changes (Longer spring bumper)

The bumper used in the previous transporter has certain issues such as the bumper are too close to the transporter itself. This affected the performance of the transporter. Therefore, two minor changes were made to the spring bumper.

Firstly the length of the spring bumper was increased to prevent collision between the spring bumper and the side panels.

Secondly the holes at the end of the bumper were changed to have two screws instead of having one in the center. This change was made because the limit switch tends to rest on the screw of the older design.

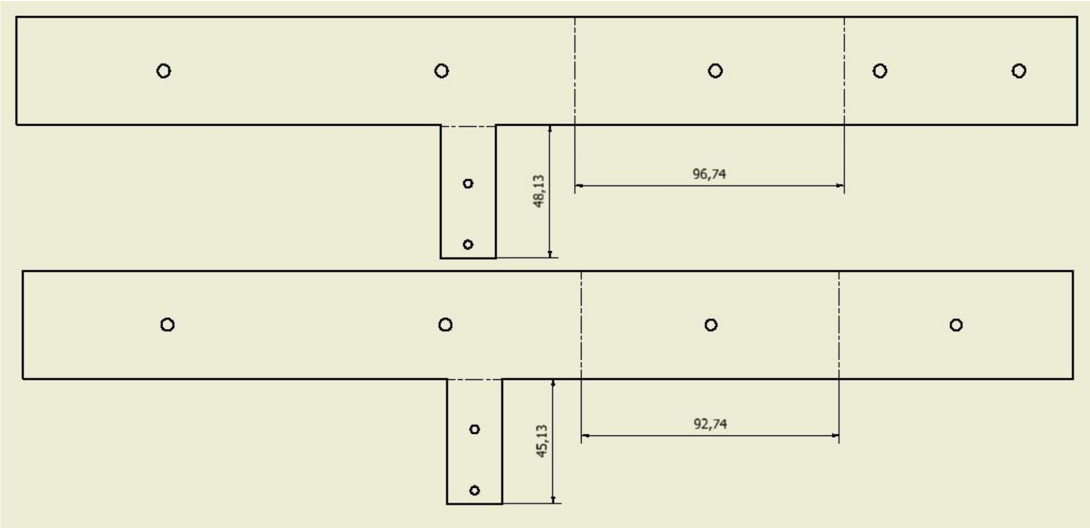


Figure 3-7 Length Difference In Spring Plates

3.2 Mechanical changes (Middle plate)

Most changes made on this layer is to accommodate the new Asus Router RT-N12 and further improve the cable management.

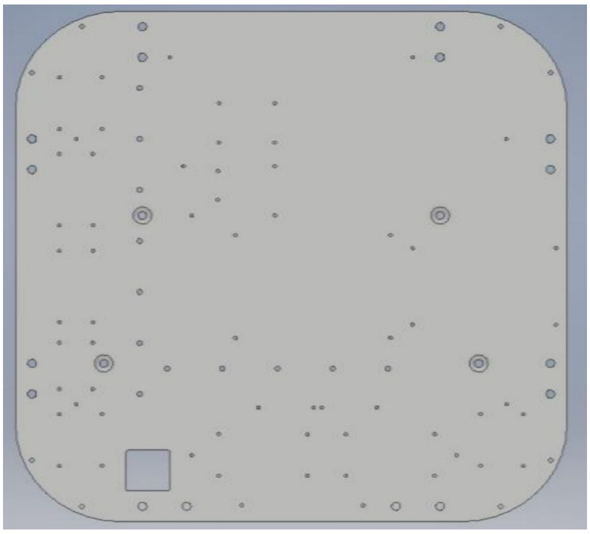


Figure 3-8 Old Middle Plate

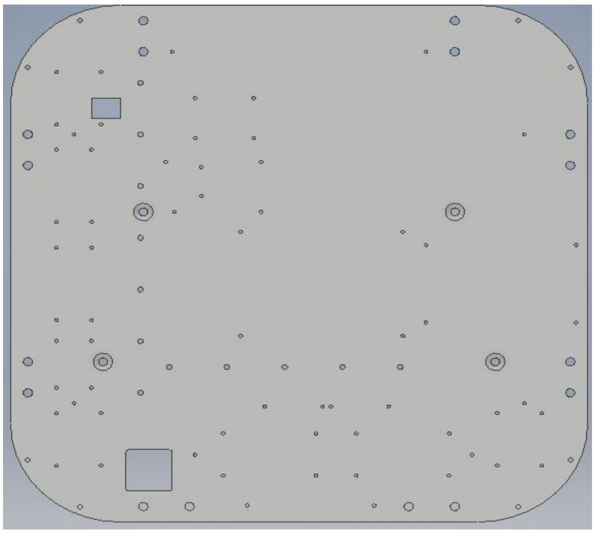


Figure 3-9 New Middle Plate

The holes for the arduino and circuit board have been shifted left to make space for the Asus Router RT-N12 which is slightly larger compared to the router used in the previous design. A new hole was also created to allow certain cables to run from the side. This will help in the cable management. Figure shows the layout of the electrical components.

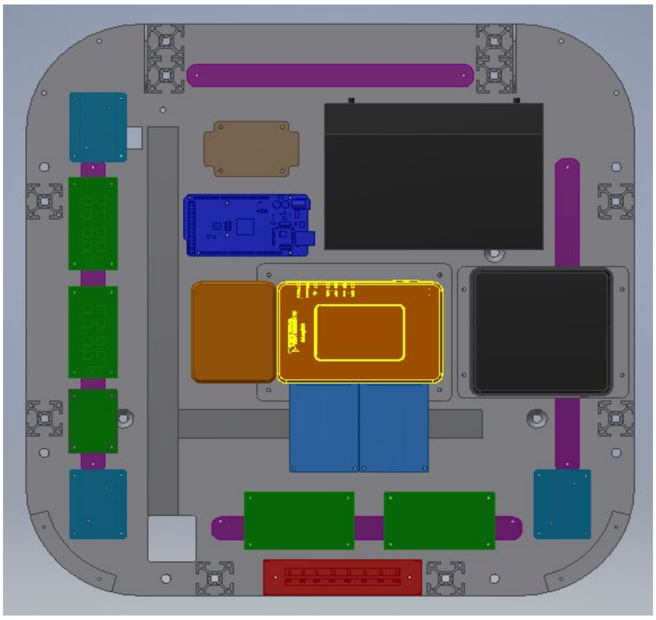


Figure 3-10 Circuit Layout With New Middle Plate

3.3 Mechanical changes (Screen size and placement)

Another feedback received was that the screen used was too small and was located in a non-ergonomic position. This will cause discomfort for the technician when performing prolonged maintenance.

The mechanical design lead looked into many different screens and ways to mount a larger screen. The team has decided to use a 13 inch Eoyo screen to provide the technician with a better view of the programs and data. The transporter has a curve body that prevents the screen to be mounted at the side without compromising the size and shape of the transporter.

Figure 3-11 New 13 Inch Screen

Our first design for the screen is to mount the screen on the top plate. The team decided to modify the flange used in the previous design. The team incorporated a custom rail into the flange.

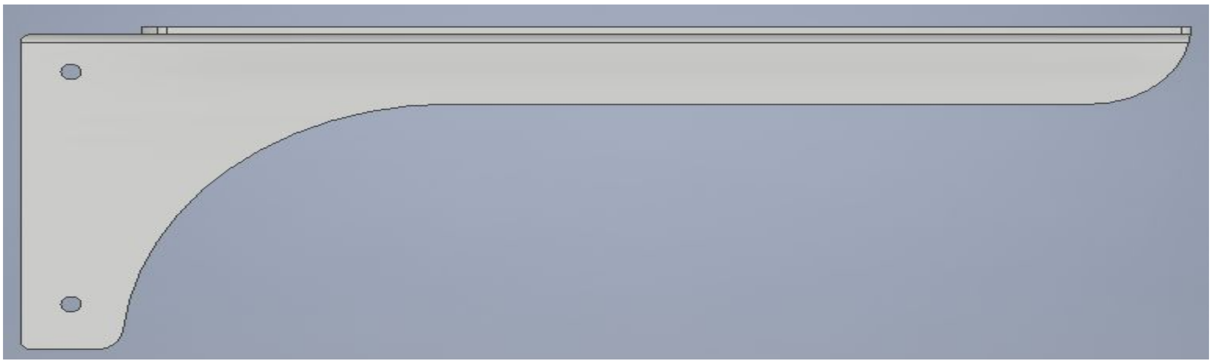


Figure 3-12 Old Flange

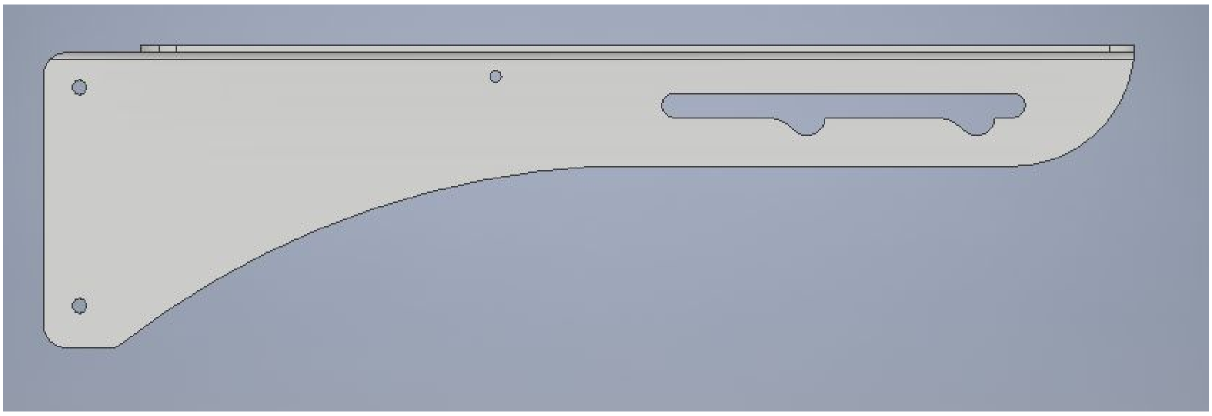


Figure 3-13 Box 1 Flange

This will position the screen at a more suitable location, this will allow the technician to perform maintenance and check at a more comfortable position.

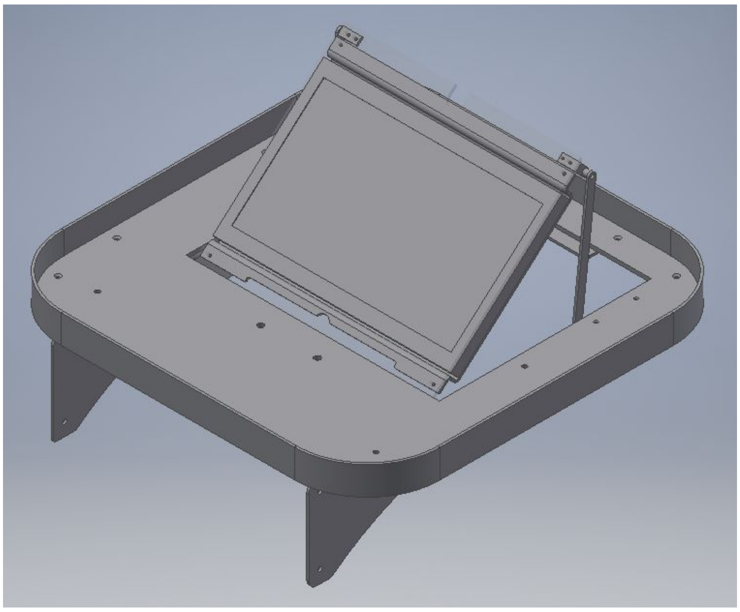


Figure 3-14 New Screen Mounting

3.3.1 Mechanical changes (Inclusion of Document Box)

The team was also challenged to create a secure document box that requires the user receiving the file to input a pin, in order to receive the file and after receiving the file the passwords will change when used the next time.

Box design 1 is to make a simple box and a simple combination lock. This documentation box is going to be mounted over the screen. This design is simple to use and implement. However, the lock use will allow anyone to open as long as they know the code. The screen is also blocked, this will make maintenance more complicated and time consuming.

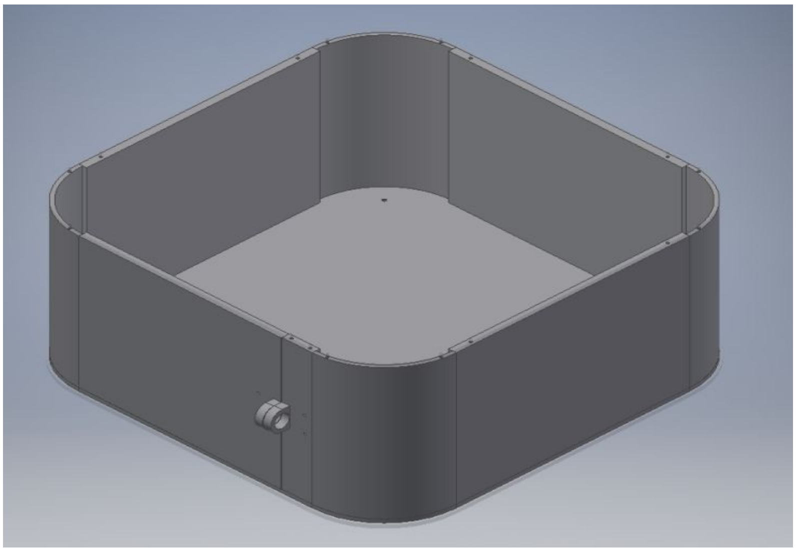


Figure 3-15 Box Design 1

The first design change we did was to replace the combination lock with a digital pin combination lock. This lock that we chose as shown in Fig 3-16 has the ability to set a one time password. The second thing the team wants to change is to place the screen at a different location.

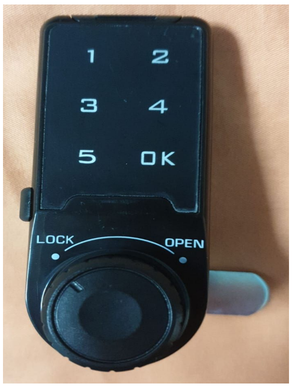


Figure 3-16 New Digital Lock

Box design 2 is the first design that the team decided to incorporate the screen into the box. This will also replace the table top used in the previous designs. As the width of the robot is slightly shorter than the screen due to the curve edges, the screen is placed vertically. This made the transport overall height to be longer.

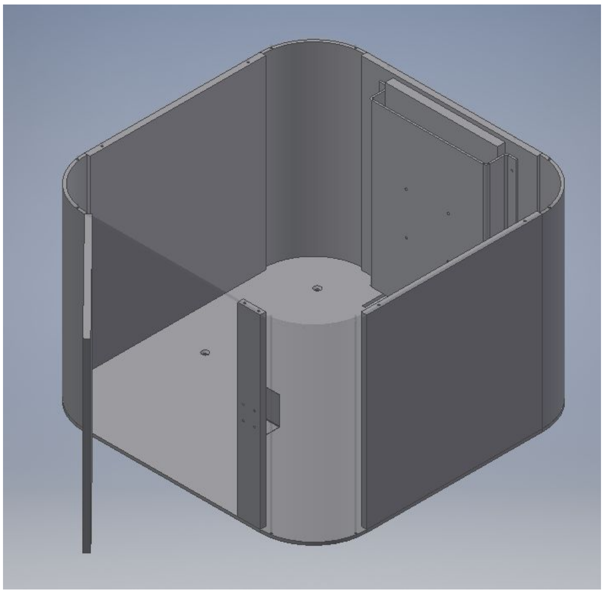


Figure 3-17 Box Design 2

Box design 3 uses the straight edge of the robot to mount the screen, this allows the transporter to fit the screen without compromising the height of the transporter. However this causes the document box to be relatively smaller.

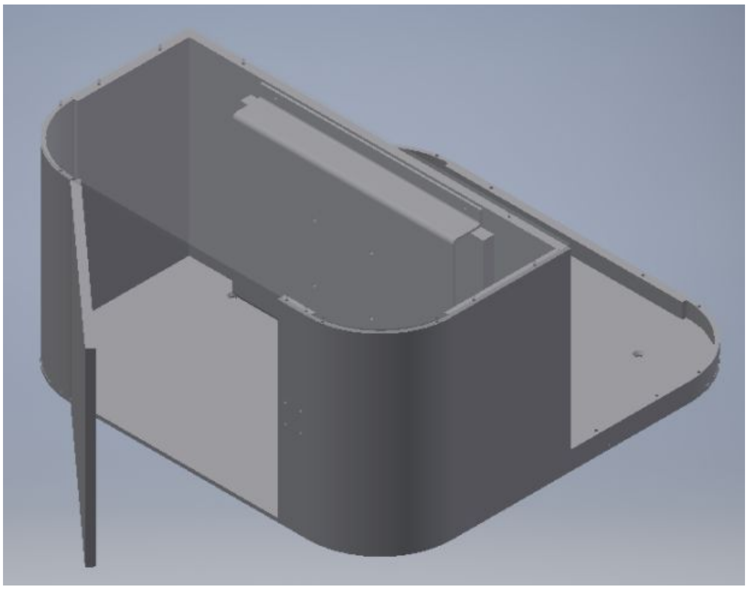


Figure 3-18 Box Design 3

Box design 4, is derived from design one, instead of covering the screen, the team mounted the screen and antenna on the top of the documentation box. The transporter is able to keep its dimension without looking distorted.

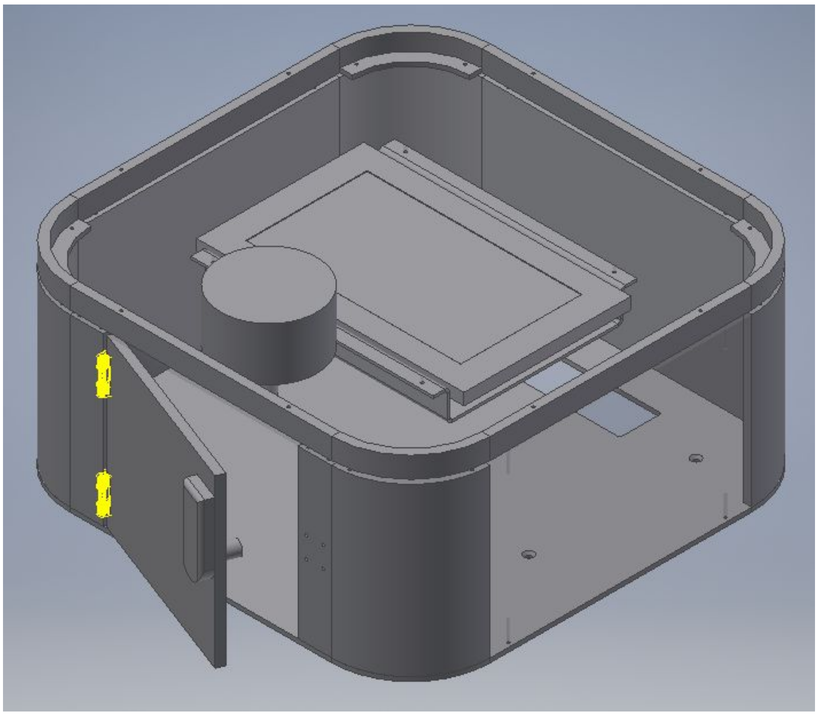


Figure 3-19 Box Design 4

Box design 5, the team chose to redesign the top cover to have layering. This gives the documentation case a relatively nicer design. However, the space provided for the documents is very little.

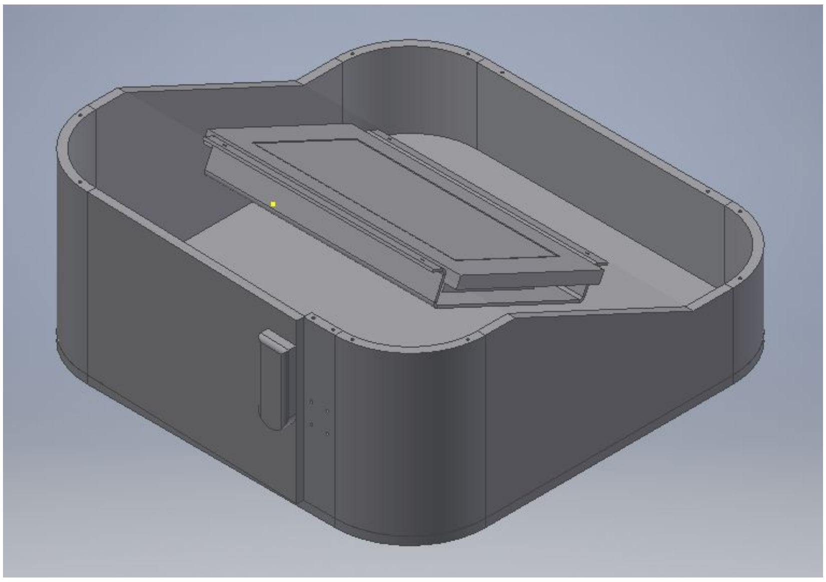


Figure 3-20 Box Design 5

3.3.2 Evaluate the box designs

Table 2: Box design 1 Advantages and Disadvantages

Advantage	Disadvantage
Easy to implement into design	Block the accessibility of the screen
	Lock is not useful for application

Table 3: Box design 2 Advantages and Disadvantages

Advantage	Disadvantage
Have screen mounted a suitable location	Transporter is too tall.
Large Space for use.	

Table 4: Box design 3 Advantages and Disadvantages

Advantage	Disadvantage
Have screen mounted a suitable location	Less space to store documents

Table 5: Box design 4 Advantages and Disadvantages

Advantage	Disadvantage
Screen is not block	Screen is not very ergonomic.
Decent amount space to store documents	
Extra space on top of case.	

Table 6: Box design 5 Advantages and Disadvantages

Advantage	Disadvantage
Looks better	Less space to store documents
Screen is place in ergonomic position	

3.3.3 Chosen design and 3D Rendering

After evaluating the advantages and the disadvantages of each design. The team decided to go for Box Design 4 as it has the best overall advantages and design.

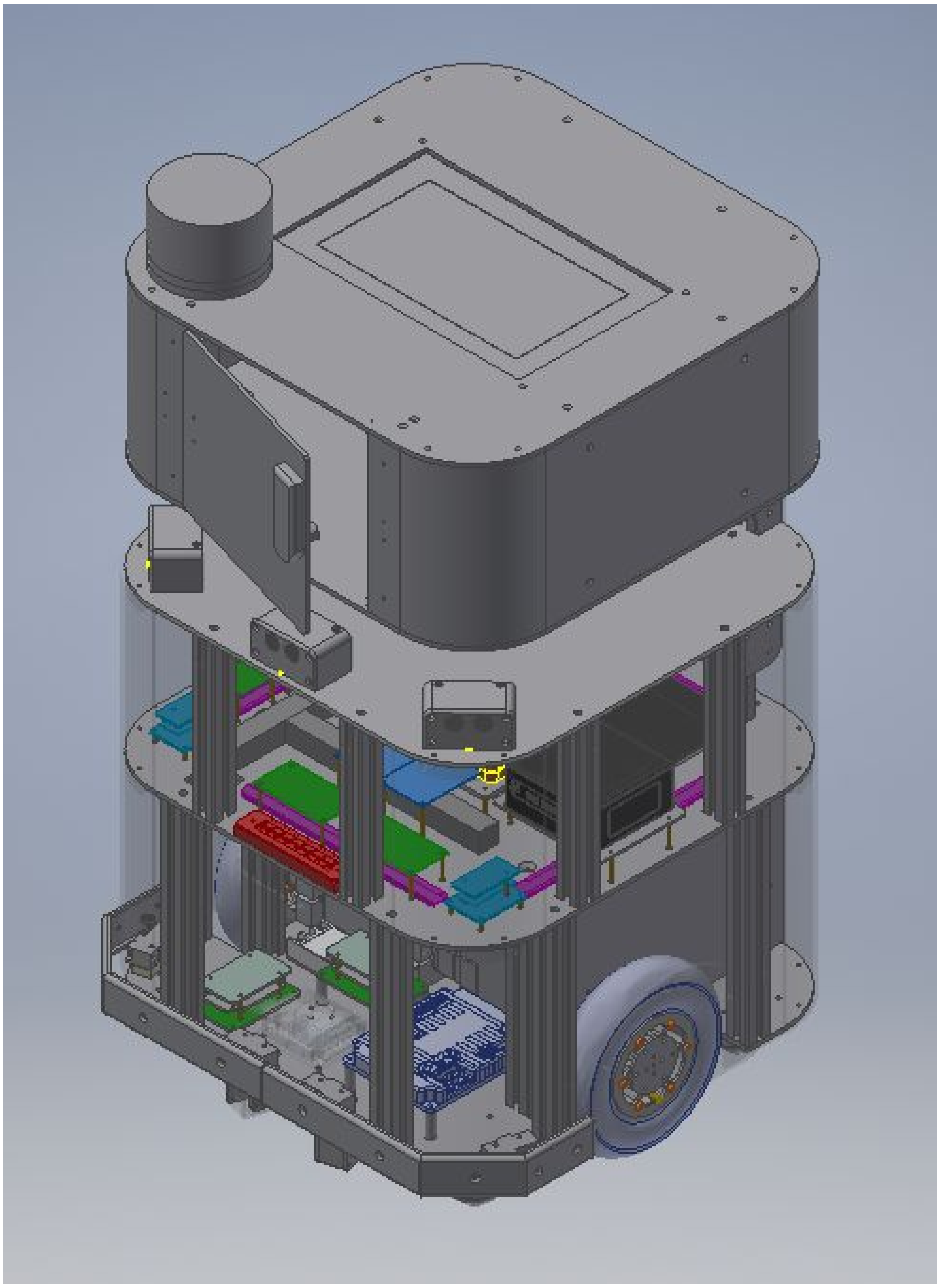


Figure 3-21 Full Rendering Of Transporter Without Shell

3.3.4 Redesign Box 4 for ease of fabrication and assembly.

The team had to redesign the box to help with the fabrication process. The addition of L-plates enable the box to be assembled quickly and efficiently. We had to change the corner box wall to help us mount the top plate without taping the pieces.

The team decided to remove the side walls due to the new placement of the screen and antenna. The top panel was also edited to help facilitate cleaning of the screen.

Using L plates to mount the cover piece, this will make the box be more durable and easy to fabricate. The screen and antenna is also placed in a different location to facilitate the use of the keyboard.

After testing the transporter can carry up to 15kg of weight, without affecting the performance and reliability of the transporter.

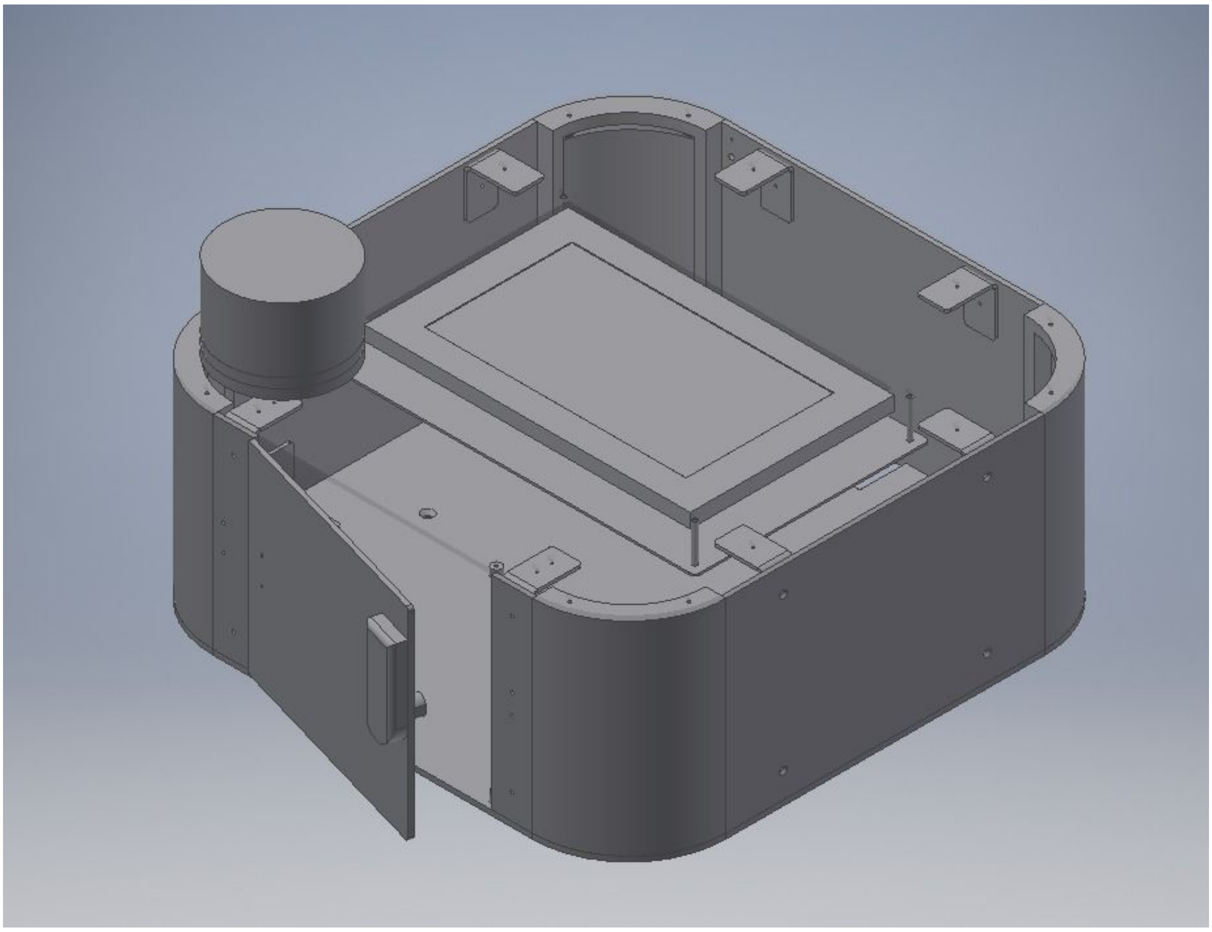


Figure 3-22 Redesigned box 4

3.4 Mechanical changes (Charger Dock)

The design of the charging dock has been changed to facilitate the new features such as the larger charging port and the RFID safety feature. Main changers are the height of the charging prongs.

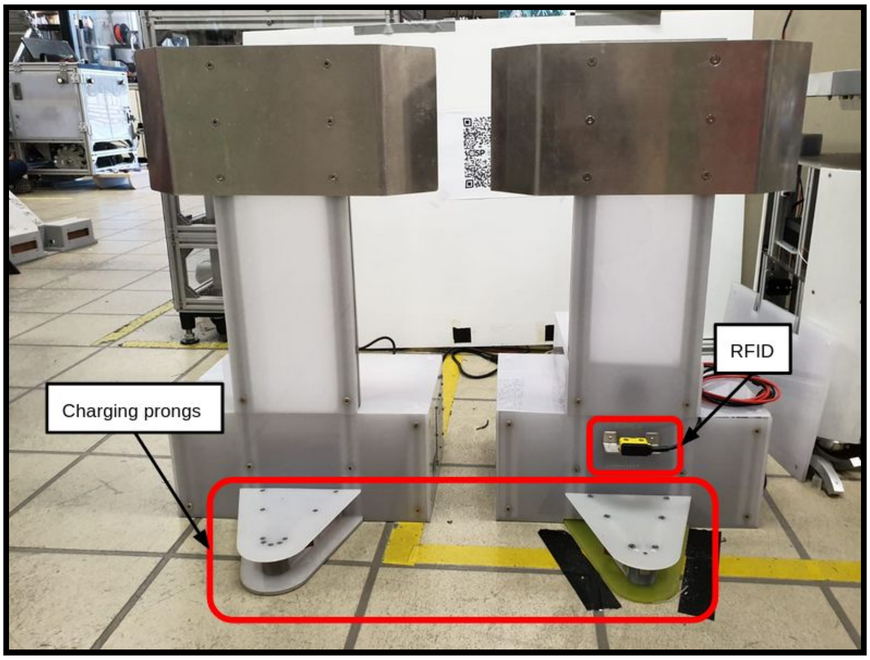


Figure 3-23 Old & New Charger Docks

The height of the charging prongs was changed due to the changes made in the charger 3.1.2. The base of the charger dock was changed from a 4.5 mm polycarbonate plate and 5 mm aluminium plate to a 5 mm fiberglass plate to accommodate the new charger port. The base plate was changed due to the height of the 2 plates being too high for the charging port to dock as the charging port is now longer compared to the old charging port.

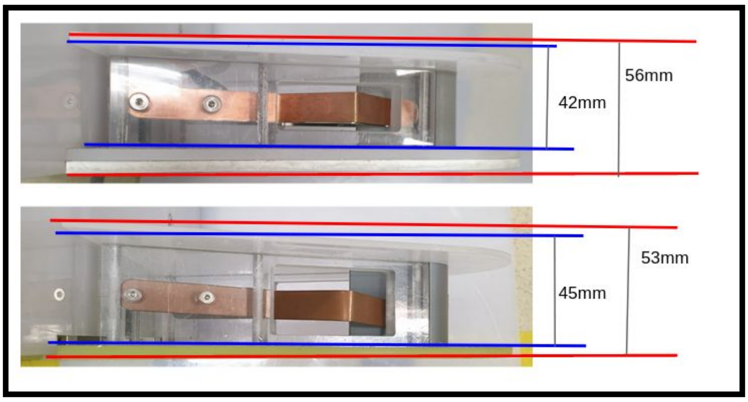


Figure 3-24 Old & New Charging Prongs

3.4.1 Mechanical changes (Contactor compartment)

The charging dock also added a new layer to accommodate the new contactor that has been added together with the RFID safety feature. It is also covered to prevent people from touching the contactor and getting shocked.

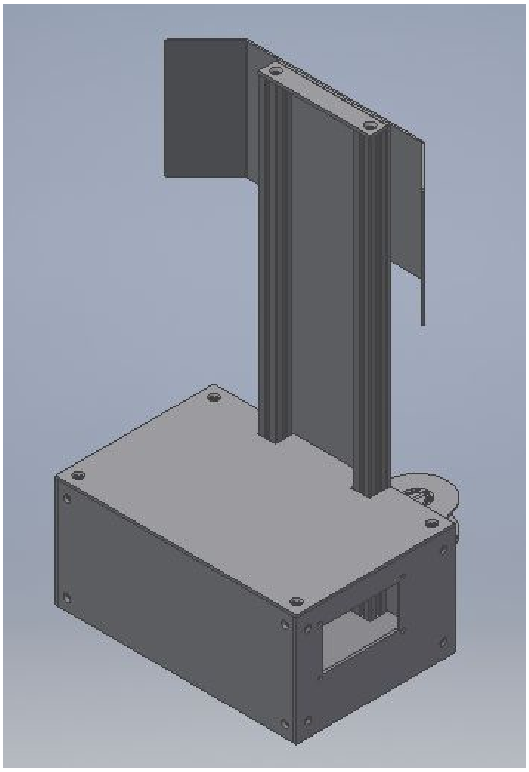


Figure 3-25 Without compartment

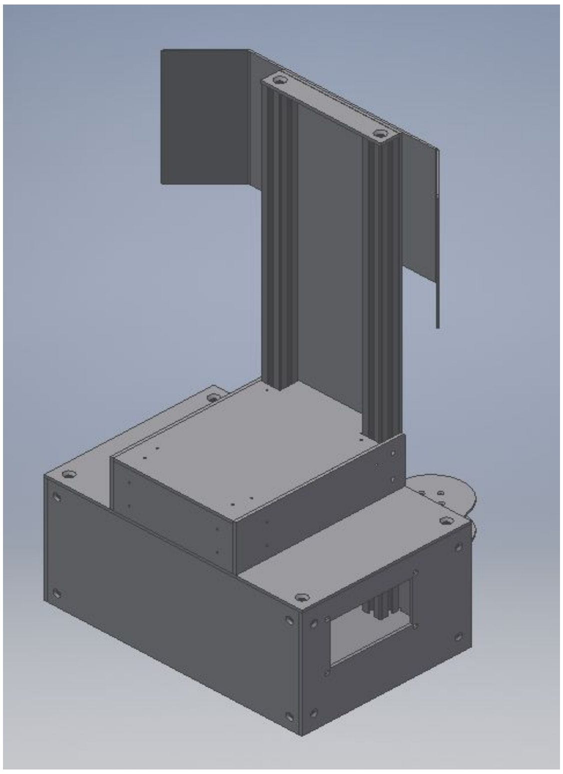


Figure 3-26 With compartment

3.4.2 Mechanical changes (Corner Piece)

The 3D printed corner piece was changed to have a 12mm aluminum insert in the 3d printed piece to hold the base plate and top plate of the charging prongs together. This change is necessary because the metal base of the charging dock was removed due to space constraints.

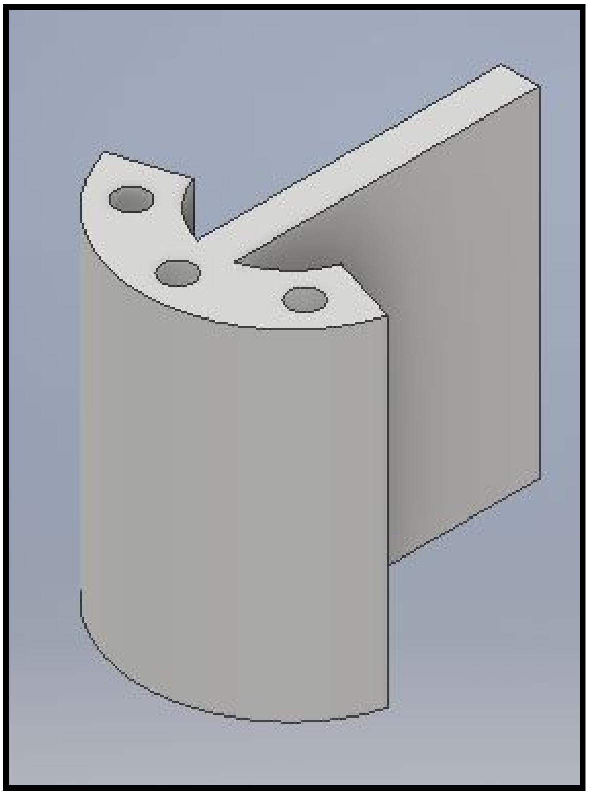


Figure 3-27 Old 3D Printed Corner Piece

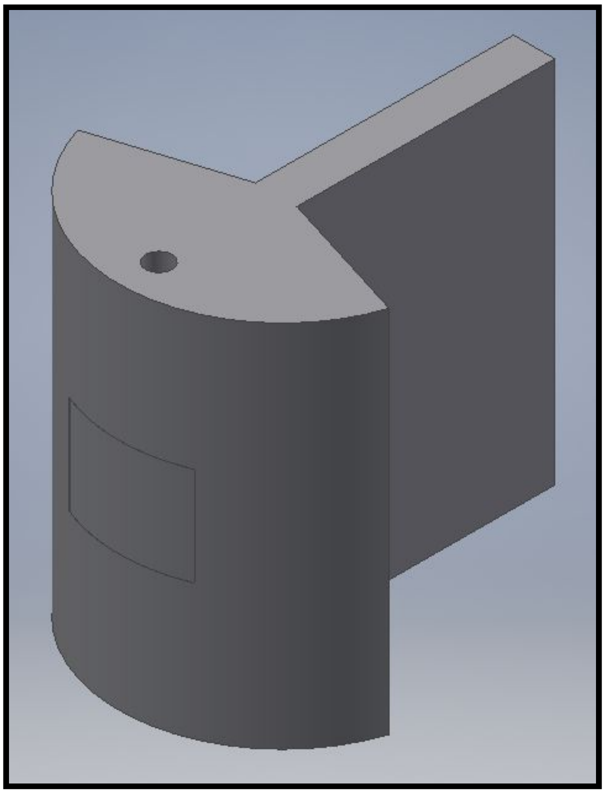


Figure 3-28 New 3D Printed Corner Piece

4. Fabrication

4.1 Waterjet Machine

The waterjet machine was mainly used to fabricate the bigger workpiece such as the base plates of the Transporter. The waterjet machine, when in optimal working condition, can cut aluminium and polycarbonate with relative ease and in a short amount of time. This means lots of workpieces can be fabricated at a single run. This machine is used mainly creating a quick prototype to test part alignment and dimensions.

The downside of using the waterjet machine is that the finish is not very smooth, it has many rough edges. This causes the part to have a visible slope on the cutting edge. Therefore this machine is used mainly to fabricate the four surface plates used in this transporter.

Figure 4-1 Waterjet Machine

4.2 Router

The CNC Router is used to fabricate parts that require a great amount of precision and fine details. Parts such as the battery box require us to use the routing machine instead of the water jet. This machine gave us an almost perfect finish, only simple deburring is needed to ensure a smooth finish.

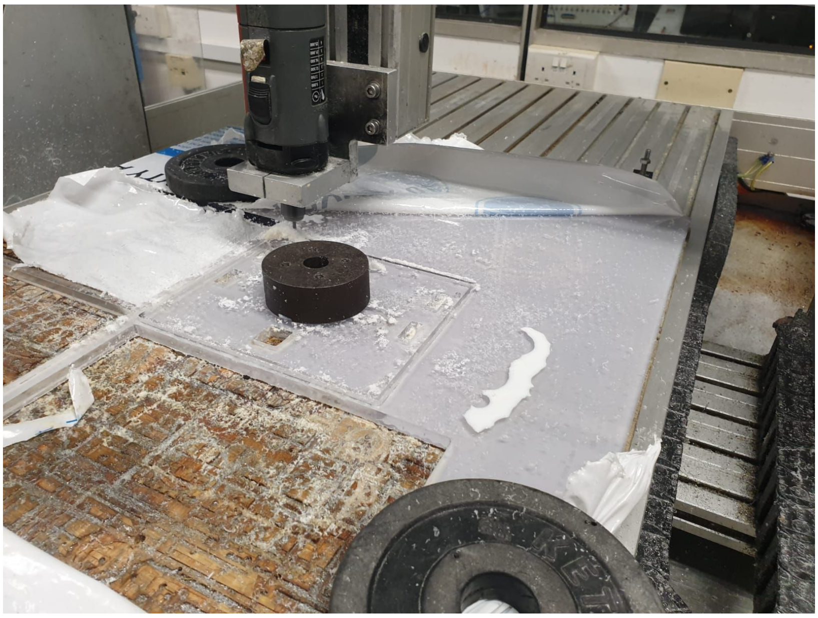


Figure 4-2 Router

4.3 Bending Machine

The Bending machine is used mainly to create 90° bends. This machine has removable clamps that enables it to bend parts with multiple bends such as the spring suspension plate and the bumpers. Other examples are mostly the Brackets, primarily the Battery and Battery Enclosure Brackets and the Tray Brackets.

Figure 4-3 Bending Machine

4.4 Drill Press

Drill press is used primarily to enlarge existing holes, countersunk and drill holes for fabricated pieces. Examples of holes drilled by this machine include the various mounting plates for the circuit boards and electronic components. Countersunk, are used when a flushed surface is needed or to debur certain holes.

Figure 4-4 Drill Press

4.5 3D printer

The 3D printer is used mainly for prototyping, however the transporter required some parts with complicated designs like the corner piece of Box 4 design. That piece would be expensive and hard to fabricate, therefore it was 3D printed.

Depending on the purpose of the 3d printed part, it will require a different infill. For load bearing or small pieces that require a certain amount of durability, it will require a higher infill.

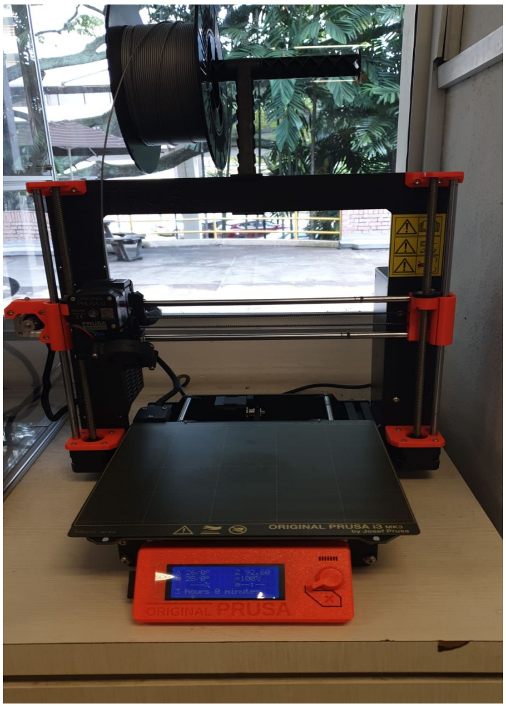


Figure 4-5 3D printer

The printer that the team is using is the Prusa mk3 unlike other machines, Pursa printers generally provide a better finish compared to other machines. Therefore not much work is needed to make the pieces better.

4.6 Milling Machine

The milling machine is used mainly to mill the aluminium profile to size. As the profiles are initially cut with a hacksaw, the ends of the profiles will be sharp and uneven after the cut. Thus, allowance is given to allow the milling machine to not only remove the sharp edges and uneven surface but to also mill it down to the exact length.

Figure 4-6 Milling Machine

5. Electrical

This section will be showing the physical connection of the components. Most connection and layout was established by the previous teams, therefore little to no changes were made. This section will briefly show how the components are connected and the function of these components.

5.1 Electrical components

The physical connection of the components was well established by the previous teams. Since there are no major changes needed, our team invested our time to learn and understand the uses of each component and how they are connected. This section will show the uses of each component.

5.1.1 Arduino Mega

Arduino Mega is a microcontroller board that has 54 digital input/output pinsof which 15 can be used as PWM outputs. It is mainly used to receive signals from the ultrasonic sensor, located at the Top Layer. All three ultrasonic sensors are connected to one 4pin for ease of programming. The signal and data received will be transmitted to the Myrio bot, for Ros programming.

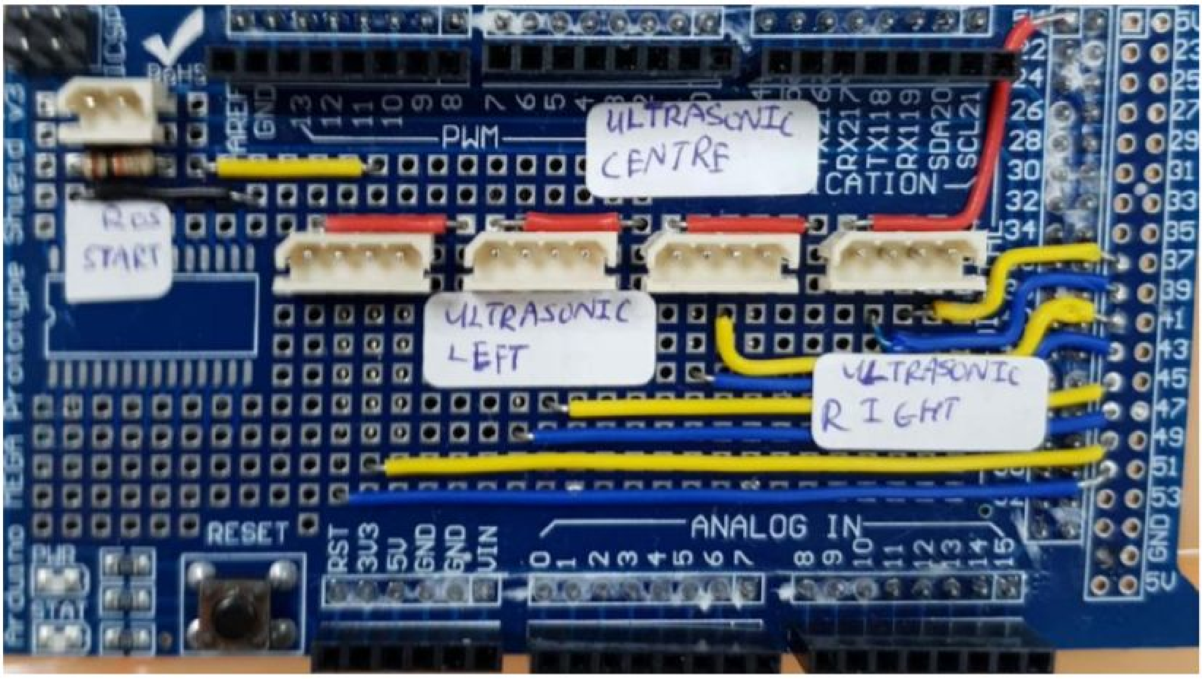


Figure 5-1 Arduino Mega

5.1.2 SICK Lidar

The TiM555 2D LiDAR sensor is a non-contact ranging solution within the TiM series from SICK. it is able to operate in different environments regardless of the surface or ambient light. The lidar is able to provide accurate measurement data from the scanned surface, making it possible to determine additional information such as the size and shape of objects.

The lidar makes use of lasers to detect objects on a 2D plane. This allows the Transporter to detect and gather information from its surrounding area. With this information, it is able to create a 2D map, and perform basic obstacle avoidance.

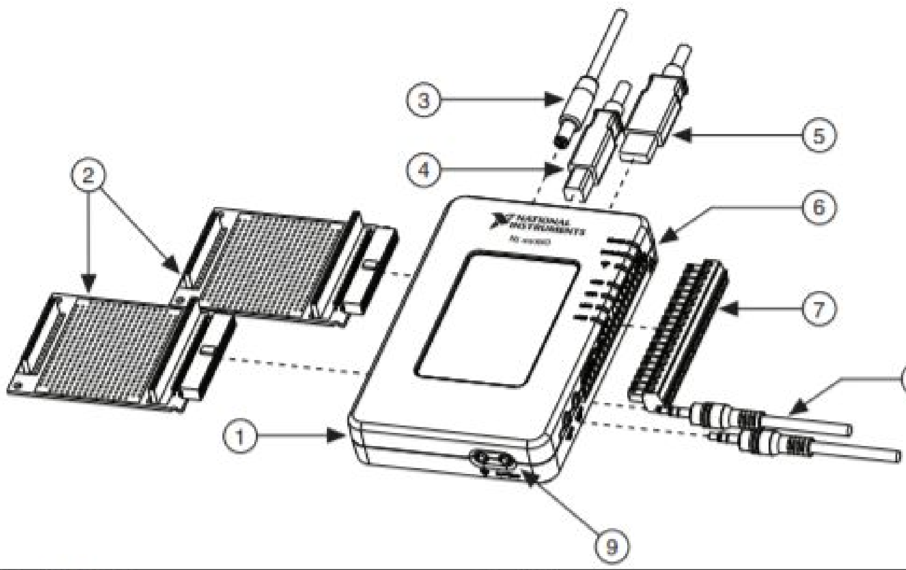
Figure 5-2 Sick Lidar (Sick, nd)

Manufacturer	LiDAR	Horizontal FOV	Min. Range	Max Range	Distance Reso-lution	Scan Rate	Interface	Hor. Angular Resolution	Vertical FOV	Power	Voltage	Mass	Size
SICK	Features: Rugged, Outdoor, Compact. Wide-Range and Low Sensitivity to Ambient Light. IP67.												
	LMS TiM55	270°	0.05m	8m (10%)		15Hz	Ethernet, Micro USB	1°	N/A	4W	9V-28V	250g	60mm x 60mm x 86mm

Figure 5-3 Sick Lidar Specification (Sick, nd)

5.1.3 NI-myRIO

The NI-Myrio(National Instrument myRIO-1900) is a portable reconfigurable I/O (RIO) device, used for design control, robotics and mechatronics systems.



1 NI myRIO-1900
2 myRIO Expansion Port (MXP) Breakouts (One Included in Kit)
3 Power Input Cable
4 USB Device Cable
5 USB Host Cable (Not Included in Kit)
6 LEDs
7 Mini System Port (MSP) Screw-Terminal Connector
8 Audio In/Out Cables (One Included in Kit)
9 Button0

Figure 5-4 Ni-myRio (NI Myrio-1900, nd)

The NI-myRIO is located in the middle-layer of the baseplate and it acts as a centralised controller that monitors input signals and controls output devices. This device is able to read the programs done in labview.

<u>**NI-myRIO-1900 specification**</u>

Processor Type: Xilinx Z-7010 Processor
Speed: 667 MHz
Processor cores: 2
USB host port: USB 2.0 Hi-Speed
USB device port: USB 2.0
Hi-Speed Quadrature encoder input: 100KHz
Number of axes: 3
Resolution: 12 bits
Sample rate: 800 S/s
Power supply voltage range: 6-16 VDC

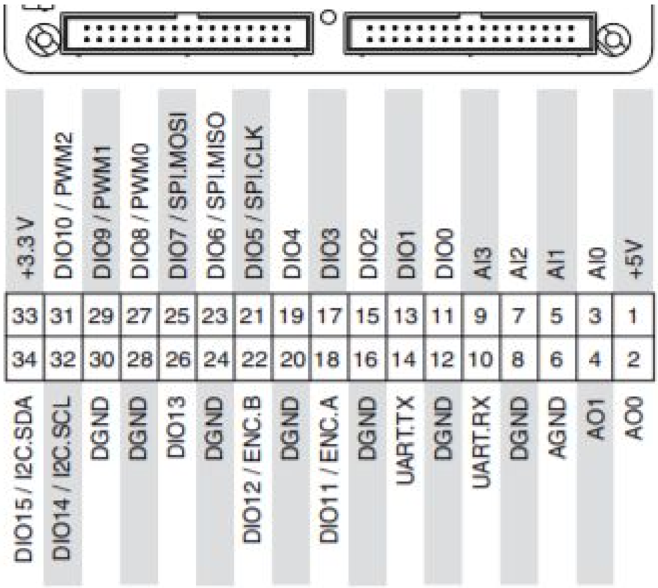


Figure 5-5 MXP connector A & B

Table 7 Pin description

Signal Name	Reference	Direction	Description
+5v	DGND	Output	+5v power output
AI<1..3>	AGND	Input	0-5v, referenced, single-ended analog input channels
AO<0..1>	AGND	Output	0-5v, referenced, single ended analog output
AGND	N/A	N/A	Reference for analog input and output
+3.3V	DGND	Output	+3.3V power output
DIO<0..15>	DGND	Input or Output	General-purpose digital lines with 3.3v output,3.3v/5v-compatible input
UART.RX	DGND	Input	UART receives input. UART line are electrically identical to DIO lines
UART.TX	DGND	Output	UART receives input. UART line are electrically identical to DIO lines
DGND	N/A	N/A	Reference for digital signal,+5v and +3.3v

5.1.4 Asus RT-N12 D1

The Asus RT-N12 D1 is used as a means for the Myrio and the (PC) to communicate with each other. This allows the Labview and ROS programs to send data to and fro through a wireless network accessible from a computer.

Figure 5-6 Asus Router

Network Standard IEEE 802.11b, IEEE 802.11g, IEEE 802.11n, IEEE 802.3, IEEE 802.3u, IPv4, IPv6

Product Segment N300 complete networking : 300 Mbps

Data Rate 802.11b : 1, 2, 5.5, 11 Mbps
802.11g : 6,9,12,18,24,36,48,54 Mbps
802.11n : up to 300 Mbps

Antenna Detachable 5 dBi antenna x 2
*Antenna type will differ according to local regulations and requirement in each country

Operating Frequency 2.4 GHz

Encryption 64-bit WEP, 128-bit WEP, WPA2-PSK, WPA-PSK, WPA-Enterprise , WPA2-Enterprise , WPS support

Management UPnP, IGMP v1/v2/v3, DNS Proxy, NTP Client, DDNS, Port Trigger, Port Forwarding, DMZ

VPN Support IPSec Pass-Through
PPTP Pass-Through
L2TP Pass-Through
PPTP server

Figure 5-7 Asus Router Specification (Asus, nd)

5.1.5 Ion Motion Control

The Ion Motion Control is used to control the speed and acceleration of each Maxon DC brush motor. The MCP motor controller is a high power, high performance motor controller built to withstand the most demanding applications. It has a programmable feature that allows the MCP to be customized for any application. It can interface with several communication standards.

Figure 5-8 Ion Motion Control

	 MCP233 (34 V max) MCP236 (60 V max)	 MCP263 (34 V max) MCP266 (60 V max)	 MCP2163 (34 V max) MCP2166 (60 V max)
Operating voltage:	10 V to 34 V (MCP2x3 versions) 10 V to 60 V (MCP2x6 versions)		
Continuous output current per channel:	30 A	60 A	120 A
Peak output current per channel:	30 A	60 A	160 A
Size(1):	88 × 72 × 26 mm	115 × 107 × 34 mm	212 × 126 × 50 mm
Weight:	140 g	340 g	1630 g
Price:	MCP233: $199.95 MCP236: $219.95	MCP263: $269.95 MCP266: $349.95	MCP2163: $549.95 MCP2166: $649.95

Figure 5-9 Ion Motion Control Specification

5.1.6 Battery Management System(BMS)

The BMS(Battery Management System) is a battery management and conservation system for high current power sources using Lithium Ion chemistry batteries. The BMS system constantly monitors the charge balance, allowing optimal charge cycle and longer battery life.

Figure 5-10 Battery Management System

<u>Battery Management System's Specification</u>

Serial Interface: 1xRS232, 1xRS485

CAN Interface: up to 1Mbit/s

Operating Voltage: 15 to 40V

Operating Temperature: -40 to +85oC

Operating environment Enclosure: Conduction plate & Cover

Min Cells: 6

Max Cells: 10

5.1.7 Solid State Relay

This relay acts as an electronic switch that is able to latch the signal provided by the switch.

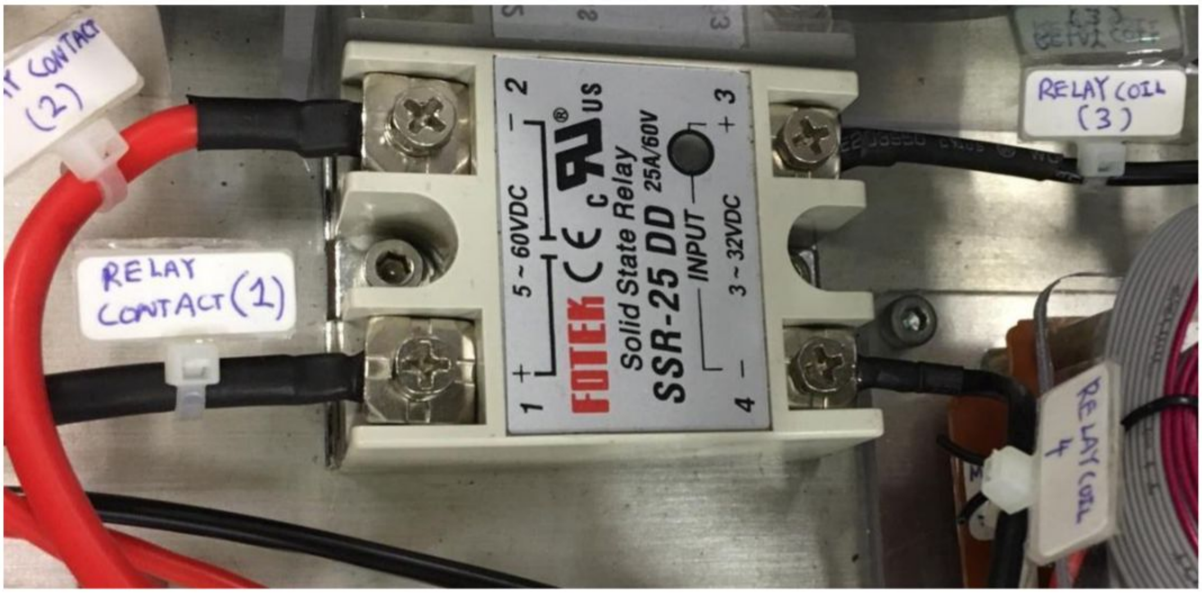


Figure 5-11 Solid State Relay

Solid State Relay Specifications

Input Voltage: 3-32V DC

Output Voltage: 5-60V DC

Output Current: 25A

On Voltage: ≤1V

One-off Time: ≤10ms

Off Leakage Current: ≤2mA

Dimension: 63*45*23.2mm

5.1.8 Maxon DC Brushed Motor

A brushed DC motor is made up of 4 basic components; the stator, the rotor(armature), brushes and commutator. This motor allows variation of the acceleration value.

Figure 5-12 Maxon Motor

<u>RE 50 ⌀ 50 mm, Graphite Brushes, 200 Watt motor Specifications</u>

Planetary Gearhead GP 52 C ⌀ 52 mm, 4.0– 30.0 Nm Ceramic Version

Gearhead data: 223089

Gearhead reduction: 43: 1

Encoder: HEDL 5540 500 CPT, 3 Channels, with Line Driver RS 422

5.1.9 Fans

The fan that we will be using is the 24v 80mm dc fan, with a thickness of 25mm. The fan will be connected to the power bar for power. We added a custom grill to prevent debris from damaging the fan or other component. Starting temperature is 23.8°**.** From our data collected as shown below we can conclude that the fan will significantly affect the temperature of the motor.

Table 8: Temperature test 1

Time	Without Fans	Fans
30 mins	52.8°	41.8°
60 mins	59.2°	44.1°

Table 9: Temperature test 2

Time	Without Fans	Fans
30 mins	52.1°	43.6°
60 mins	60.3°	45.1°

Table 10: Temperature test 3

Time	Without Fans	Fans
30 mins	52.5°	43.3°
60 mins	60.1°	45.1°

Figure 5-13 80mm Fan

5.1.10 Batteries

Figure 5-14 Batteries Used in the Transporter

Currently we are using two 12000 mAh batteries for our controlled test in our school. The result came back around 120 mins before hitting the low voltage threshold.

When the batteries are fully charged and the robot is still in the charging dock, the BMS (Battery Management System) will turn the charging current on and off periodically to prevent the batteries from overcharging.

5.1.11 Circuit Boards

This section will briefly discuss each circuit board used and their uses in the Office Transporter

5.1.11.1 Motor Board

The Motor Board is primarily used to communicate the encoder readings from the motor to the Motor Encoder Splitter Boards on the Middle Layer, which will be sent to Myrio and Ion Motion.

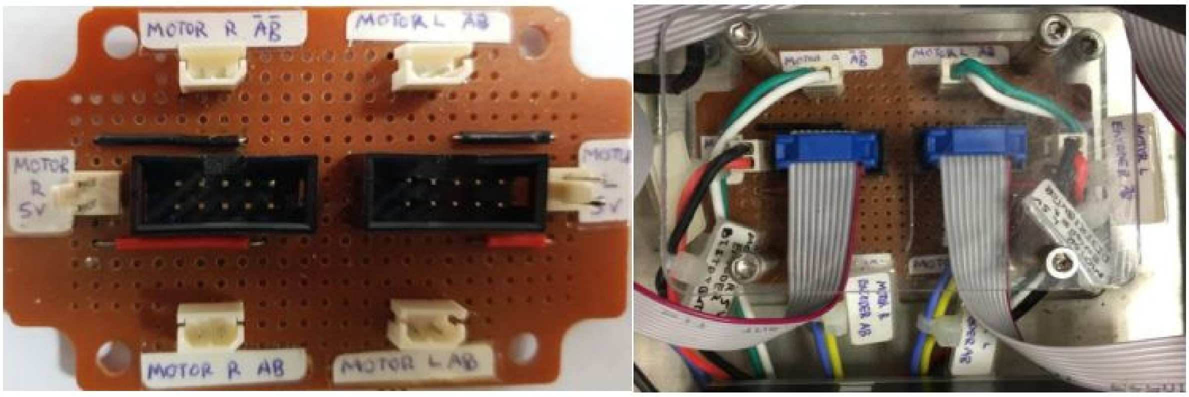


Figure 5-15 Motor Controller Board

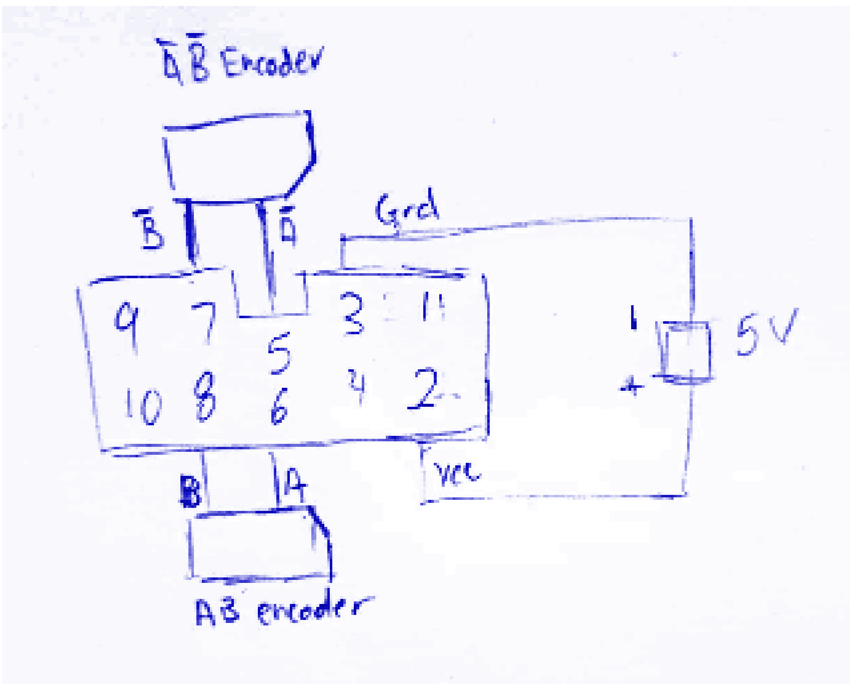


Figure 5-16 Motor Controller Internal Connection

5.1.11.2 Ion Motion Control Board

The Ion Motion Control Board is primarily responsible for transferring information from both the Myrio and the 2 motors to the Ion Motion Control. It also supply a steady 5V power to the motor encoders

Figure 5-17 Motion Control Board

5.1.11.3 Motor L and R Encoder Splitter Boards

The two encoder splitter boards are used to receive data from the Motor Board on the Bottom Layer, and transfer the data to the Myrio and the Ion Motion Board. Each encoder board receives the data and transfers it on to the MAX485. Afterwards, the data is compiled into two sets, with one set being sent to the Myrio, and the other set being sent to the Ion Motion Control. The split reduces the chance of the data being corrupted.

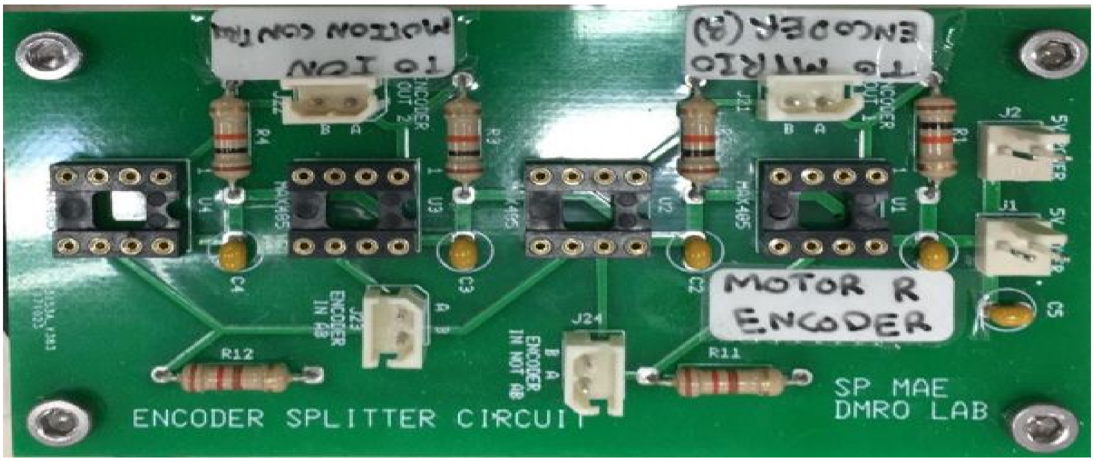


Figure 5-18 Splitter Board

5.1.11.4 Transistor Boards

These two transistor boards are used to turn on and off the LED in the buttons as well as control the LED strips in an RGB fashion.

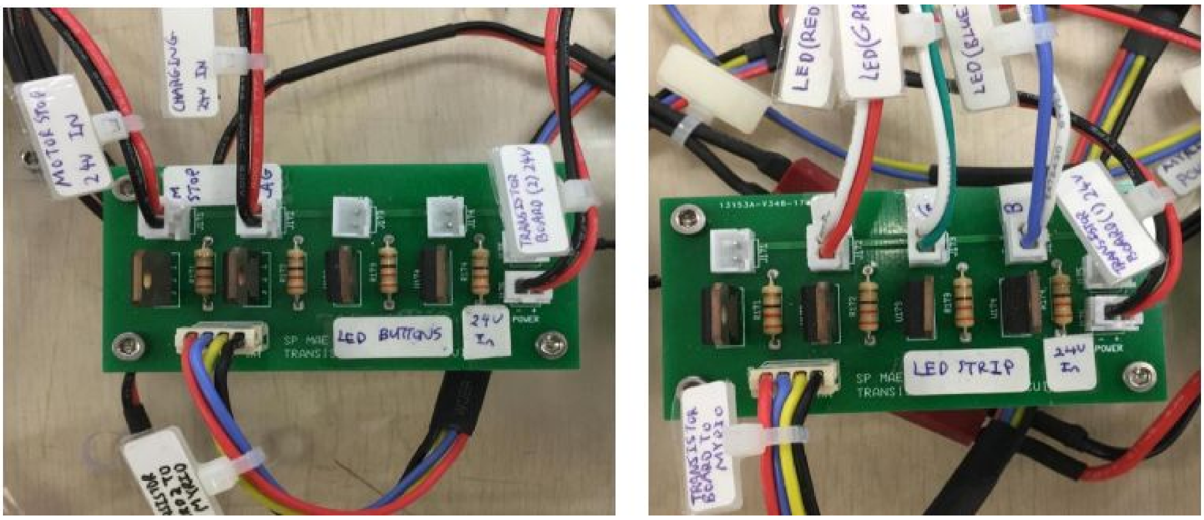


Figure 5-19 Transistor Board

5.1.11.5 Signal Transfer Boards

The function of this circuit board is to receive the input signals from the buttons and the limit switches and compile all the information before sending it to the MyRio.

Figure 5-20 Signal Transfer Board

5.1.11.6 Buck Step Down Converter

A buck converter (step-down converter) is a DC-to-DC power converter which steps down voltage this will increase the current. This regulator is used to step down the default 24V supplied from the Main Power Bar to other differing voltages for different applications. The stepped down voltage will enter a regulator (12V/5V) to automatically maintain a constant voltage level for use.

The Buck Step Down Converter the transporter will be using is the XL4015. The output can be adjusted from 1.25 - 36V.

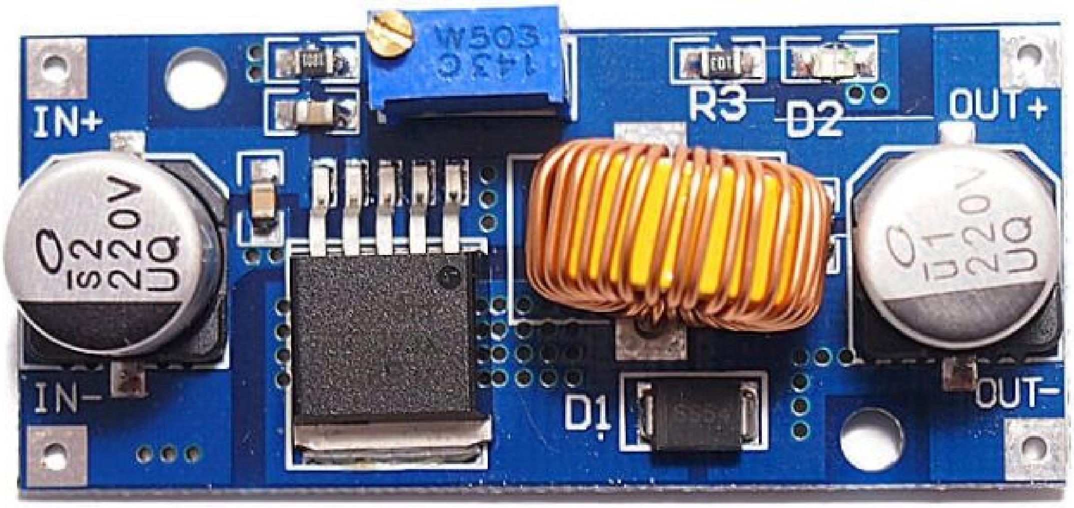


Figure 5-21 5V Step Down Regulator

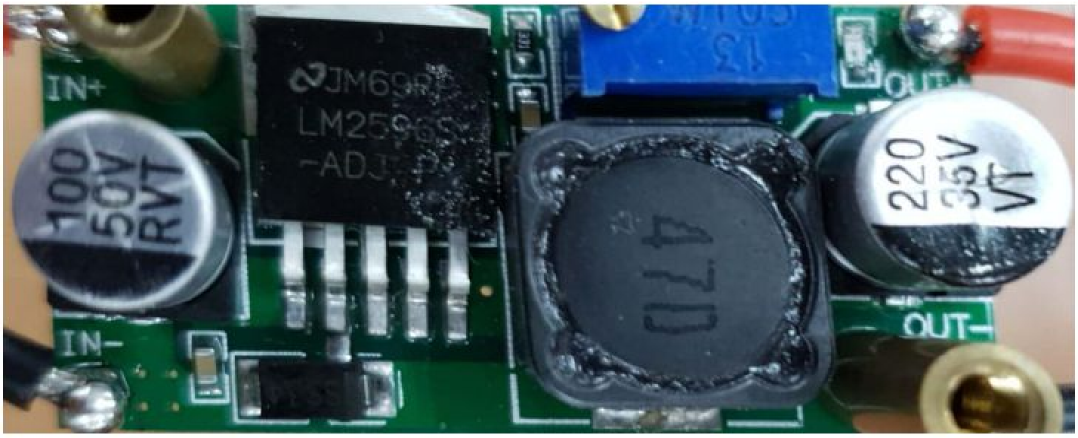


Figure 5-22 19V Step Down Regulator

There are two of these regulators being used to step down the default 24V supplied from the Main Power Bar. One of the regulators is used to step 24V down to 12V to supply power to the Monitor, Lidar and MyRio. The other regulator steps down the default 24V down to 19V to be used by the Intel NUC.

5.1.12 ProSoft Fast Industrial Hotspot RLX2

The ProSoft Technology Fast Industrial Hotspot (RLX2-IHNF) provides secure wireless solutions and good coverage for the office floor. With the implementation of this industrial hotspot the transporter is able to cover the entire SICK office without any serious deadzone. It is mainly used to help to boost wifi and to communicate with the network.

Figure 5-23 Prosoft Industrial Hotspot RLX2

5.1.13 4 dBI Omni RP-SMA MIMO antenna A2504S3-O-6

This antenna is a reliable antenna that provides antenna feeds and elements that provide maximum diversity for 2.4/5 GHz WiFi and WiMax broadband wireless frequencies.

Figure 5-24 19V Industrial Antenna

5.1.14 RFID

The RFID is a safety feature that will prevent current flow when the transporter is not in range. The RFID that the transport is using is the prototype provided by SICK. it has a range of 15mm.

Figure 5-25 RFID Receiver and Tag

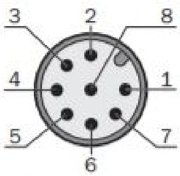


Figure 15: Device connection (male connector, M12, 8-pin, A-coded)

Table 8: Device connection pin assignment (male connector, M12, 8-pin, A-coded)

Pin	Wire color [1)]	Designation	Description
1	White	Aux	Application diagnostic output (not safe)
2	Brown	+24 V DC	Voltage supply 24 V DC
3	Green	n. c.	Not connected
4	Yellow	In 2	Enable input OSSD 2 [2)]
5	Gray	OSSD 1	OSSD 1 output
6	Pink	OSSD 2	OSSD 2 output
7	Blue	0 V	Voltage supply 0 V DC
8	Red	In 1	Enable input OSSD 1 [2)]

Figure 5-26 Sick RFID Pinout

5.1.15 Electrical Contactor

The electrical contactor is used in operation with the RFID. the RFID will send a signal to the contactor, this will enable the contactor. Therefore only when the transporter is near, the charging prongs will turn on. The connection of the charging station will be elaborated in the next section.

Figure 5-27 Contactor

Figure 5-28 Contactor mounted in the charging dock

5.2.1 Circuit Diagram

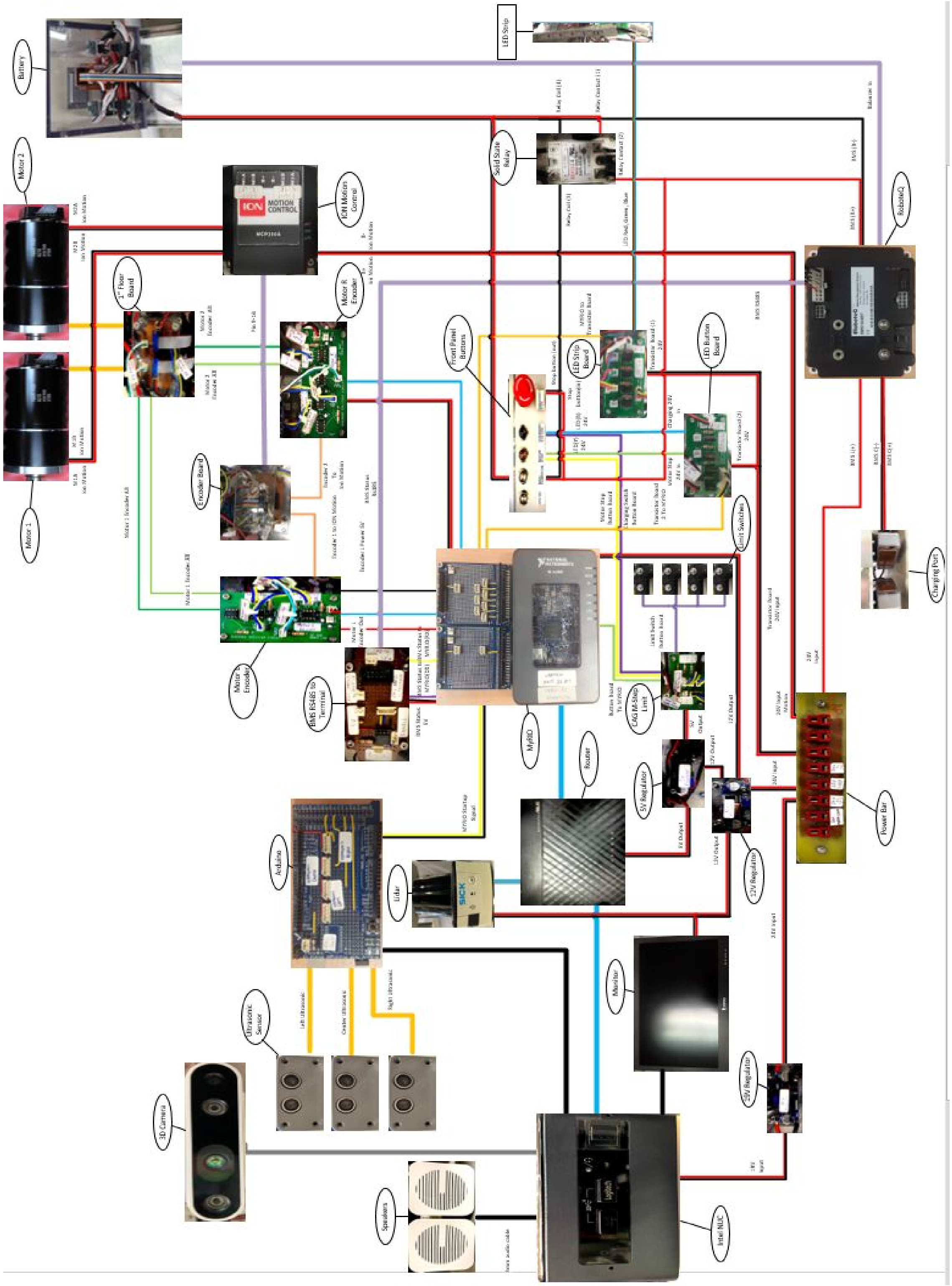


Figure 5-29 Whole Circuit

5.2.2 Top Layer

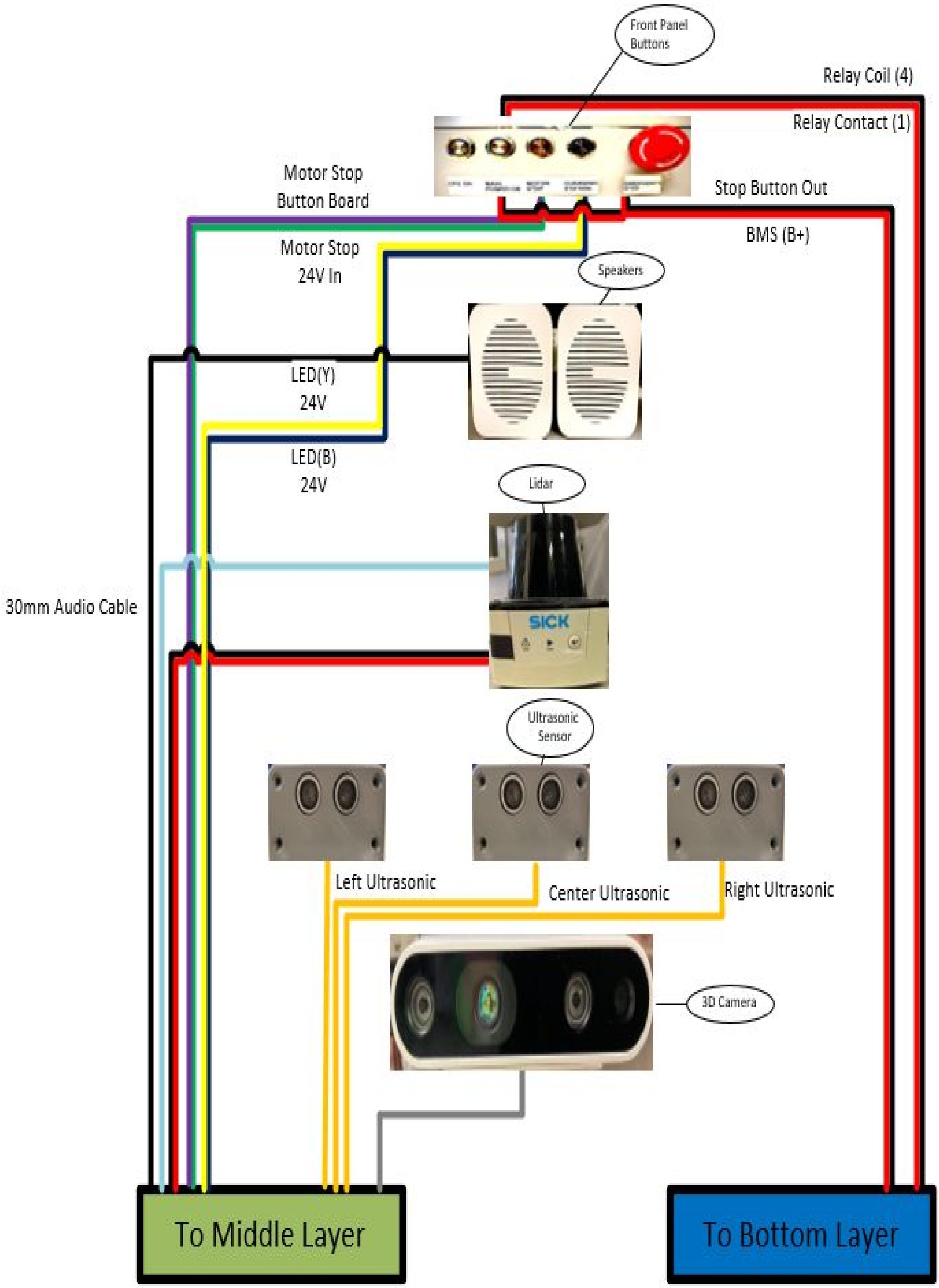


Figure 5-30 Top Layer

5.2.3 Middle Layer

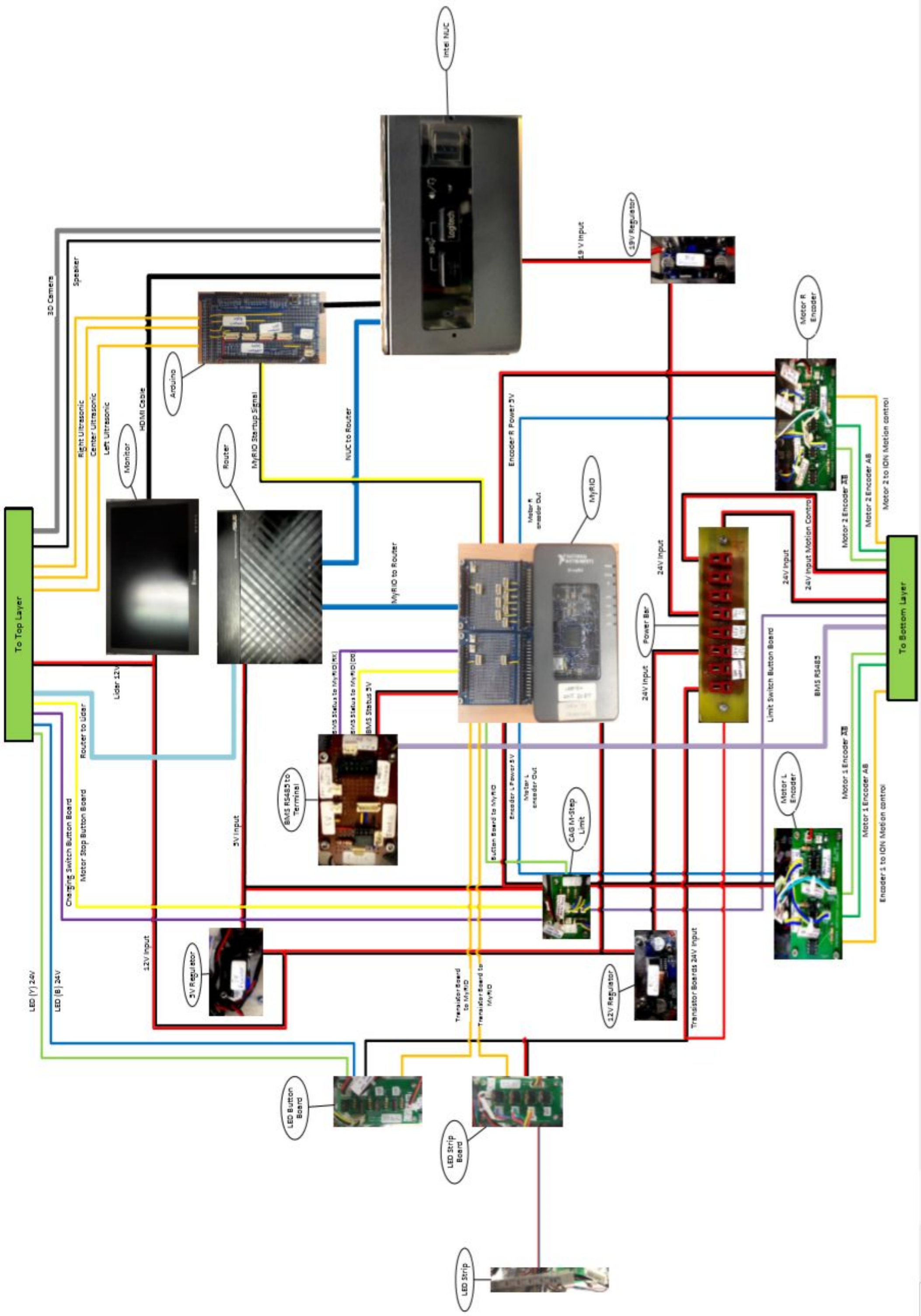


Figure 5-31 Middle layer

5.2.4 Bottom Layer

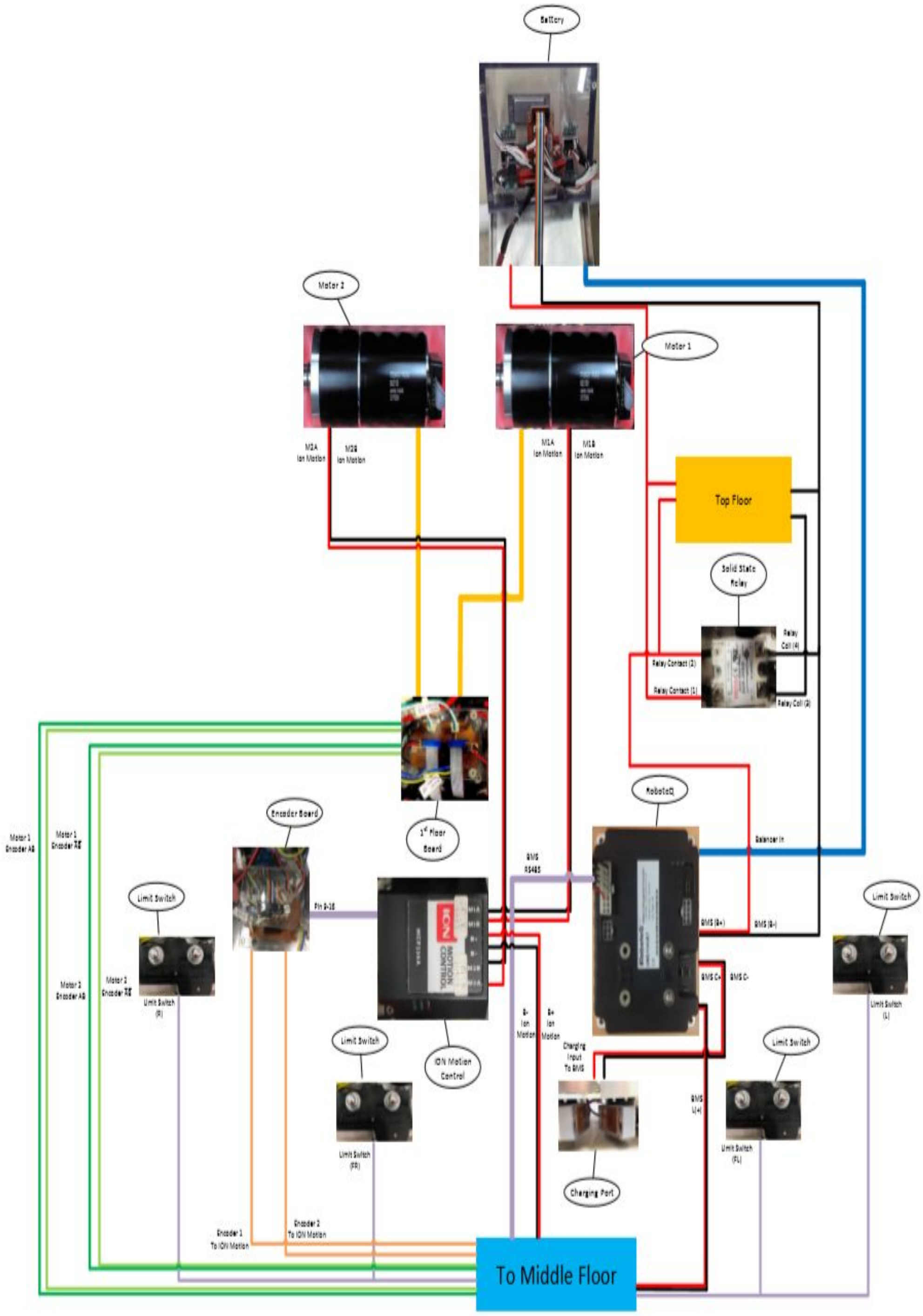


Figure 5-32 Bottom layer

5.2.5 Charging Dock

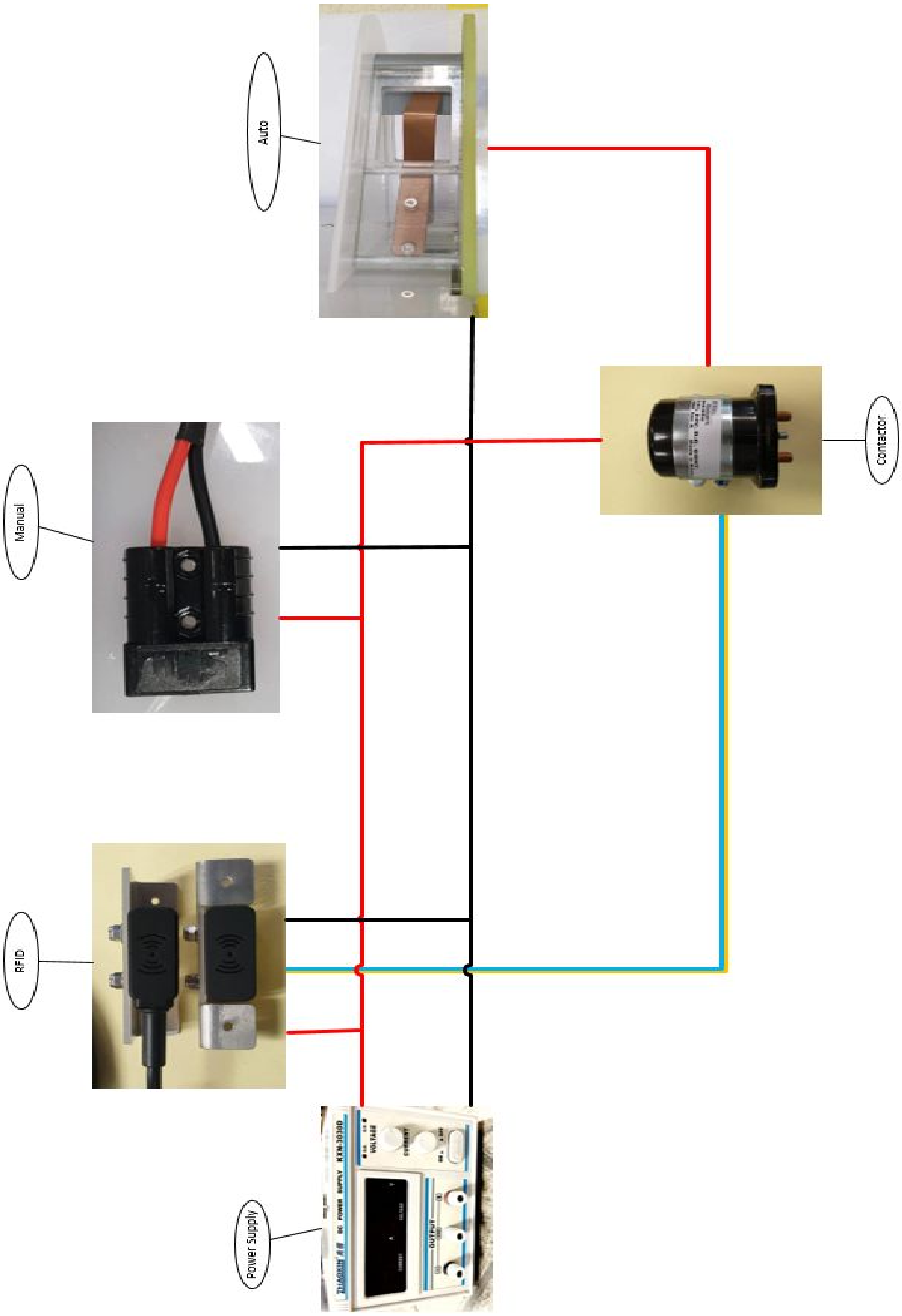


Figure 5-33 Charging Dock

6. Software Familiarisation

Our transporter is using a differential drive. The figure below shows our findings on how to calculate the X, Y position, velocity, angular velocity and radians. The Model 2.0

Table 11 Variables in the formula:

Symbols	Meaning	Value/units
$v_{(l,r)}$	**Angular Velocity of Wheels**	**deg/s**
w	**Angular Velocity of transporter**	**deg/s**
L	**Distance between wheel**	**460mm**
R	**Radius of Wheel**	**199mm**
x,y	**Position of Robot**	**-**
ø	**Orientation of Robot**	**-**

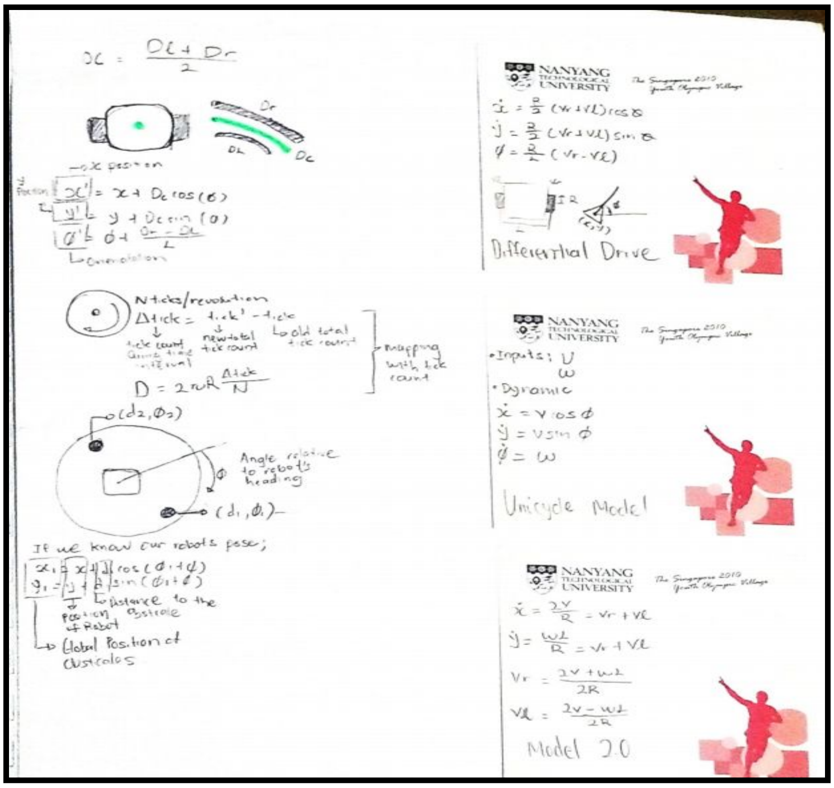


Figure 6-1 Formula recorded

Labview require various connections from block to block. The description on the different connection lines to the various blocks are shown in figure 6-2.

Figure 6-2 Labview Connection

6.1.1 Labview (Counter)

This is a simple counter program that enables us to familiarise ourselves with the labview programming software during the circuit breaker. This counter uses a for loop program and increases by 1 every time the “Count” button is pressed.

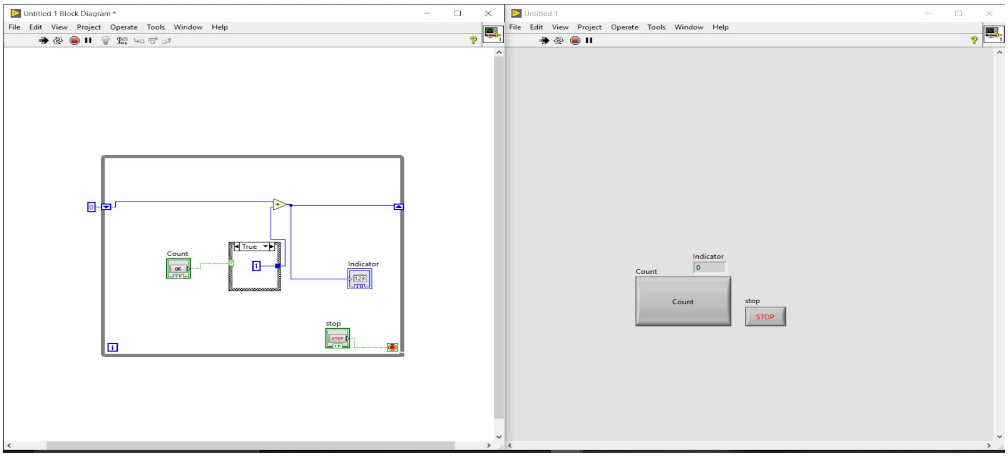


Figure 6-3 Simple Counter Program

In Figure 6-4 is a counter program used to simulate the encoder.

Once the program is initiated, the value of “CounterLoopL” will increase regardless of the switch condition and the value of “CounterL” will remain at 0. The “CounterL” will only increase or decrease once the start switch is flipped.The polarity switch is use to increase or decrease the value of “CounterL”

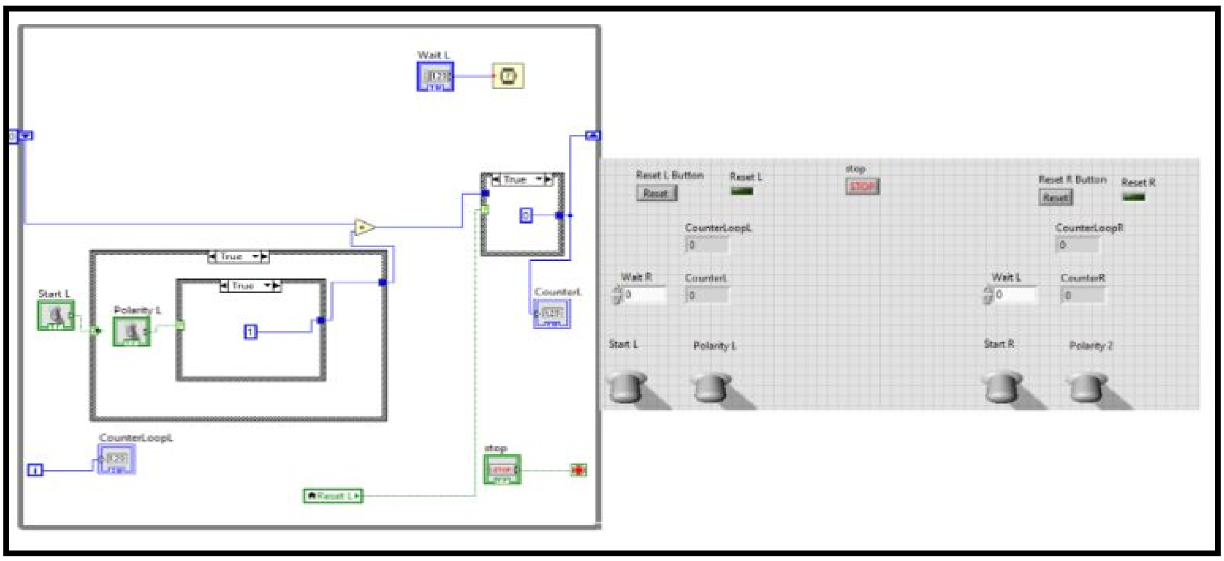


Figure 6-4 Counter acting as encoder

6.1.2 Labview and Ros communication (Labview Publisher)

Table 12 Labview icon description

Labview Block	Icon	Description
Ros_Topic_Init		Initialised a topic and return a Ros cluster(required before any read or write call)
Ros_Topic_Write		Formats the message being send into Ros
Ros_Topic_Read		Reads messages that are sent from Ros.
Ros_Topic_Close		Closes the topic
Float32Scalar		Formats and build 32bits floating point number into a message(use for building)
parse_float32_scalar		Formats and build 32bits floating point number into a message(use for recieving)

Labview numbers are represented in different forms. In figure 6-5 are some examples of how values are represented in labview.

SGL **Single-precision (SGL)**—Single-precision, floating-point numbers have 32-bit IEEE single-precision format. Use single-precision, floating-point numbers when memory savings are important and you will not overflow the range of the numbers.

DBL **Double-precision (DBL)**—Double-precision, floating-point numbers have 64-bit IEEE double-precision format. Double-precision is the default format for numeric objects. For most situations, use double-precision, floating-point numbers.

EXT **Extended-precision (EXT)**—When you save extended-precision numbers to disk, LabVIEW stores them in a platform-independent 128-bit format. In memory, the size and precision vary depending on the platform. Use extended-precision, floating-point numbers only when necessary. The performance of extended-precision arithmetic vary among platforms.

Figure 6-5 different number value types

In Figure 6-6, the program is written to understand the concept of transferring data from Labview to ROS via a local network connection. Initialize the topic, by setting up the Ros_Topic_Init.vi with the following parameters (Topic list, Message type, Update(ms), Queue). Setup node name by creating a constant (/labview) on the Ros_Topic_Init.vi.

The program includes a counter that will continue to count to 10 and reset to 0. The value is then transmitted into an element called add_int32.vi. This element is used to convert the value into a package to be posted on to Ros_Topic_Write.vi to update the topic with a new value.

The program will then be close by the Ros_Topic_Close.vi

This program is a relatively easy program to understand the basics of labview and ros communication.

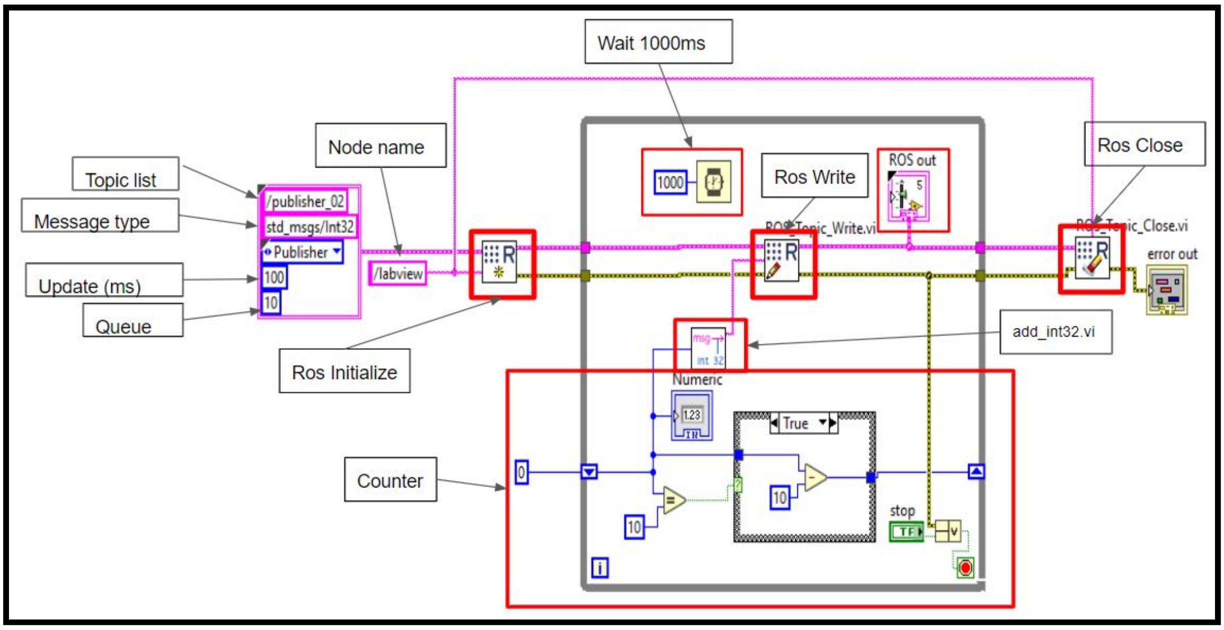


Figure 6-6 Labview Publisher Program

6.1.3 Labview (Condition for Labview Main Loop)

The condition for the main loop to run is shown in figure 6-7. Labview waits for the ROS PC to be ready signaled from the arduino before the main code is able to run.

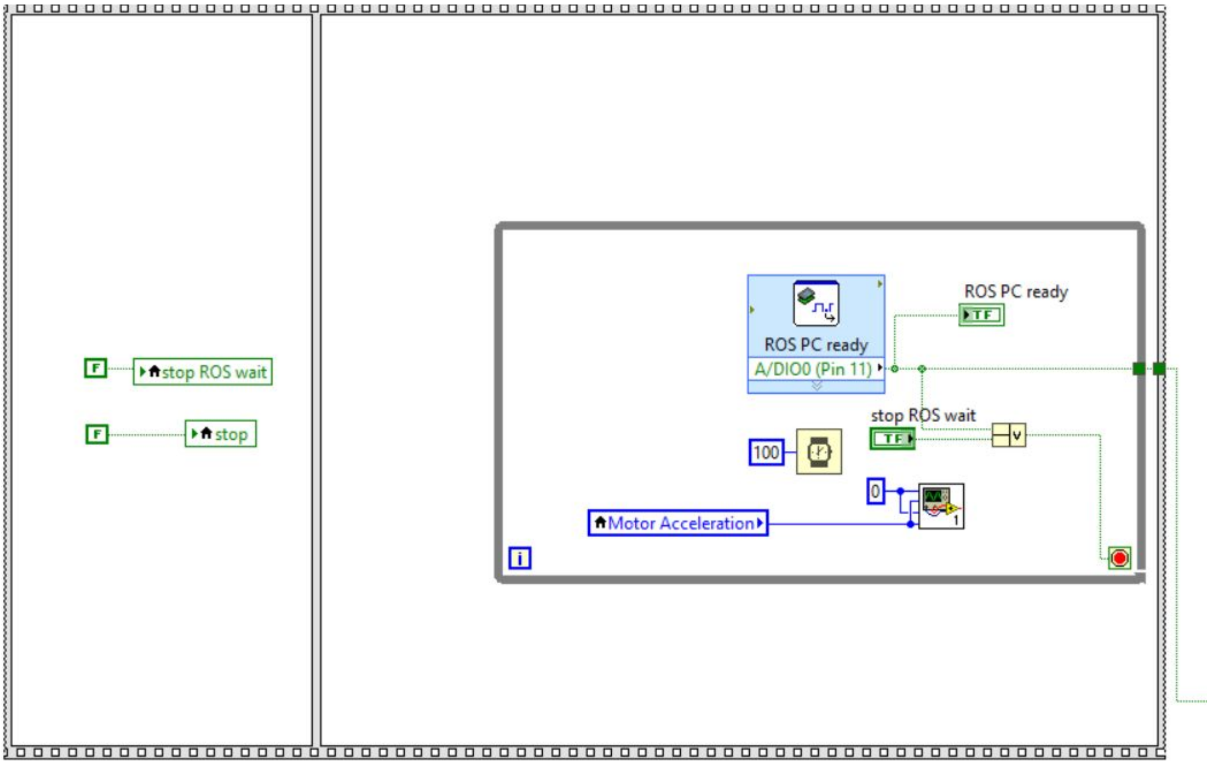


Figure 6-7 Loop Condition for main program

6.1.4 Labview and Ros communication (Labview Subscriber)

The labview subscriber is a program that receives data from the ros pc and projects it out onto labview. The program utilizes an element known as Ros_Topic_read.vi to receive the code. The program will get the values from the topic /subscriber_02

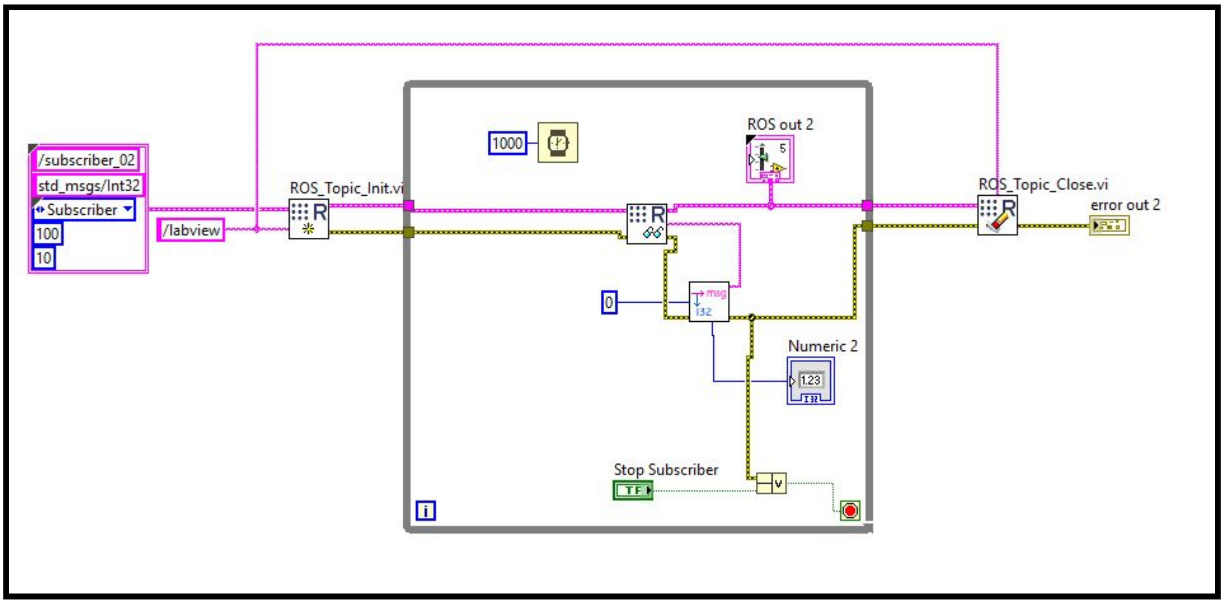


Figure 6-8 Labview Subscriber Program

6.1.5 Labview (Calculation of Motor Speed)

Using the formula node we are able to calculate our motor speed by inputting the code as shown in Figure 6-9. The code takes the input value of the encoder and calculates the difference between the starting and the final values of the encoder in degrees and degrees/sec. Encoder is measured in ticks,as such the total tick is divided by the difference in encoder to find the velocity in degree/seconds.

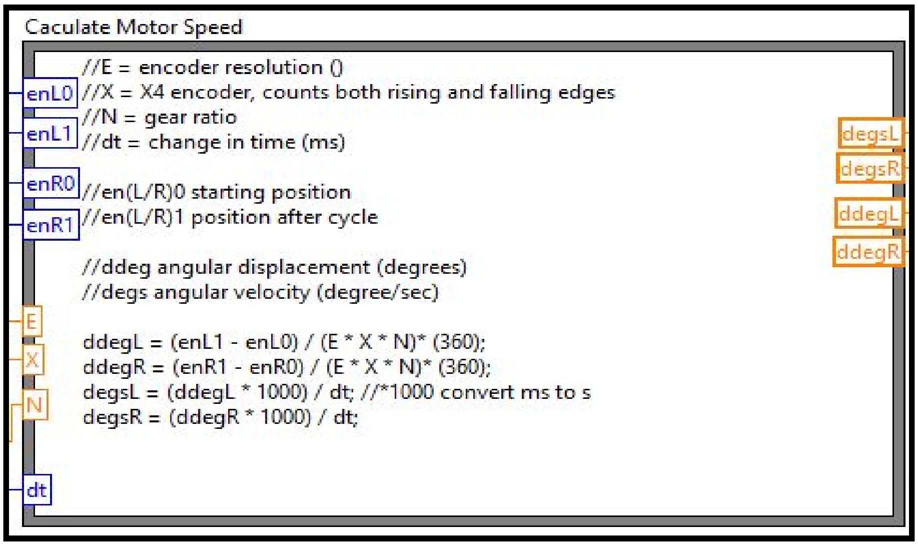


Figure 6-9 Labview Calculation For Motor speed.

6.1.6 Labview (DC motor inverse kinematics)

This part of the code uses inverse kinematics to calculate the angular velocity of the transporter.

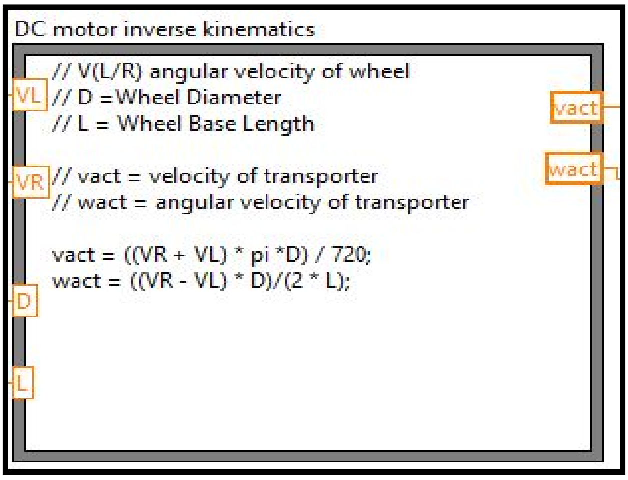


Figure 6-10 DC Motor Inverse Kinematics

6.1.7 Labview (Calculate Transporter Location and publisher)

This part of the code calculates the x, y, and w (rotational) positions of the transporter and inputs them along with the velocity and angular velocity of the transporter into a cluster . The data in the cluster is portrayed into a graph and will also be sent to ros (ros_lv_project_01/odomlvtoros) using a publisher program as shown in figure 6-10.

In figure 6-11, labview publishes the odometry to ROS for manual and auto navigation

- x1 & y1 is represented as initial position
- x2 & y2 is represented as final position
- x3 & y3 includes the orientation of the robot

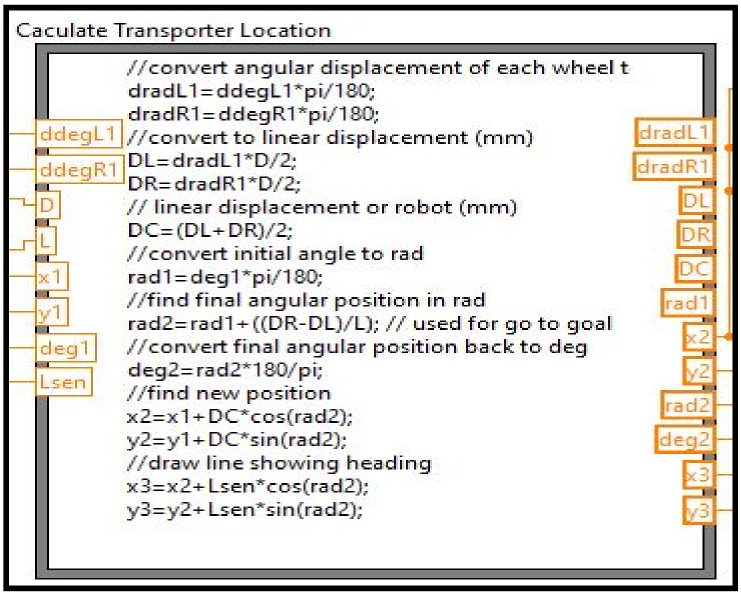


Figure 6-11 DC Motor Inverse Kinematics

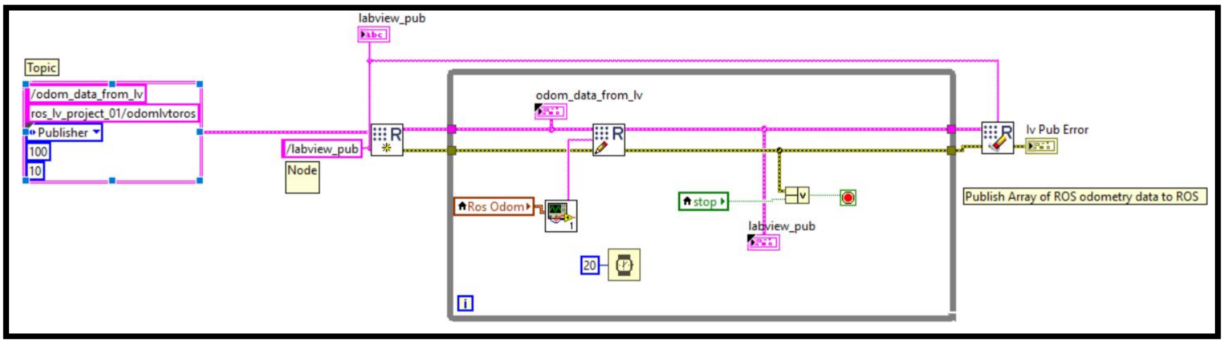


Figure 6-12 Labview Odometry Publisher to Ros.

6.1.8 Labview (BMS)

This section of labview takes value from the BMS and displays it into the labview front panel. In figure 6-13, labview gets the value by searching the string input scripted in BMS and matching it with the search input. The value is then projected into the labview front panel as a value and a graph as shown in figure 6-134

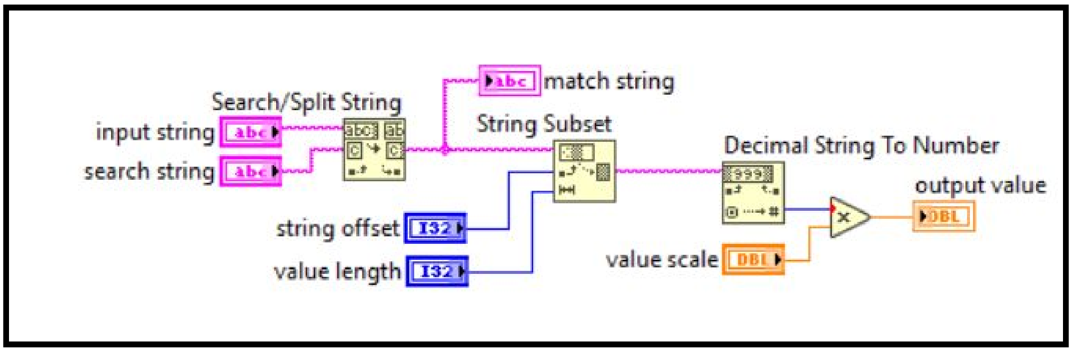


Figure 6-13 String value from BMS

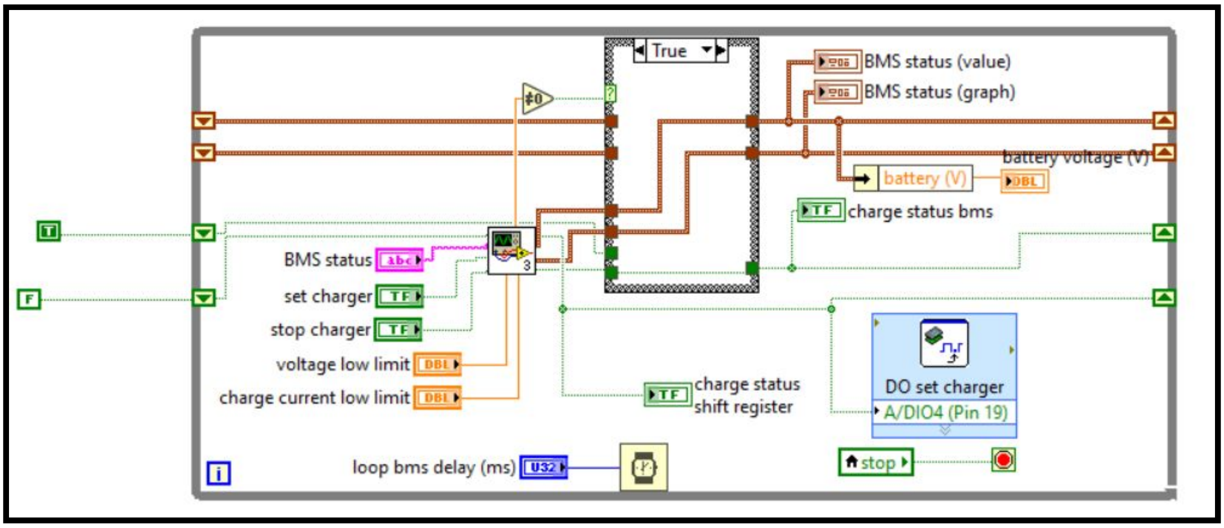


Figure 6-14 BMS status

BMS uses MicroBasic scripting language to obtain the voltage for the overall as well as each cell of the battery. Labview reads the string and matches it to receive the output displayed by the BMS.

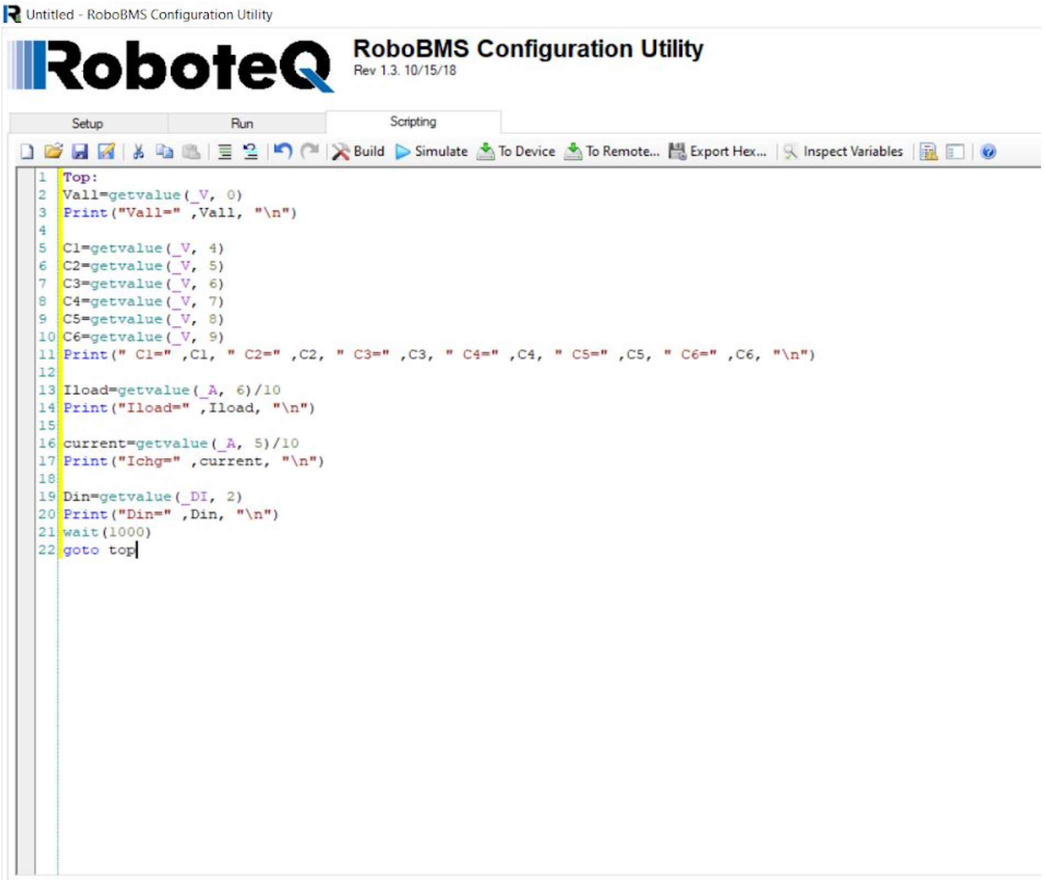


Figure 6-15 BMS scripting

6.1.9 Labview Joytest

Using the value obtained from ROS in figure 6-16, labview uses the value and converts Vcom into radian and calculates the velocity. The velocity is then transmitted to the motor encoder as seen in figure 6-17.

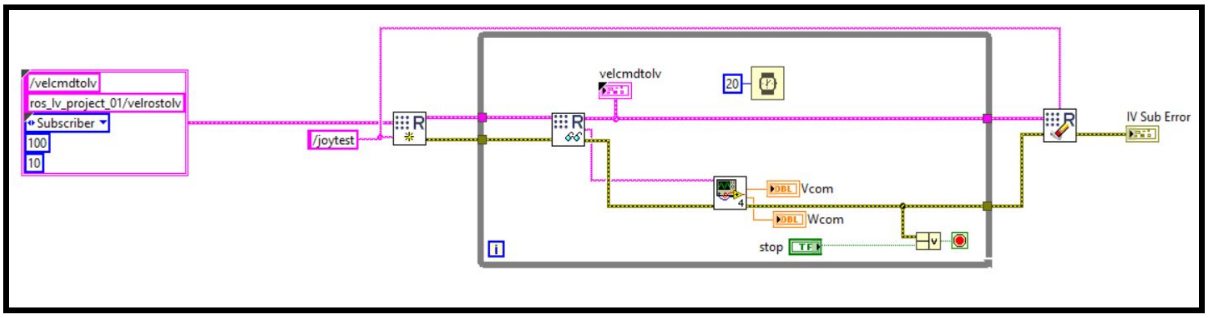


Figure 6-16 Vcom & Wcom Subscriber

In Figure 6-17, labview uses cyclic redundancy check calculation to check for error from the message received. The message is first converted into binary bits and using the cyclic redundancy check calculation, errors can be detected when there are remainders through division. After calculating for error the message is sent as a string into the ion motion controller.

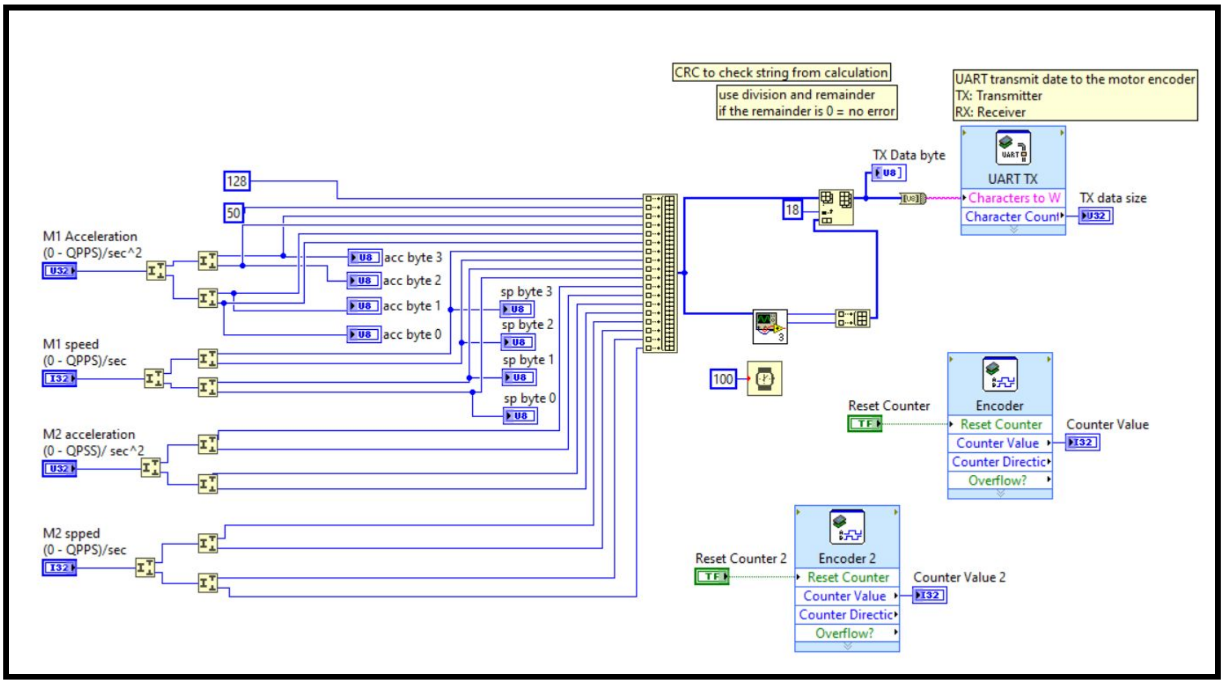


Figure 6-17 Cyclic Redundancy Check calculation

6.1.10 Labview Switch input

In figure 6-18, labview reads the input from the button board and bumper. According to the activated switches, labview will match it to the respective LED colours.

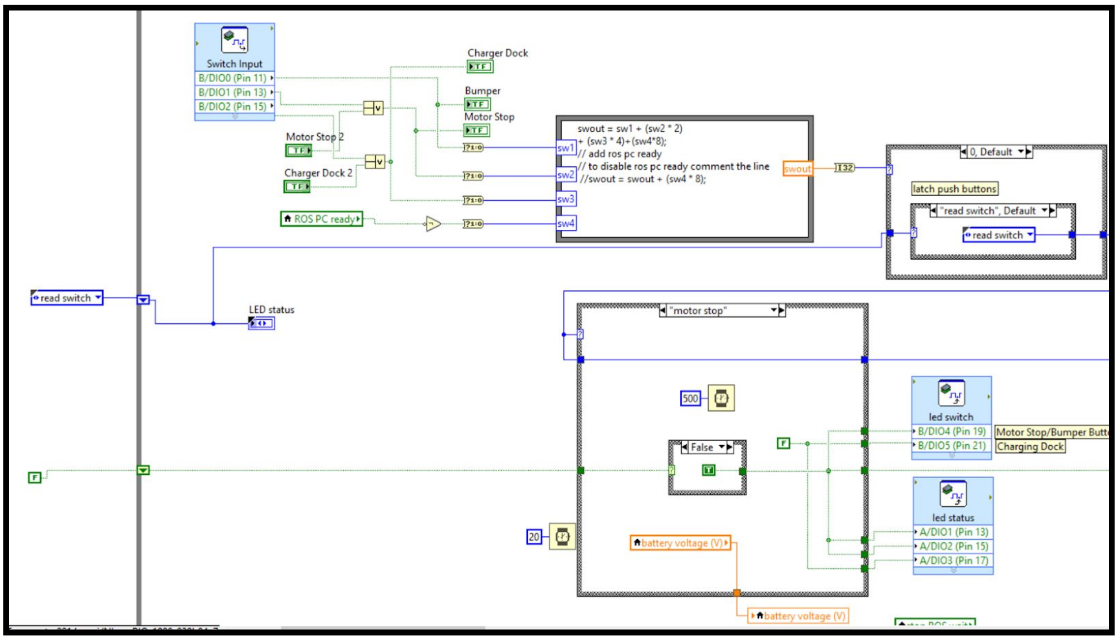


Figure 6-18 switch input

According to the LED status set by the input received from the switches, it will indirectly control the ion motion controller to perform the various actions required of the switch input.

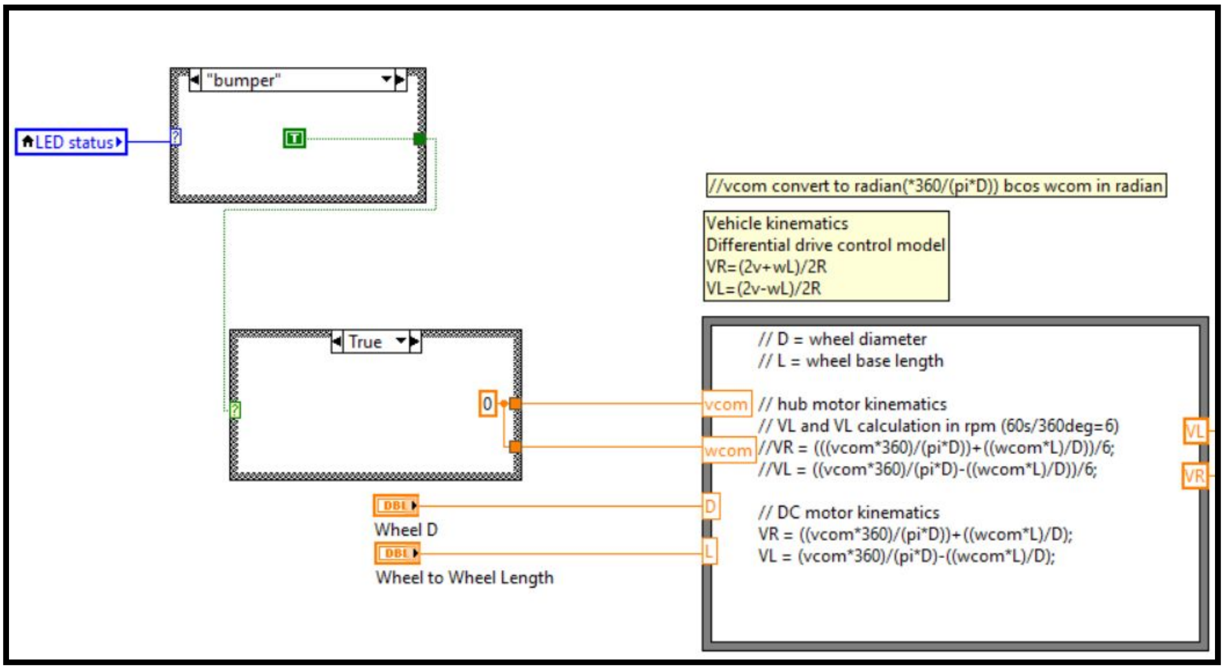


Figure 6-19 Led status

6.1.11 Labview WayPoint

In this segment of the program, labview reads the input waypoint button from the front panel and runs the necessary line of program to send the goal index into the queue, as seen in figure 6-20-1.

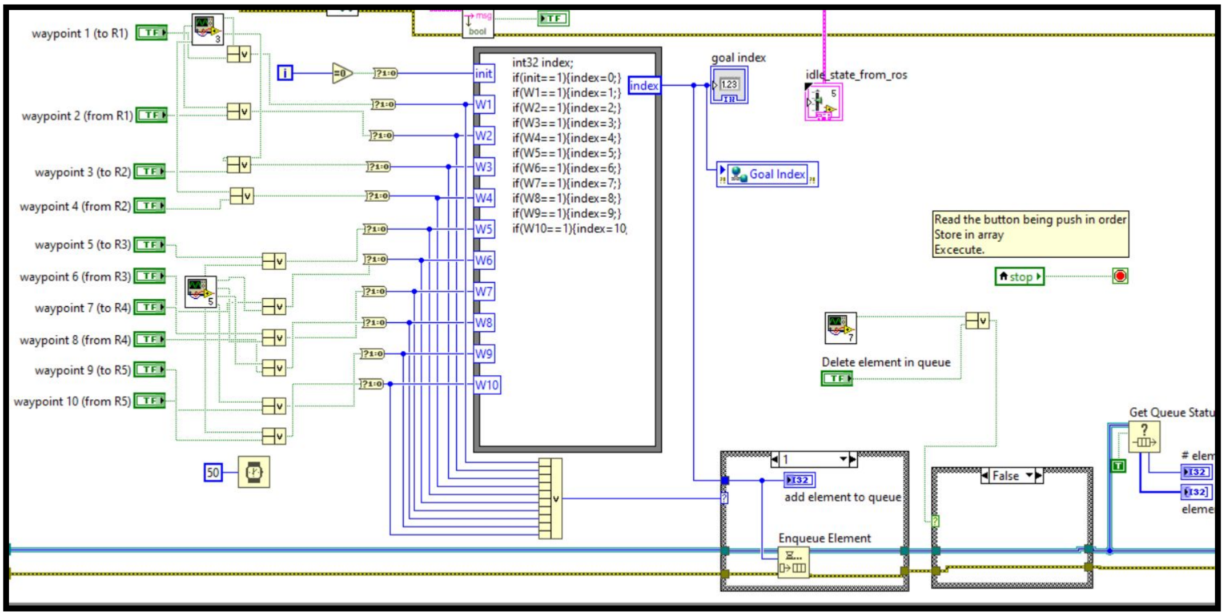


Figure 6-20-1 Waypoint

Once the goal index is added to the queue, labview will await for the start button to be pressed. After which the goal will be sent to ROS for navigation. If the cancel button is pressed, the goal index will be overwritten with 100 and the transporter will stop moving towards the waypoint queued immediately.

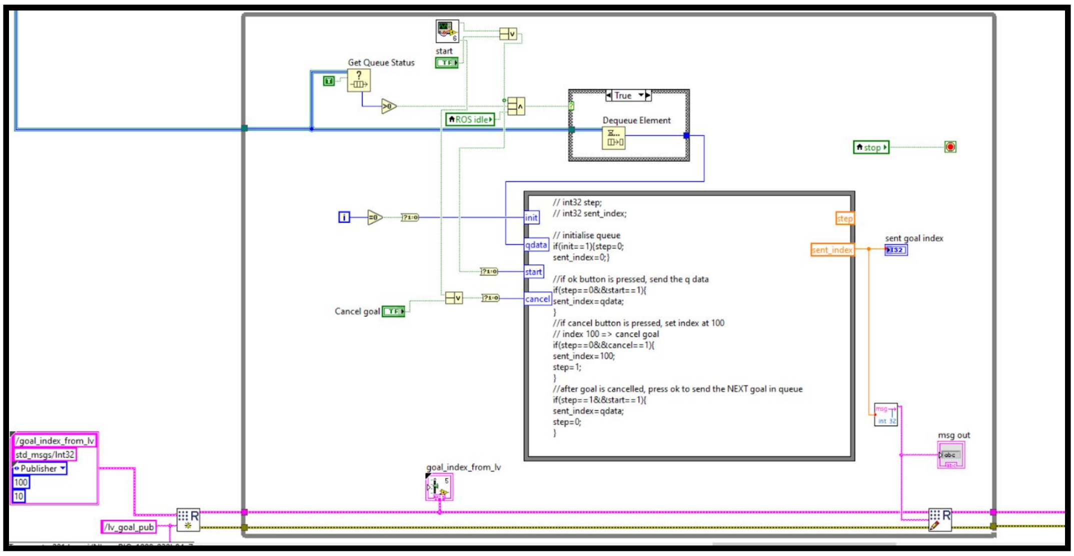


Figure 6-20-2 Waypoint

6.1.12 Labview Data Dashboard

Shared variable is another alternative for the user to select the waypoint.Shared variable is used to share data across the network. As such,using the application known as Data Dashboard we are able to control the waypoint input from an IPad device.

With the limitation of being only able to use switches in Data Dashboard, an Edge Detect block is added to detect only the rising edge of the switch to allow for a single input once the switch is activated on the application as seen in figure 6-22.

Figure 6-21 Logo

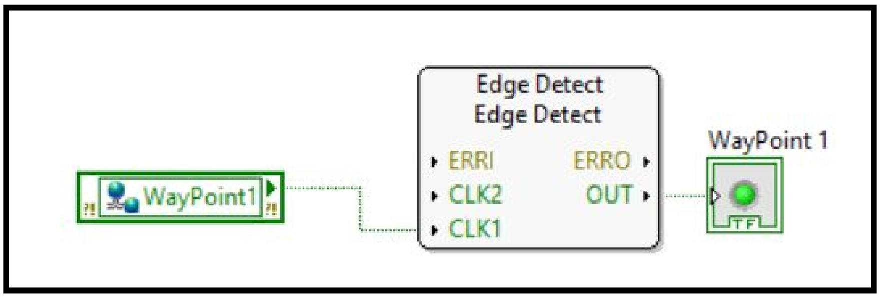


Figure 6-22 Shared Variable

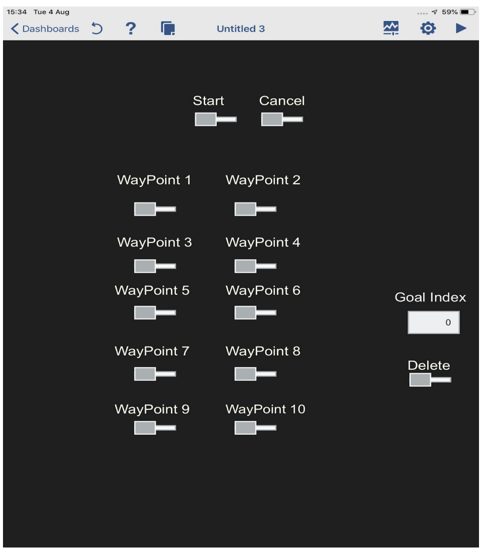


Figure 6-23 Application control panel

Figure 6-22 is a view of the application control panel, it allows the user to select up to 10 waypoints. Once the waypoint is selected, the value is delivered to ROS through labview and proceeds to navigate.

As seen in figure 6-24,shared variables use the myRio as the host to deploy the various shared variables.The “written” value is then written on the Ipad device as a waypoint, the value change will be returned to myRio for the value to be updated and published. The Ipad device must also be connected to the router to allow the control of the waypoint.

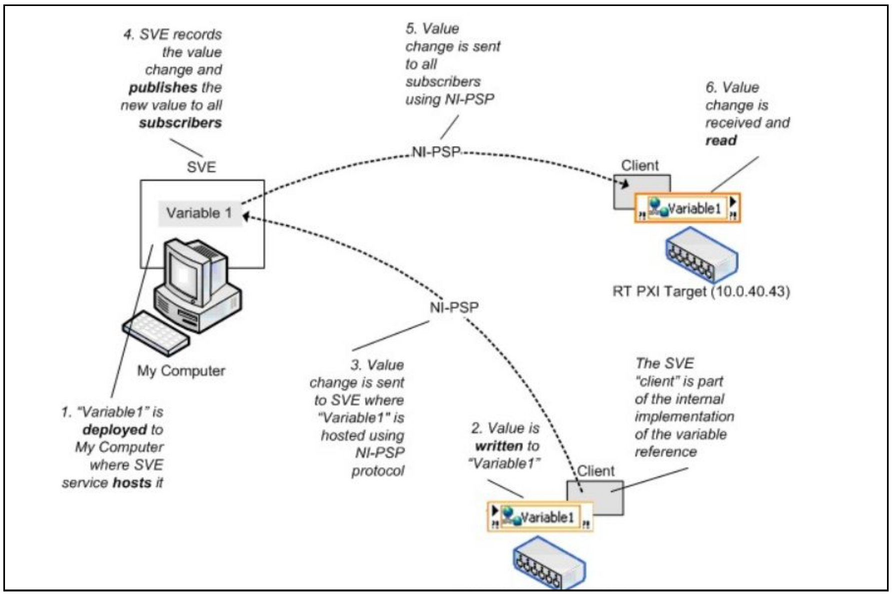


Figure 6-24 Shared variable

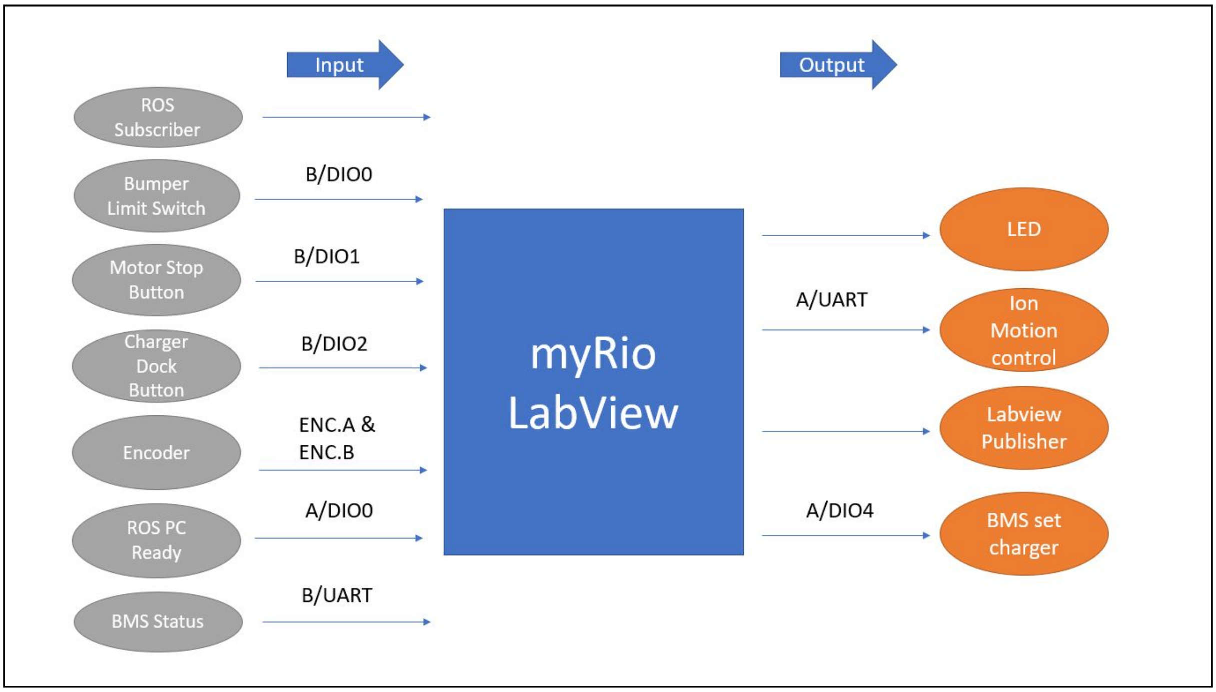


Figure 6-25 Labview Flowchart

6.2 Ros

ROS is an open-source, meta-operating system for the transporter.

6.2.1 How Ros work

In ROS, programs are usually written for a specific purpose, these programs are known as **Nodes**. Nodes will communicate with each other through **Topics**. Topics are name channels where nodes can share data on. These data are known as **Messages**. All nodes can subscribe and publish through and from multiple topics.

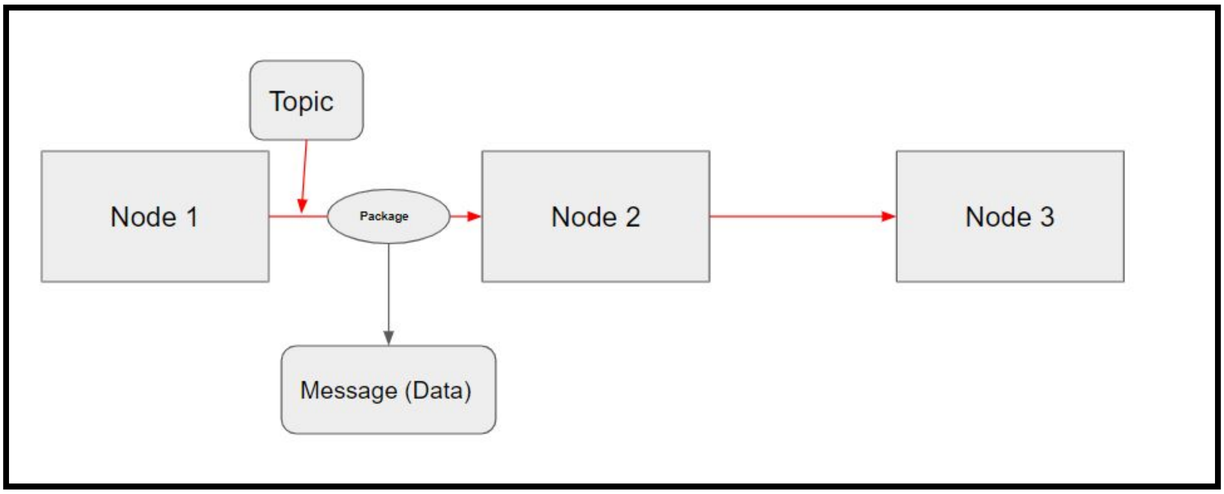


Figure 6-26 nodes/topics/message

Ros Master keeps track of all other nodes under the same local host. It also informs subscribers about nodes publishing on the same topic. The **Publisher** and **Subscriber** will then establish a peer to peer connection to transfer messages.

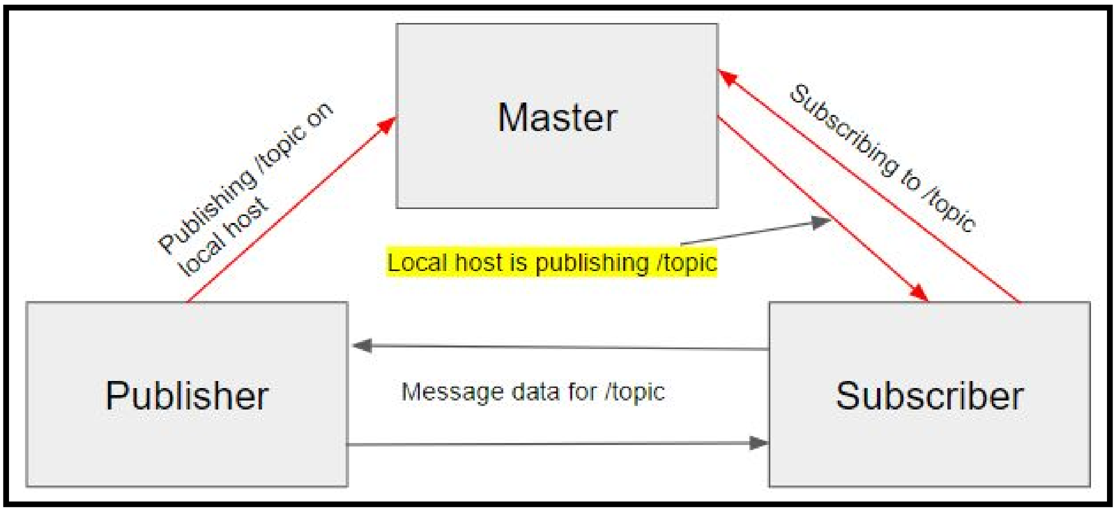


Figure 6-27 Communication between nodes

6.2.2 ROS Custom messages

Message files are simple text files that describe the fields of a ROS message. They are used to generate source code for messages in different languages. One of the custom messages for the transporter is known as the “odomlvtros.msg” ; this message file is used to receive the data given by Labview (6.1.6).

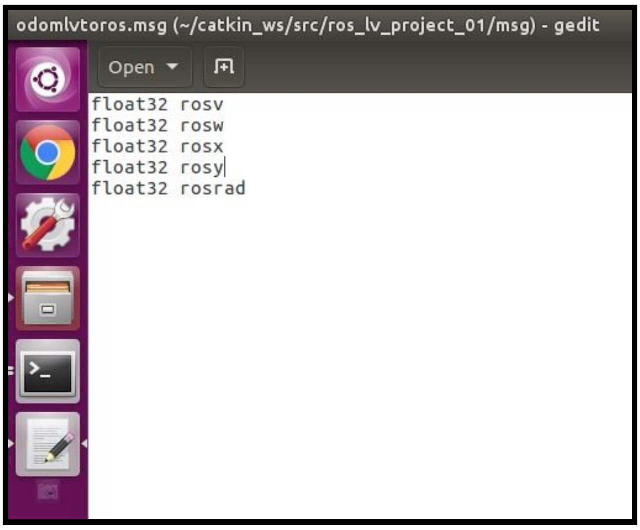


Figure 6-28 odomlvtros.msg

msgs are just simple text files with a field type and field name per line. The field type commonly used are int32, float 32 and strings

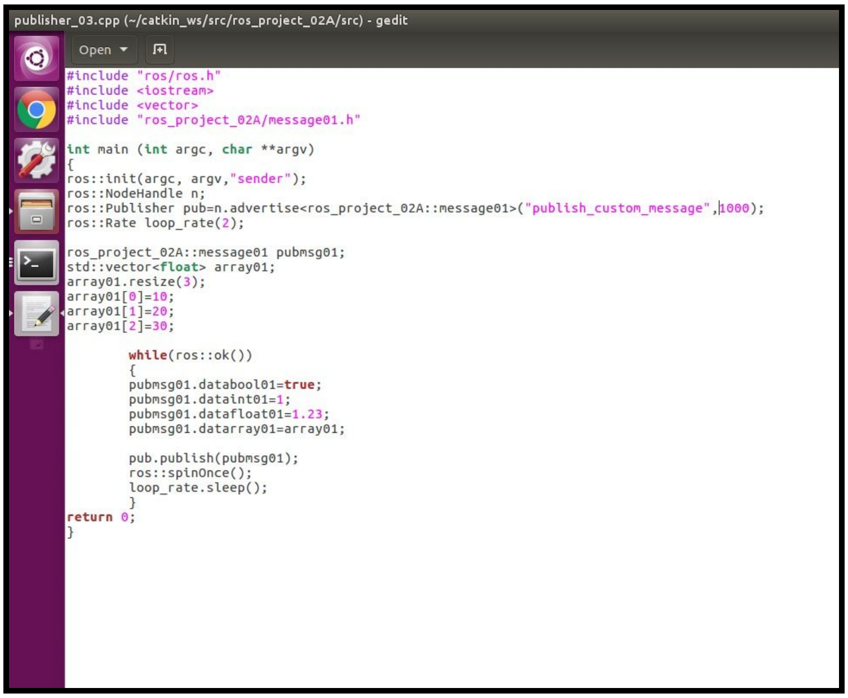
6.2.3 ROS simple publisher

These programs help to understand how publishing and subscribing works in ros. Figure x is a publishing program, it is publishing databool01, dataint01, datafloat01 and data array 01.

Table 13 Data used in the publisher program:

Data	Type	Value in Program
databool01	True/False	True
dataint01	Whole numbers	1
datafloat01	Decimals	1.23
data array 01	Multiple data	10, 20 ,30

“ros::Publisher pub=n.advertise<ros_project_02A::message01>(“publish_custom_message”,1000)”
This line of code allows the information and data to be uploaded to the topic /publish_custom_message.



```
publisher_03.cpp (~/catkin_ws/src/ros_project_02A/src) - gedit
Open

#include "ros/ros.h"
#include <iostream>
#include <vector>
#include "ros_project_02A/message01.h"

int main (int argc, char **argv)
{
ros::init(argc, argv,"sender");
ros::NodeHandle n;
ros::Publisher pub=n.advertise<ros_project_02A::message01>("publish_custom_message",1000);
ros::Rate loop_rate(2);

ros_project_02A::message01 pubmsg01;
std::vector<float> array01;
array01.resize(3);
array01[0]=10;
array01[1]=20;
array01[2]=30;

        while(ros::ok())
        {
        pubmsg01.databool01=true;
        pubmsg01.dataint01=1;
        pubmsg01.datafloat01=1.23;
        pubmsg01.datarray01=array01;

        pub.publish(pubmsg01);
        ros::spinOnce();
        loop_rate.sleep();
        }
return 0;
}
```

Figure 6-29 Ros Publisher Program

By running the program, the data and information is uploaded to a topic called /publish_custom_message. We are able to use rostopic echo /publish_custom_message to see the data. Rostopic echo is a way to check and troubleshoot the program to check if the data are being transmitted properly.

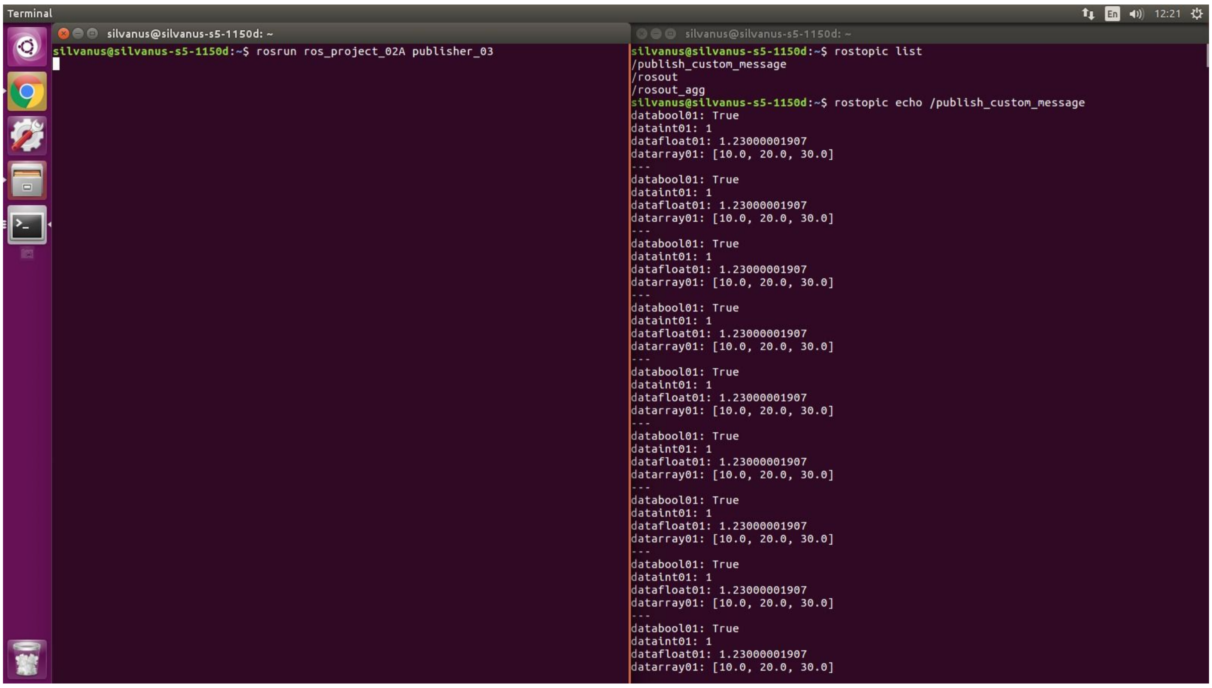


Figure 6-30 Ros Publisher Program Running Figure 6-31 Rostopic Echo

6.2.4 ROS simple subscriber

“ros::Subscriber sub=n.subscribe(“publish_custom_message”,1000,subscriber_03)” This line of code allows the program to subscribe and get information through the topic /publish_custom_message.

Figure 6-32 Ros Subscriber Program

By using rosrun ros_project_02A subscriber_03 we are able to run the subscriber program and see the values and data from the publisher.

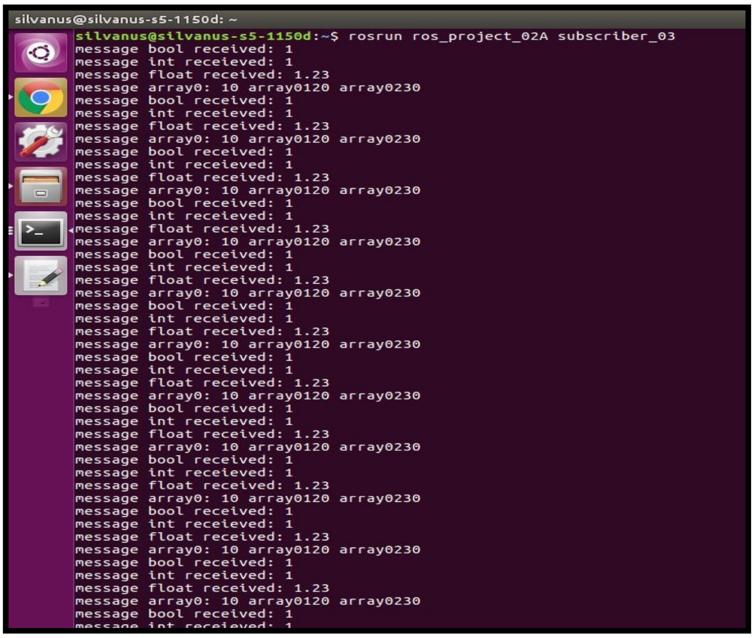


Figure 6-33 Ros Subscriber Program Running

6.2.5 ROS Gmapping

The transporter uses a lidar to map its surroundings; it will create a map as shown in figure x. The map is a global costmap, this will create virtual boundaries that the transporter will try to avoid.

Figure 6-34 W1421 Map

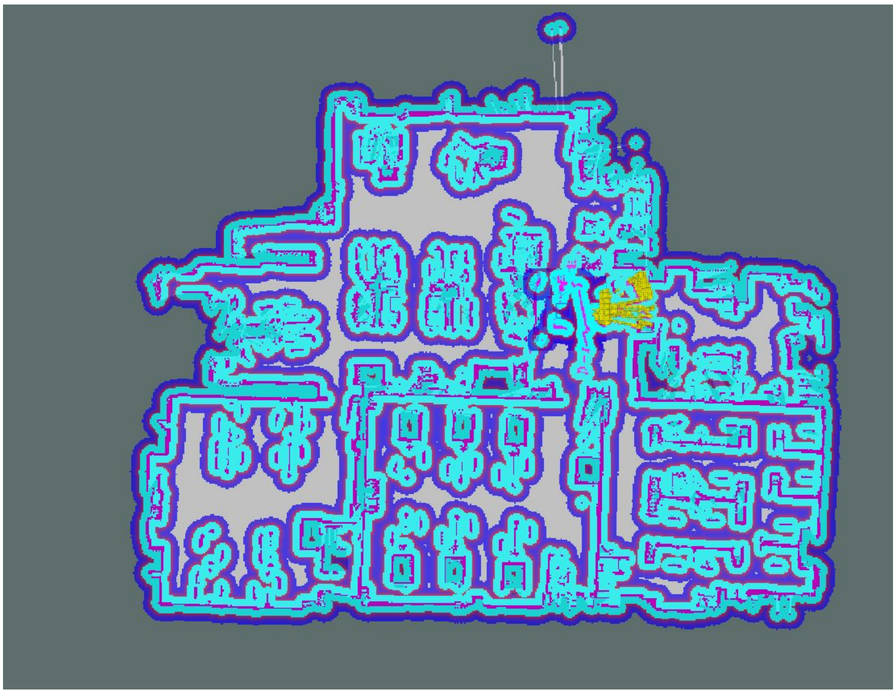


Figure 6-35 W1421 Map global costmap

6.2.6 ROS waypoint program

This program will receive goals sent by Labview via topic /goal_index_from_lv. It subscribes to the data and acquires waypoints stored in the waypoints_door_map_190527_02.yaml as shown in figure x. Waypoint x,y,z,w represents the coordinates in reference to the map that was generated. Waypoint dx,dy,dz,dw are the door coordinates. The transporter will navigate to the door coordinate and check if the door is open or closed.

```
x:  [-0.51614,2.13211,-0.318907,1.6818]
y:  [-7.46762,-7.33526,-0.0305424,-0.852472]
z:  [0.68758,0.70549,-0.00253022,0.00119973]
w:  [0.72611,0.70872,0.999997,0.999999]

dx:  [0.152315,2.11943,-0.335594,-5.60665]
dy:  [-2.28441,-2.24885,-1.27659,-6.68491]
dz:  [-0.701864,-0.706005,0.69839,0.00369706]
dw:  [0.712311,0.708207,0.715718,0.999993]
```

Figure 6-36 waypoints coordinates in param file

The next part of the code contains functions that are activated by the robot performing certain actions.

feedbackcallback is called whenever move_base has a position update. The function prints out the current x and y coordinates of the robot.

activecallback is called when move_base has received a goal. The function prints out a message saying that it has received a goal, set the goal_received value to true, say “goal received, moving towards goal”, and play a song.

donecallback is activated by the robot reaching its goal, the goal being cancelled, or the robot being unable to reach the goal.

If the robot reaches the goal, it stops all sounds being played by the robot, sets the goal_reached value to true, sets the ros_idle value to true, prints out a message saying that the robot has reached the goal, and plays a sound that says “Goal reached”. If the goal is cancelled, it will print out a message saying that the goal has been preempted, set ros_idle to true, and goal_reached to false. If the robot is unable to reach the goal, it will print out a message saying that something went wrong, the robot is not able to reach the goal, and set goal_reached to false.

```
ros::Publisher pub_lvstart;
ros::Publisher pub;
boost::shared_ptr<sound_play::SoundClient> sc;

//initialise the global variables
std_msgs::Bool rosready;
bool goal_reached=false;
bool goal_received=false;
bool door=false;
bool idle=true;
int  goal_index=0;

//audio path
std::string tune="/home/silvanus/catkin_ws/src/ros_lv_project_01/audio/nf.wav";
std::string audio01goalreceived="/home/silvanus/catkin_ws/src/ros_lv_project_01/audio/audio_01_goal_received.wav";
std::string audio02goalreached="/home/silvanus/catkin_ws/src/ros_lv_project_01/audio/audio_02_goal_reached.wav";
std::string audio03dingdong="/home/silvanus/catkin_ws/src/ros_lv_project_01/audio/audio_03_ding_dong.wav";

//update the goal index from labview.
void goal_indexcallback(const std_msgs::Int32::ConstPtr &goal){
goal_index=goal->data;
}
```

Figure 6-37 initializing variables

```
//donecallback is called when the robot has reached the goal.
void donecallback(const actionlib::SimpleClientGoalState& state, const move_base_msgs::MoveBaseResultConstPtr &ptr ){
//stop all sounds
sc->stopAll();
//Print out the current state (preempted=cancel goal,succeeded=reached goal,others=error)
std::cout<<"Status:"<<state.toString()<<std::endl;
//Statements to print upon sucessfully reaching the goal.
if(state.toString()=="SUCCEEDED"){
std::cout<<"The goal has been reached!"<<std::endl;
idle=true;
//declare goal reached as true.
goal_reached=true;
//run audio message
//sc->say("goal reached");
sc->playWave(audio03dingdong);
ros::Duration(2.0).sleep();
sc->playWave(audio02goalreached);
}
else if(state.toString()=="PREEMPTED"){
std::cout<<"The goal has been pre-empted."<<std::endl;
goal_reached=false;
goal_received=false;
}
//Statements to print otherwise.
else{
std::cout<<"The goal has not been reached! something went wrong!"<<std::endl;
goal_reached=false;
}
} // end of donecallback

//feedbackcallback is called when position feedback is received from move base.
void feedbackcallback(const move_base_msgs::MoveBaseFeedbackConstPtr &feedback){
std::cout<<"Moving Towards goal. X:"<<(feedback->base_position.pose.position.x)<<" Y:"<<(feedback->base_position.pose.position.y)<<std::endl;
}

//activecallback is called when move base has received a goal.
void activecallback(){
std::cout<<"Move base just received a goal! Moving towards goal."<<std::endl;
//declare goal received as true.
goal_received=true;
//run audio message
//sc->say("goal received, moving towards goal");
sc->playWave(audio03dingdong);
ros::Duration(2.0).sleep();
sc->playWave(audio01goalreceived);
//delay which audio message is played
ros::Duration(5.0).sleep();
sc->playWave(tune);
}
```

Figure 6-38 Code for donecall back, feedbackcallback and activecallback.

The following program int main code is used to run the main program of this source file. The code will start by initializing all the publishers, subscribers and variables that are needed in this src file. Followed by its function which is to get the value that is stored in the param file “waypoints_door_map_190527_02.yaml”.

```
int main(int argc, char **argv){
//initialise the current goal as 0.
int current_goal=0;
int operation;
int state=1;
int array_index;
//create the move base goal variable.
move_base_msgs::MoveBaseGoal goal;

ros::init(argc,argv,"move_base_goal_sender");
//create the action client object,specifying the name of the action server.
actionlib::SimpleActionClient<move_base_msgs::MoveBaseAction>ac("move_base",true);

ros::NodeHandle n;
//create a subscriber to sub to the labview buttons topic.
ros::Subscriber sub=n.subscribe("goal_index_from_lv",100,goal_indexcallback);

ros::Subscriber door_sub=n.subscribe("door_detected",100,door_detect);

pub_lvstart=n.advertise<std_msgs::Bool>("lvstart",20);
rosready.data=false;
pub_lvstart.publish(rosready);

pub=n.advertise<std_msgs::Bool>("idle_state_from_ros",20);
//vectors to store final goal data
std::vector<double> x,y,z,w;

//create the sound client
//the reset function takes in the address of an object, and
//causes the pointer to point to that object.
sc.reset(new sound_play::SoundClient);

//vectors to store door goal data, position of vehicle outside door before entering the goal
std::vector<double> dx,dy,dz,dw;

//load parameters from the yaml file.
n.getParam("/multiple_goal_door_node/x",x);
n.getParam("/multiple_goal_door_node/y",y);
n.getParam("/multiple_goal_door_node/z",z);
n.getParam("/multiple_goal_door_node/w",w);

n.getParam("/multiple_goal_door_node/dx",dx);
n.getParam("/multiple_goal_door_node/dy",dy);
n.getParam("/multiple_goal_door_node/dz",dz);
n.getParam("/multiple_goal_door_node/dw",dw);
```

Figure 6-39 Main waypoint program

This part of the code gets the waypoints from the specified waypoint.yaml file, and checks the size of the array to determine if the waypoints are loaded in correctly.

```
//check the size of the array.
int net_elements=x.size();
if(y.size()==net_elements&&z.size()==net_elements&&w.size()==net_elements&&dx.size()==net_elements&&dy.size()==net_elements&&dz.size()==net_elements&&dw.size()==net_elements){
std::cout<<"Successfully loaded all waypoints!"<<std::endl;
std::cout<<"Waiting for the move_base server to start! "<<std::endl;
//wait for a connection with the action server.
ac.waitForServer();
std::cout<<"The server has started!"<<std::endl;
//loop rate object ensures that the loop runs at 10 hz.
ros::Rate loop_rate(10);
```

Figure 6-40 Code to check the size of the array

The code will read the condition of the transporter to determine the operation that it is supposed to carry out.

```
while(ros::ok()){
  std_msgs::Bool idle_pub;
  idle_pub.data=idle;
  pub.publish(idle_pub);
  //delay the loop, just enough for it to run at 10 hz.
  loop_rate.sleep();
  //run the spin function
  ros::spinOnce();

  //check if move towards goal
  if(goal_reached==false&&goal_received==false&&goal_index!=0&&goal_index!=100){operation=1;}
  //check if cancel goal button has been pressed.
  else if(goal_received==true&&goal_reached==false&&goal_index==100){operation=2;}
  //check if the program as reached the goal.
  else if(goal_reached==true&&goal_received==true){operation=3;}
  //skip this iteration
  else{continue;}
```

Figure 6-41 Goal operation Code

Table 14 Goal operation and meaning of operation.

Robot operation	Goal reached	Goal received	Goal index	Meaning
1	False	False	≠ 100	Idle waiting for goal
2	False	True	= 100	Goal cancelled
3	True	True	-	Robot is in front of door

Case 1 determines which goal should be sent to move_base. If the state is 1, the goal that is sent to move_base will be the door goal, and if the state is 3, the goal sent to move_base will be the final goal.

Case 2 is activated when the goal has been cancelled, it calls the actionclient to cancel all goals, set goal_received to false, goal_reached to false, and ros_idle to true.

Case 3 is activated when the robot is outside a room with the door closed. If the door is closed(i.e door == true), the robot will do nothing. When the door is opened, goal_reached and goal_received is set to false, and state is set to 3 to allow the robot to go to the final goal.

```
switch(operation){
// move towards goal
case 1:
//set the array_index, array_index[0]=goal_index[1 set to 0]
array_index=goal_index-1;

//populate the goal with data.
goal.target_pose.header.frame_id="map";
goal.target_pose.header.stamp=ros::Time::now();

//state 1 is the intermediate goal outside the door before the final goal
if(state==1){
goal.target_pose.pose.position.x=dx[array_index];
goal.target_pose.pose.position.y=dy[array_index];
goal.target_pose.pose.orientation.w=dw[array_index];
goal.target_pose.pose.orientation.z=dz[array_index];
}
//state 3 is the final goal after clearing the door
else if(state==3){
  goal.target_pose.pose.position.x=x[array_index];
  goal.target_pose.pose.position.y=y[array_index];
  goal.target_pose.pose.orientation.w=w[array_index];
  goal.target_pose.pose.orientation.z=z[array_index];
}
// ac=action client
ac.sendGoal(goal,&donecallback,&activecallback,&feedbackcallback);
current_goal=goal_index;
idle=false;
break;
```

Figure 6-42 Case 1

```
// cancel goal
case 2:
idle=true;
state=1; // move to next door goal
ac.cancelAllGoals();
goal_received=false;
goal_reached=false;
break;

case 3:
//if there is a door in front of the room.
// continue = continue to check this condition and keep waiting in front of the door until the door opens
if(state==1&&door==true){continue;}
//if the door to the room is not closed
else if(state==1&&door==false){
goal_reached=false;goal_received=false;
state=3;  // move to final goal
}
//skip this loop iteration if the desired goal is the one which has just been achieved.
// continue = continue to check this condition and keep waiting in the final goal until a new goal is received
else if(state==3&&current_goal==goal_index){continue;}
//reset the goal reached and goal received variable to enable a new goal to be sent to the action server.
else{goal_reached=false;goal_received=false;state=1;}
break;
}
```

Figure 6-43 Case 2 and 3

6.2.7 Waypoint Editing

Using waypoint_editor_gui, we are able to set add or remove waypoints that the transporter needs. Door goal is the first waypoint the transporter will try to reach. It will check to see if the door is closed or open. Afterwhich the transporter will continue to the user's intended waypoint.

Figure 6-44 Waypoint gui

6.3 Ros Param

A parameter server is a shared, multivariate dictionary that is accessible via network APIs. Nodes use this server to store and retrieve parameters at runtime. As it is not designed for high-performance, it is best used for static, non-binary data such as configuration parameters.

6.3.1 Dynamic Window Approach planner (DWA Planner)

This package provides an implementation of the Dynamic Window Approach to local robot navigation on a plane. Given a global plan to follow and a costmap, the local planner produces velocity commands to send to a mobile base. The parameters for this planner are also dynamically reconfigurable.

6.3.2 rqt_reconfigure

This rqt plugin succeeds former dynamic_reconfigure's GUI (reconfigure_gui), and provides a way to view and edit the parameters that are accessible via dynamic_reconfigure. This allows us to change the parameter without editing the parameter files, it allows us to fine tune the robot without disruption.

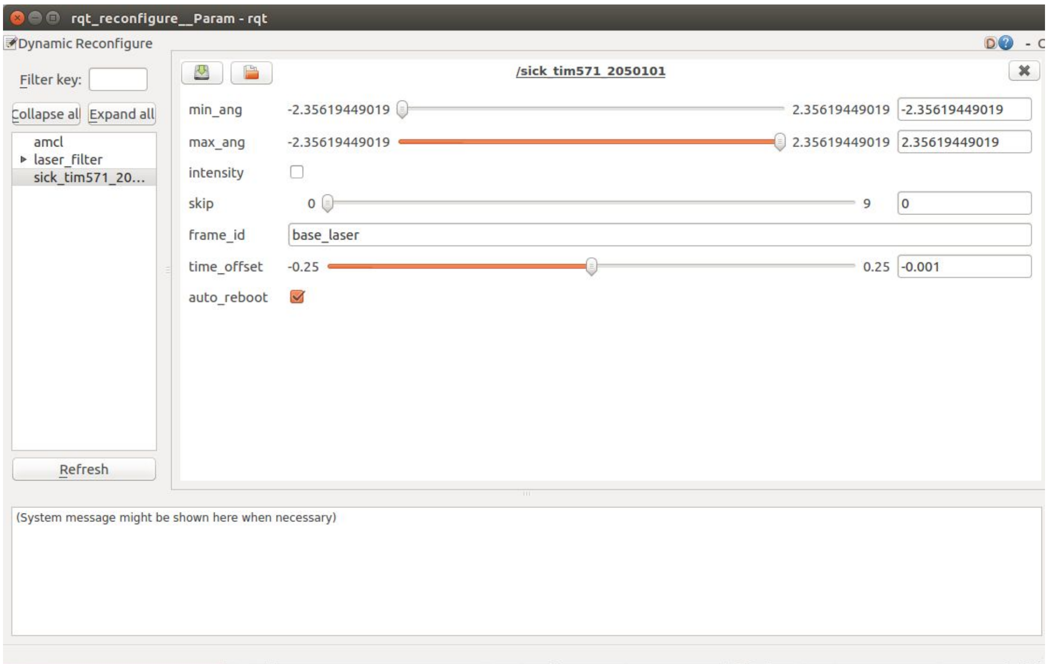


Figure 6-45 Rqt_reconfigure GUI

6.3.3 global_planer_params

Global Planner uses the map generated to create a route for the transporter to take while avoiding the static obstacles.

```
GlobalPlanner:

 lethal_cost:  253
 neutral_cost: 66 #66
 cost_factor: 0.55 #0.55
 use_dijkstra: true
```

FIgure 6-46 Global planner parameters

Table 15 Global planer parameters.

Variables	Meaning
Lethal Cost	Area of which if the transporter were to enter it will collide into an obstacle
Neutral Cost	How the robot is position when the navigating through obstacles
Cost Factor	How wide the transporter turns.
Use Dijkstra	Dijkstra's algorithm is mainly used to find the shortest path from a starting node / point to the target node / point in a weighted graph.

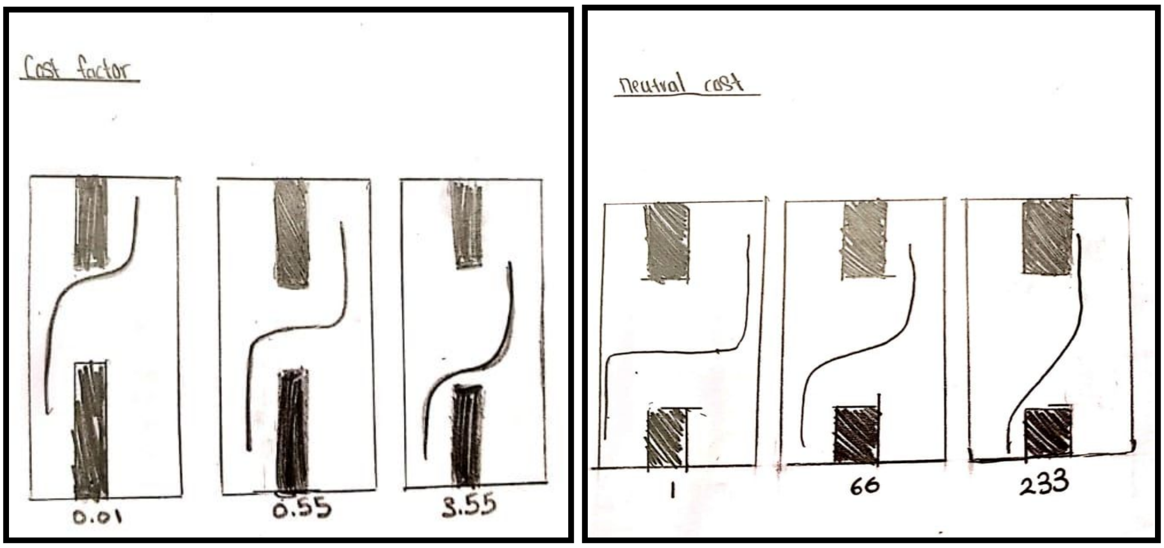


Figure 6-47 Cost Factor and Neutral Cost navigation patterns based on values

6.3.4 Base_local_planner

This planner uses different variables to simulate possible routes. Afterwhich the transporter will follow the best simulated path.

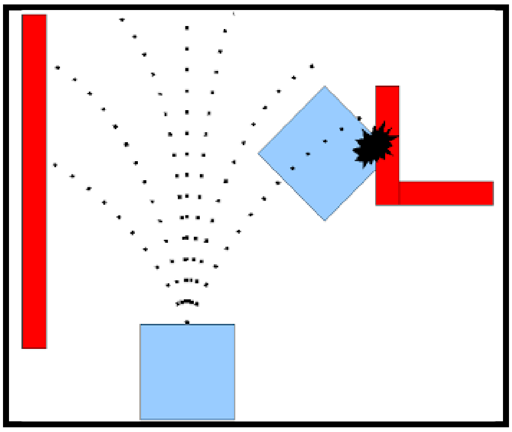


Figure 6-48 DWA Planner Trajectory (rosWiki,nd)

6.3.4.1 Important variables

Table 16 Param Variables

Variables	Meaning	Values
Goal_distance_bias	How attached the robot is to the global path. Higher the value lesser the attraction	15.0
Path_distance_Bias	much the local planner should stay close to the global path	34
Occdist_scale	how much the robot should attempt to avoid ob-stacles	0.13
Sim_time	Time allowed for the robot to run simulated plans. Values can affect the flexibility and efficiency of robots.	3.8
Vx_samples	determine how many translational velocity samples to take in x direction.	10
Vth_samples	Controls the number of rotational velocities sample	20

Note: Vx and Vth depends on how much computation power you have. Vth should usually be higher than Vx/ Vy as turning is more complicated. By increasing the values, the more CPU resources will be used.
The objective of this plan is scoring the trajectory and finding the lowest cost. Cost is calculated using the formula shown in figure 6-55.

$$\begin{aligned} cost &= \texttt{path\_distance\_bias} * (\text{distance}(m) \text{ to path from the endpoint of the trajectory}) \\ &+ \texttt{goal\_distance\_bias} * (\text{distance}(m) \text{ to local goal from the endpoint of the trajectory}) \\ &+ \texttt{occdist\_scale} * (\text{maximum obstacle cost along the trajectory in obstacle cost } (0\text{-}254)) \end{aligned}$$

Figure 6-49 Cost calculation

```
DWAPlannerROS:

# Robot Configuration Parameters
# vel_x is in (m/s)
# vel_theta is in (rad/s)
  max_trans_vel: 0.4 # max command pure forward velocity without turning (m/s)
  min_trans_vel: 0.05 # min command pure forward velocity without turning (m/s)
  max_vel_x: 0.4
  min_vel_x: -0.1

  max_vel_y: 0.0  # diff drive robot not required
  min_vel_y: 0.0  # diff drive robot not required

  max_rot_vel:  0.75  # max 90 deg/s
  min_rot_vel:  0.17  # min 10 deg/s
  min_in_place_vel_theta: 0.52  # min pure angular velocity (rad/s = 30 deg/s)

  acc_lim_x: 0.4  # max linear acceleration (m/s2)
  acc_lim_y: 0.0
  acc_lim_th: 3.14  # max angular acceleration (rad/s2)
  use_dwa: false
  escape_vel: -0.1
  backup_vel: -0.1


# Scoring parameters
  path_distance_bias: 34.0     #34.0
  goal_distance_bias: 15.0     #20.0
  occdist_scale: 0.13          #0.02
  pdist_scale: 1.5
  forward_point_distance: 0.0  #0.325


# Goal Tolerance Parameters
  xy_goal_tolerance: 0.2 # goal distance error (m)
  yaw_goal_tolerance: 0.0872  # goal heading error (0.055rad = 3deg) current=5DEG
  latch_xy_goal_tolerance: true


# Forward Simulation Parameters
  sim_time: 3.8 # amount of time to forward simulate the path (s), longer time > plan further
  vx_samples: 10  # number of steps in the linear velocity range
  vy_samples: 0
  vth_samples: 20  # number of steps in the angular velocity range
  sim_granularity: 0.025  # trajectory step size (m)

  Prune_plan: true
```

Figure 6-50 DWA Planner code

6.3.5 Costmap_common_params

The parameter here affects both the global and local cost maps

- Footprint is one of the important variables in this param file. Footprint represents the contour of the mobile base.
- Voxel_decay: the time in seconds before the marked points by the 3D camera disappear from the costmap
- Vertical / horizontal fov angle: The field of view in front of the robot to clear points that were previously marked by the depth camera

```
# Costmap common parameters apply to the local and global costmap

map_type: costmap
transform_tolerance: 0.2
obstacle_range: 2.5
raytrace_range: 3.0
# vehicle footprint coordinates (vehicle size) from vehicle centre (differential wheel centre) starting from bottom right
# cater 0.05m clearance
footprint: [
[-0.25,-0.25],
[0.25,-0.25],
[0.25,0.25],
[-0.25,0.25]
]


# Lidar obstacle detection setting
# marking - mark obstacles in the map
# clearing - clear marking when no obstacle present
obstacle_layer:
  observation_sources: laser_scan_sensor
  laser_scan_sensor: {sensor_frame: base_laser, data_type: LaserScan, topic: scan, marking: true, clearing: true}


# Ultrasonic sensor range setting
range_sensor_layer:
  clear_threshold:    0.46  # if probability >= 46% that there is NO obstacle then clear obstacle marking
  mark_threshold:     0.92  # if probability >= 92% that there is AN obstacle then mark obstacle marking
  clear_on_max_reading: true
  topics: ["/us_left_range","/us_right_range","/us_front_range"]


# camera rgb depth layer setting
rgbd_obstacle_layer:
  enabled:               true
# voxel_decay - takes t seconds to unmark the obstacle after camera moves away from obstacle
  voxel_decay:           3      #seconds if linear, e^n if exponential
  decay_model:           0      #0=linear, 1=exponential, -1=persistent
  voxel_size:            0.05   #meters
  track_unknown_space:   true   #default space is unknown
  observation_persistence: 0.0  #seconds
  max_obstacle_height:   2.0    #meters
  unknown_threshold:     15 |   #voxel height
  mark_threshold:        3  #voxel height
  update_footprint_enabled: true
  combination_method:    1      #1=max, 0=override
  obstacle_range:        3.0    #meters
  origin_z:              0.0    #meters
  publish_voxel_map:     true   # default off
  transform_tolerance:   0.2    # seconds
  mapping_mode:          false  # default off, saves map not for navigation
  map_save_duration:     60     #default 60s, how often to autosave
  observation_sources:   rgbd1_clear rgbd1_mark
  rgbd1_mark:
    data_type: PointCloud2
    topic: camera/depth/color/points  # camera obstacle marking topic
```

Figure 6-51 Costmap common param

6.3.6 Global/Local_costmap_params

Global costmap is generated by inflating the obstacles on the map provided to the navigation stack. Only difference between global and local costmap is that local cost maps do not include costmap_prohibition as it is centered on the robot instead of on the map.

Plugins determine which sensors are used to mark obstacles in the map. In the global costmap, we have the costmap prohibition layer plugin. This allows us to set virtual walls that the robot is unable to pass through to block off areas.

Table 17 Global costmap params

Variables	Meaning
inflation_radius	controls how far away the zero cost point is from the obstacle
cost_scaling_factor	inversely proportional to the cost of a cell. Setting it higher will make the decay curve more steep

Inflation radius affects how the robot navigates. A high value will disable the transporter from navigating through tight spaces.

Cost scaling factor value cannot be too high else it will not avoid obstacles smoothly. Having a low value will prevent the transporter from getting itself unstuck.

```
# global costmap used for the path planning

global_costmap:
  global_frame: map
  robot_base_frame: base_link
  update_frequency: 10  # for vehicle control (Hz)
  publish_frequency: 3.0  # for rviz display (Hz)
  static_map: true
  rolling_window: false  # map fixed

# plugins define the sensors used to mark obstacles

  plugins:
    - {name: static_layer,    type: "costmap_2d::StaticLayer"}  # map
    - {name: obstacle_layer,  type: "costmap_2d::ObstacleLayer"}  # lidar layer
    - {name: rgbd_obstacle_layer, type: "spatio_temporal_voxel_layer/SpatioTemporalVoxelLayer"}  # 3D camera layer
#    - {name: costmap_prohibition_layer,   type: "costmap_prohibition_layer_namespace::CostmapProhibitionLayer"}
#    - {name: range_sensor_layer,   type: "range_sensor_layer::RangeSensorLayer"}  # ultrasonic sensor layer (if enabled put this line above the inflation layer)
    - {name: inflation_layer, type: "costmap_2d::InflationLayer"}  # obstacle margin


# inflation layer steeper over a short distance
inflation_layer:
   inflation_radius: 0.7 # refer ros costmap > 6.inflation
   cost_scaling_factor: 1.23  # gradient of exponential curve
```

Figure 6-52 Local costmap param and plugins

6.3.7 Move_base_params

Move base param contains parameters that are required for move base.

By setting shutdown costmaps false will disable allow the transporter to update its cost map while in idle enabling it will prevent the transportation from moving after idle.

Recovery_behavior_enabled is set to true to allow the robot to execute recovery_behaviours. The reset will reset the costmap to its initial state without any obstacles. This will remove all obstacles point that was previously detached by the sensors

Table 18 Move base params

Variables	Meaning	value
Planner frequency	Frequency of which the global plan is updated	10
Controller frequency	the rate at which the move_base control loop runs.	20
Oscillation timeout	time in seconds that the robot is allowed to oscillate. 0 is used to allow manual overwrite before transporter canceles its goal	0.0

```
shutdown_costmaps: false
planner_frequency: 10
controller_frequency: 20
planner_patience: 8.0
controller_patience: 8.0
oscillation_timeout: 0.0  # if vehicle stuck for 10s it stops path planning
oscillation_distance: 0.2  # vehicle is oscillating if it is moving within 0.2m distance
conservative_reset_dist: 0.10

recovery_behaviour_enabled: true
recovery_behaviours:
 - name: 'conservative_reset'
   type: 'clear_costmap_recovery/ClearCostmapRecovery'

 - name: 'aggressive_reset'
   type: 'clear_costmap_recovery/ClearCostmapRecovery'

conservative_reset:
 reset_distance: 0.0
 layer_names: ["obstacle_layer"] #, "rgbd_obstacle_layer"]

aggressive_reset:
 reset_distance: 0.0
 layer_names: ["obstacle_layer"] #, "rgbd_obstacle_layer"]
```

Figure 6-53 Move base param code

6.4 Rs_camera.launch

This part of the code sets the resolution of the camera. If the value of resolution is set too high, Rviz will not be able to visualize the points properly. It will also affect the CPU performance. A lower value will prevent the transporter from detecting smaller objects.

```
<arg name="fisheye_width"        default="640"/>
<arg name="fisheye_height"       default="480"/>
<arg name="enable_fisheye"       default="false"/>

<arg name="depth_width"          default="640"/>
<arg name="depth_height"         default="480"/>
<arg name="enable_depth"         default="true"/>

<arg name="infra_width"         default="640"/>
<arg name="infra_height"        default="480"/>
<arg name="enable_infra1"        default="false"/>
<arg name="enable_infra2"        default="false"/>

<arg name="color_width"          default="640"/>
<arg name="color_height"         default="480"/>
<arg name="enable_color"         default="true"/>

<arg name="fisheye_fps"          default="30"/>
<arg name="depth_fps"            default="30"/>
<arg name="infra_fps"            default="30"/>
<arg name="color_fps"            default="30"/>
<arg name="gyro_fps"             default="400"/>
<arg name="accel_fps"            default="250"/>
<arg name="enable_gyro"          default="true"/>
<arg name="enable_accel"         default="true"/>
```

Figure 6-54 realsense camera resolution settings.

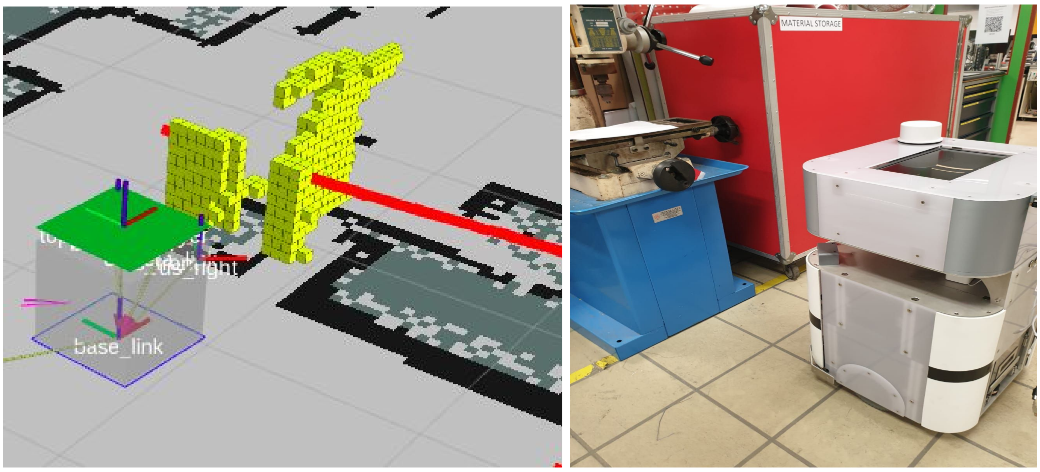


Figure 6-55 Detecting objects using 3d camera

7. Conclusion

This Internship Equivalent has taught us many things, from applying concepts that we have learnt to how to work together as a cohesive group. Indeed there are many obstacles that we have to go through such as the Covid situation. With the help of our supervisor and the support of our family and friends, we are able to work from home and continue to learn more things as we grow.

This Project has granted us insight on how the working world is like by providing a platform to collaborate with Sick sensors intelligences. We have learned how to make changes based on the requirements of our clients.

One of the requirements is to create a documentation box to store files that are sensitive. We have to go through many design changes and iteration to ensure the design is efficient and easy to use.

This office transporter has gone through 3 batches of hard work to achieve its design and reliability. From making it smaller to making it reliable to navigate its surrounding. We have learnt many skills such as programming Labview and ROS and machining to better understand how our transporter is able to communicate with its surroundings.

8. Budget

Table 19 Budget:

Office Transporter Project Code: 20518					
Component	**Description**	**Company**	**Unit**	**Cost/Unit**	**Total Cost**
Electrical					
Eyoyo 13 Inch Monitor 1920*1080	Monitor Screen	Eyoyo, China	1	$203.19	$203.19
Asus Router RT-N12	Router	Asus	1	$56.49	$56.49
Digital Electronic Password Keypad	25mm Lock	Brandless, China	1	$17.11	$17.11
Max Flow MFD802502	80mm DC Brushless Fan	E-Top electronics,Singapore	2	$10	$20
ProSoft Fast Industrial Hotspot RLX2	WiFi Router	Masstron Pte Ltd ,Singapore	2	$1292	$2,584.00
4 dBI Omni RP-SMA MIMO antenna	Antenna	Masstron Pte Ltd ,Singapore	2	$361	$722.00
SMA Cable	Antenna extension cable	JFL Electronics Pte Ltd	2	$24.7	$69.65
Type C cable	Cable	Sim Lim square	1	$15	$15
USB ports extension	Type C extension	Sim Lim Square	1	$15	$15
Belnet Ethernet flat cable	CAT 7 Patch cords 1m		2	$4.90	$9.80
Mechanical					
Ball Bearings	Ø40 mm	Yew Kee Bearings Antech Pte. Ltd	4	$90.95	$363.80
Temperature gun			1	$69.	$69.
Mechanical Hinge					

9. Recommendation

Table 20 Recommendation:

Problems	Recommendation
Transporter wheels get rather noisy when moving around	• Find an alternate caster wheel and or improve suspension.
Screen position is not ergonomic for prolonged use.	• Tilt the screen at an angle. • Change the position of the screen.
Document box door is rather small. Making it harder to put large items in.	• Redesign the box's door.
Transporter when undocking will reverse, will collide into people around it	• Add Bumpers at the back or additional sensors

10. Reference

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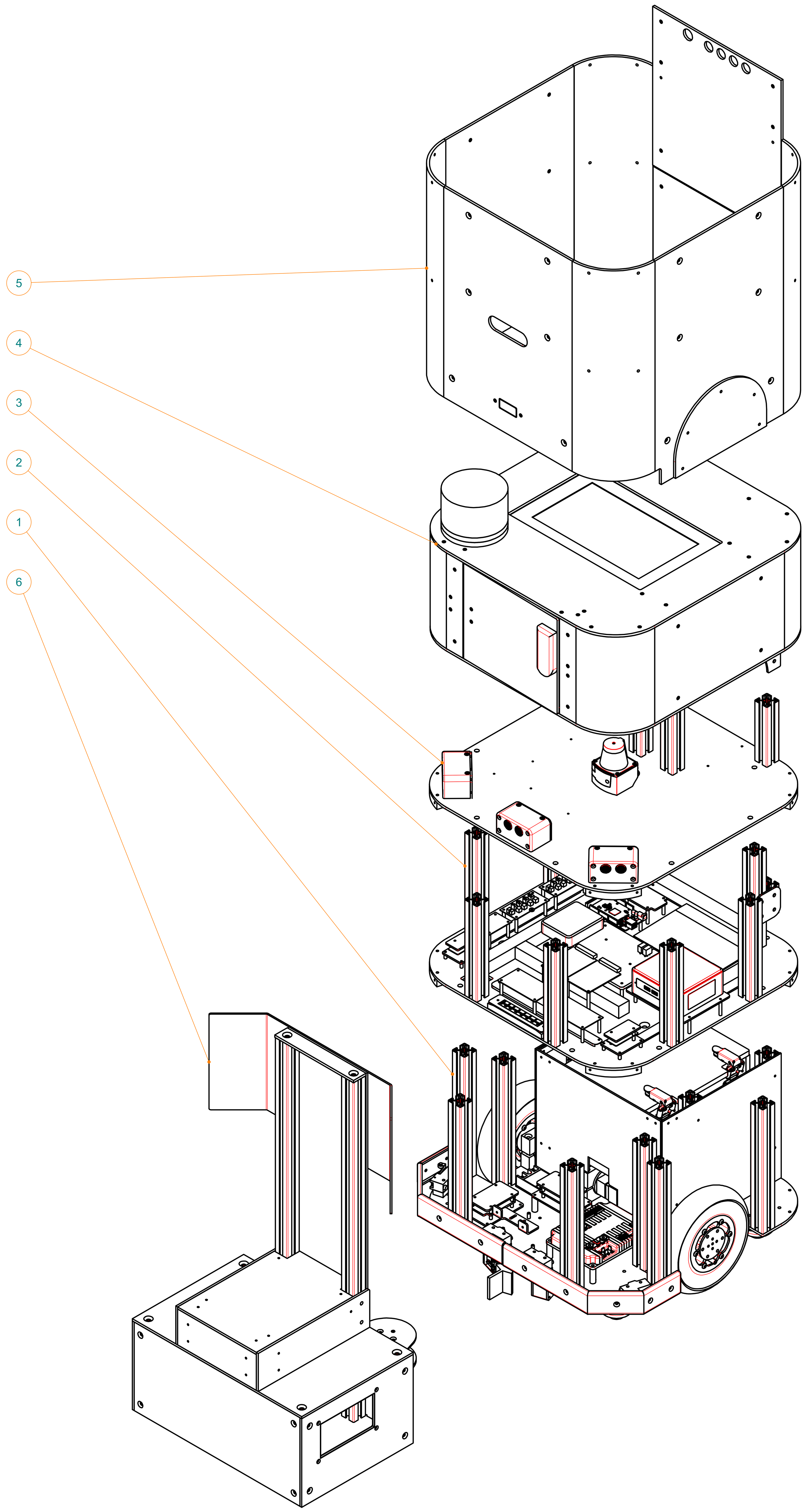
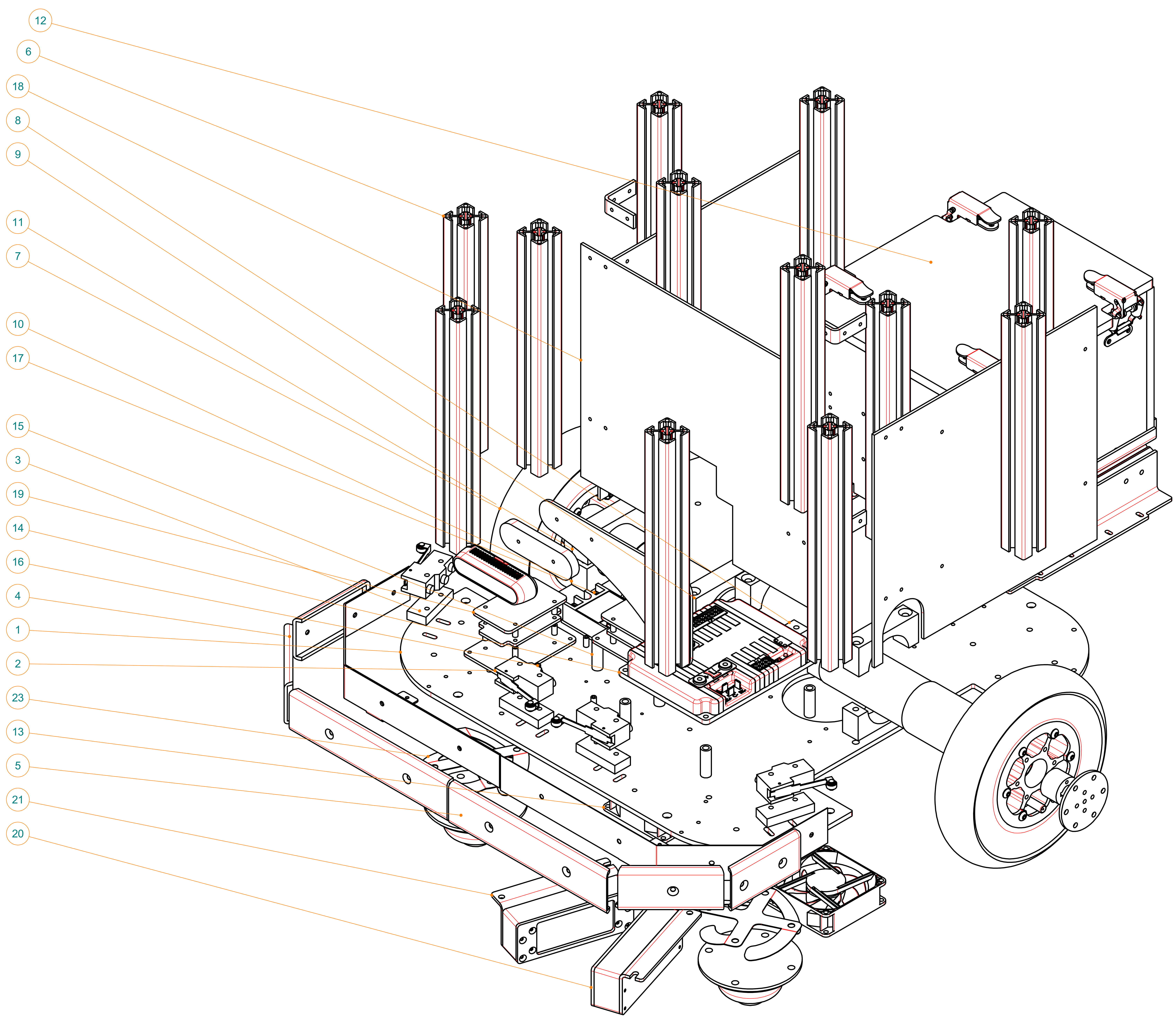
Parts List		
ITEM	DESCRIPTION	QTY
1	Base Level	1
2	Middle Level	1
3	Top Level	1
4	Document Box	1
5	Casing	1
6	charging station 2	1



SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed: LOW ZHONG SHENG	Date: 6/8/2020	Project Title: OFFICE TRANSPORTER		
	Checked: SILVANUS SNG	Date: 7/8/2020	Projection	Dwg No.	
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor: TAN TUAN KIAT	Date: 7/8/2020	Scale: 1:4	Sheet: 1	Size: A0

Parts List

ITEM	DESCRIPTION	QTY	MATERIAL
1	Bottom Base Plate	1	Aluminum
2	Limit Switch	4	
3	Limit Switch Mount	4	Polycarbonate
4	Right Sping bumper	1	Spring Steel
5	Left Spring Bumper	1	Spring Steel
6	180mm Profile	12	Aluminum
7	Rubber Wheel Asembly	2	
8	Main Motor Inner Base Mount	2	Aluminum
9	Main Motor Inner Cover Mount	2	Aluminum
10	Main Motor Outer Base Mount	2	Aluminum
11	Main Motor Outer Cover Mount	2	Aluminum
12	Battery Box Assembly	1	
13	DC FAN 80 X 80 X 25	2	
14	STEP_BMS10XX	1	
15	Level 1 spacer	8	
16	Spacer for Ion	4	
17	Main Relay Body	1	
18	Battery Enclosure	1	
19	Encoder	2	
20	Right Charger	1	
21	Left Charger	1	
22	Motor Controller	1	
23	Bearing Wheels	4	



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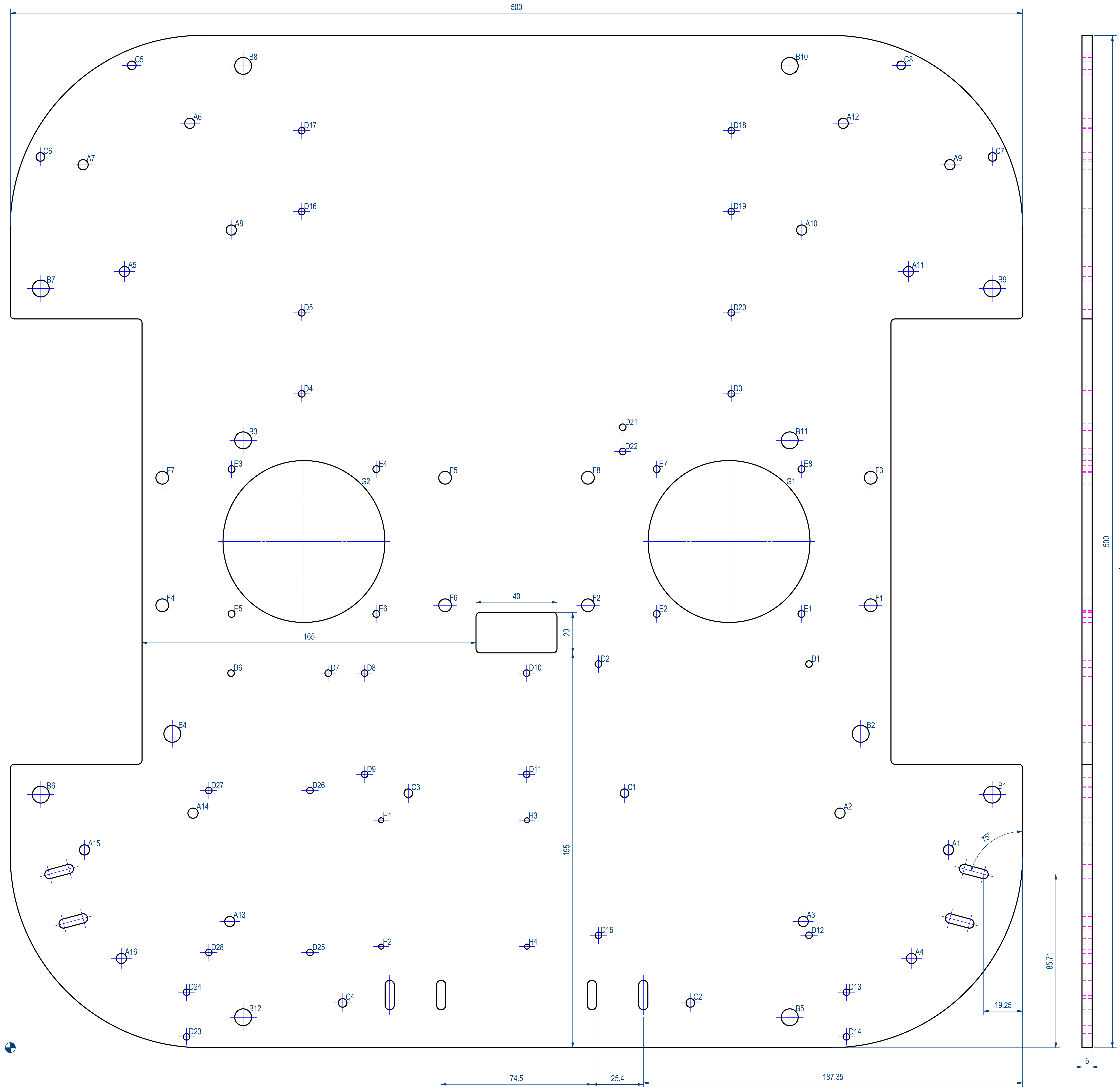
Hole Table

HOLE	XDIM	YDIM	DESCRIPTION
A1	463.38	97.68	Ø5 THRU
A2	409.82	115.88	Ø5 THRU
A3	391.62	62.32	Ø5 THRU
A4	445.18	44.12	Ø5 THRU
A5	56.38	383.39	Ø5 THRU
A6	88.62	456.61	Ø5 THRU
A7	35.89	436.12	Ø5 THRU
A8	109.11	403.88	Ø5 THRU
A9	464.11	436.12	Ø5 THRU
A10	390.89	403.88	Ø5 THRU
A11	443.62	383.39	Ø5 THRU
A12	411.38	456.61	Ø5 THRU
A13	108.38	62.32	Ø5 THRU
A14	90.18	115.88	Ø5 THRU
A15	36.62	97.68	Ø5 THRU
A16	54.82	44.12	Ø5 THRU
B1	485	125	Ø8.3 THRU
B2	420	155	Ø8.3 THRU
B3	115	300	Ø8.3 THRU
B4	80	155	Ø8.3 THRU
B5	385	15	Ø8.3 THRU
B6	15	125	Ø8.3 THRU
B7	15	375	Ø8.3 THRU
B8	115	485	Ø8.3 THRU
B9	485	375	Ø8.3 THRU
B10	385	485	Ø8.3 THRU
B11	385	300	Ø8.3 THRU
B12	115	15	Ø8.3 THRU
C1	303.4	125.7	Ø4.2 THRU
C2	335.87	22.14	Ø4.2 THRU
C3	196.6	125.7	Ø4.2 THRU
C4	164.13	22.14	Ø4.2 THRU
C5	60	485.2	Ø4.2 THRU
C6	14.8	440	Ø4.2 THRU
C7	485.2	440	Ø4.2 THRU
C8	440	485.2	Ø4.2 THRU
D1	394.5	189.5	Ø3.3 THRU
D2	290.5	189.5	Ø3.3 THRU
D3	356.1	323	Ø3.3 THRU
D4	143.9	323	Ø3.3 THRU
D5	143.9	363	Ø3.3 THRU
D6	109	185	Ø3.3 THRU
D7	157	185	Ø3.3 THRU
D8	175	185	Ø3.3 THRU
D9	175	135	Ø3.3 THRU
D10	255	185	Ø3.3 THRU
D11	255	135	Ø3.3 THRU
D12	394.5	55.5	Ø3.3 THRU
D13	413	27.38	Ø3.3 THRU
D14	413	5.38	Ø3.3 THRU
D15	290.5	55.5	Ø3.3 THRU
D16	143.9	413	Ø3.3 THRU
D17	143.9	453	Ø3.3 THRU
D18	356.1	453	Ø3.3 THRU
D19	356.1	413	Ø3.3 THRU
D20	356.1	363	Ø3.3 THRU
D21	302.5	306.5	Ø3.3 THRU
D22	302.5	294.5	Ø3.3 THRU
D23	87	5.38	Ø3.3 THRU
D24	87	27.38	Ø3.3 THRU
D25	148	47	Ø3.3 THRU
D26	148	127	Ø3.3 THRU
D27	98	127	Ø3.3 THRU
D28	98	47	Ø3.3 THRU

Hole Table

HOLE	XDIM	YDIM	DESCRIPTION
E1	390.75	214.25	Ø3.4 THRU
E2	319.25	214.25	Ø3.4 THRU
E3	109.25	285.75	Ø3.4 THRU
E4	180.75	285.75	Ø3.4 THRU
E5	109.25	214.25	Ø3.4 THRU
E6	180.75	214.25	Ø3.4 THRU
E7	319.25	285.75	Ø3.4 THRU
E8	390.75	285.75	Ø3.4 THRU
F1	425	218.5	Ø6.3 THRU
F2	285.3	218.5	Ø6.3 THRU
F3	425	281.5	Ø6.3 THRU
F4	75	218.5	Ø6.3 THRU
F5	214.7	281.5	Ø6.3 THRU
F6	214.7	218.5	Ø6.3 THRU
F7	75	281.5	Ø6.3 THRU
F8	285.3	281.5	Ø6.3 THRU
G1	355	250	Ø80 -10 DEEP
G2	145	250	Ø80 -10 DEEP
H1	183.16	112.31	Ø2.5 THRU
H2	183.16	49.95	Ø2.5 THRU
H3	255.16	112.31	Ø2.5 THRU
H4	255.16	49.95	Ø2.5 THRU



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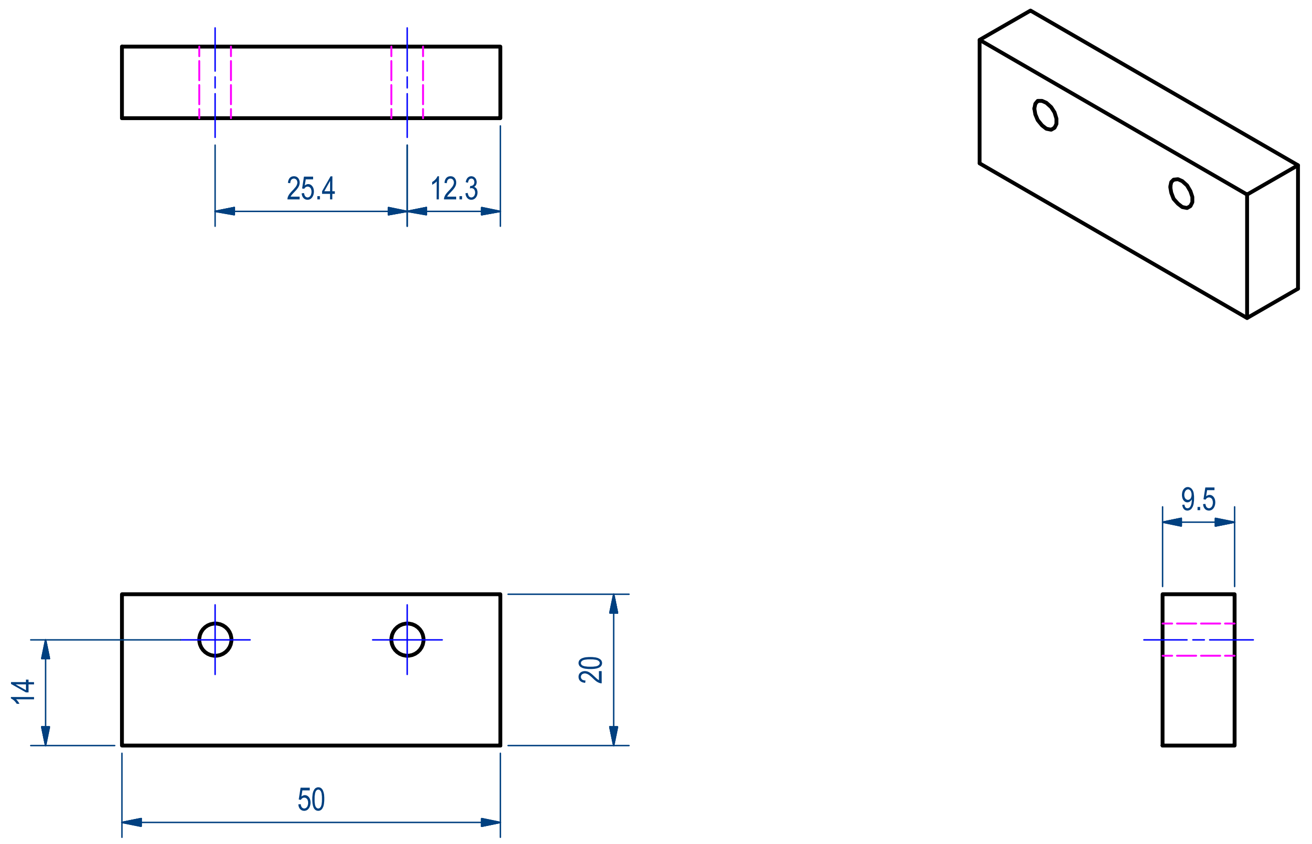

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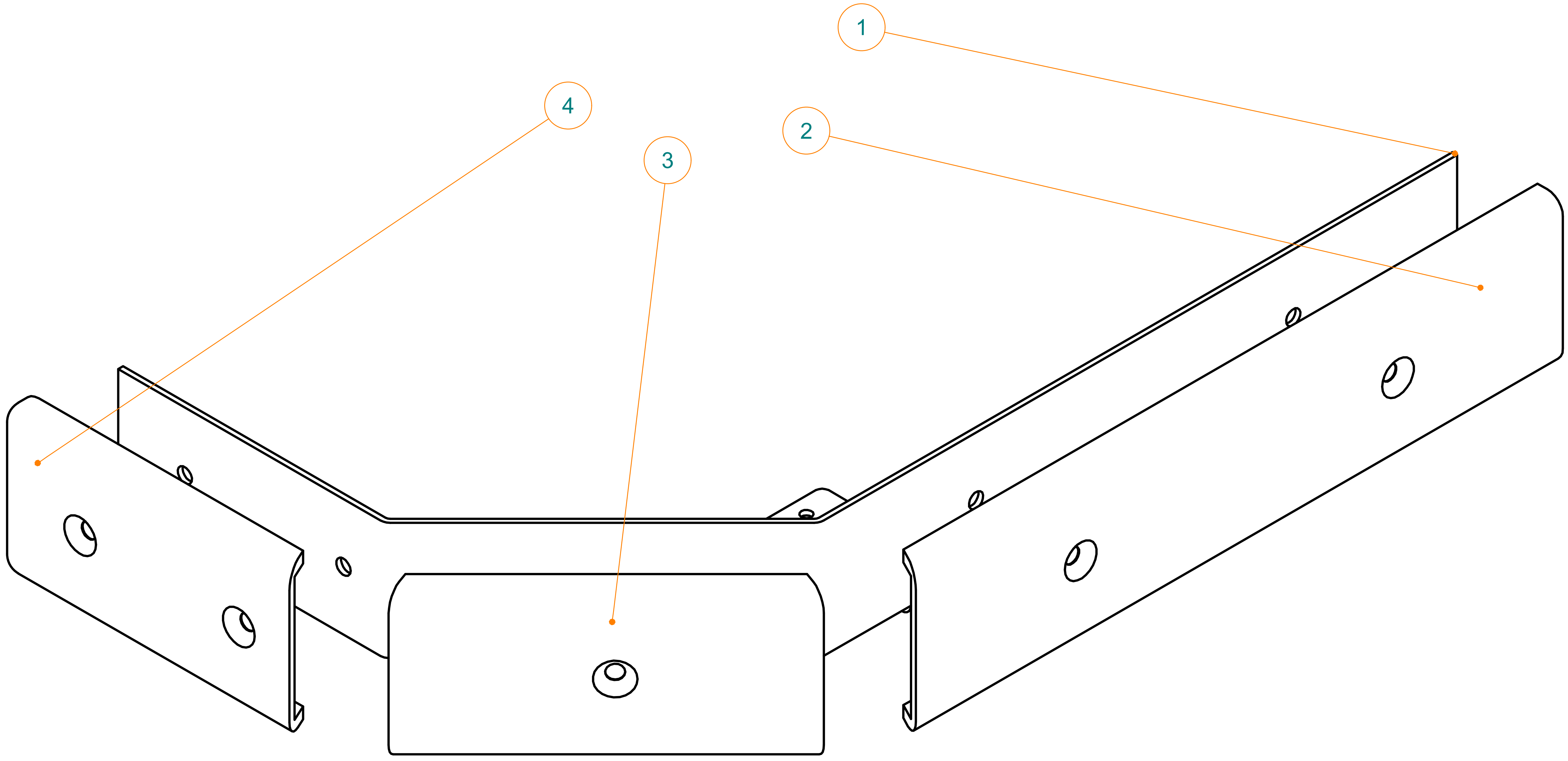
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor TAN TUAN KIAT	Date 7/8/2020	Scale 1:1	Sheet 1	Size A4

Parts List

ITEM	DESCRIPTION	QTY	MATERIAL
1	Right Spring Steel Bumper	1	Spring Steel
2	Right Bumper Front	1	PLA
3	Right Bumper bended side	1	PLA
4	Right Bumper side	1	PLA



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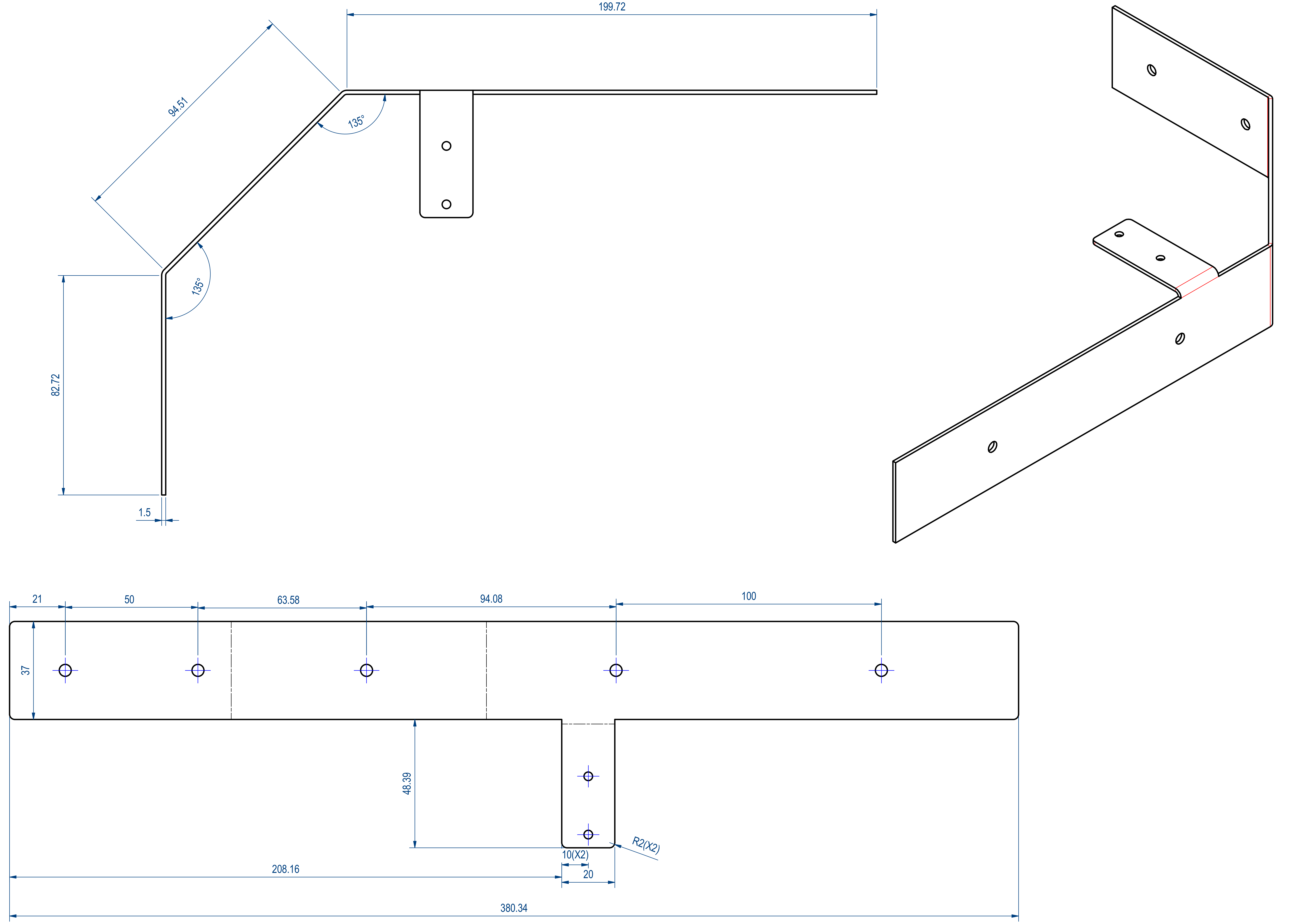

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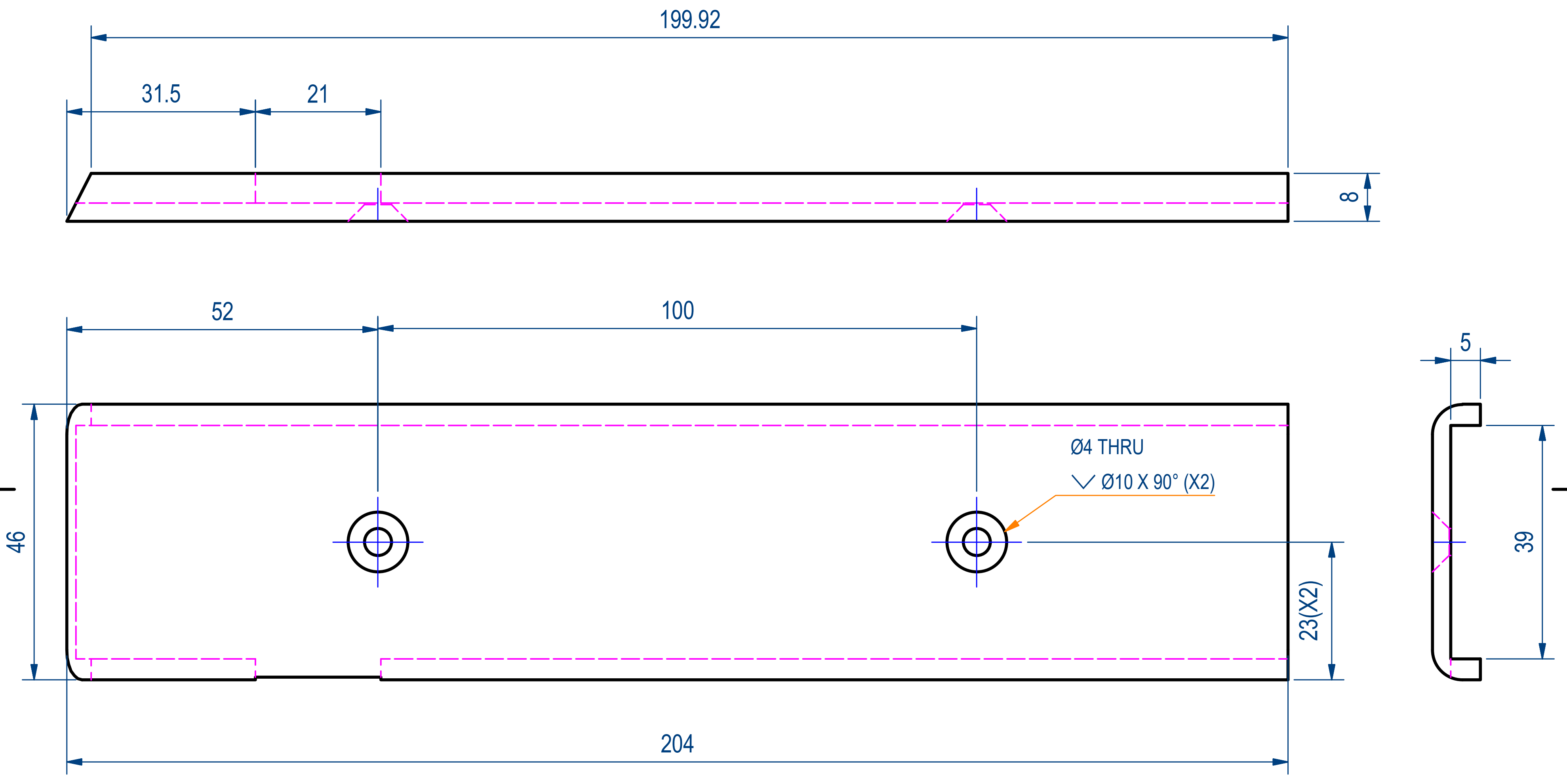
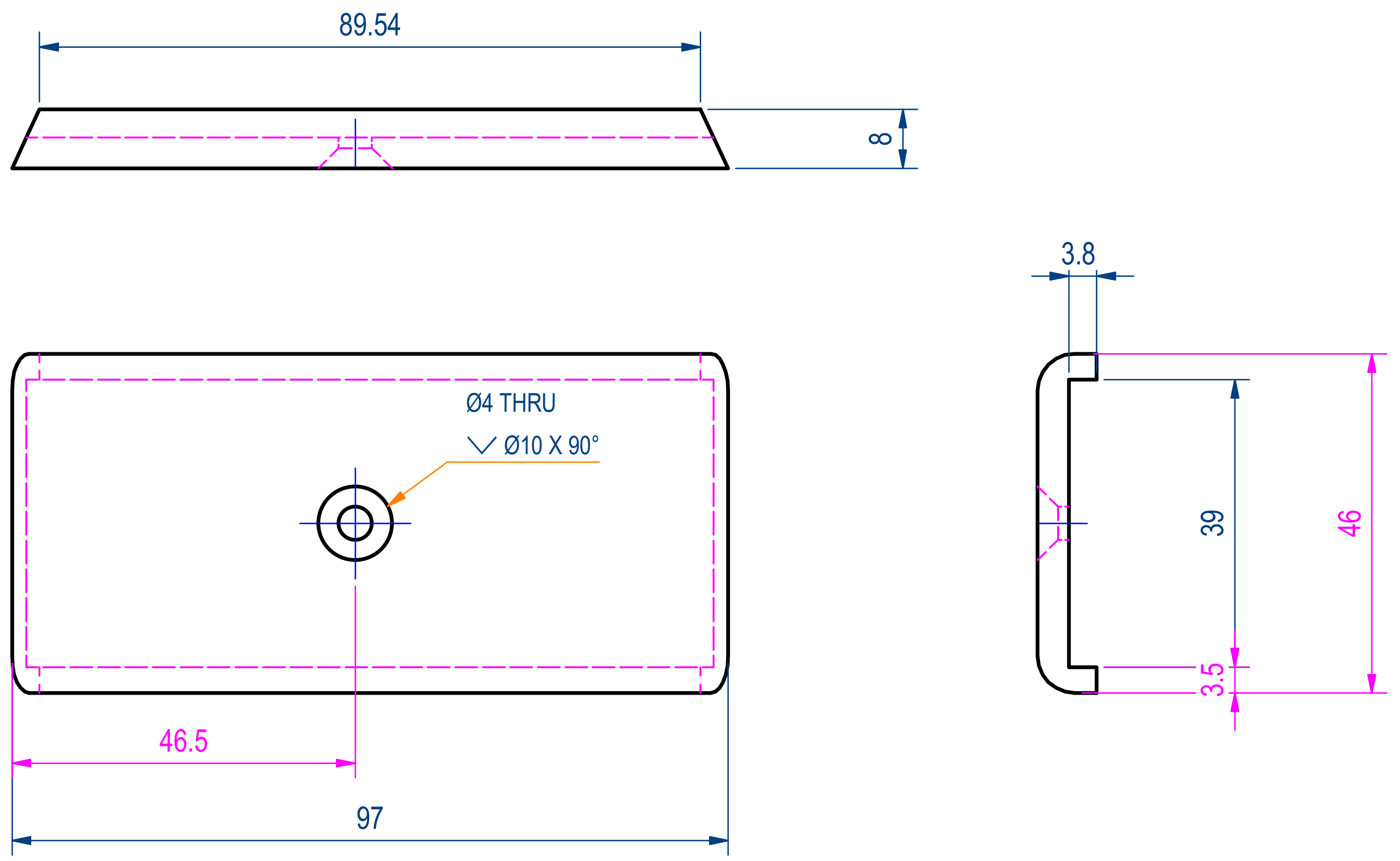
	Checked: SAMUEL WONG	Date: 7/8/2020	Projection	Dwg No.
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor: TAN TUAN KIAT	Date: 7/8/2020	Scale: 1:1	Sheet: 1 / Size: A2



SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed LOW ZHONG SHENG	Date 6/8/2020	Project Title OFFICE TRANSPORTER		
	Checked SAMUEL WONG	Date 7/8/2020	Projection	Dwg No.	
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor TAN TUAN KIAT	Date 7/8/2020	Scale 1:1	Sheet 1	Size A4



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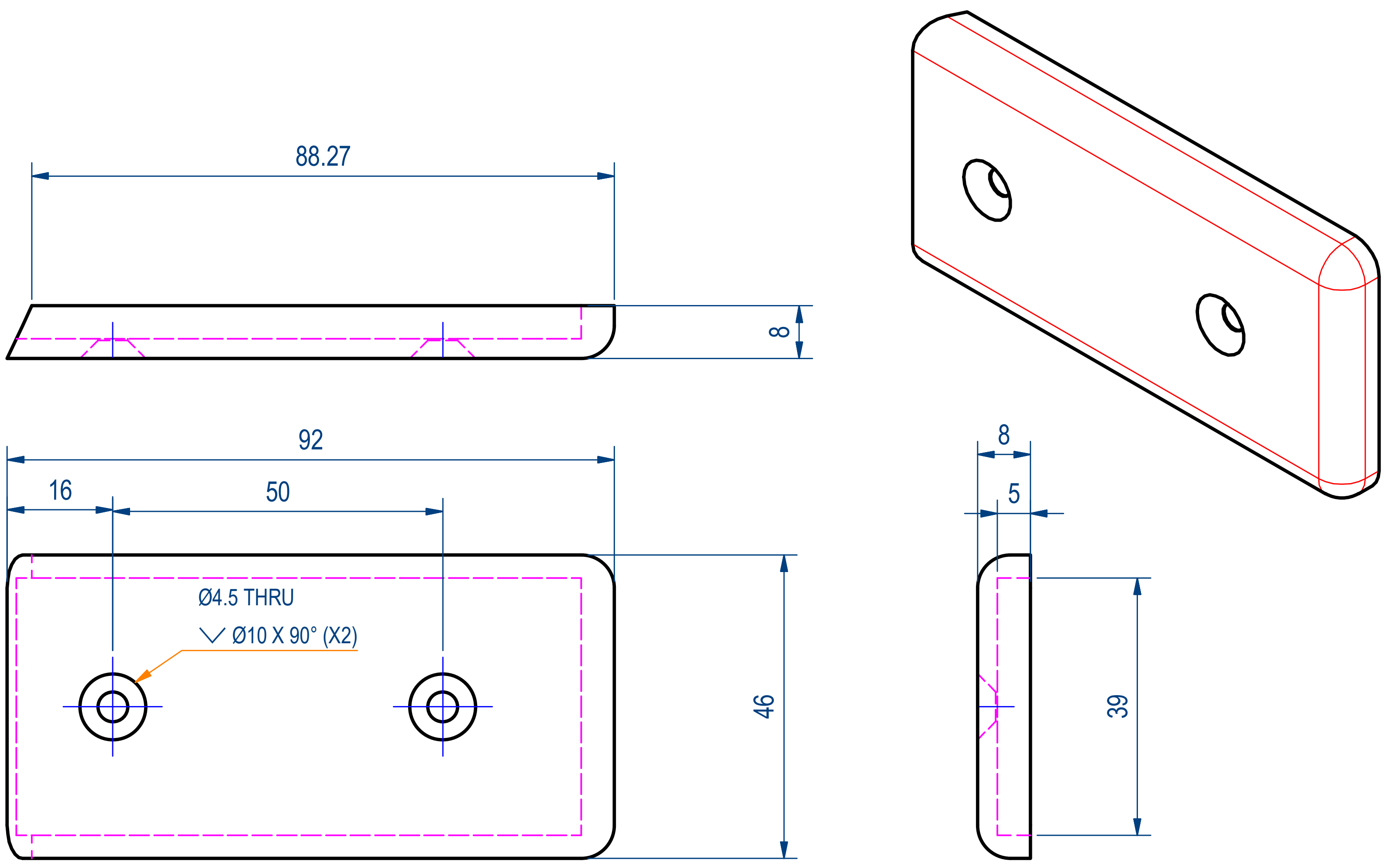
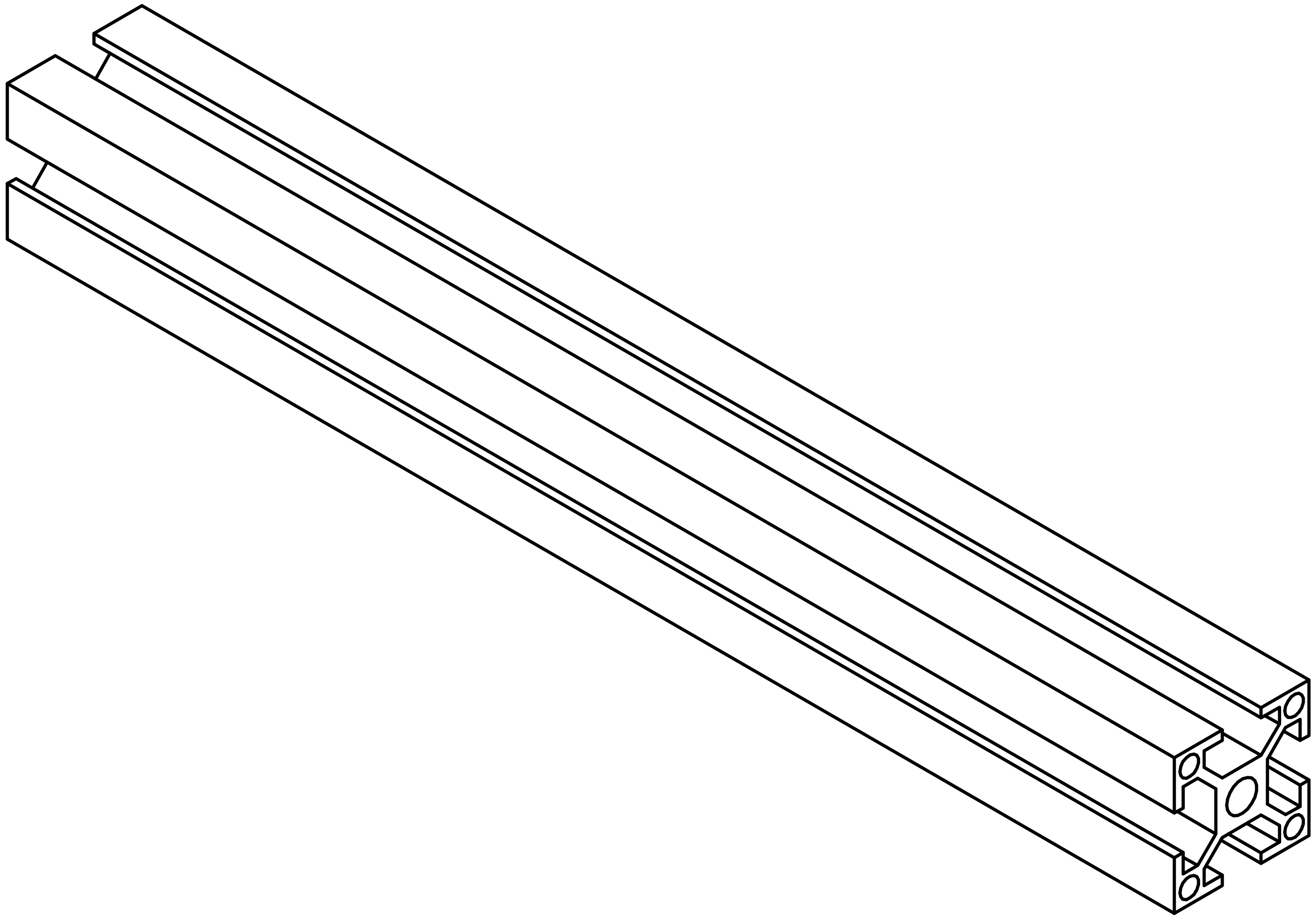
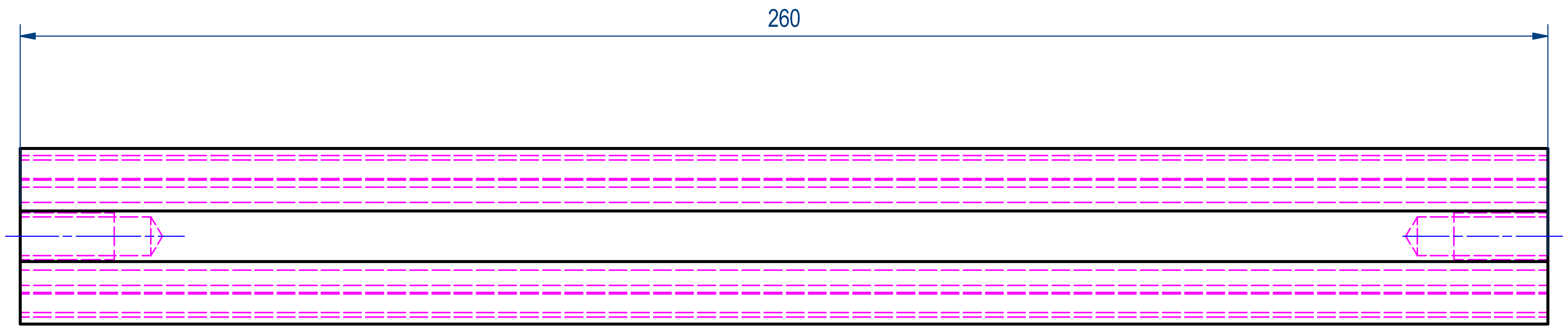
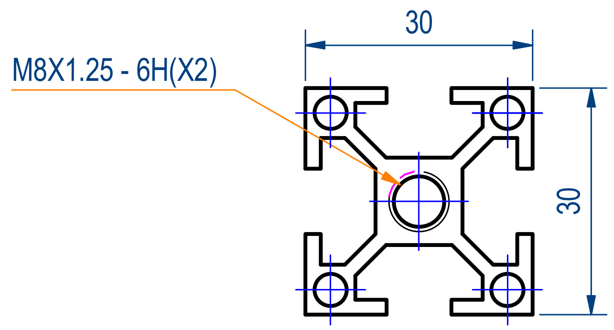
	Checked SAMUEL WONG	Date 7/8/2020	Projection	Dwg No.	
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor TAN TUAN KIAT	Date 7/8/2020	Scale 1:1	Sheet 1	Size A4



SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed: LOW ZHONG SHENG	Date: 6/8/2020	Project Title: OFFICE TRANSPORTER		
	Checked: SAMUEL WONG	Date: 7/8/2020	Projection	Dwg No.	
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor: TAN TUAN KIAT	Date: 7/8/2020	Scale: 1:1	Sheet: 1	Size: A4



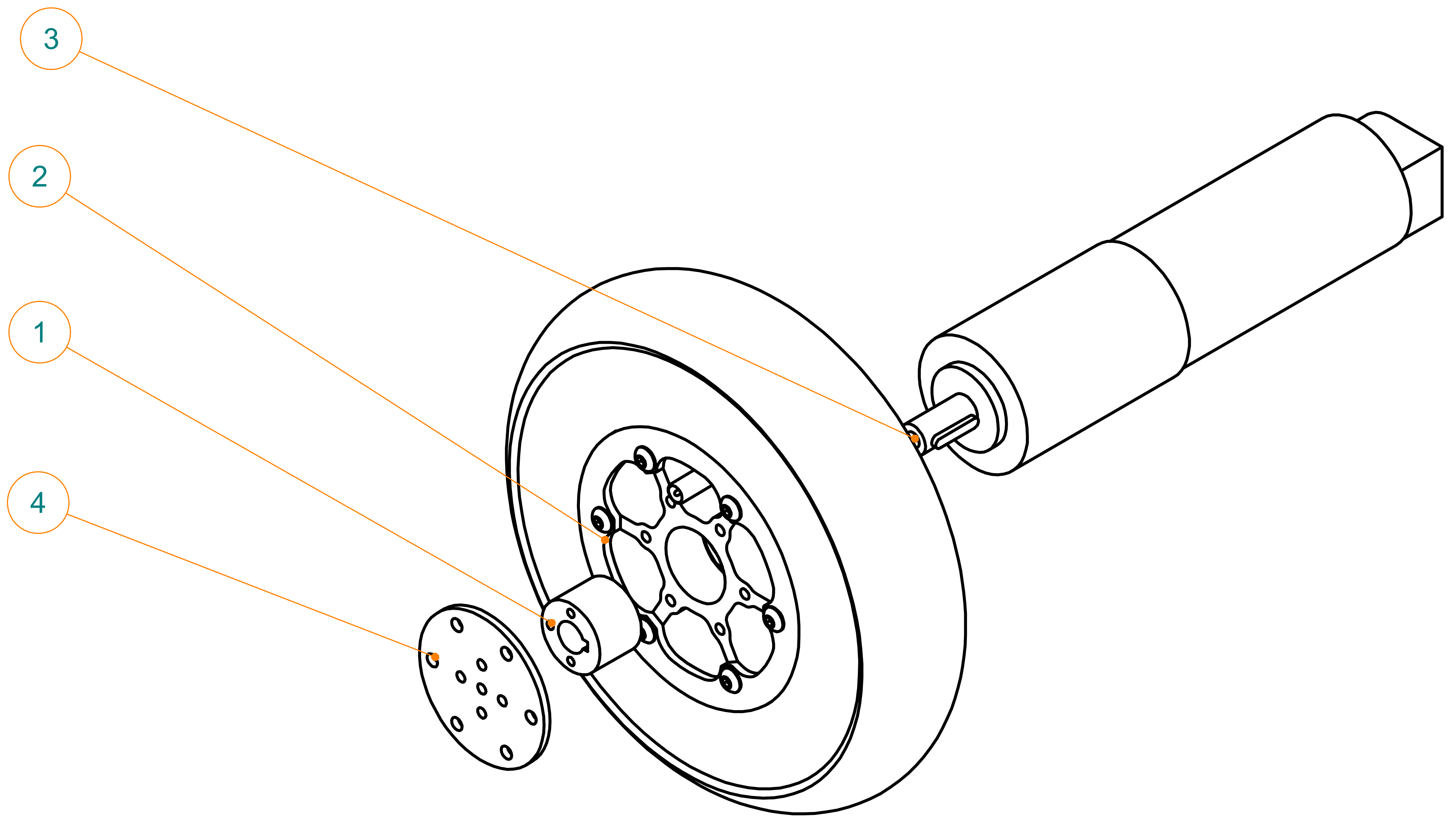




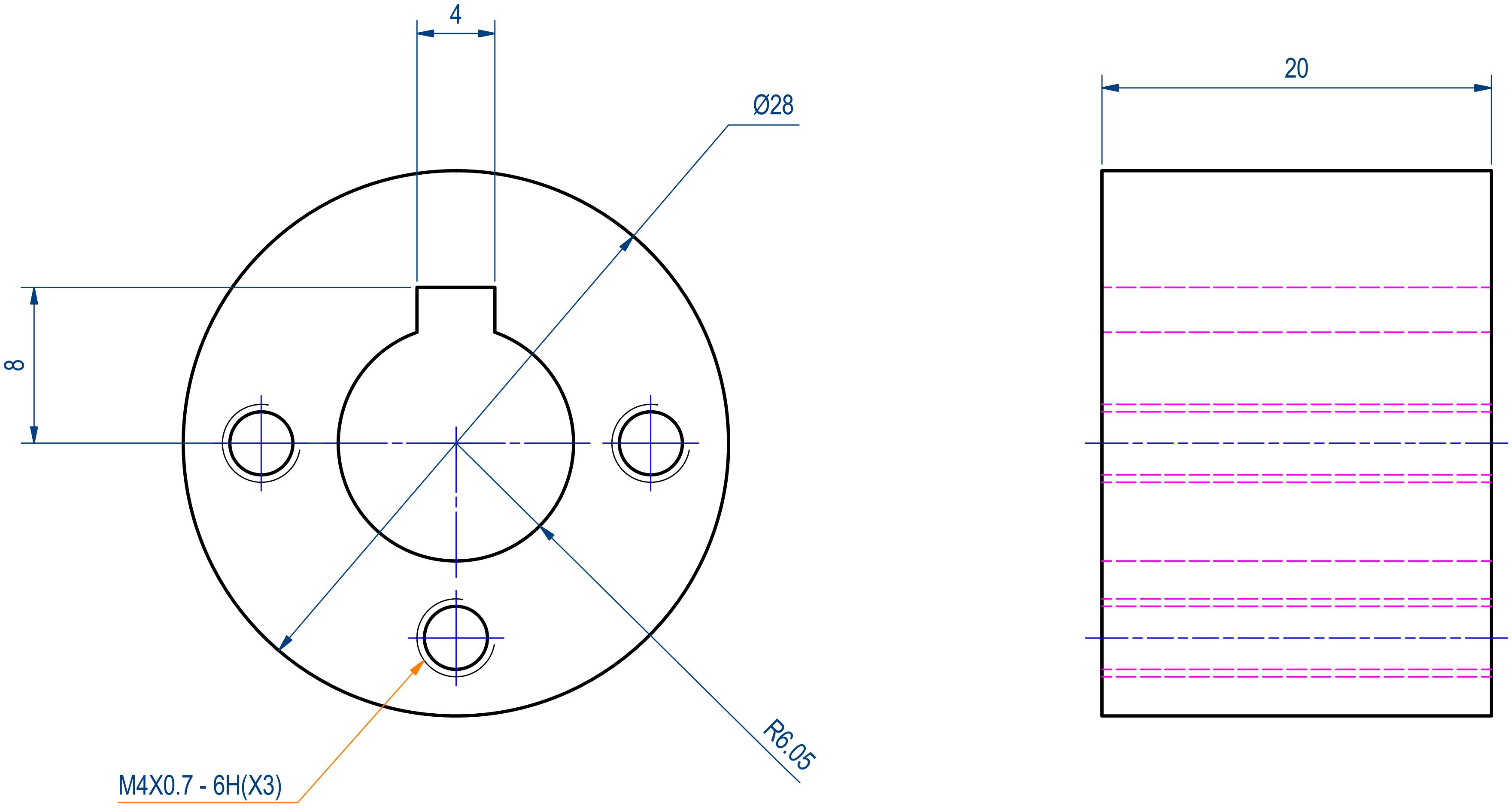
SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed: LOW ZHONG SHENG	Date: 6/8/2020	Project Title: OFFICE TRANSPORTER
	Checked: SILVANUS SNG	Date: 7/8/2020	Projection / Dwg No.
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor: TAN TUAN KIAT	Date: 7/8/2020	Scale: 1:1 / Sheet: 1 / Size: A3

Parts List

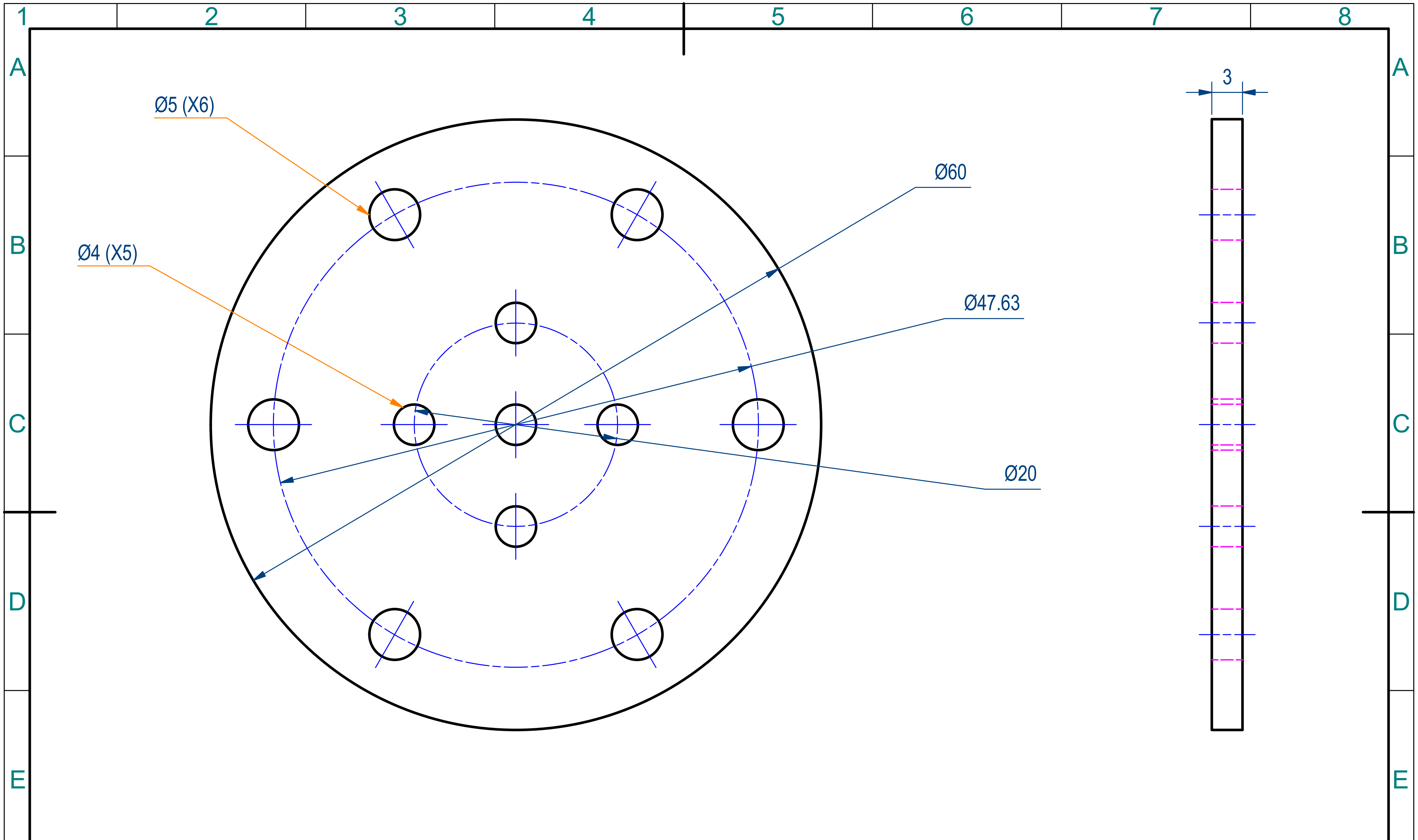
ITEM	DESCRIPTION	QTY	MATERIAL
1	Main Motor Collar	1	Aluminum
2	Rubber Wheel	1	
3	Brush Motor	1	
4	Main Motor Mounting Plate	1	Aluminum



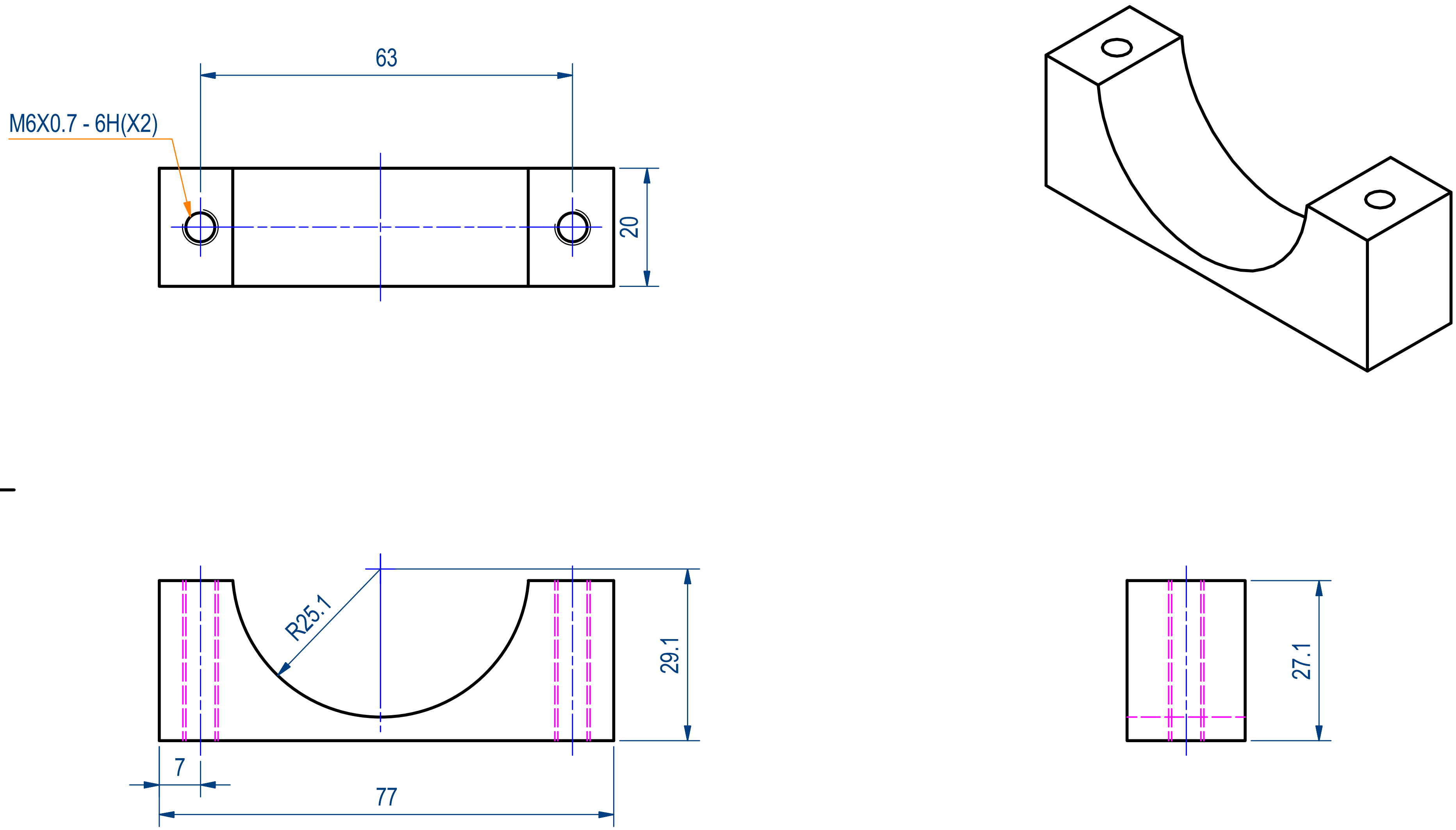
SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed: SILVANUS SNG	Date: 6/8/2020	Project Title: OFFICE TRANSPORTER
	Checked: LOW ZHONG SHENG	Date: 7/8/2020	Projection / Dwg No.
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor: TAN TUAN KIAT	Date: 7/8/2020	Scale: 1:2 / Sheet: 1 / Size: A3



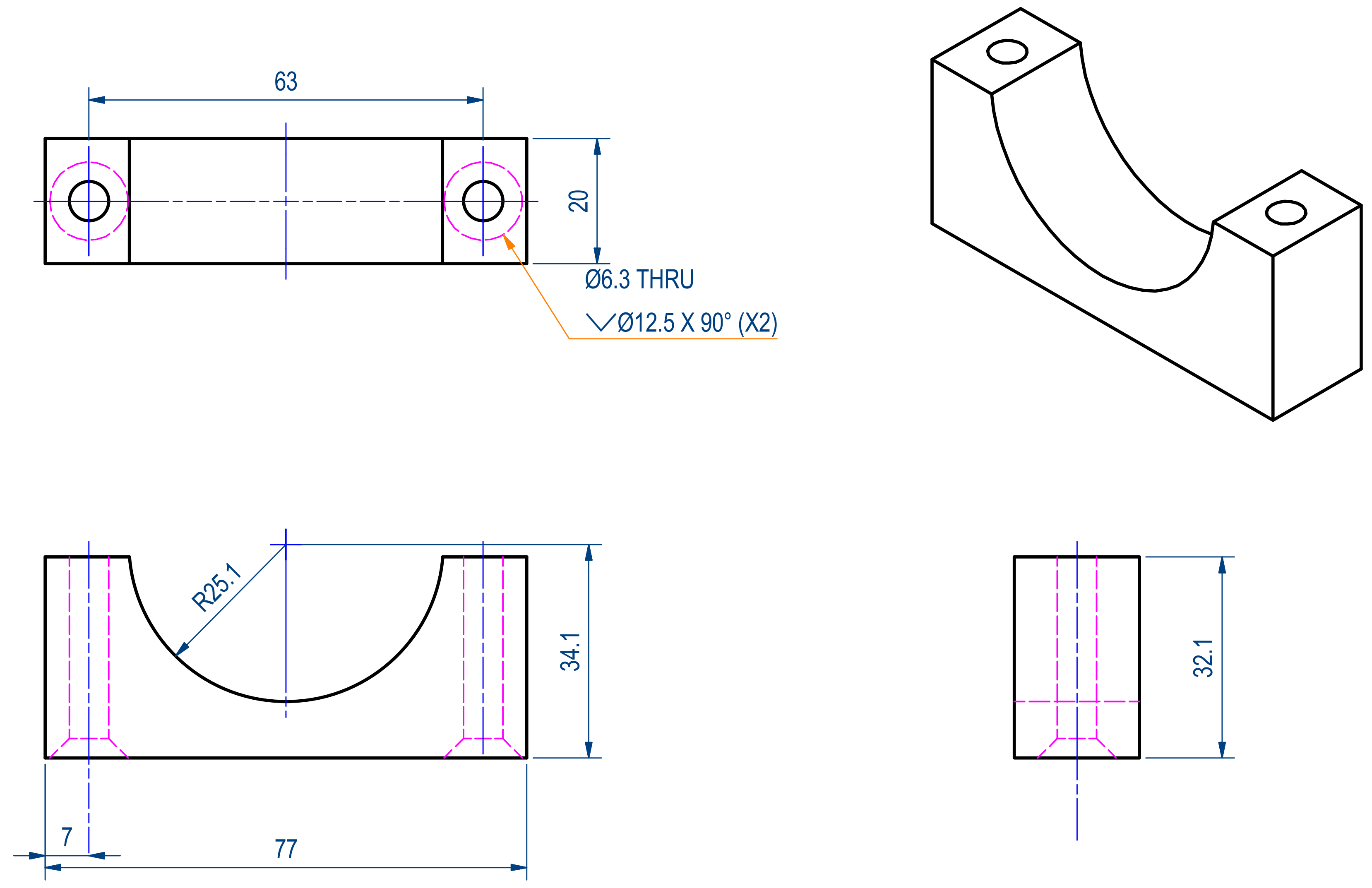
SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed: LOW ZHONG SHENG	Date: 6/8/2020	Project Title: OFFICE TRANSPORTER		
	Checked: SILVANUS SNG	Date: 7/8/2020	Projection	Dwg No.	
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor: TAN TUAN KIAT	Date: 7/8/2020	Scale: 3:1	Sheet: 1	Size: A4



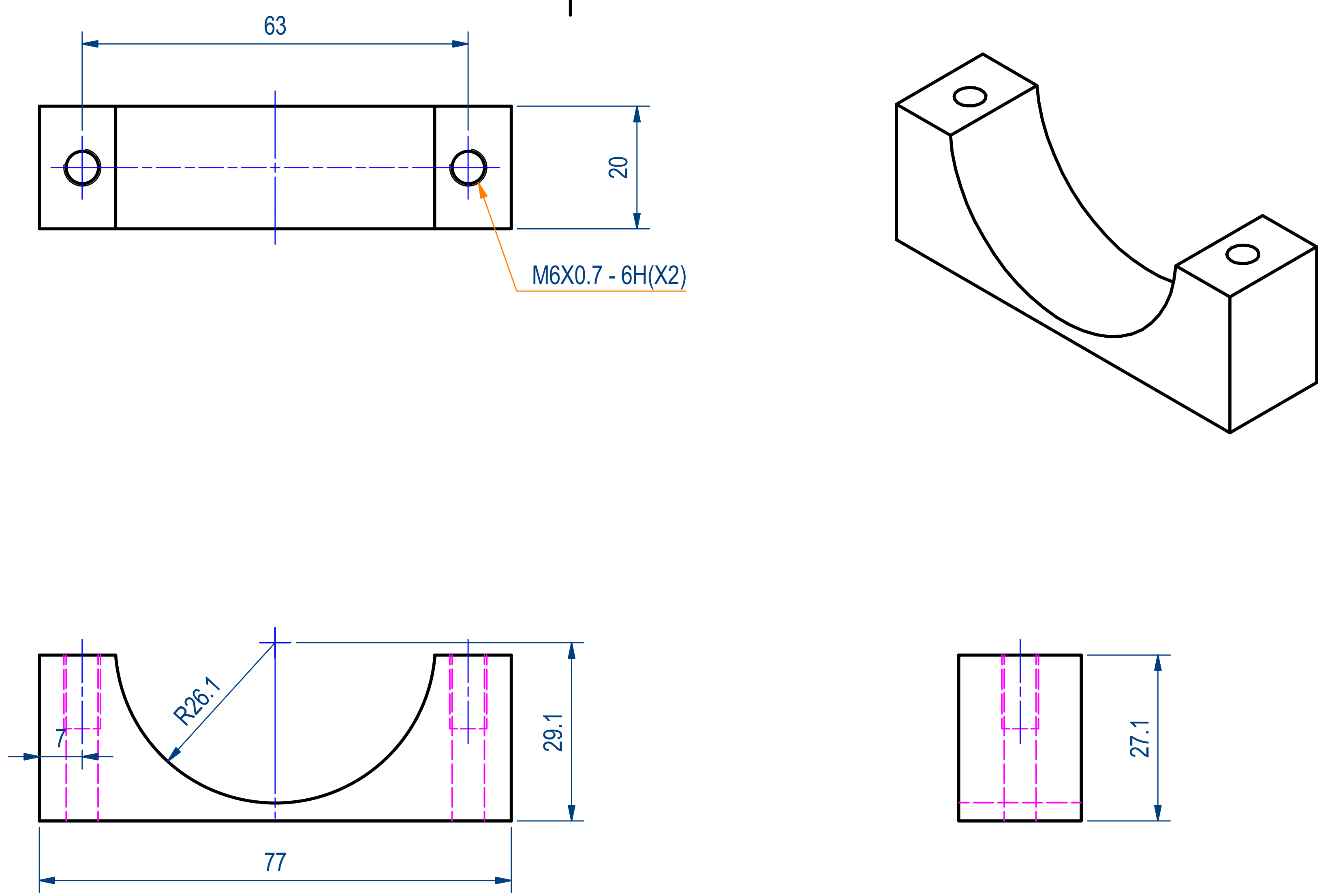
SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed LOW ZHONG SHENG	Date 6/8/2020	Project Title OFFICE TRANSPORTER		
	Checked SAMUEL WONG	Date 7/8/2020	Projection	Dwg No.	
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor TAN TUAN KIAT	Date 7/8/2020	Scale 2:1	Sheet 1	Size A4



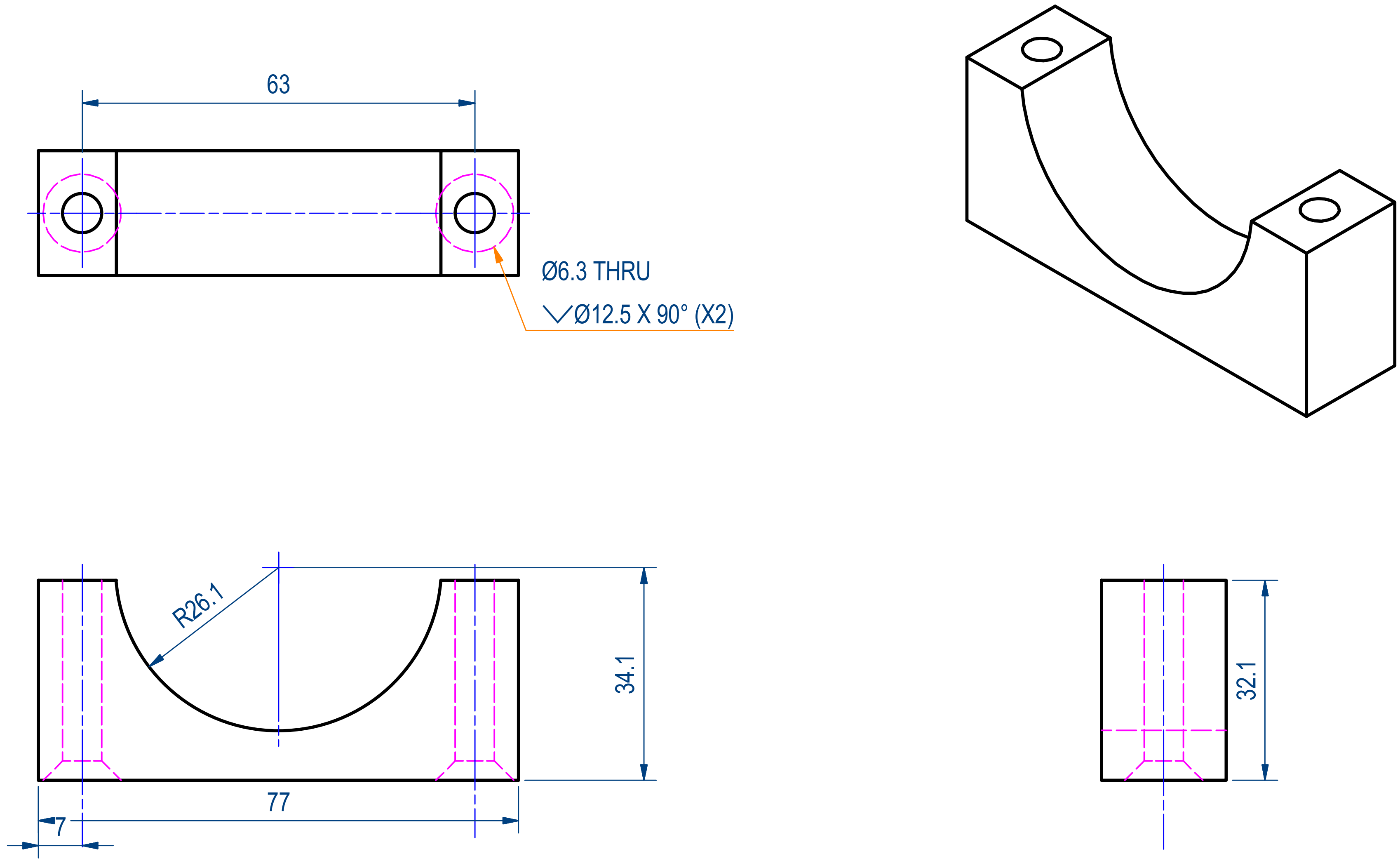
SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed LOW ZHONG SHENG	Date 6/8/2020	Project Title OFFICE TRANSPORTER	
	Checked JARED TAN	Date 7/8/2020	Projection	Dwg No.
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor TAN TUAN KIAT	Date 7/8/2020	Scale 1:1	Sheet 1 / Size A4



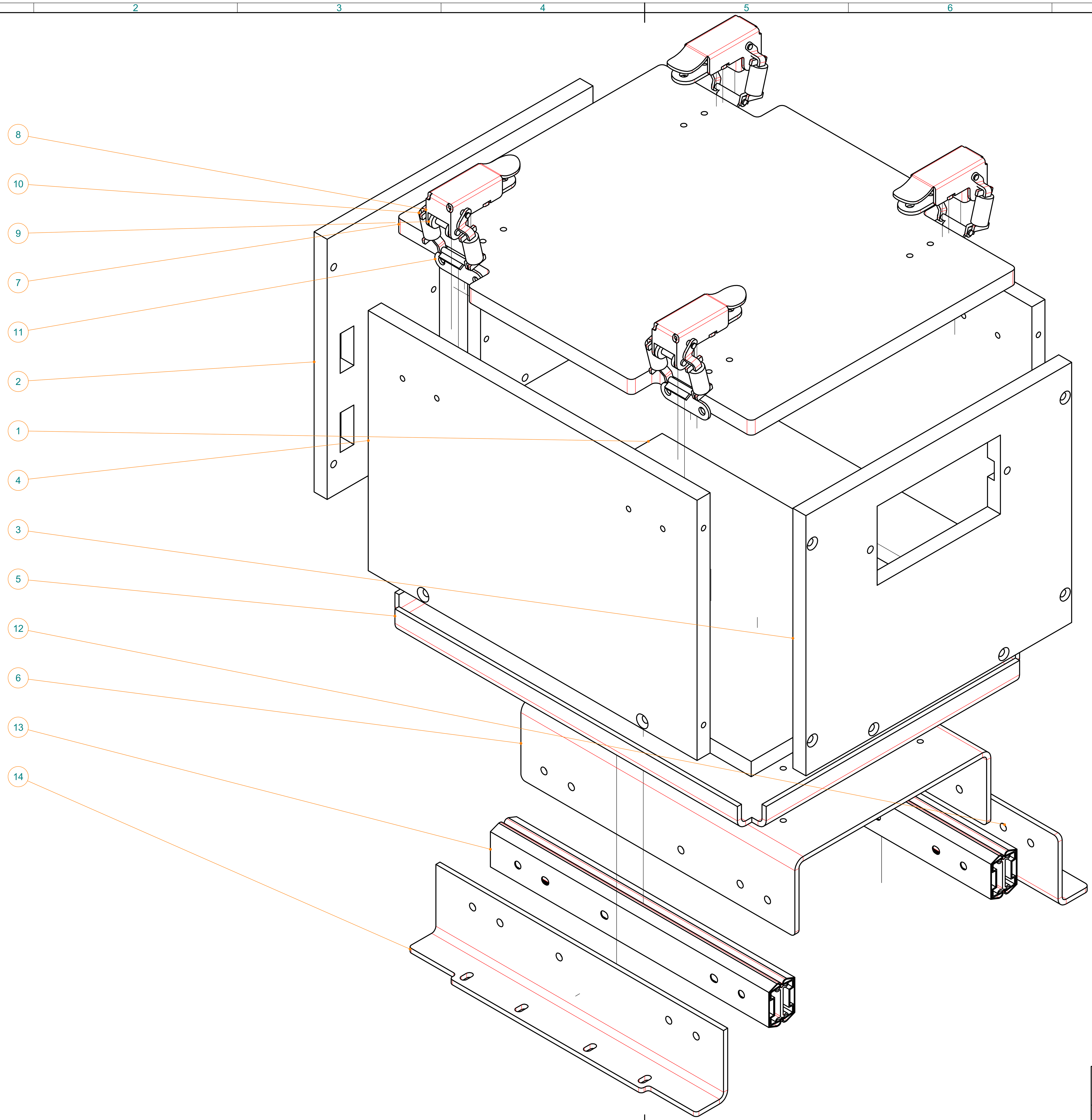
SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed LOW ZHONG SHENG	Date 6/8/2020	Project Title OFFICE TRANSPORTER			
	Checked SILVANUS SNG	Date 7/8/2020	Projection		Dwg No.	
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor TAN TUAN KIAT	Date 7/8/2020	Scale 1:1		Sheet 1	Size A4



SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed LOW ZHONG SHENG	Date 6/8/2020	Project Title OFFICE TRANSPORTER		
	Checked SILVANUS SNG	Date 7/8/2020	Projection	Dwg No.	
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor TAN TUAN KIAT	Date 7/8/2020	Scale 1:1	Sheet 1	Size A4

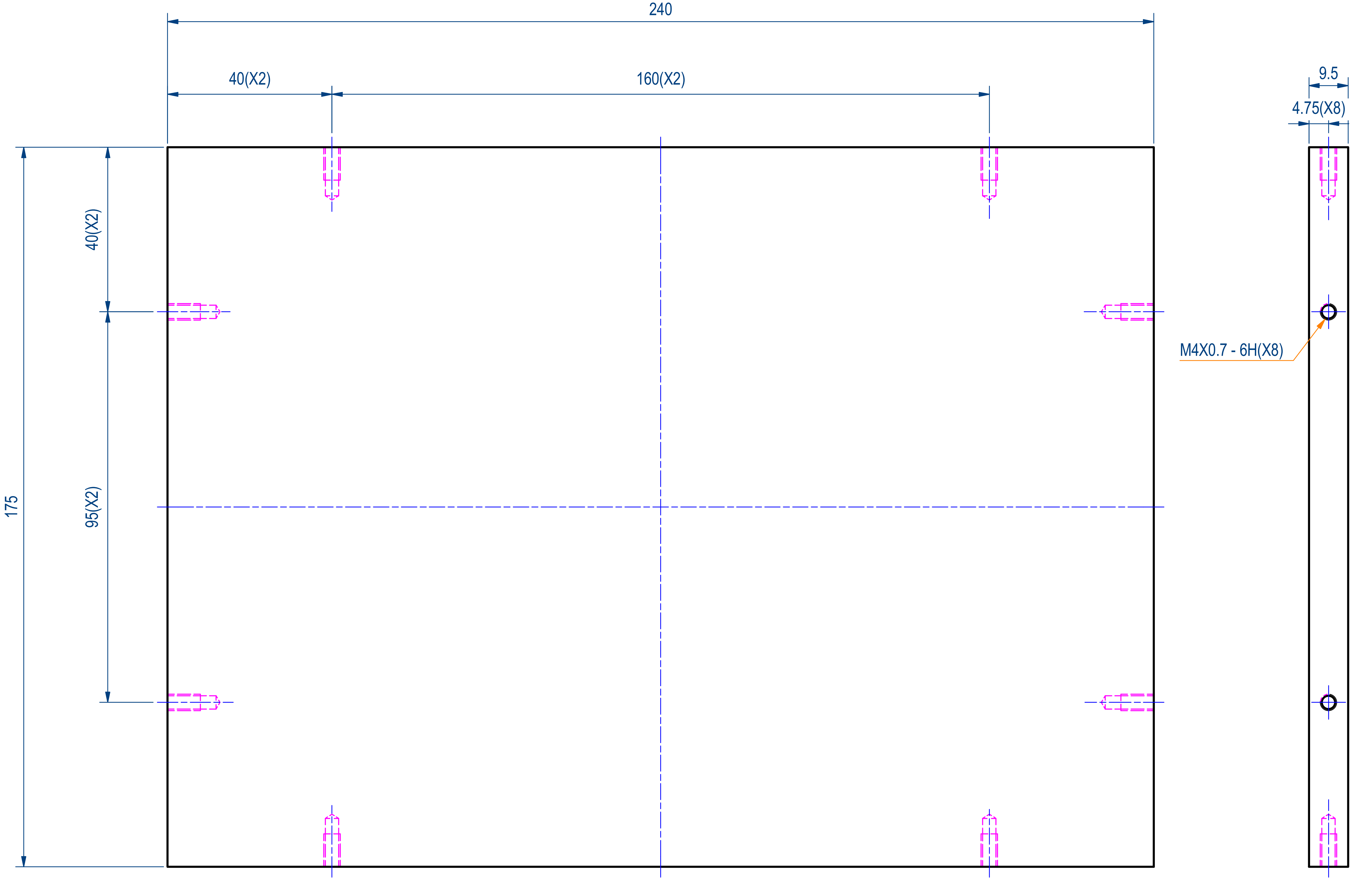


SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed LOW ZHONG SHENG	Date 6/8/2020	Project Title OFFICE TRANSPORTER			
	Checked SILVANUS SNG	Date 7/8/2020	Projection	Dwg No.		
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor TAN TUAN KIAT	Date 7/8/2020	Scale 1:1	Sheet 1	Size A4	



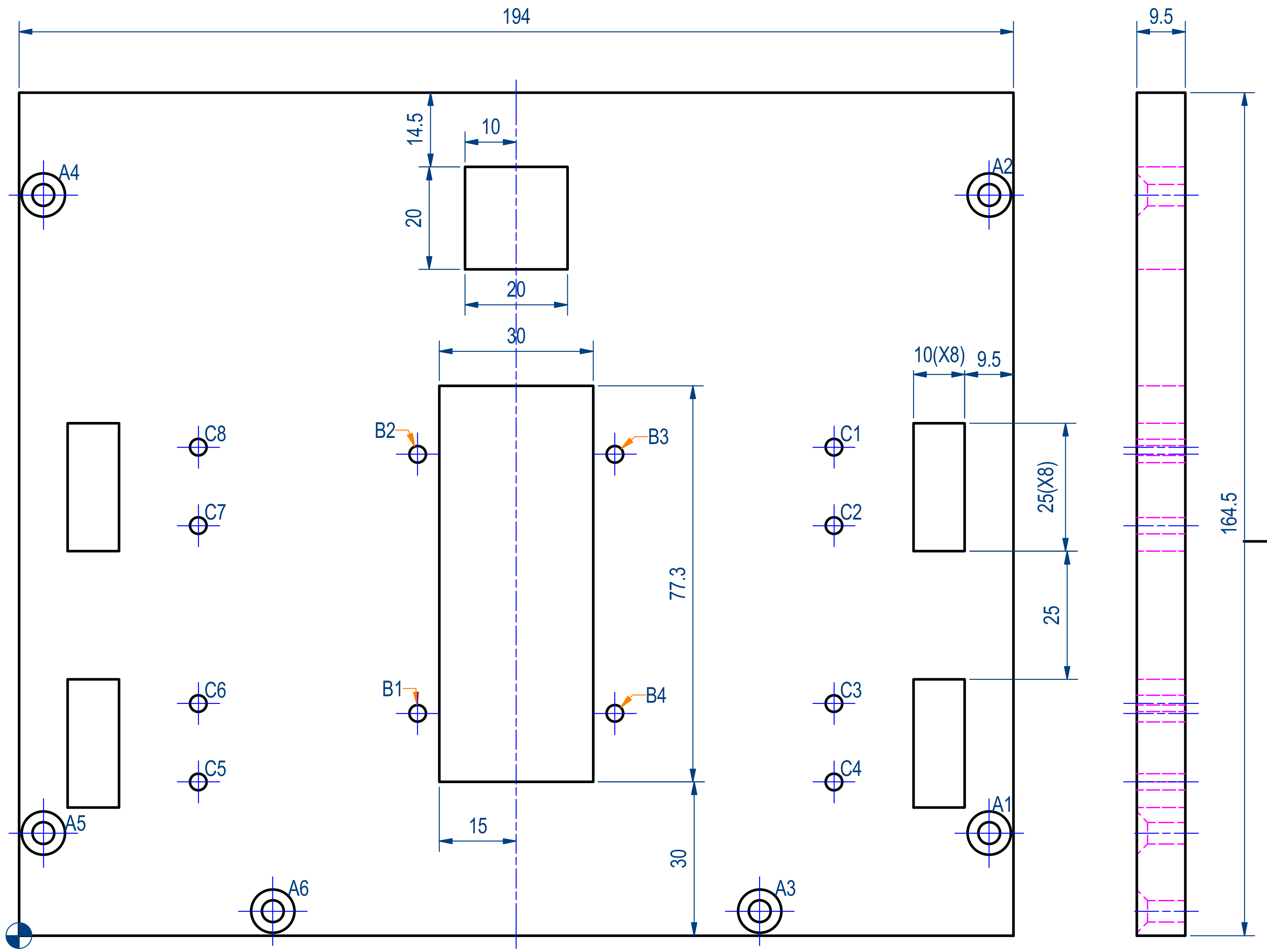
Parts List			
ITEM	DESCRIPTION	QTY	MATERIAL
1	Box Bottom	1	Polycarbonate
2	Box Back	1	Polycarbonate
3	Box Front	1	Polycarbonate
4	Box Side	2	Polycarbonate
5	Top Sliding Tray	1	Aluminum
6	Bottom Sliding Tray	1	Aluminum
7	Box Lid	1	Polycarbonate
8	PKBSK2_1	4	Generic
9	PKBSK2_11	4	Generic
10	PKBSK2_2	4	Generic
11	PKBSK2_4	4	Generic
12	Left Battery Mount	1	Aluminum
13	SSRXY2708	2	
14	Right Battery Mount	1	Aluminum

SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed SILVANUS SNG	Date 6/8/2020	Project Title OFFICE TRANSPORTER		
	Checked LOW ZHONG SHENG	Date 7/8/2020	Projection	Dwg No.	
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor TAN TUAN KIAT	Date 7/8/2020	Scale 1:1	Sheet 1	Size A1



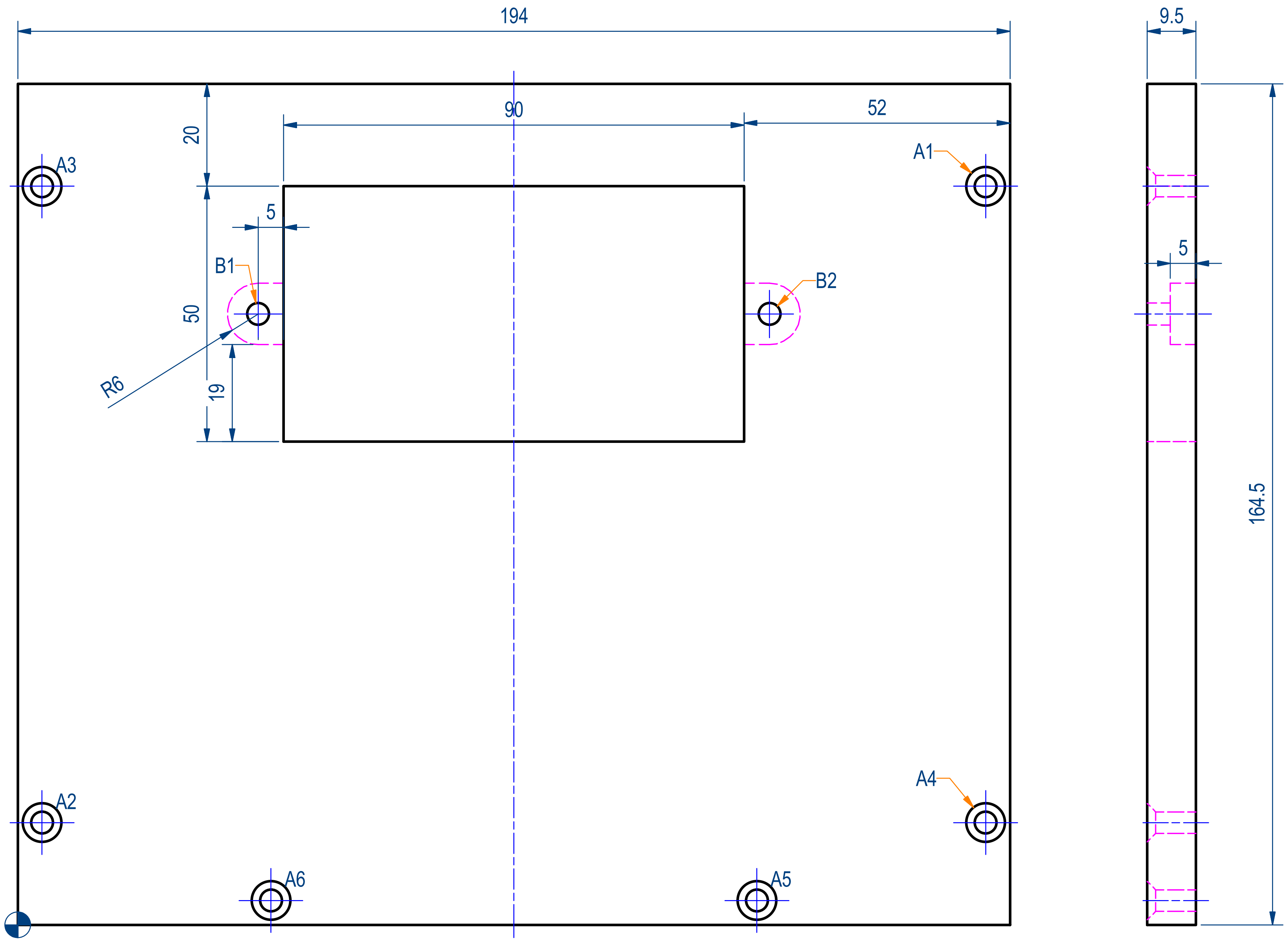
SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed LOW ZHONG SHENG	Date 6/8/2020	Project Title OFFICE TRANSPORTER
	Checked SAMUEL WONG	Date 7/8/2020	Projection / Dwg No.
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor TAN TUAN KIAT	Date 7/8/2020	Scale 1:1 / Sheet 1 / Size A3

Hole Table			
HOLE	XDIM	YDIM	DESCRIPTION
A1	189.25	20	Ø4.2 THRU ⌵ Ø8.4 X 90°
A2	189.25	144.5	Ø4.2 THRU ⌵ Ø8.4 X 90°
A3	144.5	4.75	Ø4.2 THRU ⌵ Ø8.4 X 90°
A4	4.75	144.5	Ø4.2 THRU ⌵ Ø8.4 X 90°
A5	4.75	20	Ø4.2 THRU ⌵ Ø8.4 X 90°
A6	49.5	4.75	Ø4.2 THRU ⌵ Ø8.4 X 90°
B1	77.75	43.35	Ø3.3 THRU
B2	77.75	93.95	Ø3.3 THRU
B3	116.25	93.95	Ø3.3 THRU
B4	116.25	43.35	Ø3.3 THRU
C1	159	95.3	Ø3.2 THRU
C2	159	80	Ø3.2 THRU
C3	159	45.3	Ø3.2 THRU
C4	159	30	Ø3.2 THRU
C5	35	30	Ø3.2 THRU
C6	35	45.3	Ø3.2 THRU
C7	35	80	Ø3.2 THRU
C8	35	95.3	Ø3.2 THRU



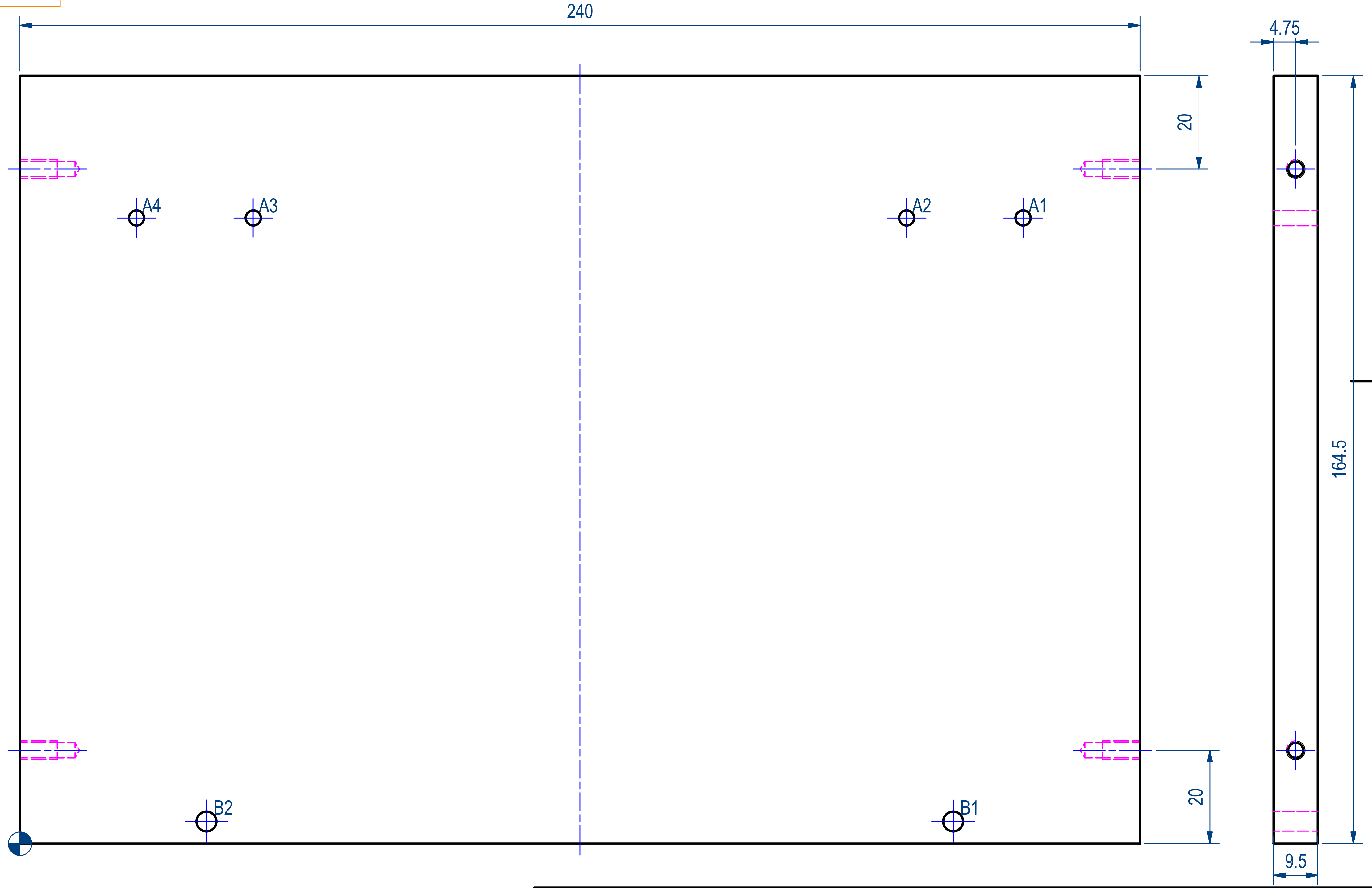
SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed LOW ZHONG SHENG	Date 6/8/2020	Project Title OFFICE TRANSPORTER		
	Checked SAMUEL WONG	Date 7/8/2020	Projection	Dwg No.	
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor TAN TUAN KIAT	Date 7/8/2020	Scale 1:1	Sheet 1	Size A3

Hole Table			
HOLE	XDIM	YDIM	DESCRIPTION
A1	189.25	144.5	Ø4.2 THRU ⌵ Ø7.5 X 90°
A2	4.75	20	Ø4.2 THRU ⌵ Ø7.5 X 90°
A3	4.75	144.5	Ø4.2 THRU ⌵ Ø7.5 X 90°
A4	189.25	20	Ø4.2 THRU ⌵ Ø7.5 X 90°
A5	144.5	4.75	Ø4.2 THRU ⌵ Ø7.5 X 90°
A6	49.5	4.75	Ø4.2 THRU ⌵ Ø7.5 X 90°
B1	47	119.5	Ø4.3 THRU
B2	147	119.5	Ø4.3 THRU

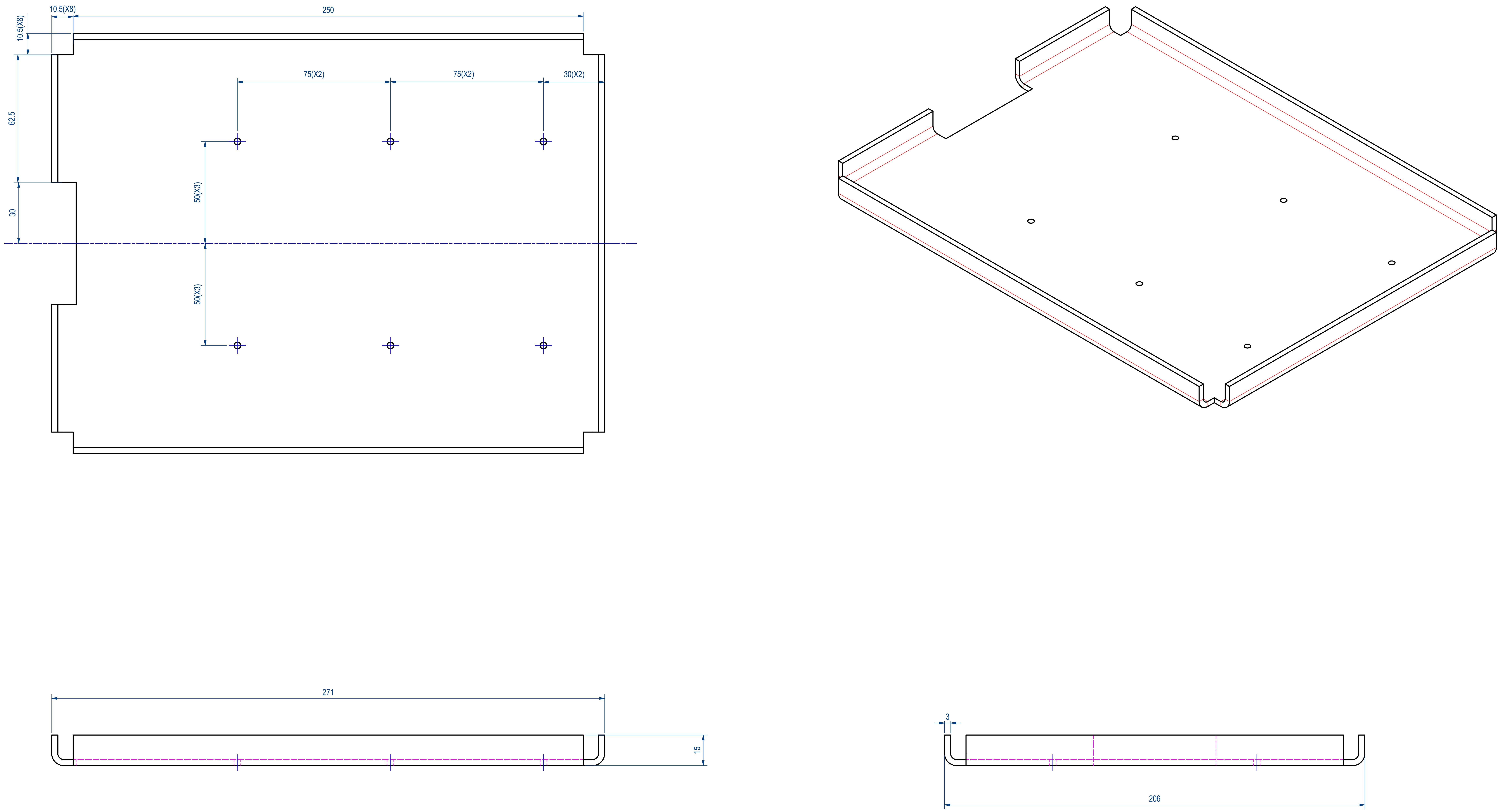


SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed: LOW ZHONG SHENG	Date: 6/8/2020	Project Title: OFFICE TRANSPORTER		
	Checked: SAMUEL WONG	Date: 7/8/2020	Projection	Dwg No.	
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor: TAN TUAN KIAT	Date: 7/8/2020	Scale: 1:1	Sheet: 1	Size: A3

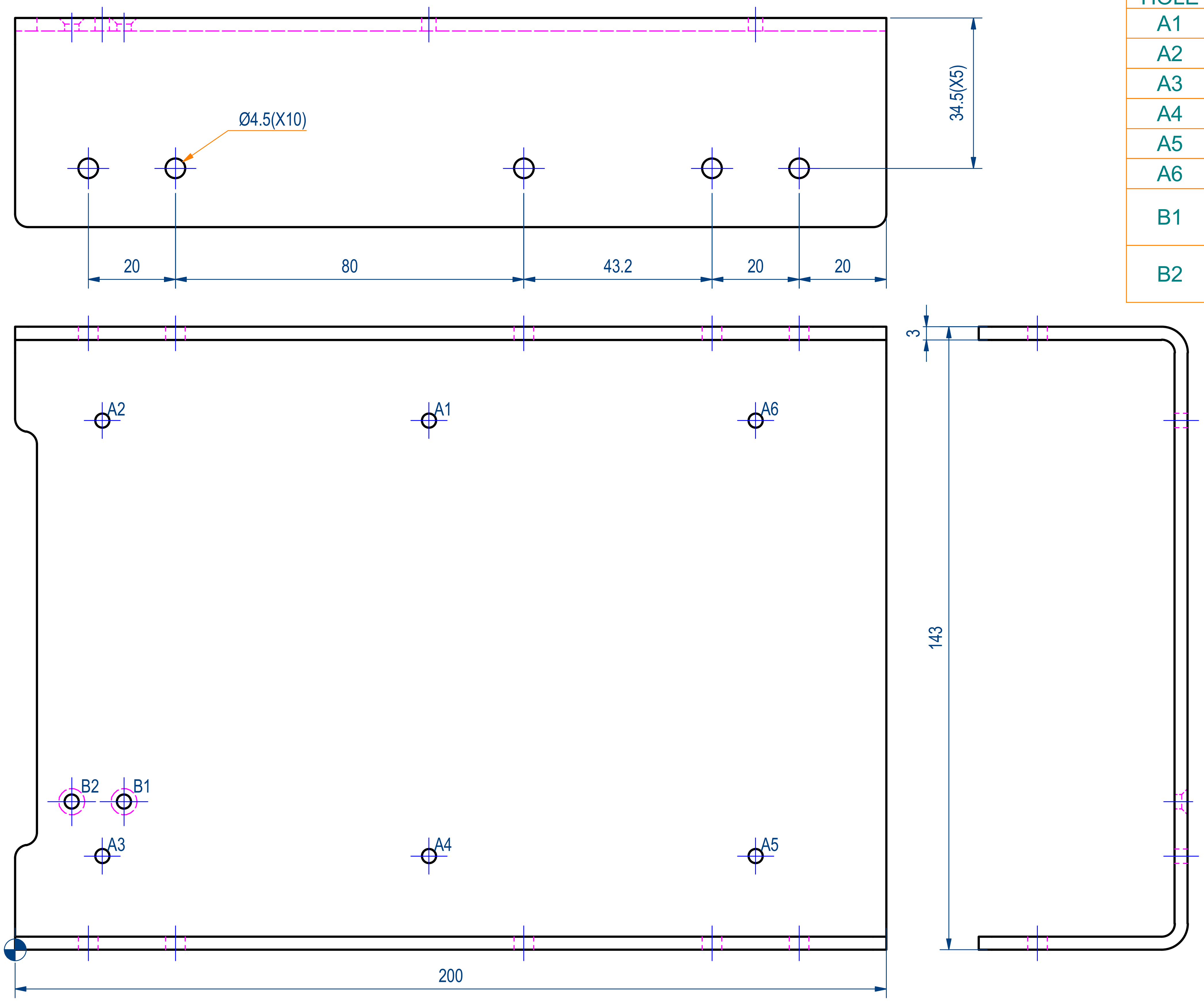
Hole Table			
HOLE	XDIM	YDIM	DESCRIPTION
A1	215	134	Ø3.3 THRU
A2	190	134	Ø3.3 THRU
A3	50	134	Ø3.3 THRU
A4	25	134	Ø3.3 THRU
B1	200	4.75	Ø4.2 THRU
B2	40	4.75	Ø4.2 THRU



SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed: SAMUEL WONG	Date: 6/8/2020	Project Title: OFFICE TRANSPORTER
	Checked: LOW ZHONG SHENG	Date: 7/8/2020	Projection / Dwg No.
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor: TAN TUAN KIAT	Date: 7/8/2020	Scale: 1:1 / Sheet: 1 / Size: A3



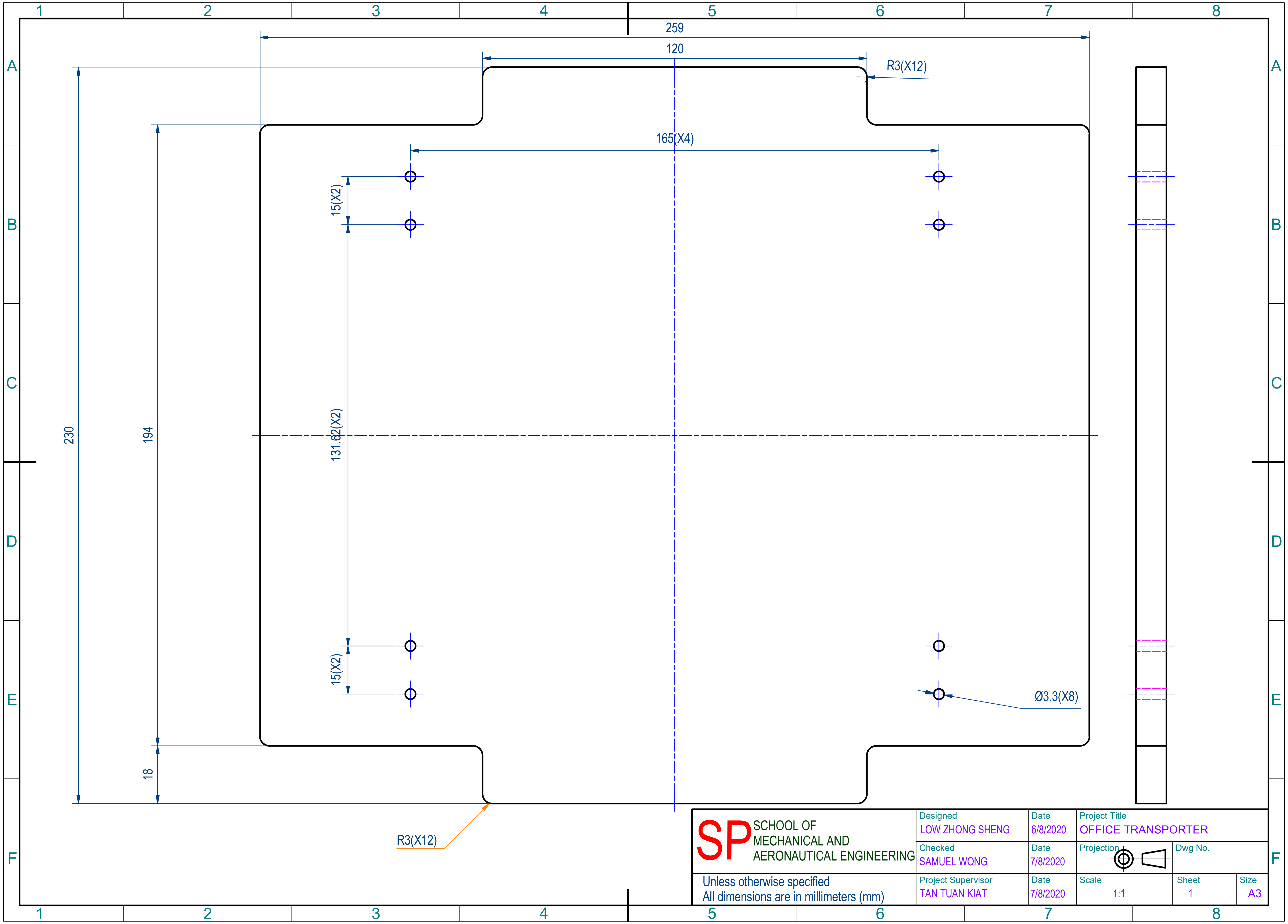
SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed: LOW ZHONG SHENG	Date: 6/8/2020	Project Title: OFFICE TRANSPORTER		
	Checked: SILVANUS SNG	Date: 7/8/2020	Projection	Dwg No.	
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor: TAN TUAN KIAT	Date: 7/8/2020	Scale: 1:1	Sheet: 1	Size: A1

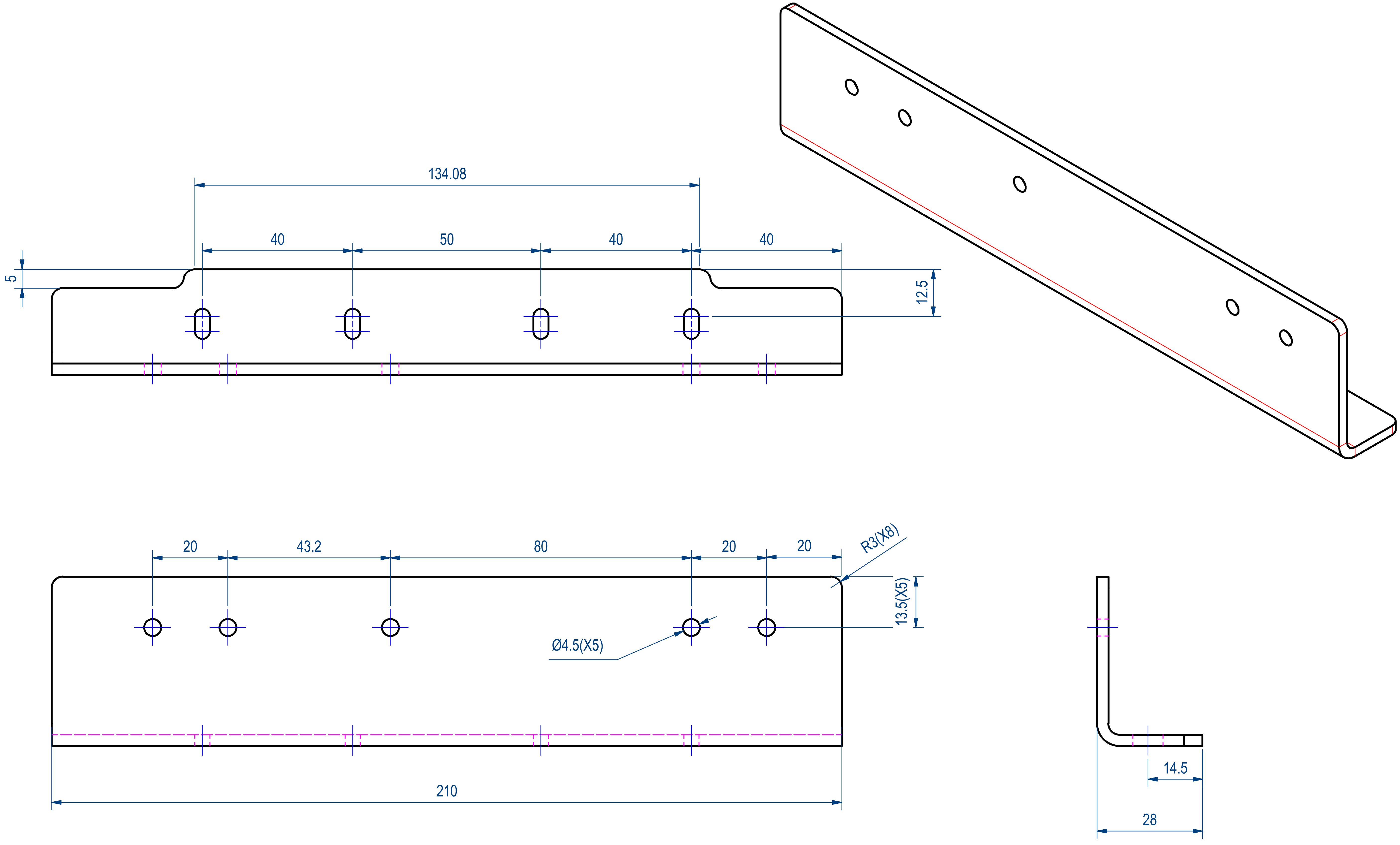


Hole Table

HOLE	XDIM	YDIM	DESCRIPTION
A1	95	121.5	Ø3.3 THRU
A2	20	121.5	Ø3.3 THRU
A3	20	21.5	Ø3.3 THRU
A4	95	21.5	Ø3.3 THRU
A5	170	21.5	Ø3.3 THRU
A6	170	121.5	Ø3.3 THRU
B1	25	34	Ø3.3 THRU ⌵ Ø6 X 90°
B2	13	34	Ø3.3 THRU ⌵ Ø6 X 90°

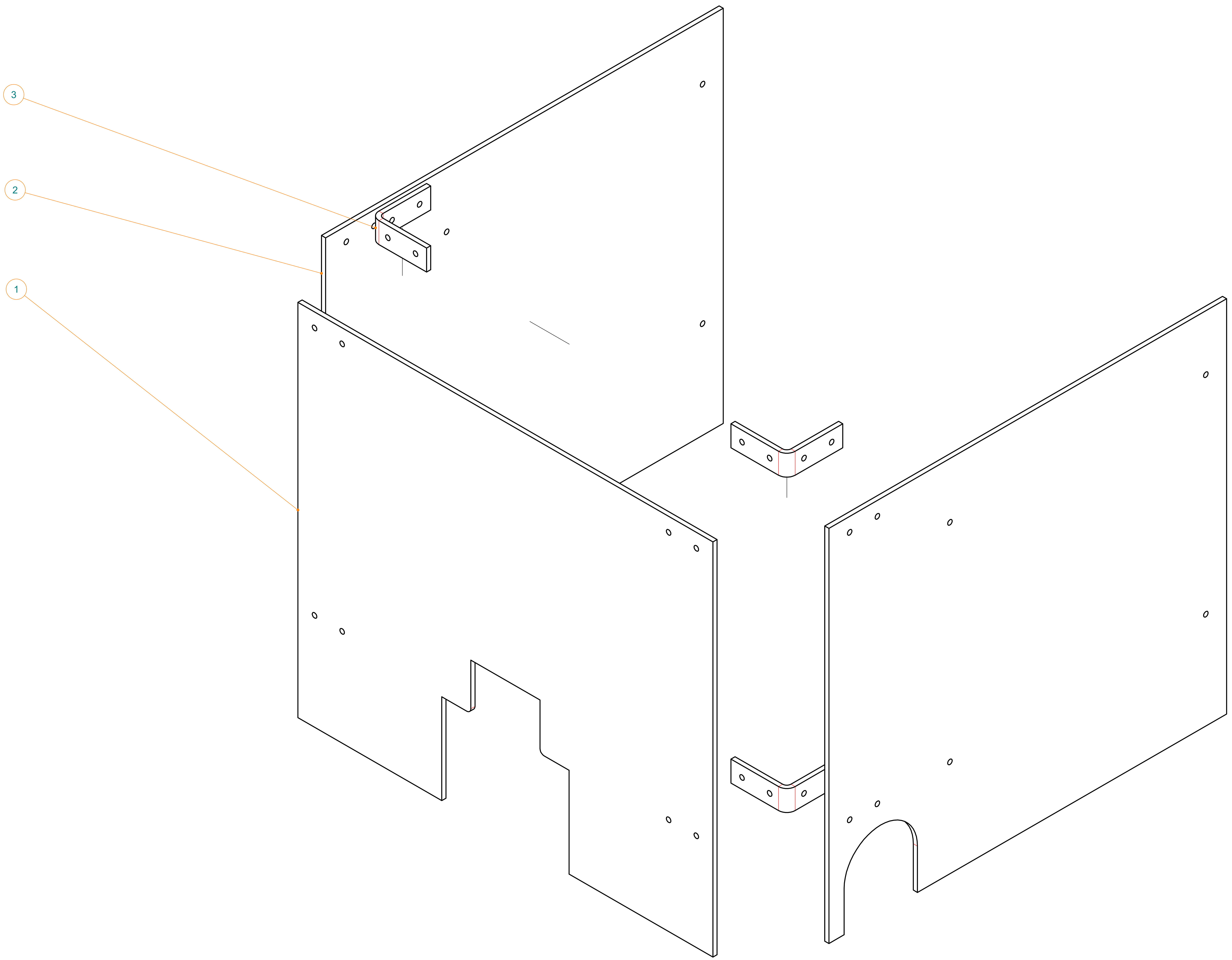
SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed LOW ZHONG SHENG	Date 6/8/2020	Project Title OFFICE TRANSPORTER
	Checked SILVANUS SNG	Date 7/8/2020	Projection / Dwg No.
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor TAN TUAN KIAT	Date 7/8/2020	Scale 1:1 / Sheet 1 / Size A3


259
120
R3(X12)
165(X4)
15(X2)
131.62(X2)
15(X2)
230
194
18
Ø3.3(X8)
R3(X12)
SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING
Unless otherwise specified
All dimensions are in millimeters (mm)
Designed
LOW ZHONG SHENG
Date
6/8/2020
Checked
SAMUEL WONG
Date
7/8/2020
Project Supervisor
TAN TUAN KIAT
Date
7/8/2020
Project Title
OFFICE TRANSPORTER
Projection
Dwg No.
Scale
1:1
Sheet
1
Size
A3



SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed LOW ZHONG SHENG	Date 6/8/2020	Project Title OFFICE TRANSPORTER		
	Checked SAMUEL WONG	Date 7/8/2020	Projection	Dwg No.	
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor TAN TUAN KIAT	Date 7/8/2020	Scale 1:1	Sheet 1	Size A3

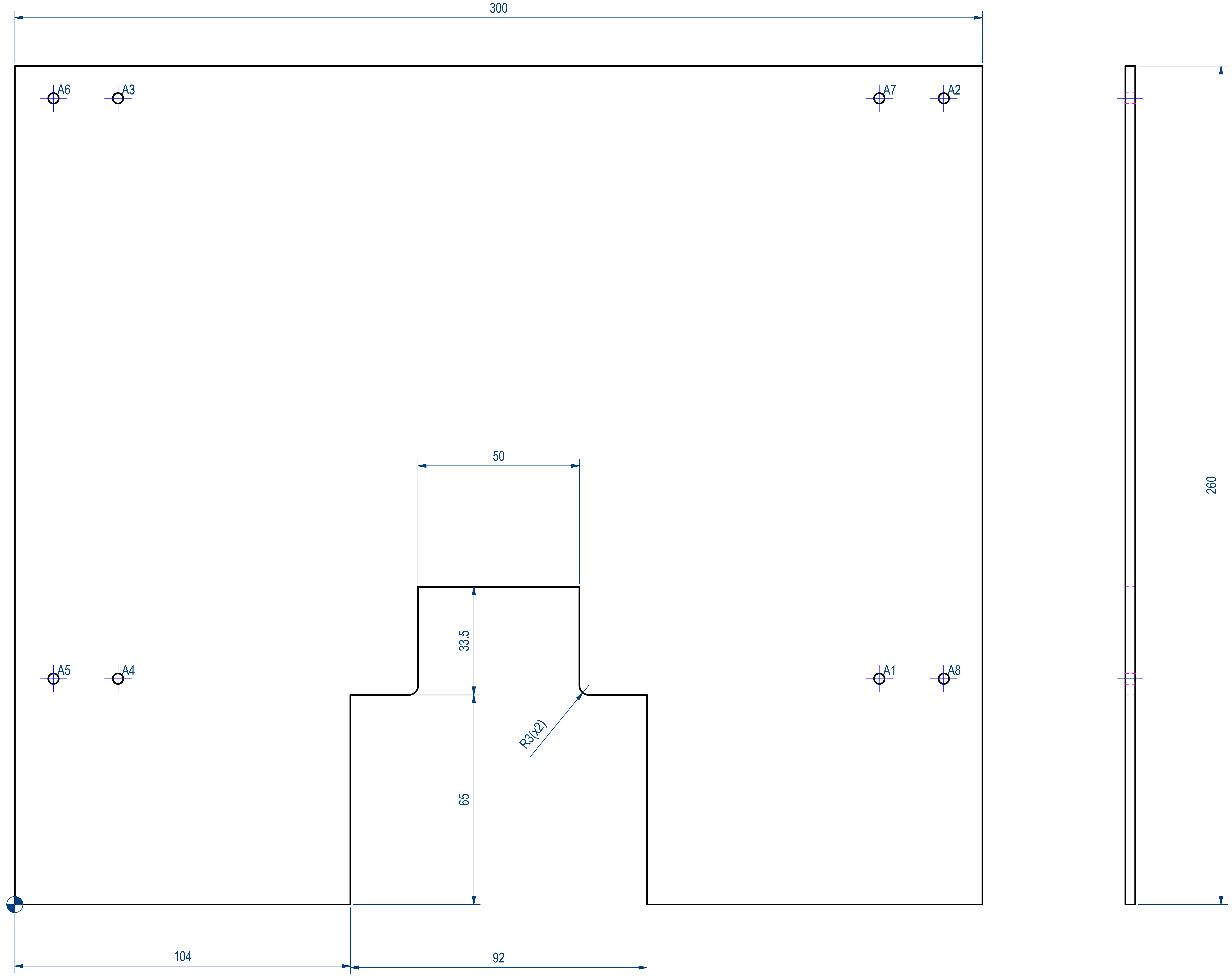
Parts List			
ITEM	DESCRIPTION	QTY	MATERIAL
1	Front Battery Enclosure	1	Polycarbonate
2	Battery Enclosure Side Walls	2	Polycarbonate
3	Lplate for Battery Enclosure	4	Aluminum



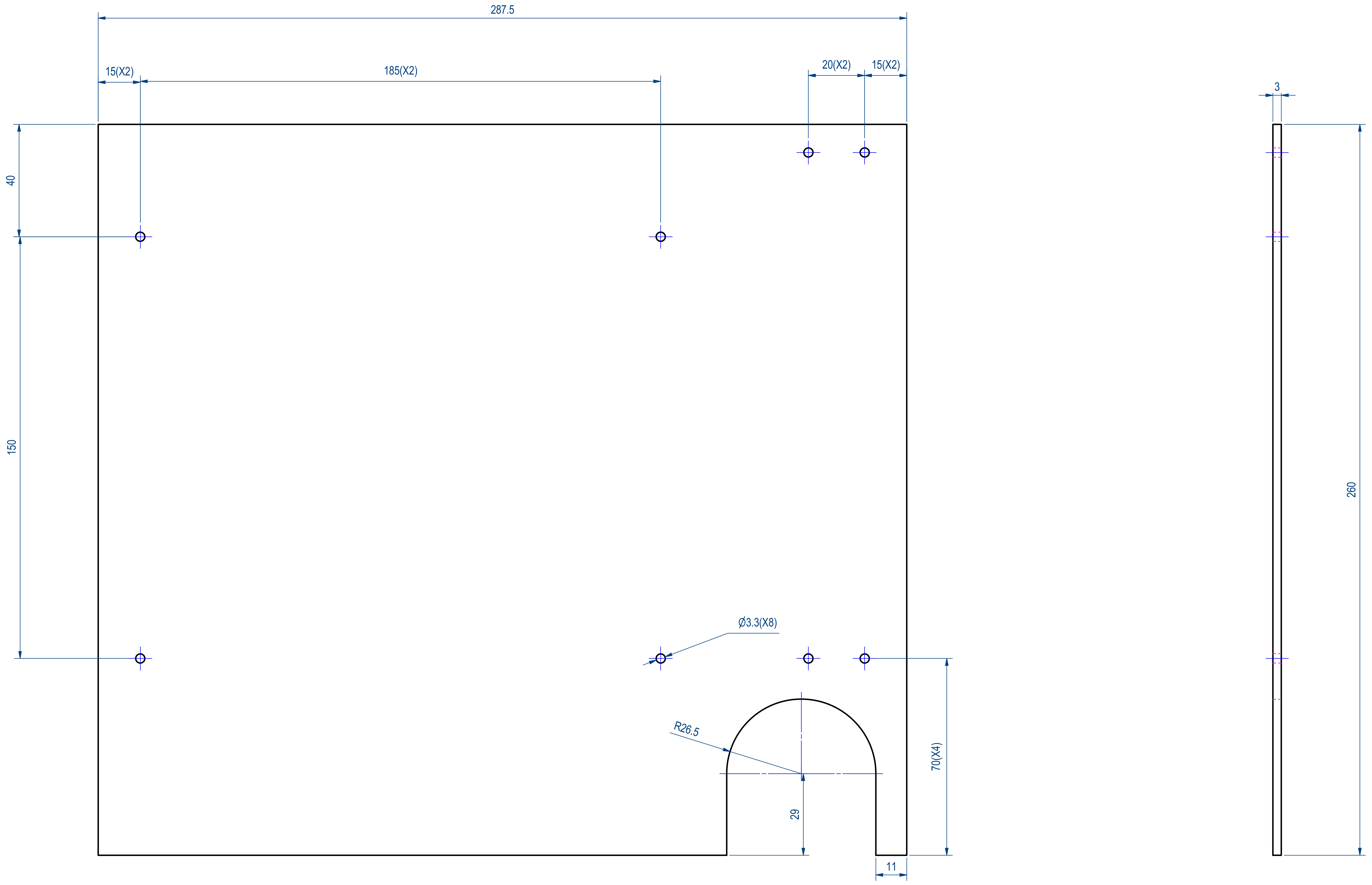
SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed SILVANUS SNG	Date 6/8/2020	Project Title OFFICE TRANSPORTER
	Checked LOW ZHONG SHENG	Date 7/8/2020	Projection / Dwg No.
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor TAN TUAN KIAT	Date 7/8/2020	Scale 1:1 / Sheet 1 / Size A1

Hole Table

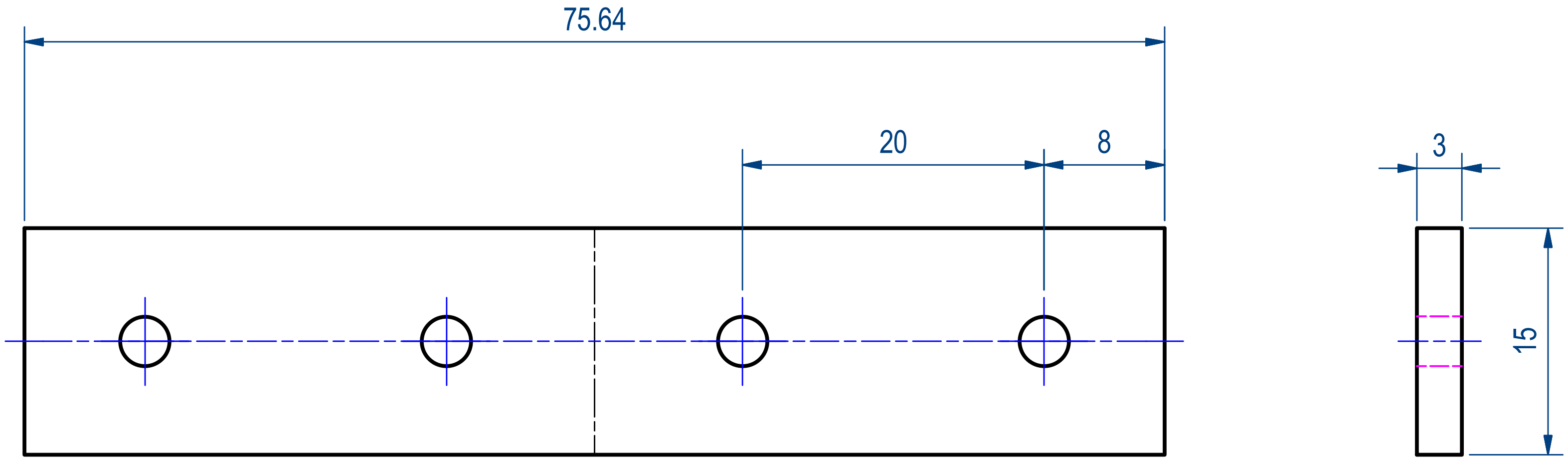
HOLE	XDIM	YDIM	DESCRIPTION
A1	268	70	Ø3.3 THRU
A2	288	250	Ø3.3 THRU
A3	32	250	Ø3.3 THRU
A4	32	70	Ø3.3 THRU
A5	12	70	Ø3.3 THRU
A6	12	250	Ø3.3 THRU
A7	268	250	Ø3.3 THRU
A8	288	70	Ø3.3 THRU



SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed: LOW ZHONG SHENG	Date: 6/8/2020	Project Title: OFFICE TRANSPORTER
	Checked: SAMUEL WONG	Date: 7/8/2020	Projection / Dwg No.
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor: TAN TUAN KIAT	Date: 7/8/2020	Scale: 1:1 / Sheet: 1 / Size: A2

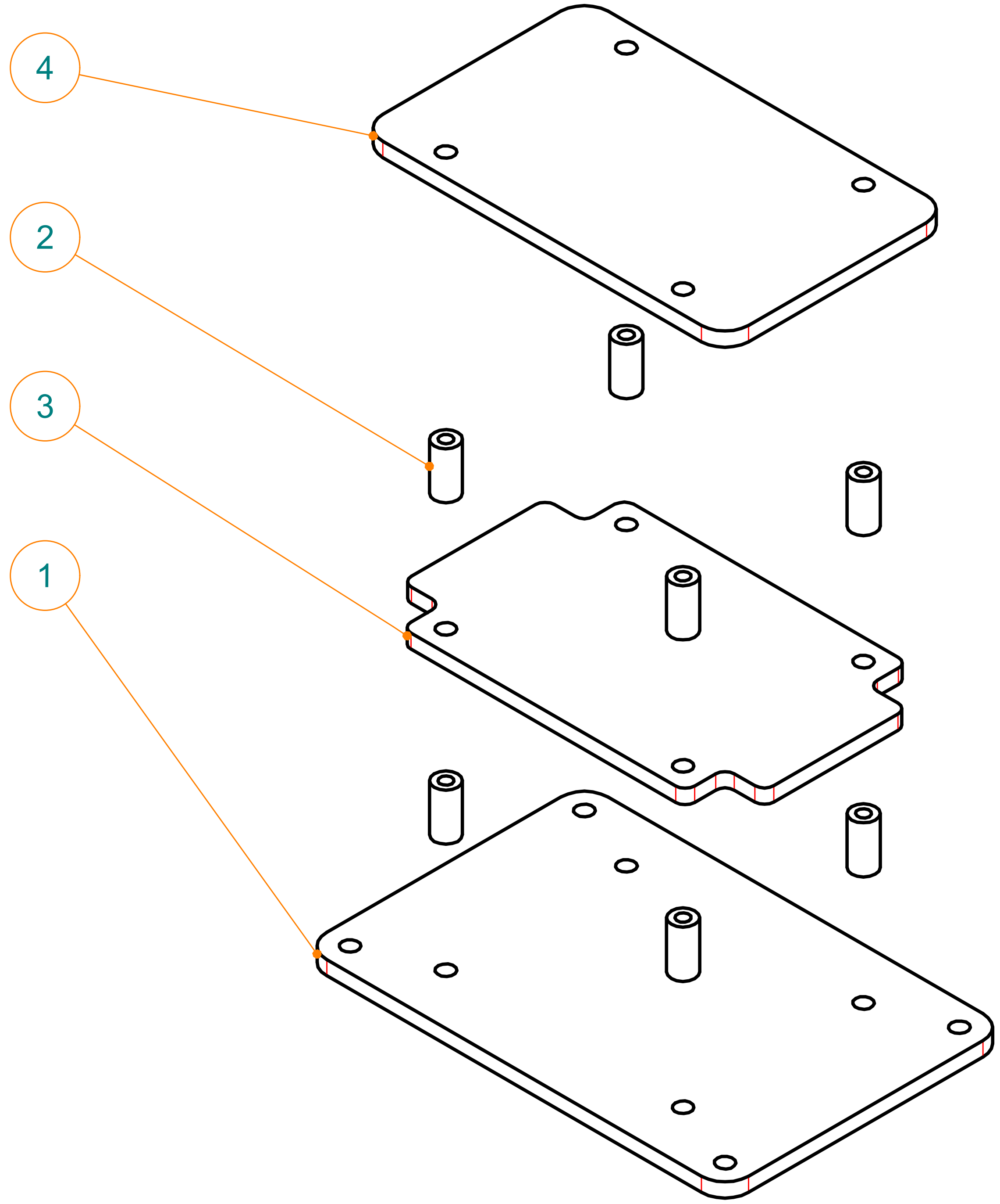


SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed: LOW ZHONG SHENG	Date: 6/8/2020	Project Title: OFFICE TRANSPORTER		
	Checked: JARED TAN	Date: 7/8/2020	Projection	Dwg No.	
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor: TAN TUAN KIAT	Date: 7/8/2020	Scale: 1:1	Sheet: 1	Size: A2



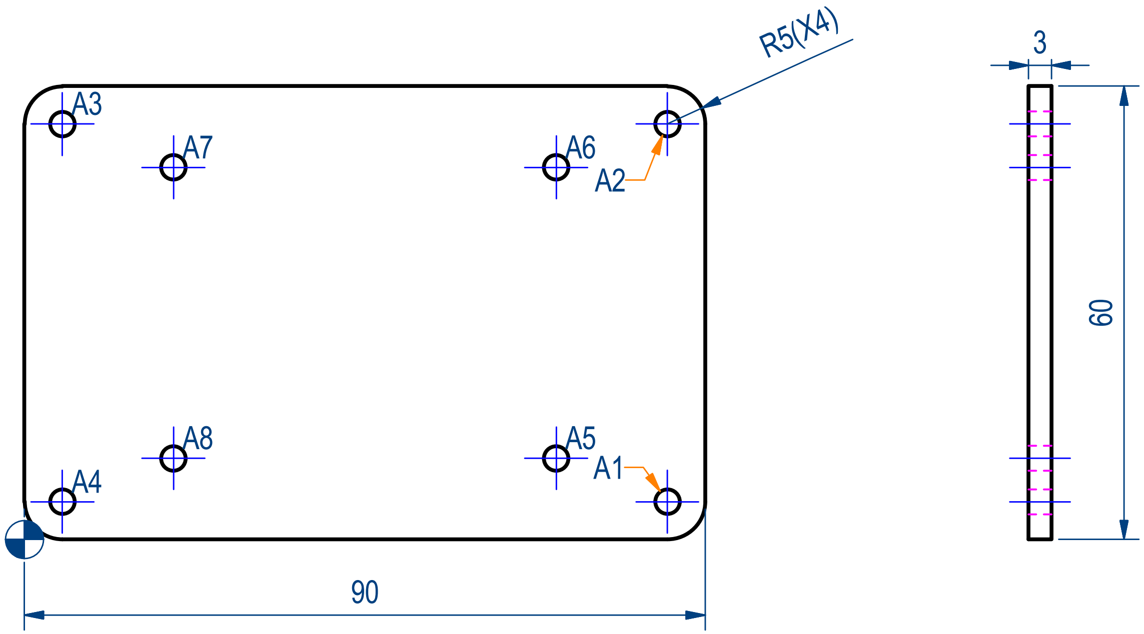
SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed LOW ZHONG SHENG	Date 6/8/2020	Project Title OFFICE TRANSPORTER		
	Checked SILVANUS SNG	Date 7/8/2020	Projection	Dwg No.	
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor TAN TUAN KIAT	Date 7/8/2020	Scale 2:1	Sheet 1	Size A4

Parts List			
ITEM	DESCRIPTION	QTY	MATERIAL
1	Encoder Board Mounting Plate	1	Polycarbonate
2	Spacer for Ion	8	
3	Circuit Protector Plate	1	Polycarbonate
4	Encoder Board Top Plate	1	Polycarbonate

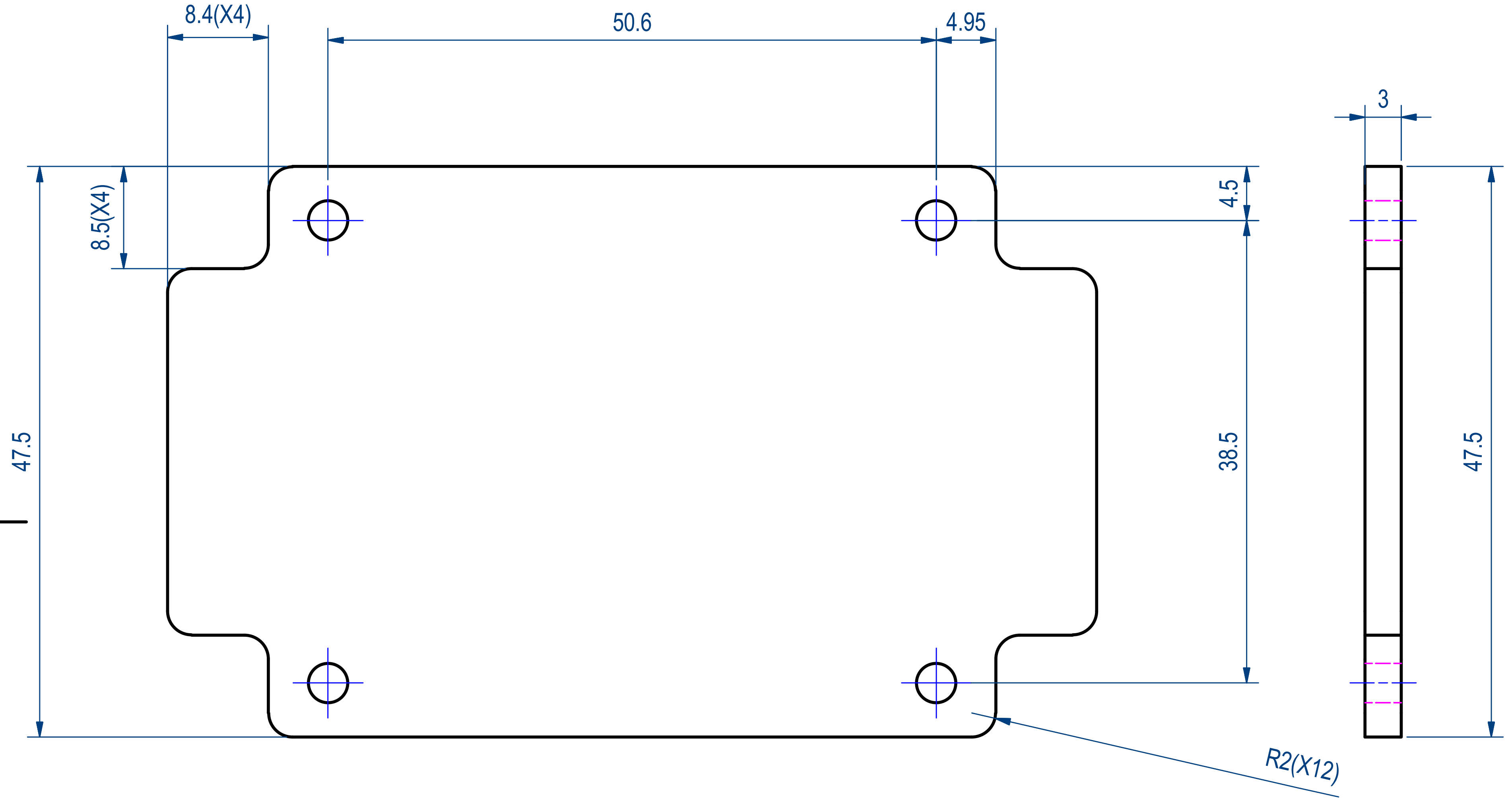


SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed: LOW ZHONG SHENG	Date: 6/8/2020	Project Title: OFFICE TRANSPORTER
	Checked: SILVANUS SNG	Date: 7/8/2020	Projection / Dwg No.
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor: TAN TUAN KIAT	Date: 7/8/2020	Scale: 1:1 / Sheet: 1 / Size: A3

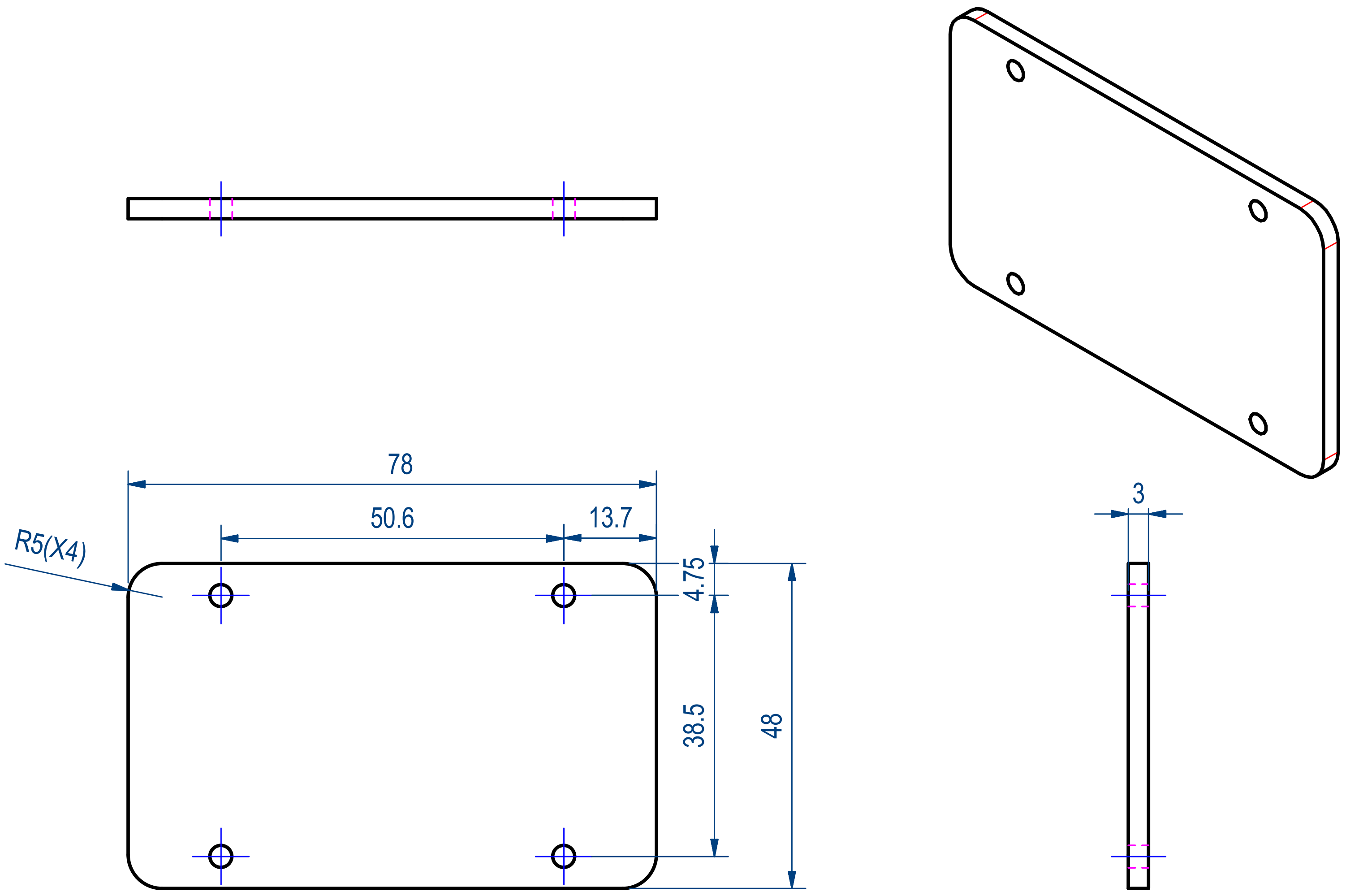
Hole Table			
HOLE	XDIM	YDIM	DESCRIPTION
A1	85	5	Ø3.3 THRU
A2	85	55	Ø3.3 THRU
A3	5	55	Ø3.3 THRU
A4	5	5	Ø3.3 THRU
A5	70.3	10.75	Ø3.3 THRU
A6	70.3	49.25	Ø3.3 THRU
A7	19.7	49.25	Ø3.3 THRU
A8	19.7	10.75	Ø3.3 THRU



SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed LOW ZHONG SHENG	Date 6/8/2020	Project Title OFFICE TRANSPORTER		
	Checked SILVANUS SNG	Date 7/8/2020	Projection	Dwg No.	
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor TAN TUAN KIAT	Date 7/8/2020	Scale 1:1	Sheet 1	Size A4



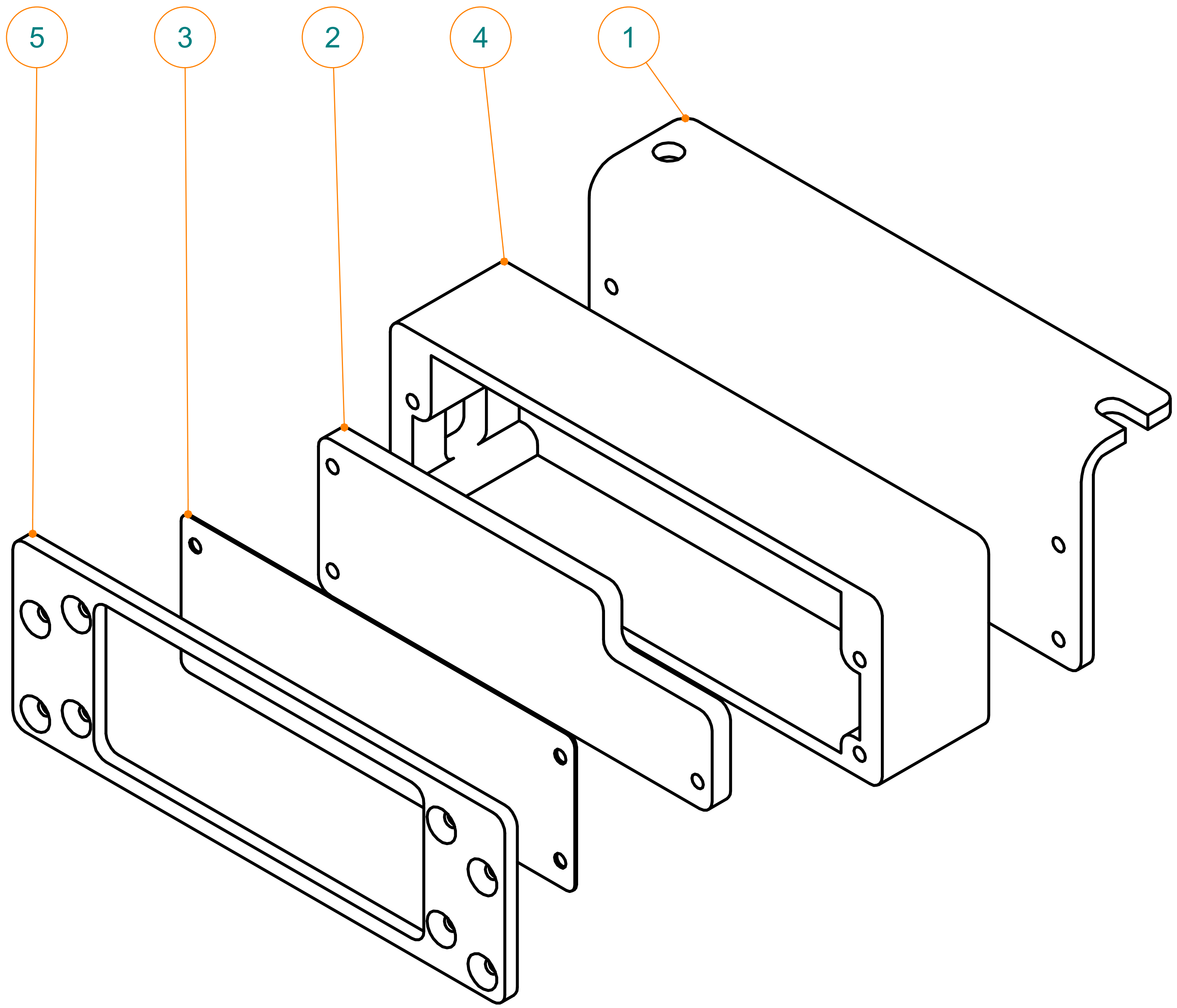
SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed LOW ZHONG SHENG	Date 6/8/2020	Project Title OFFICE TRANSPORTER
	Checked JARED TAN	Date 7/8/2020	Projection / Dwg No.
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor TAN TUAN KIAT	Date 7/8/2020	Scale 2:1 / Sheet 1 / Size A4



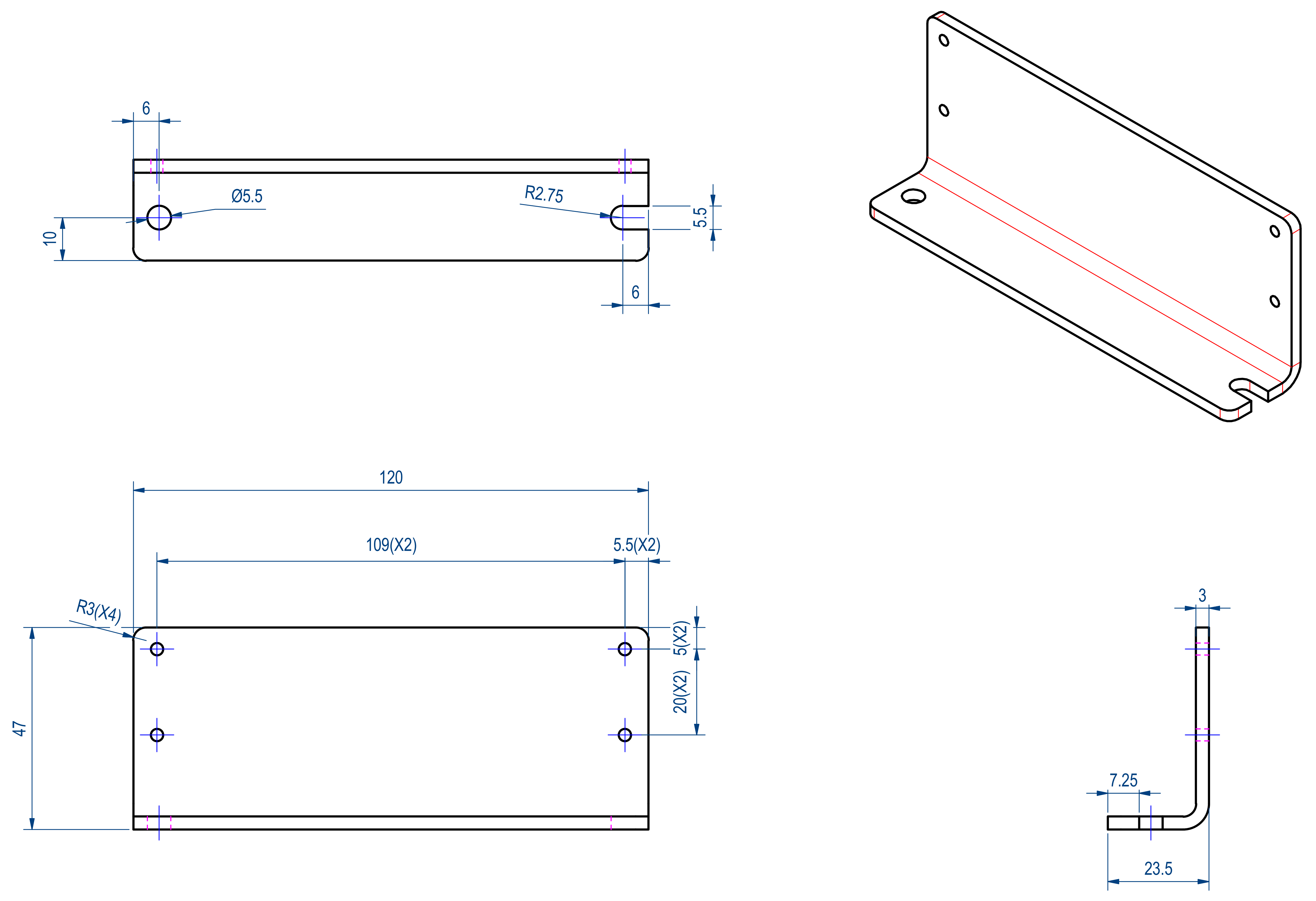
SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed LOW ZHONG SHENG	Date 6/8/2020	Project Title OFFICE TRANSPORTER	
	Checked SILVANUS SNG	Date 7/8/2020	Projection	Dwg No.
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor TAN TUAN KIAT	Date 7/8/2020	Scale 1:1	Sheet 1 / Size A4

Parts List

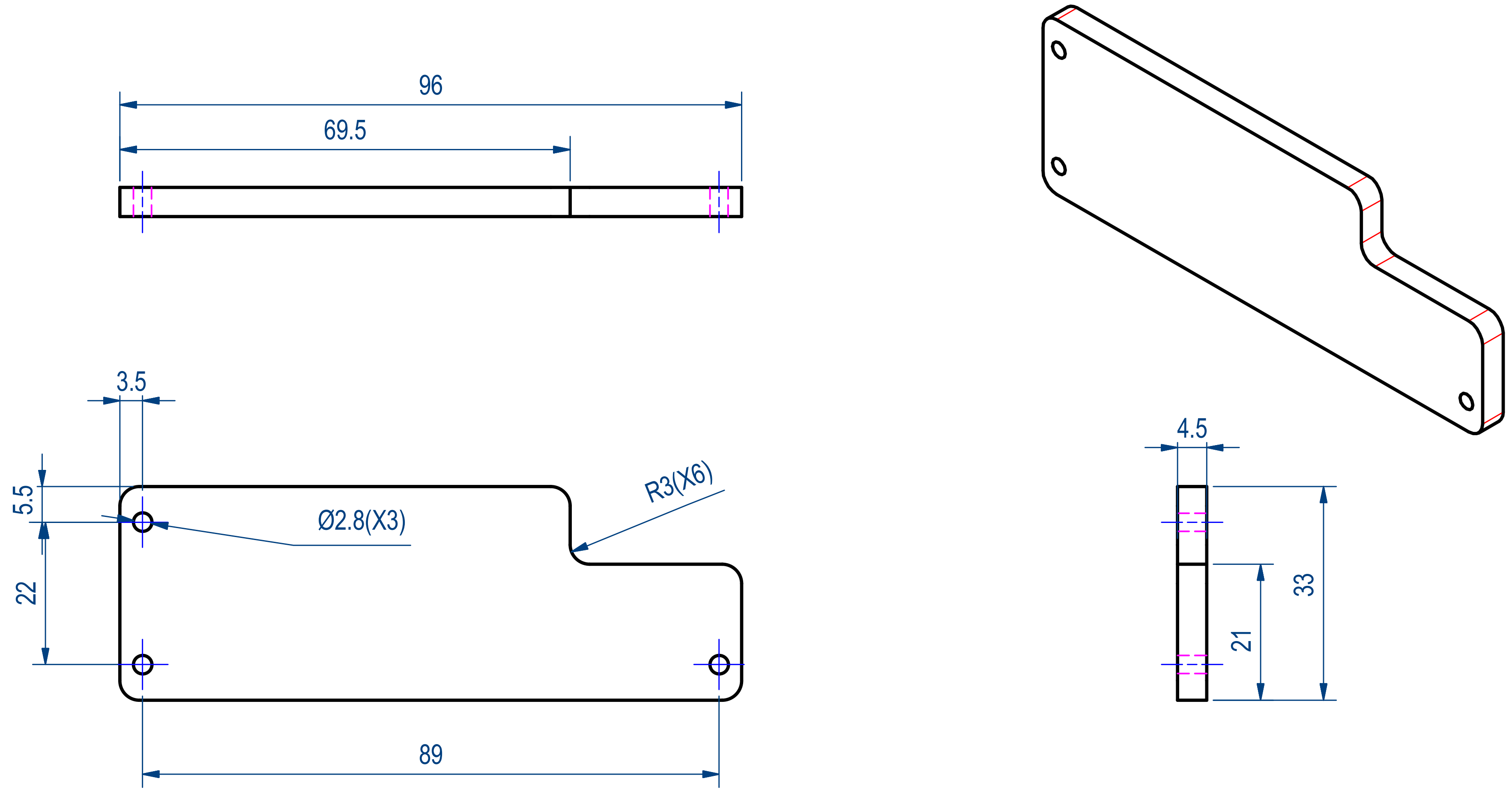
ITEM	DESCRIPTION	QTY	MATERIAL
1	Lplate Charger Mount	1	Aluminium
2	Back Copper Plate Holder	1	Polycarbonate
3	Copper Plate	1	Copper
4	Charger Case	1	PLA
5	Front Copper Plate Holder	1	Polycarbonate



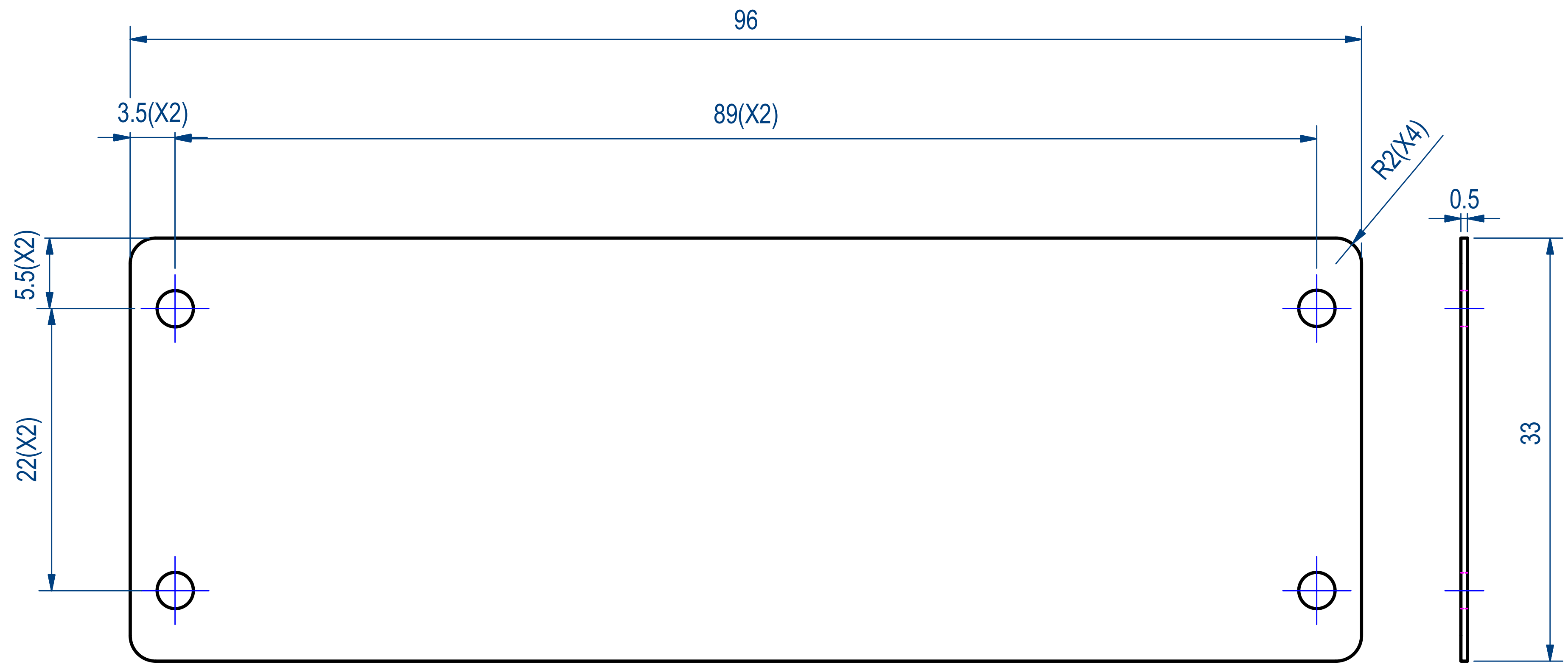
SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed LOW ZHONG SHENG	Date 6/8/2020	Project Title OFFICE TRANSPORTER		
	Checked SILVANUS SNG	Date 7/8/2020	Projection	Dwg No.	
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor TAN TUAN KIAT	Date 7/8/2020	Scale 1:1	Sheet 1	Size A3



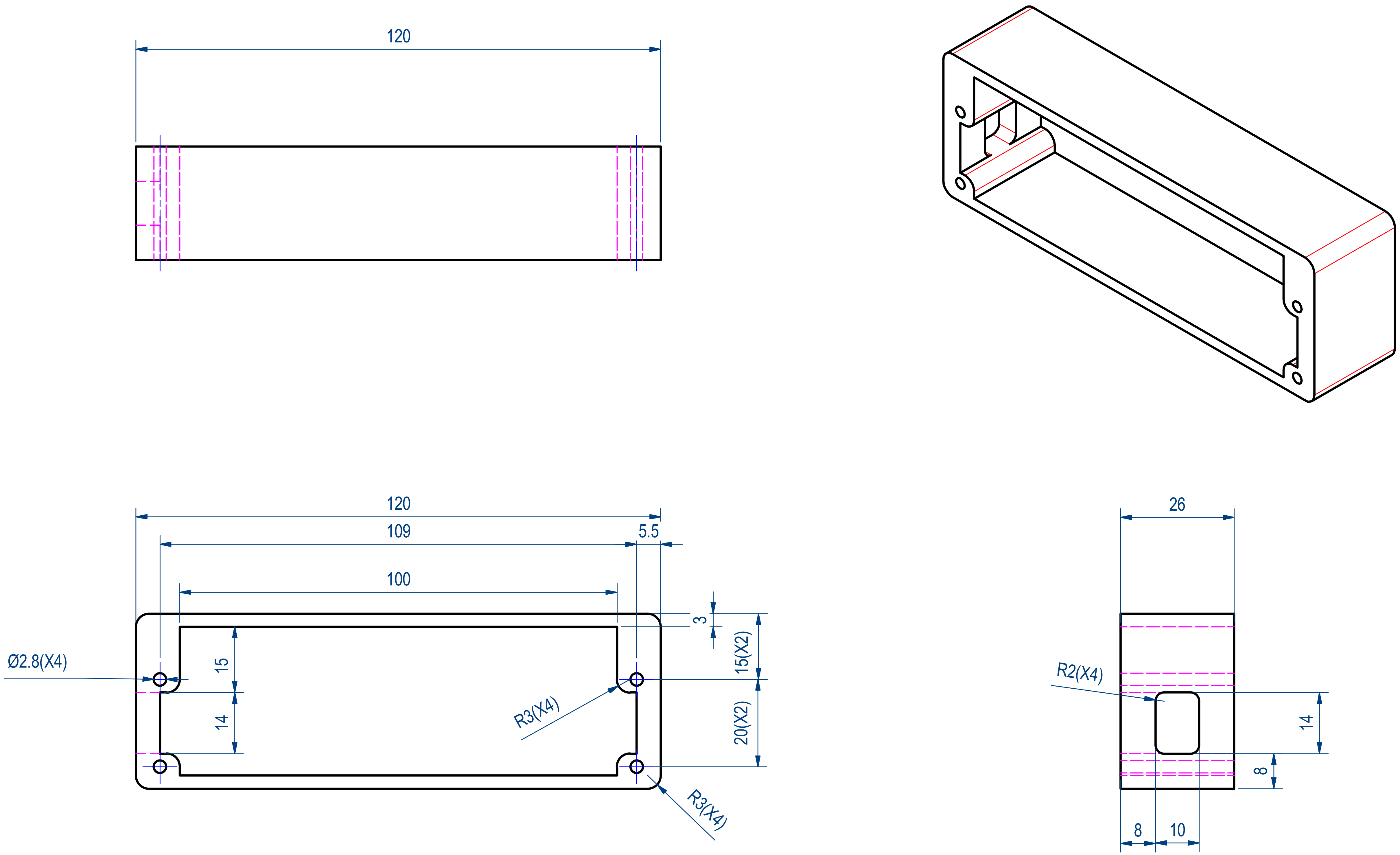
SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed: SAMUEL WONG	Date: 6/8/2020	Project Title: OFFICE TRANSPORTER	
	Checked: SILVANUS SNG	Date: 7/8/2020	Projection	Dwg No.
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor: TAN TUAN KIAT	Date: 7/8/2020	Scale: 1:1	Sheet: 1 / Size: A3



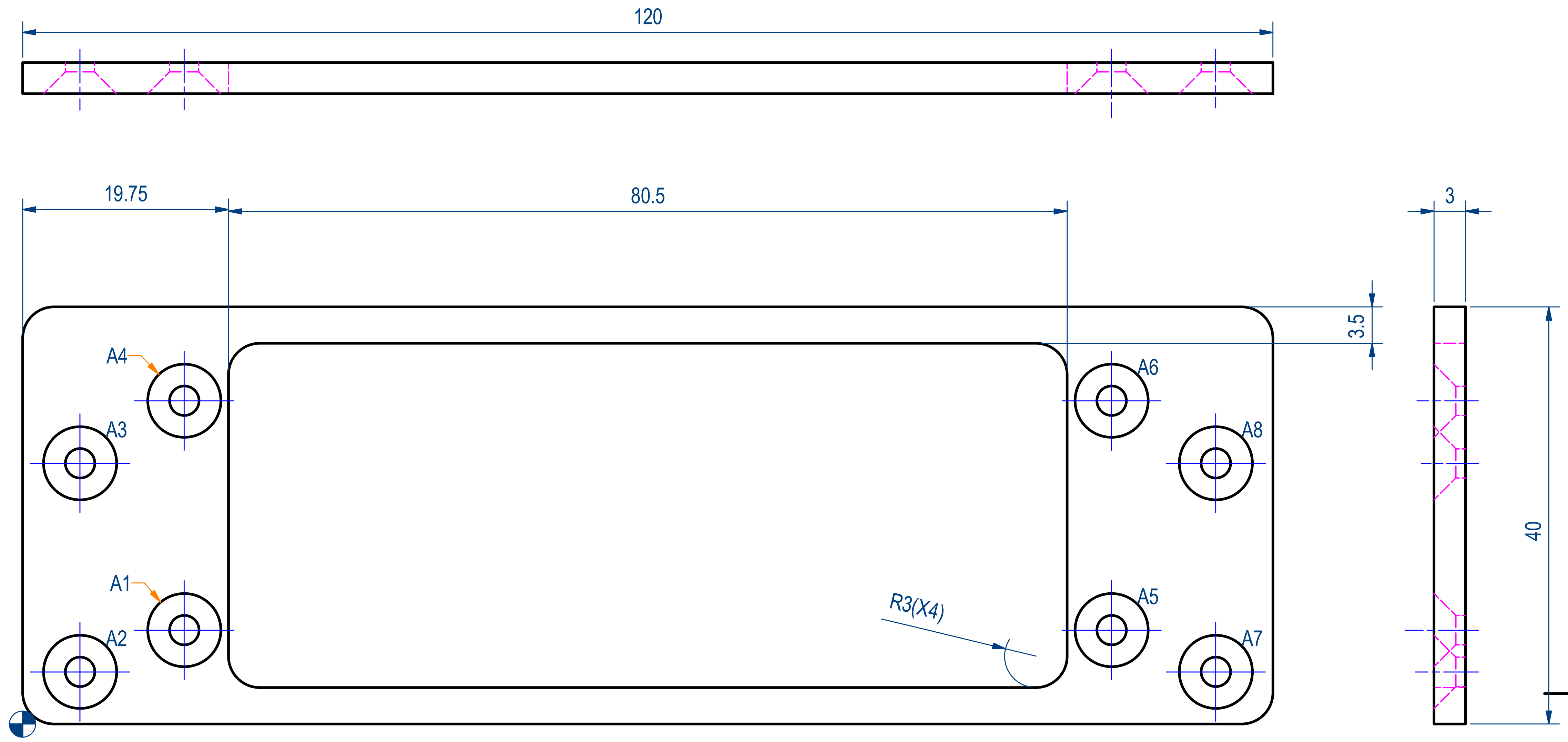
SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed LOW ZHONG SHENG	Date 6/8/2020	Project Title OFFICE TRANSPORTER		
	Checked SAMUEL WONG	Date 7/8/2020	Projection	Dwg No.	
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor TAN TUAN KIAT	Date 7/8/2020	Scale 1:1	Sheet 1	Size A4



SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed SAMUEL WONG	Date 6/8/2020	Project Title OFFICE TRANSPORTER		
	Checked LOW ZHONG SHENG	Date 7/8/2020	Projection	Dwg No.	
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor TAN TUAN KIAT	Date 7/8/2020	Scale 2:1	Sheet 1	Size A4



SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed: LOW ZHONG SHENG	Date: 6/8/2020	Project Title: OFFICE TRANSPORTER		
	Checked: SAMUEL WONG	Date: 7/8/2020	Projection	Dwg No.	
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor: TAN TUAN KIAT	Date: 7/8/2020	Scale: 1:1	Sheet: 1	Size: A3

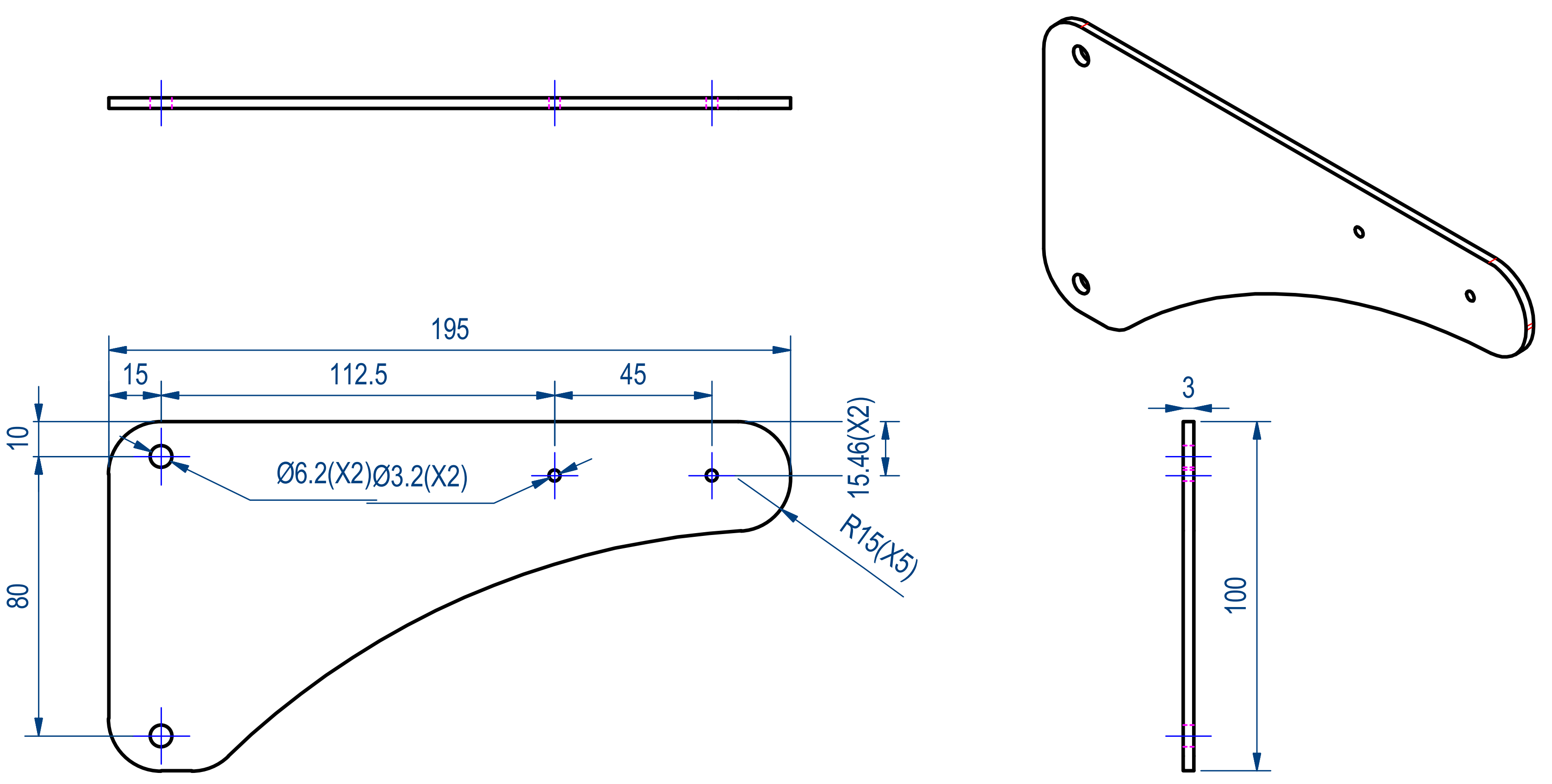


Hole Table			
HOLE	XDIM	YDIM	DESCRIPTION
A1	15.5	9	Ø2.8 THRU ⌵ Ø7 X 90°
A2	5.5	5	Ø2.8 THRU ⌵ Ø7 X 90°
A3	5.5	25	Ø2.8 THRU ⌵ Ø7 X 90°
A4	15.5	31	Ø2.8 THRU ⌵ Ø7 X 90°
A5	104.5	9	Ø2.8 THRU ⌵ Ø7 X 90°
A6	104.5	31	Ø2.8 THRU ⌵ Ø7 X 90°
A7	114.5	5	Ø2.8 THRU ⌵ Ø7 X 90°
A8	114.5	25	Ø2.8 THRU ⌵ Ø7 X 90°

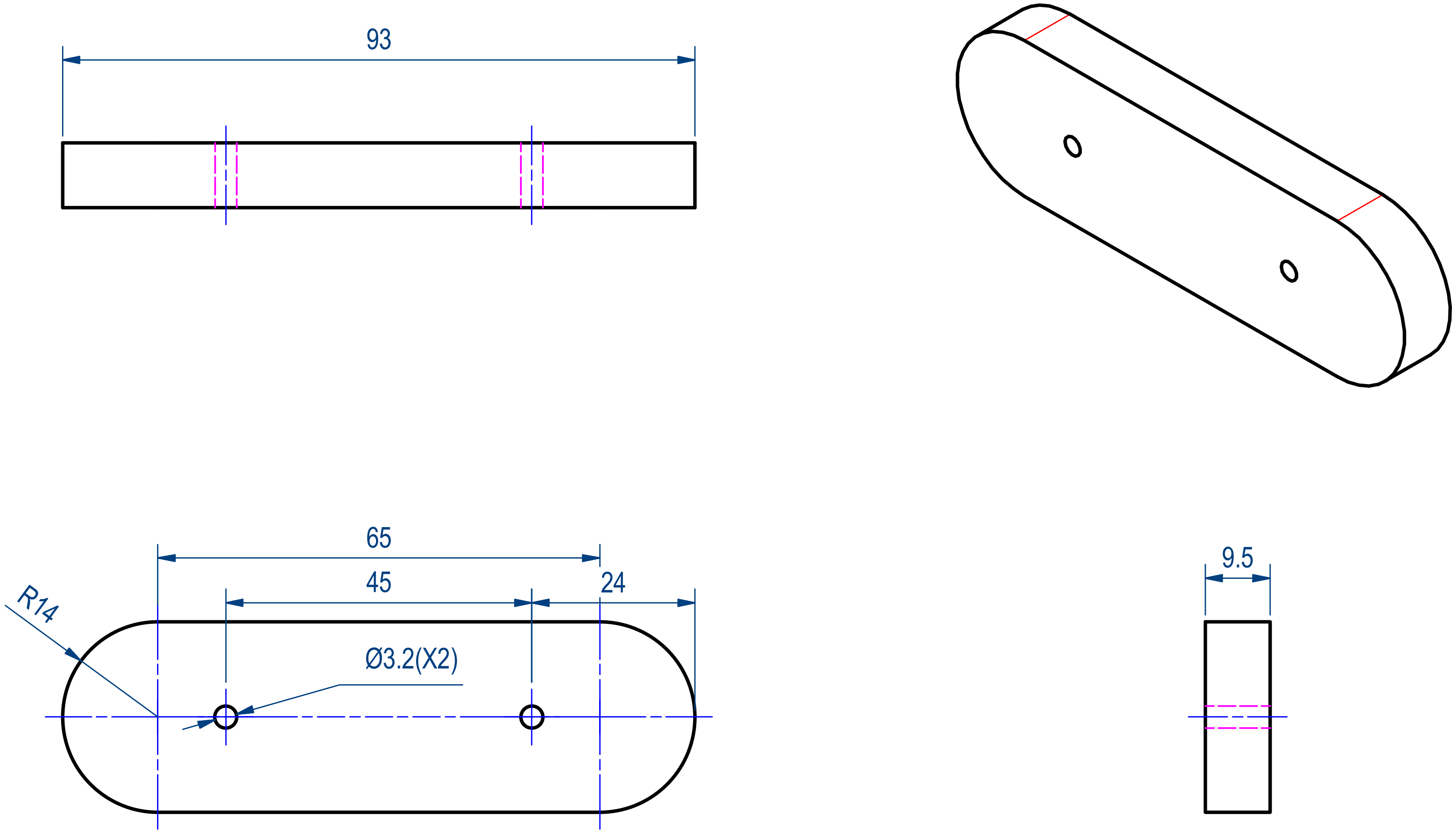
SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING

Designed	Date	Project Title		
LOW ZHONG SHENG	6/8/2020	OFFICE TRANSPORTER		
Checked	Date	Projection	Dwg No.	
SAMUEL WONG	7/8/2020			
Project Supervisor	Date	Scale	Sheet	Size
TAN TUAN KIAT	7/8/2020	2:1	1	A3

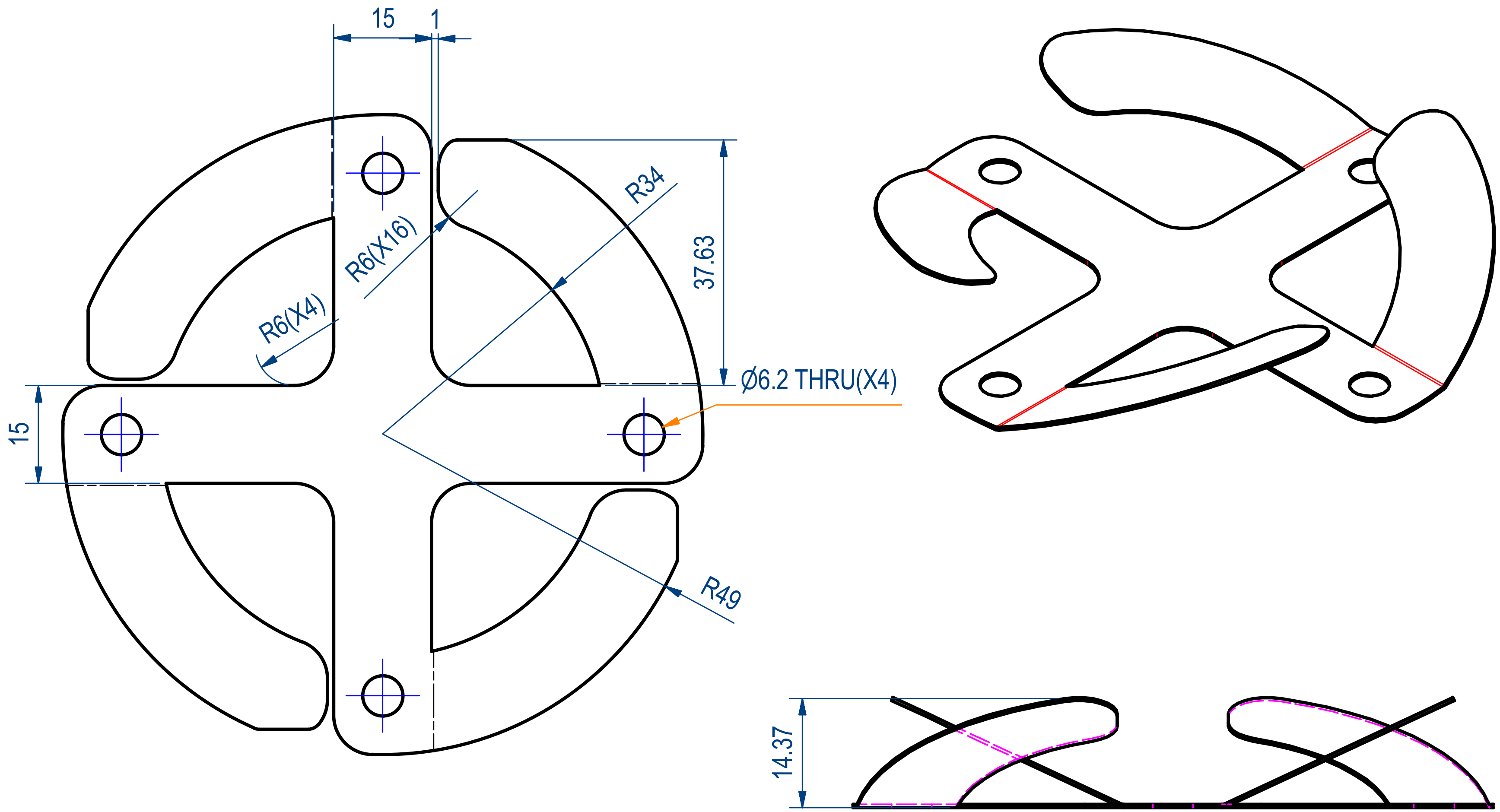
Unless otherwise specified
All dimensions are in millimeters (mm)



SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed: SAMUEL WONG	Date: 6/8/2020	Project Title: OFFICE TRANSPORTER		
	Checked: LOW ZHONG SHENG	Date: 7/8/2020	Projection	Dwg No.	
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor: TAN TUAN KIAT	Date: 7/8/2020	Scale: 1:2	Sheet: 1	Size: A4



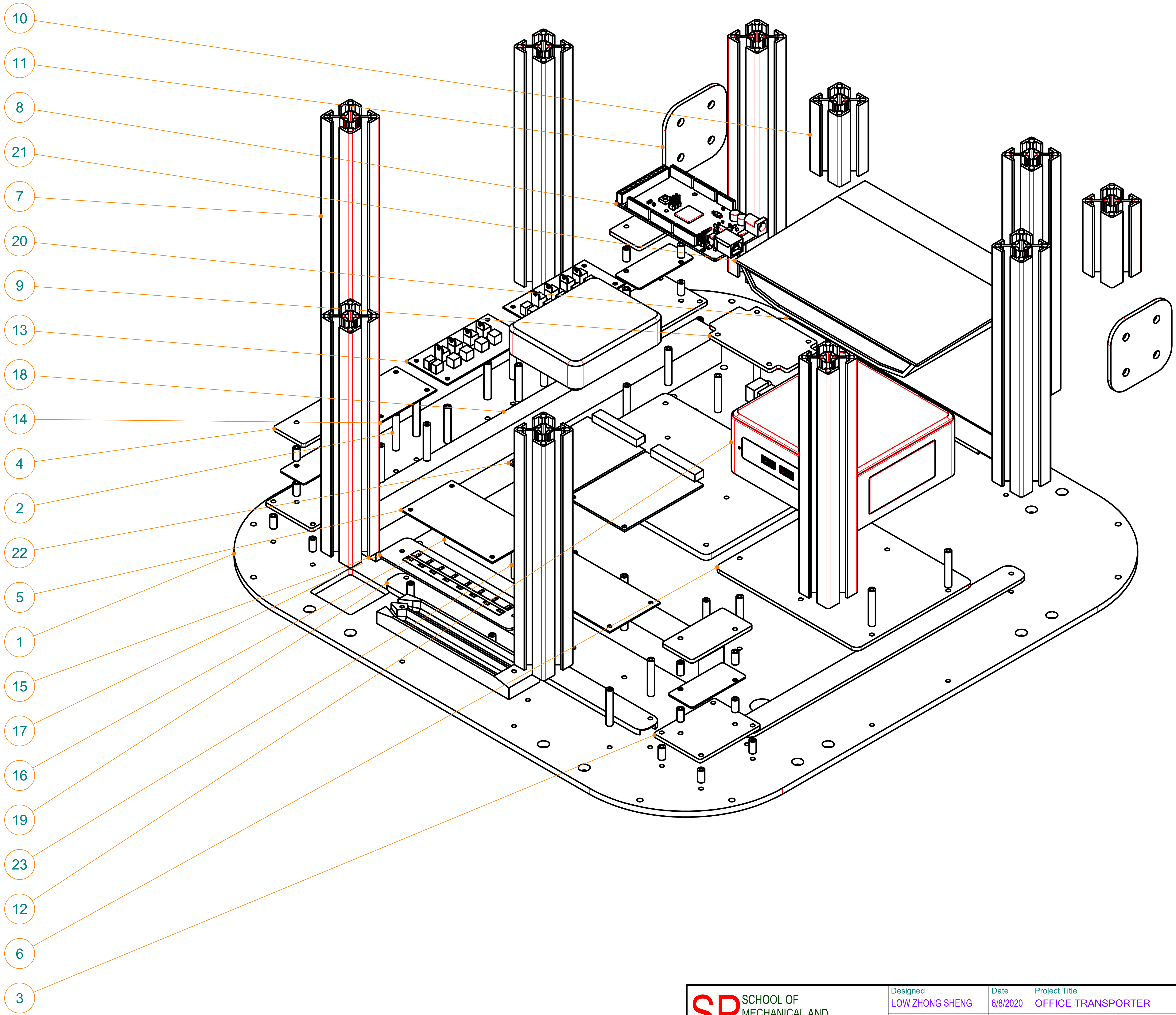
SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed LOW ZHONG SHENG	Date 6/8/2020	Project Title OFFICE TRANSPORTER	
	Checked SAMUEL WONG	Date 7/8/2020	Projection	Dwg No.
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor TAN TUAN KIAT	Date 7/8/2020	Scale 1:1	Sheet 1 | Size A4



SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed: LOW ZHONG SHENG	Date: 6/8/2020	Project Title: OFFICE TRANSPORTER	
	Checked: SAMUEL WONG	Date: 7/8/2020	Projection	Dwg No.
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor: TAN TUAN KIAT	Date: 7/8/2020	Scale: 1:1	Sheet: 1 / Size: A4

Parts List

ITEM	DESCRIPTION	QTY	MATERIAL
1	Middle Base Plate	1	Aluminum
2	Level 2 spacer	38	
3	19v Regulator	2	
4	5v Regulator	1	
5	Motor Encoders	2	
6	Mini Pc Mounting Plate	1	
7	200mm Profile	8	Aluminum
8	Arduino Mega	1	
9	Circuit Protector Plate	1	Polycarbonate
10	60mm Profile	2	Aluminum
11	Aluminium Mount	2	Aluminum
12	Mini Pc	1	
13	PCB board	2	
14	Small PCB	1	
15	Trunking	1	
16	Trunking SHORT	1	
17	POWER BAR	1	
18	LED Bar Side	2	
19	LED Bar Front	1	
20	LED Bar Back	1	
21	Router Asus	1	
22	Myrio	1	
23	Level 2 spacer 45	4	



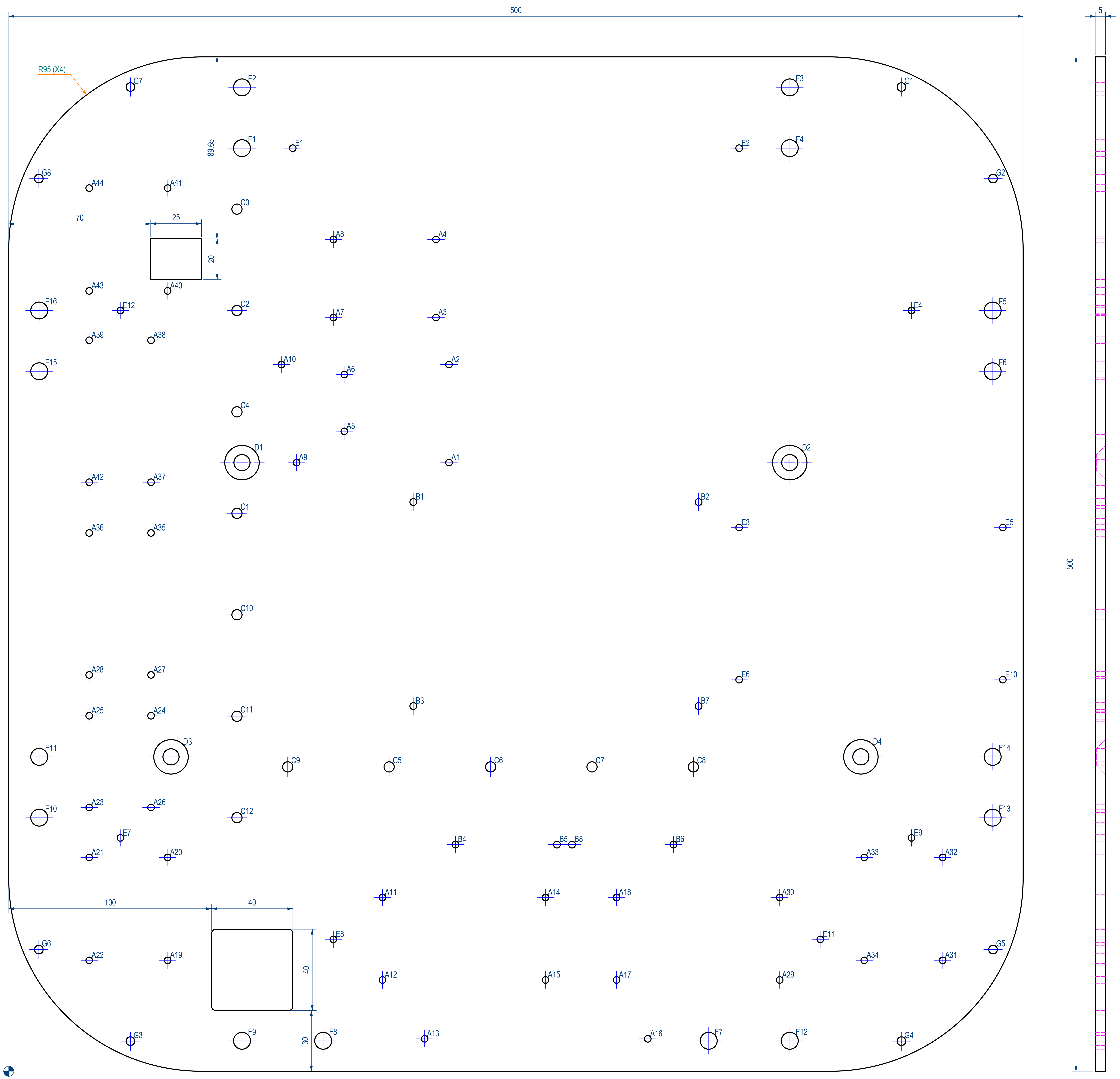
SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed: LOW ZHONG SHENG	Date: 6/8/2020	Project Title: OFFICE TRANSPORTER	
	Checked: SILVANUS SNG	Date: 7/8/2020	Projection	Dwg No.
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor: TAN TUAN KIAT	Date: 7/8/2020	Scale: 1:2	Sheet: 1 Size: A2

Hole Table

HOLE	XDIM	YDIM	DESCRIPTION
A1	217	300	Ø3.3 THRU
A2	217	348.34	Ø3.3 THRU
A3	210.6	371.5	Ø3.3 THRU
A4	210.6	410	Ø3.3 THRU
A5	165.37	315.44	Ø3.3 THRU
A6	165.37	343.46	Ø3.3 THRU
A7	160	371.5	Ø3.3 THRU
A8	160	410	Ø3.3 THRU
A9	141.87	300	Ø3.3 THRU
A10	134.37	348.34	Ø3.3 THRU
A11	184.2	85.6	Ø3.3 THRU
A12	184.2	45	Ø3.3 THRU
A13	205	16	Ø3.3 THRU
A14	264.6	85.6	Ø3.3 THRU
A15	264.6	45	Ø3.3 THRU
A16	315	16	Ø3.3 THRU
A17	299.6	45	Ø3.3 THRU
A18	299.6	85.6	Ø3.3 THRU
A19	78.35	54.65	Ø3.3 THRU
A20	78.35	105.35	Ø3.3 THRU
A21	39.65	105.35	Ø3.3 THRU
A22	39.65	54.65	Ø3.3 THRU
A23	39.65	130	Ø3.3 THRU
A24	70.15	175.2	Ø3.3 THRU
A25	39.65	175.2	Ø3.3 THRU
A26	70.15	130	Ø3.3 THRU
A27	70.15	195.35	Ø3.3 THRU
A28	39.65	195.35	Ø3.3 THRU
A29	380	45	Ø3.3 THRU
A30	380	85.6	Ø3.3 THRU
A31	460.35	54.65	Ø3.3 THRU
A32	460.35	105.35	Ø3.3 THRU
A33	421.65	105.35	Ø3.3 THRU
A34	421.65	54.65	Ø3.3 THRU
A35	70.15	265.35	Ø3.3 THRU
A36	39.65	265.35	Ø3.3 THRU
A37	70.15	290.35	Ø3.3 THRU
A38	70.15	360.35	Ø3.3 THRU
A39	39.65	360.35	Ø3.3 THRU
A40	78.35	384.65	Ø3.3 THRU
A41	78.35	435.35	Ø3.3 THRU
A42	39.65	290.35	Ø3.3 THRU
A43	39.65	384.65	Ø3.3 THRU
A44	39.65	435.35	Ø3.3 THRU
B1	199.4	280.6	Ø3.4 THRU
B2	340	280.6	Ø3.4 THRU
B3	199.4	180	Ø3.4 THRU
B4	220.2	111.75	Ø3.4 THRU
B5	270.2	111.75	Ø3.4 THRU
B6	327.65	111.75	Ø3.4 THRU
B7	340	180	Ø3.4 THRU
B8	277.65	111.75	Ø3.4 THRU
C1	112.5	275	Ø5 THRU
C2	112.5	375	Ø5 THRU
C3	112.5	425	Ø5 THRU
C4	112.5	325	Ø5 THRU
C5	187.5	150	Ø5 THRU
C6	237.5	150	Ø5 THRU
C7	287.5	150	Ø5 THRU
C8	337.5	150	Ø5 THRU
C9	137.5	150	Ø5 THRU
C10	112.5	225	Ø5 THRU
C11	112.5	175	Ø5 THRU
C12	112.5	125	Ø5 THRU

Hole Table

HOLE	XDIM	YDIM	DESCRIPTION
D1	115	300	Ø8 THRU ⌵ Ø17 X 90°
D2	385	300	Ø8 THRU ⌵ Ø17 X 90°
D3	80	155	Ø8 THRU ⌵ Ø17 X 90°
D4	420	155	Ø8 THRU ⌵ Ø17 X 90°
E1	140	455	Ø3.2 THRU
E2	360	455	Ø3.2 THRU
E3	360	268	Ø3.2 THRU
E4	445	375	Ø3.2 THRU
E5	490	268	Ø3.2 THRU
E6	360	193	Ø3.2 THRU
E7	55	115	Ø3.2 THRU
E8	160	65	Ø3.2 THRU
E9	445	115	Ø3.2 THRU
E10	490	193	Ø3.2 THRU
E11	400	65	Ø3.2 THRU
E12	55	375	Ø3.2 THRU
F1	115	455	Ø8.3 THRU
F2	115	485	Ø8.3 THRU
F3	385	485	Ø8.3 THRU
F4	385	455	Ø8.3 THRU
F5	485	375	Ø8.3 THRU
F6	485	345	Ø8.3 THRU
F7	345	15	Ø8.3 THRU
F8	155	15	Ø8.3 THRU
F9	115	15	Ø8.3 THRU
F10	15	125	Ø8.3 THRU
F11	15	155	Ø8.3 THRU
F12	385	15	Ø8.3 THRU
F13	485	125	Ø8.3 THRU
F14	485	155	Ø8.3 THRU
F15	15	345	Ø8.3 THRU
F16	15	375	Ø8.3 THRU
G1	440	485.2	Ø4.2 THRU
G2	485.2	440	Ø4.2 THRU
G3	60	14.8	Ø4.2 THRU
G4	440	14.8	Ø4.2 THRU
G5	485.2	60	Ø4.2 THRU
G6	14.8	60	Ø4.2 THRU
G7	60	485.2	Ø4.2 THRU
G8	14.8	440	Ø4.2 THRU



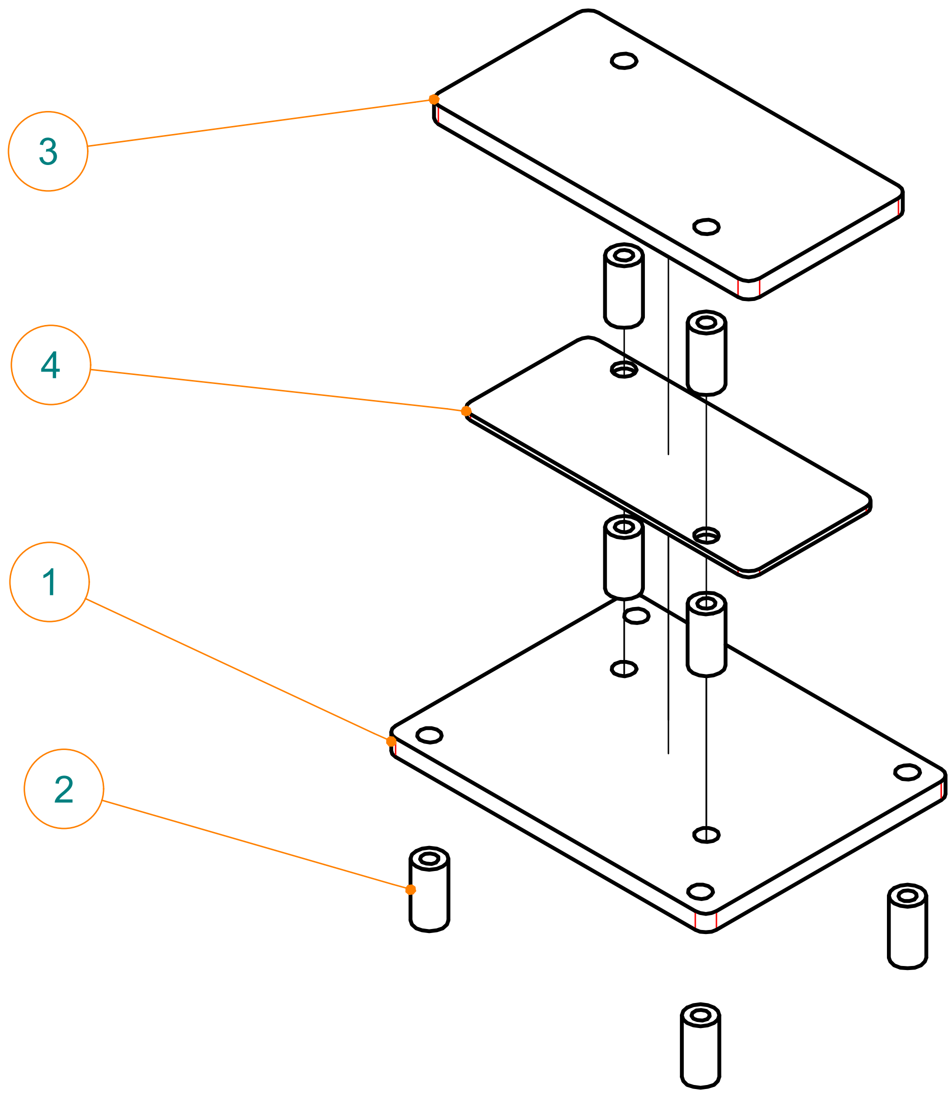
SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING

Unless otherwise specified
All dimensions are in millimeters (mm)

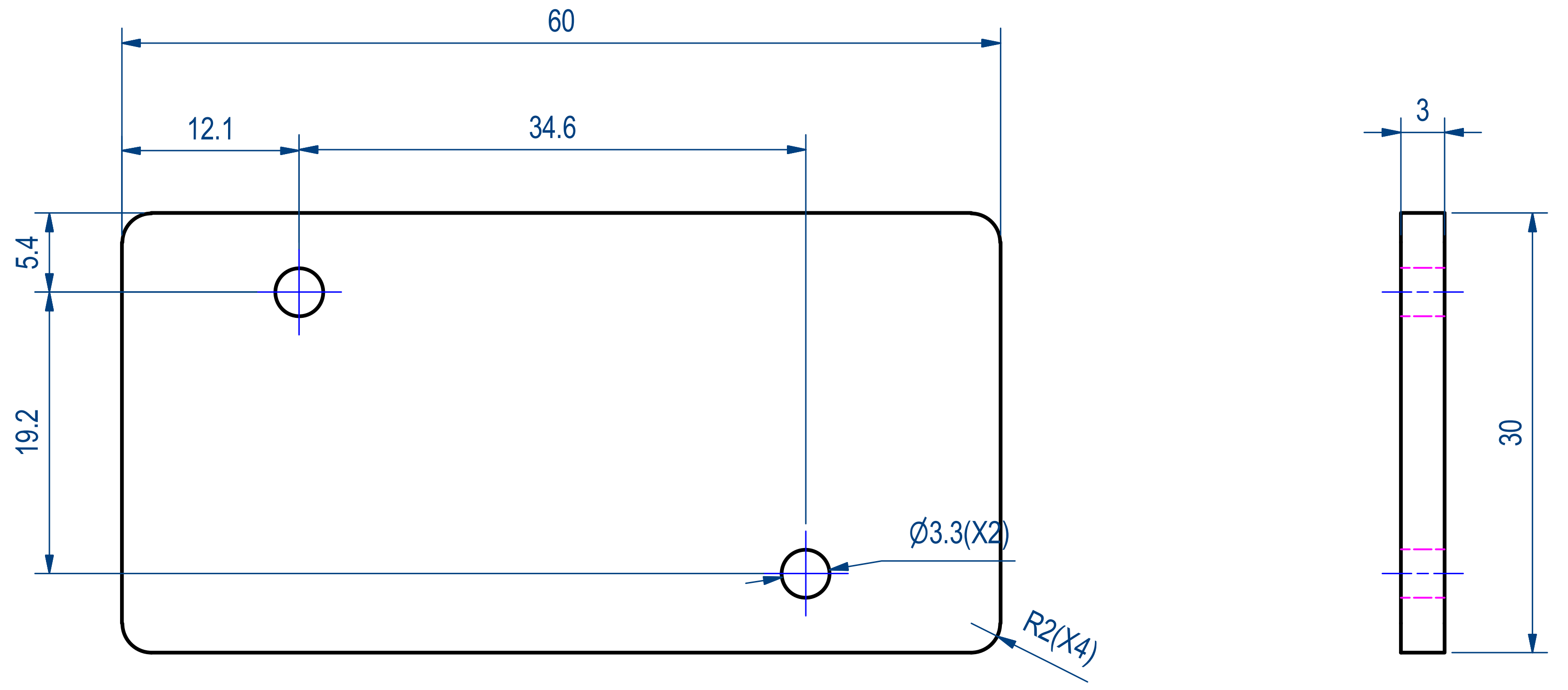
Designed: LOW ZHONG SHENG	Date: 6/8/2020	Project Title: OFFICE TRANSPORTER	
Checked: SILVANUS SNG	Date: 7/8/2020	Projection	Dwg No.
Project Supervisor: TAN TUAN KIAT	Date: 7/8/2020	Scale: 1:1	Sheet: 1 · Size: A1

Parts List

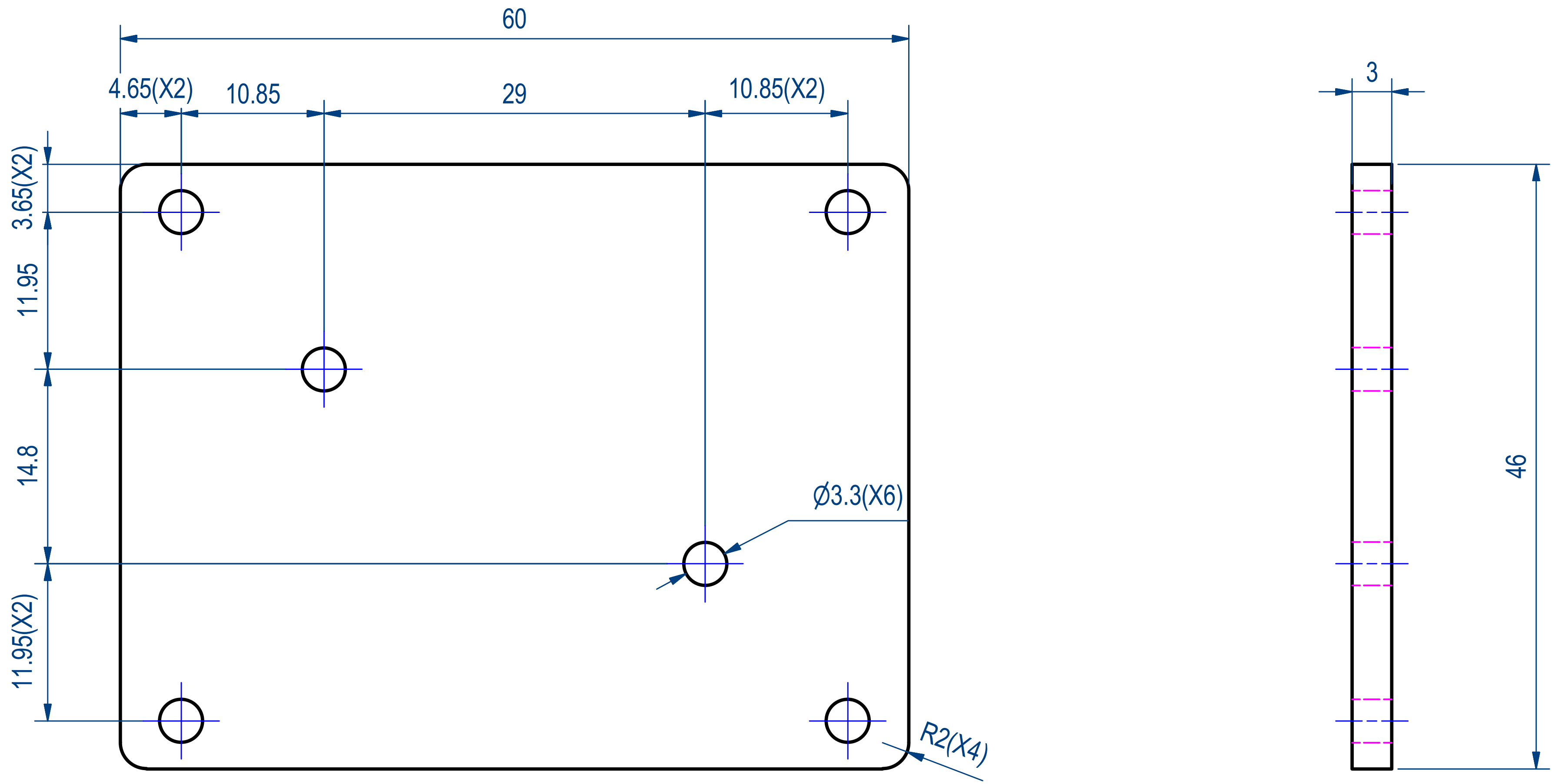
ITEM	DESCRIPTION	QTY	MATERIAL
1	19V Regulator Mounting Plate	1	Polycarbonate
2	Spacer for Ion	8	
3	19V Regulator Cover	1	Polycarbonate
4	19V Regulator	1	



SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed: LOW ZHONG SHENG	Date: 6/8/2020	Project Title: OFFICE TRANSPORTER		
	Checked: SILVANUS SNG	Date: 7/8/2020	Projection	Dwg No.	
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor: TAN TUAN KIAT	Date: 7/8/2020	Scale: 1:1	Sheet: 1	Size: A4



SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed LOW ZHONG SHENG	Date 6/8/2020	Project Title OFFICE TRANSPORTER			
	Checked SAMUEL WONG	Date 7/8/2020	Projection	Dwg No.		
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor TAN TUAN KIAT	Date 7/8/2020	Scale 2:1	Sheet 1	Size A4	



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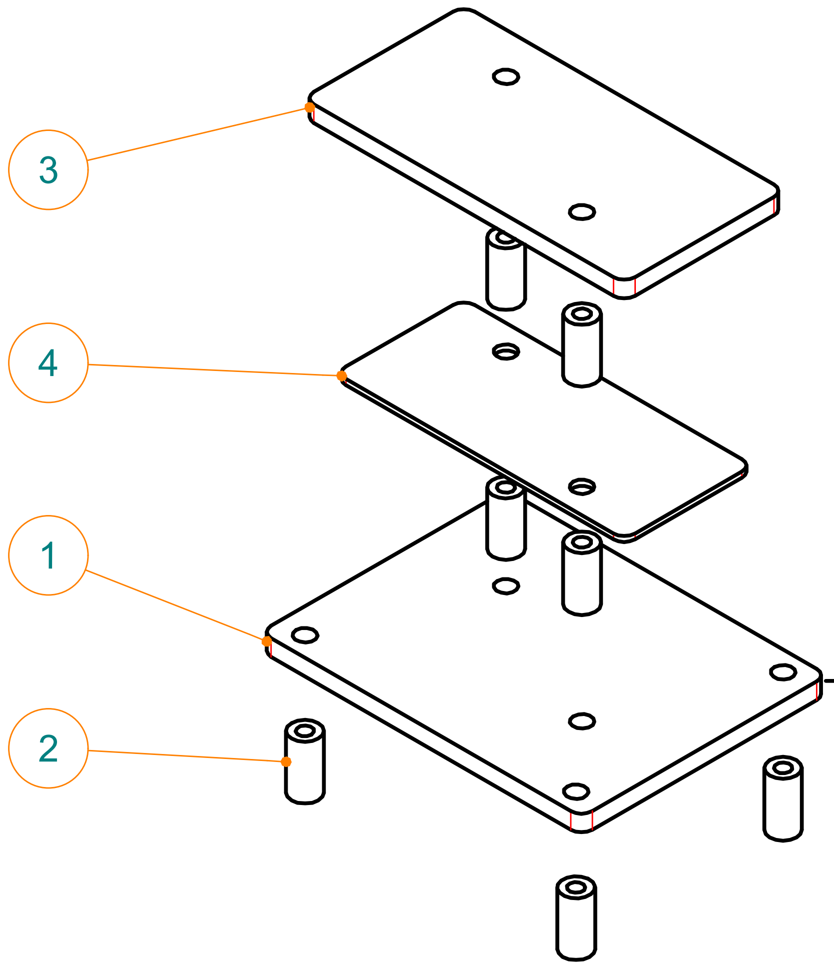
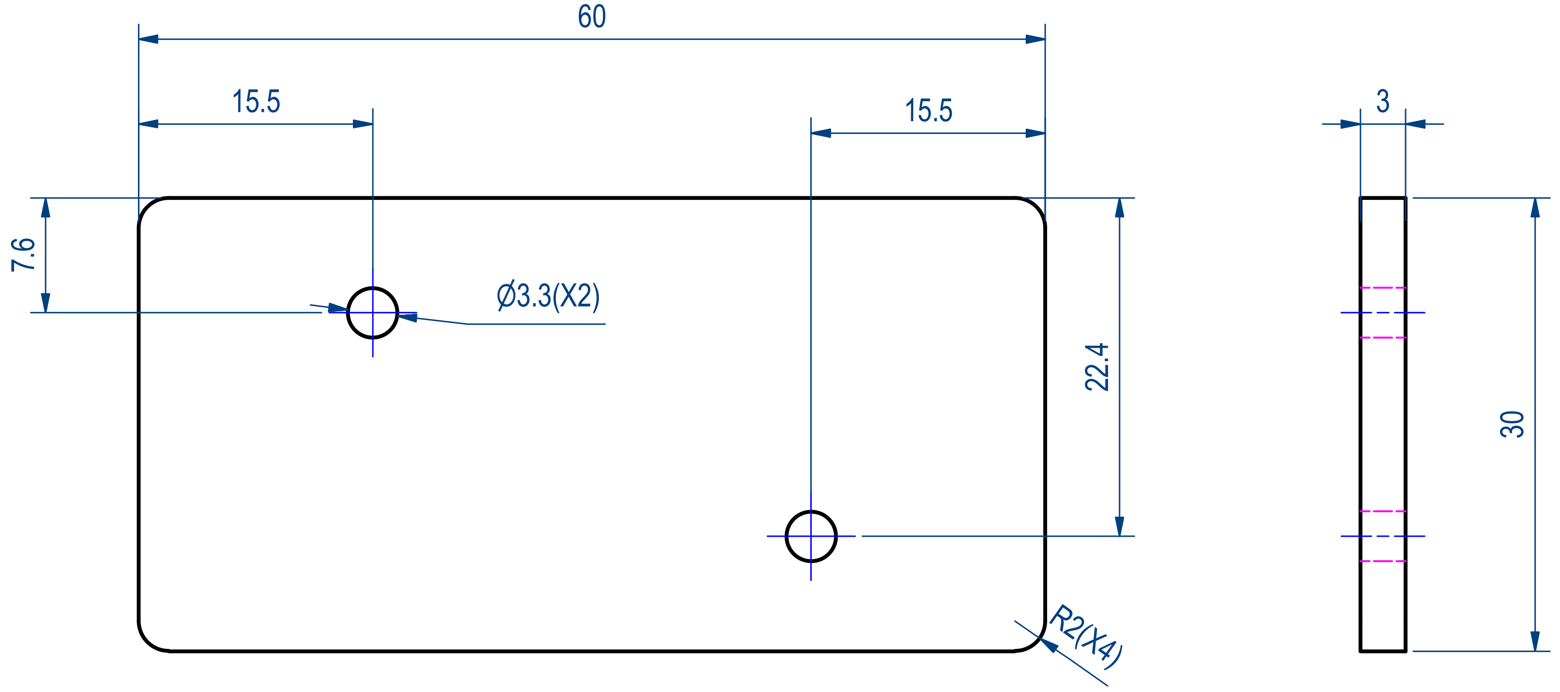
	Checked SAMUEL WONG	Date 7/8/2020	Projection	Dwg No.	
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor TAN TUAN KIAT	Date 7/8/2020	Scale 2:1	Sheet 1	Size A4

Parts List			
ITEM	DESCRIPTION	QTY	MATERIAL
1	5V Regulator Mounting Plate	1	Polycarbonate
2	Spacer for Ion	8	
3	5V Regulator Cover Plate	1	Polycarbonate
4	5V Regulator	1	



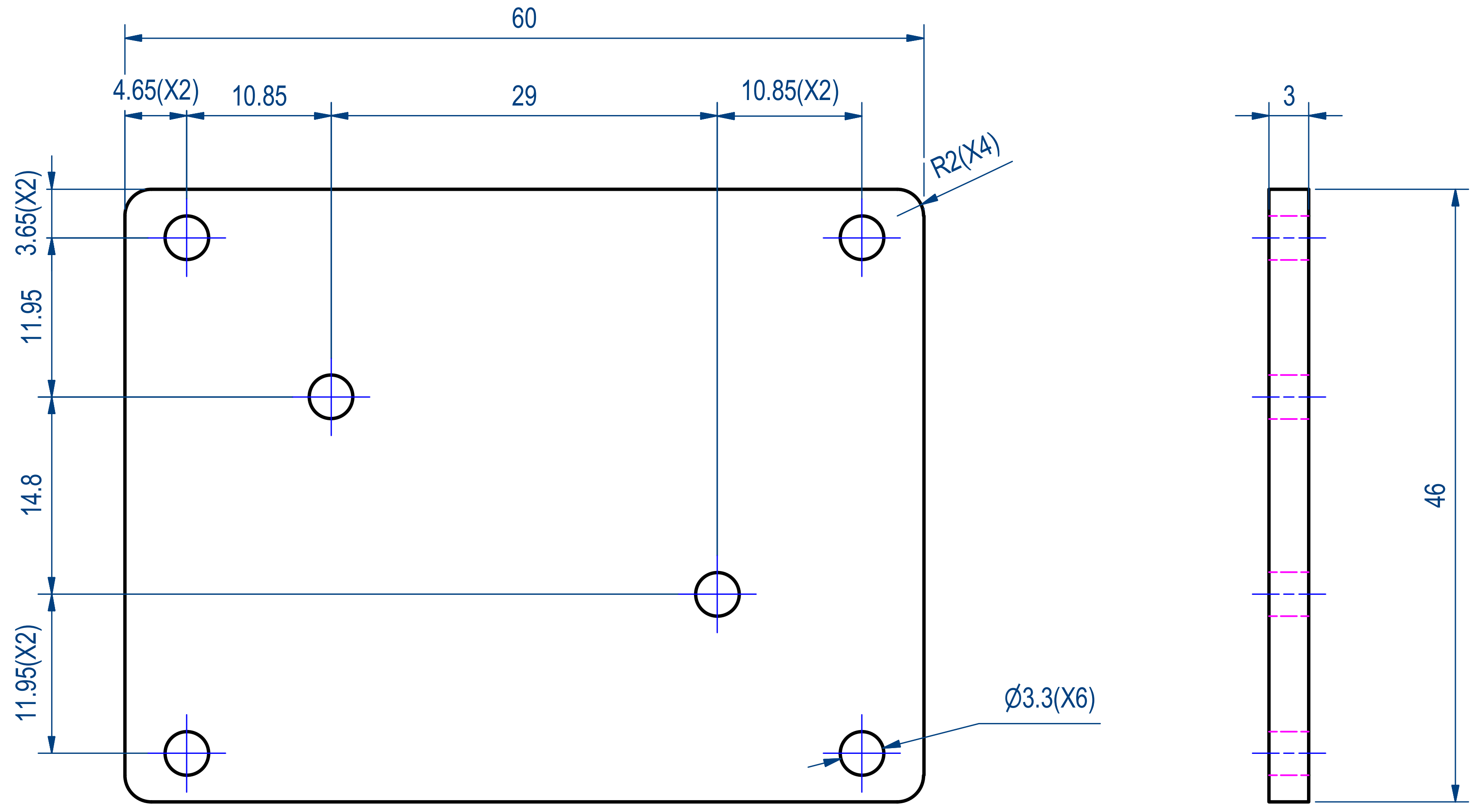
SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed LOW ZHONG SHENG	Date 6/8/2020	Project Title OFFICE TRANSPORTER	
	Checked SILVANUS SNG	Date 7/8/2020	Projection	Dwg No.
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor TAN TUAN KIAT	Date 7/8/2020	Scale 1:1	Sheet 1 / Size A4



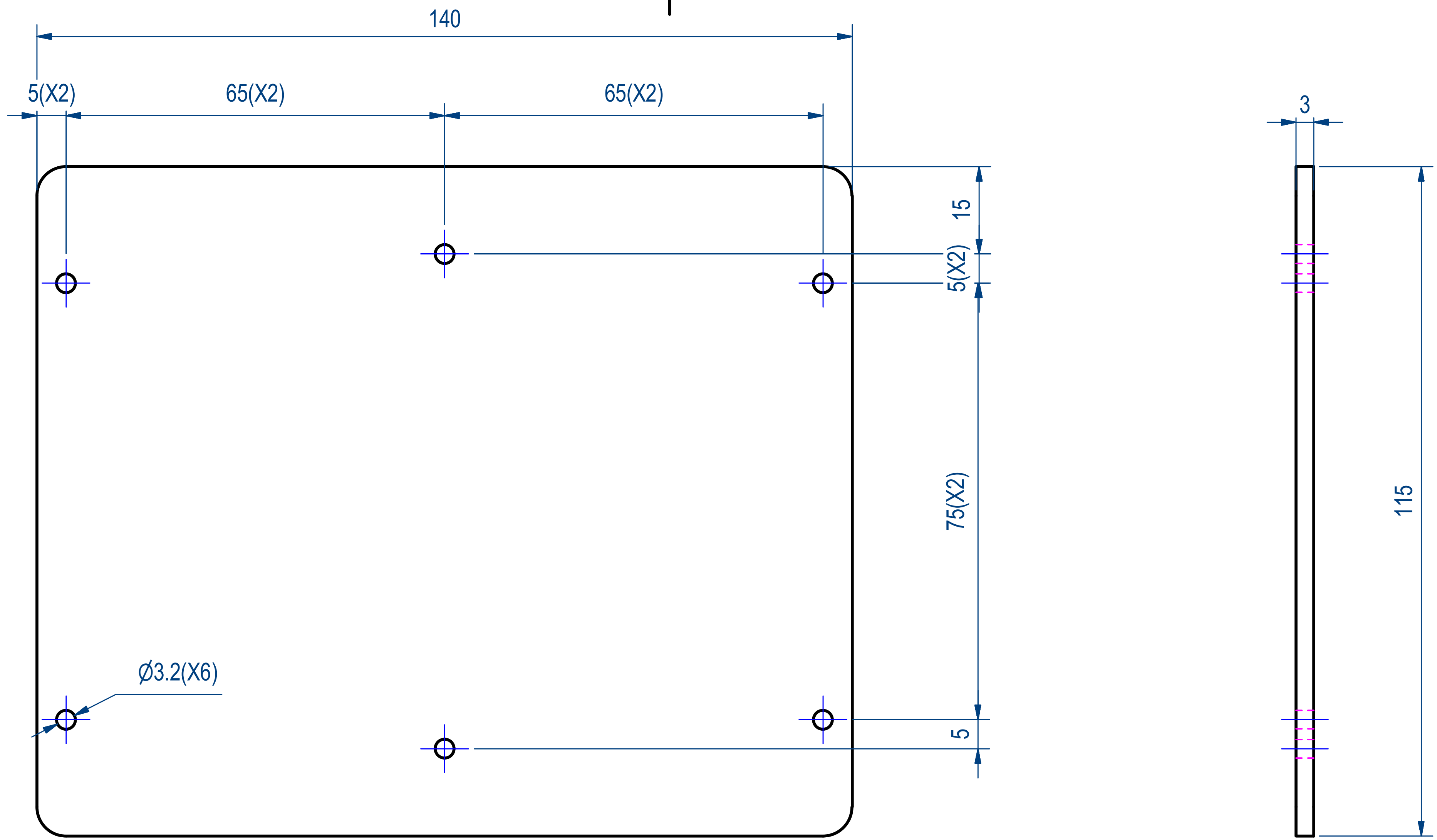
SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING

Designed	Date	Project Title	
LOW ZHONG SHENG	6/8/2020	OFFICE TRANSPORTER	
Checked	Date	Projection	Dwg No.
SAMUEL WONG	7/8/2020		
Project Supervisor	Date	Scale	Sheet / Size
TAN TUAN KIAT	7/8/2020	2:1	1 / A4

Unless otherwise specified
All dimensions are in millimeters (mm)



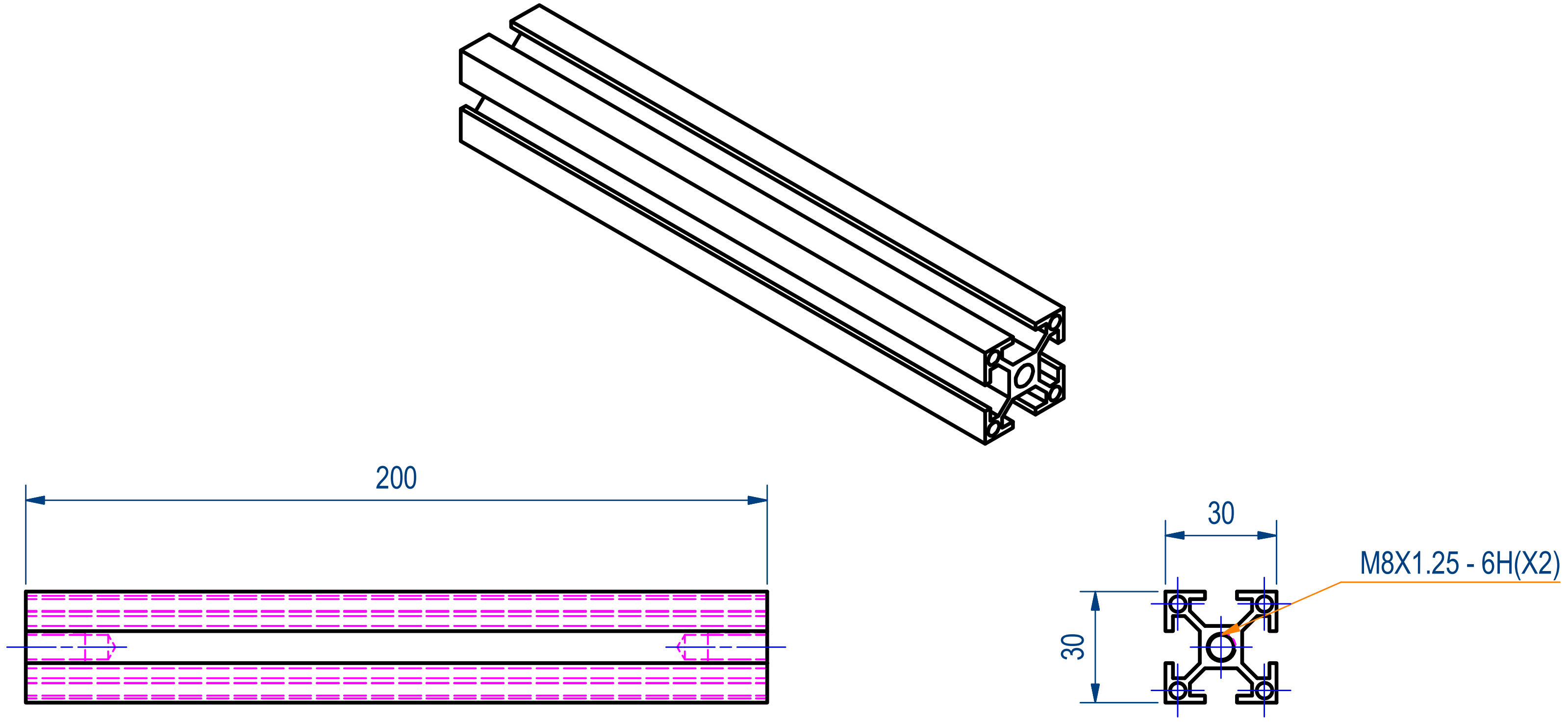
SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed: LOW ZHONG SHENG	Date: 6/8/2020	Project Title: OFFICE TRANSPORTER		
	Checked: SAMUEL WONG	Date: 7/8/2020	Projection	Dwg No.	
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor: TAN TUAN KIAT	Date: 7/8/2020	Scale: 2:1	Sheet: 1	Size: A4



SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING

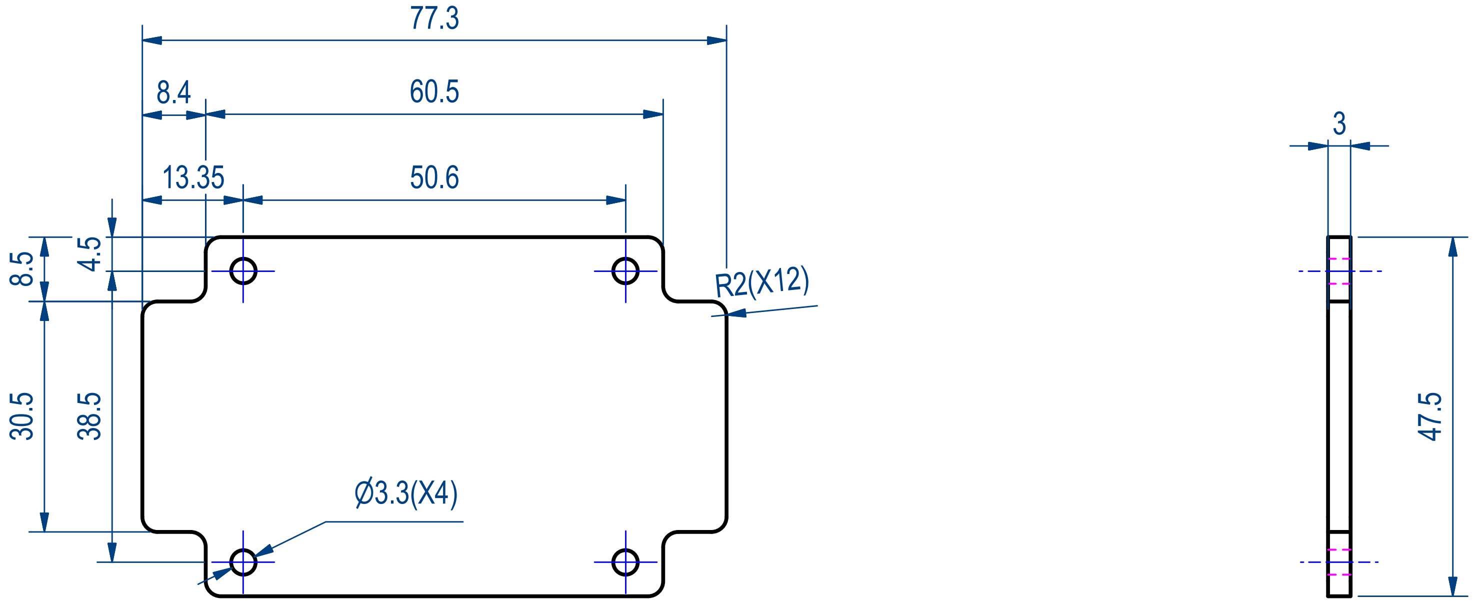
Unless otherwise specified
All dimensions are in millimeters (mm)

Designed LOW ZHONG SHENG	Date 6/8/2020	Project Title OFFICE TRANSPORTER		
Checked JARED TAN	Date 7/8/2020	Projection	Dwg No.	
Project Supervisor TAN TUAN KIAT	Date 7/8/2020	Scale 1:1	Sheet 1	Size A4



SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed LOW ZHONG SHENG	Date 6/8/2020	Project Title OFFICE TRANSPORTER	
	Checked SILVANUS SNG	Date 7/8/2020	Projection	Dwg No.
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor TAN TUAN KIAT	Date 7/8/2020	Scale 1:2	Sheet 1

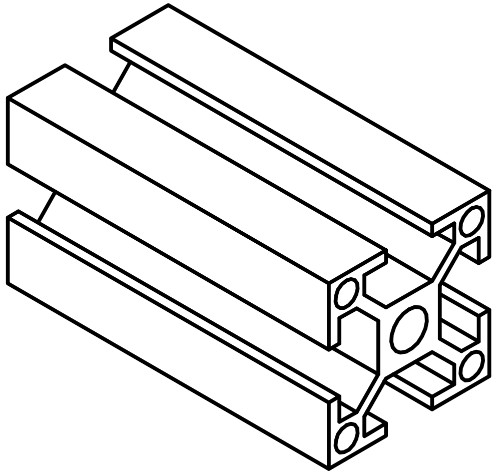
Size A4

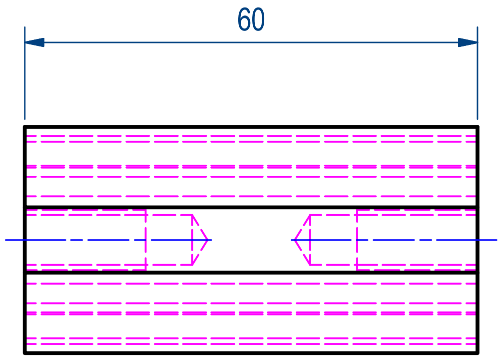


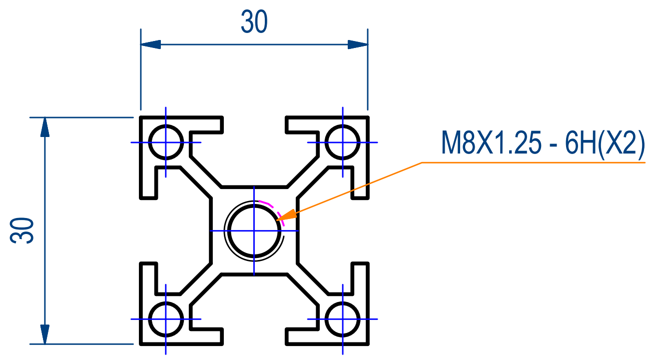
SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING

Unless otherwise specified
All dimensions are in millimeters (mm)

Designed: LOW ZHONG SHENG	Date: 6/8/2020	Project Title: OFFICE TRANSPORTER			
Checked: JARED TAN	Date: 7/8/2020	Projection	Dwg No.		
Project Supervisor: TAN TUAN KIAT	Date: 7/8/2020	Scale: 1:1	Sheet: 1	Size: A4	







SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed LOW ZHONG SHENG	Date 6/8/2020	Project Title OFFICE TRANSPORTER			
	Checked SILVANUS SNG	Date 7/8/2020	Projection	Dwg No.		
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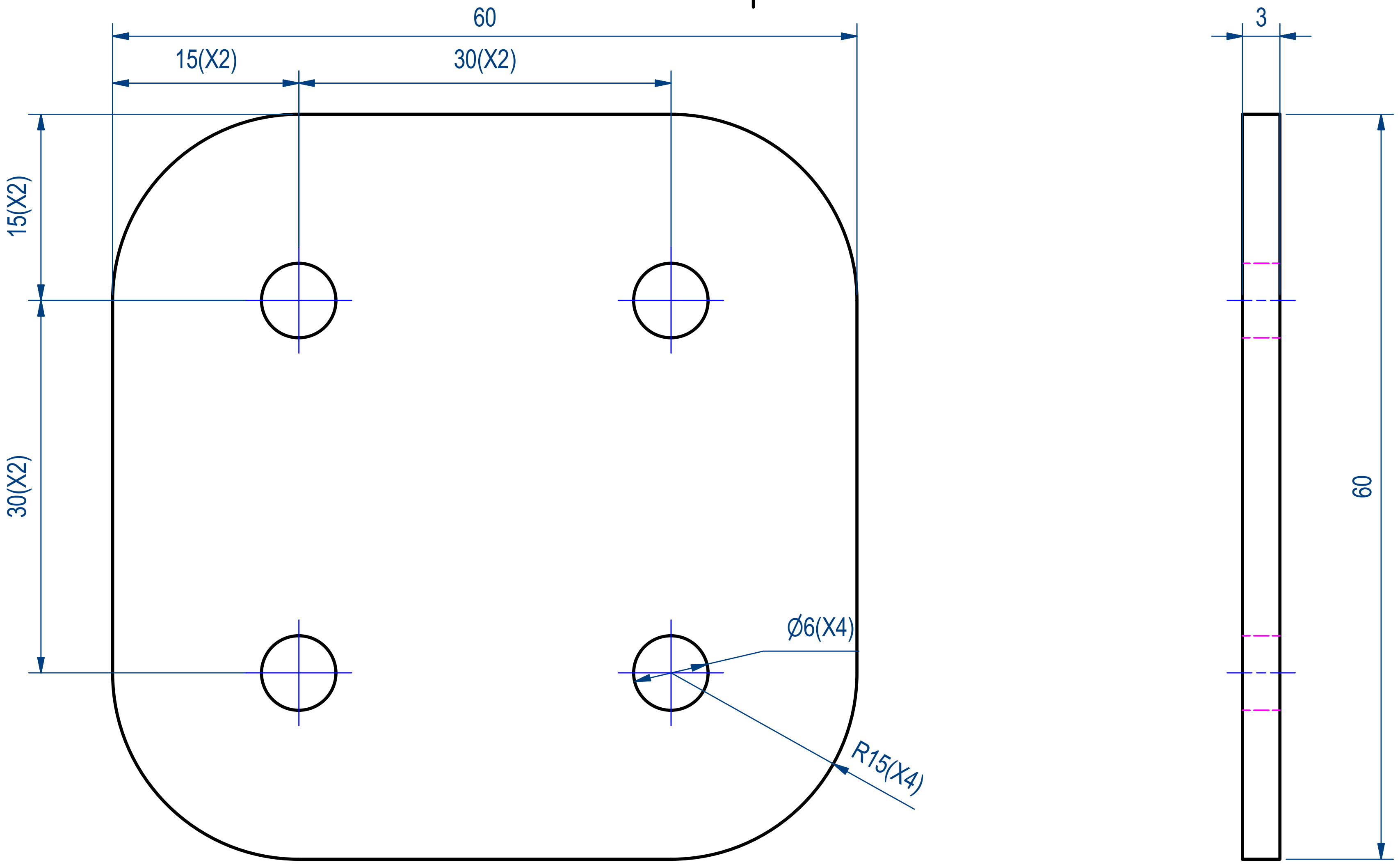
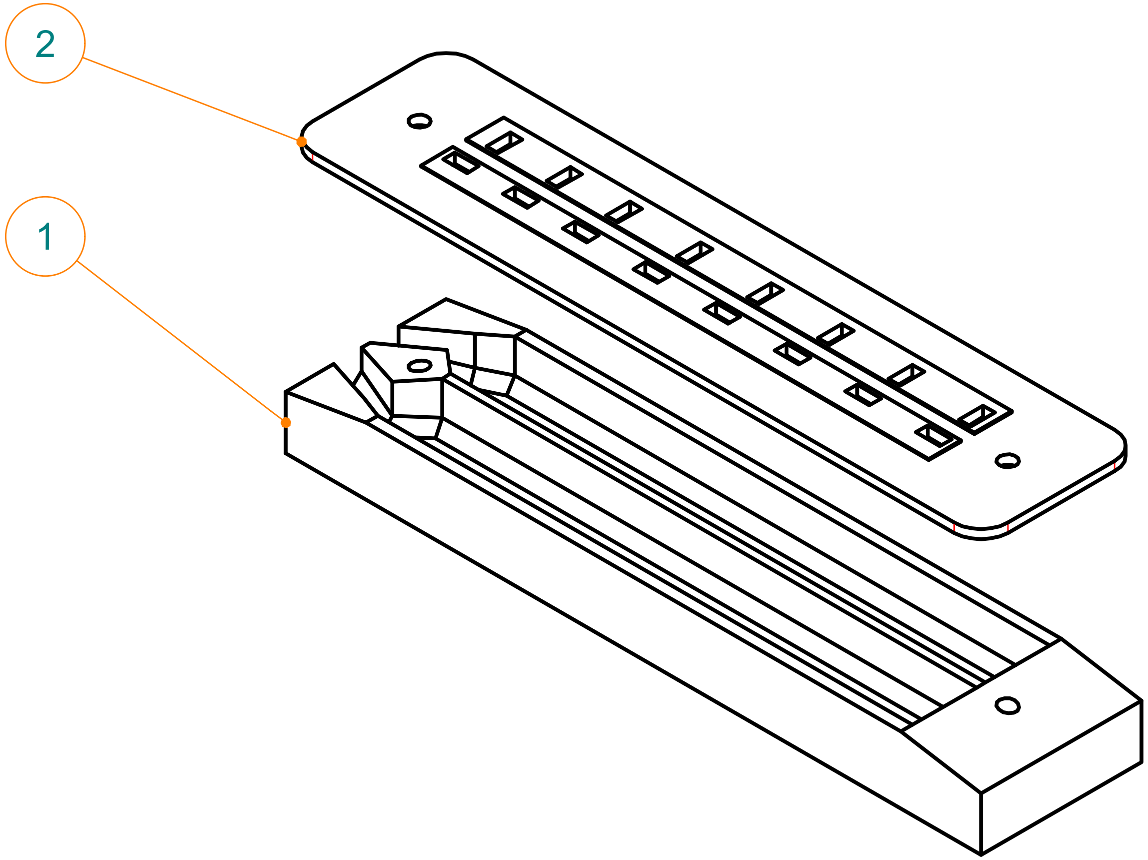


SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed LOW ZHONG SHENG	Date 6/8/2020	Project Title OFFICE TRANSPORTER		
	Checked SILVANUS SNG	Date 7/8/2020	Projection	Dwg No.	
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor TAN TUAN KIAT	Date 7/8/2020	Scale 2:1	Sheet 1	Size A4

Parts List		
ITEM	DESCRIPTION	QTY
1	Power Bar Enclosure	1
2	Power Bar Cover	1



SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed LOW ZHONG SHENG	Date 6/8/2020	Project Title OFFICE TRANSPORTER		
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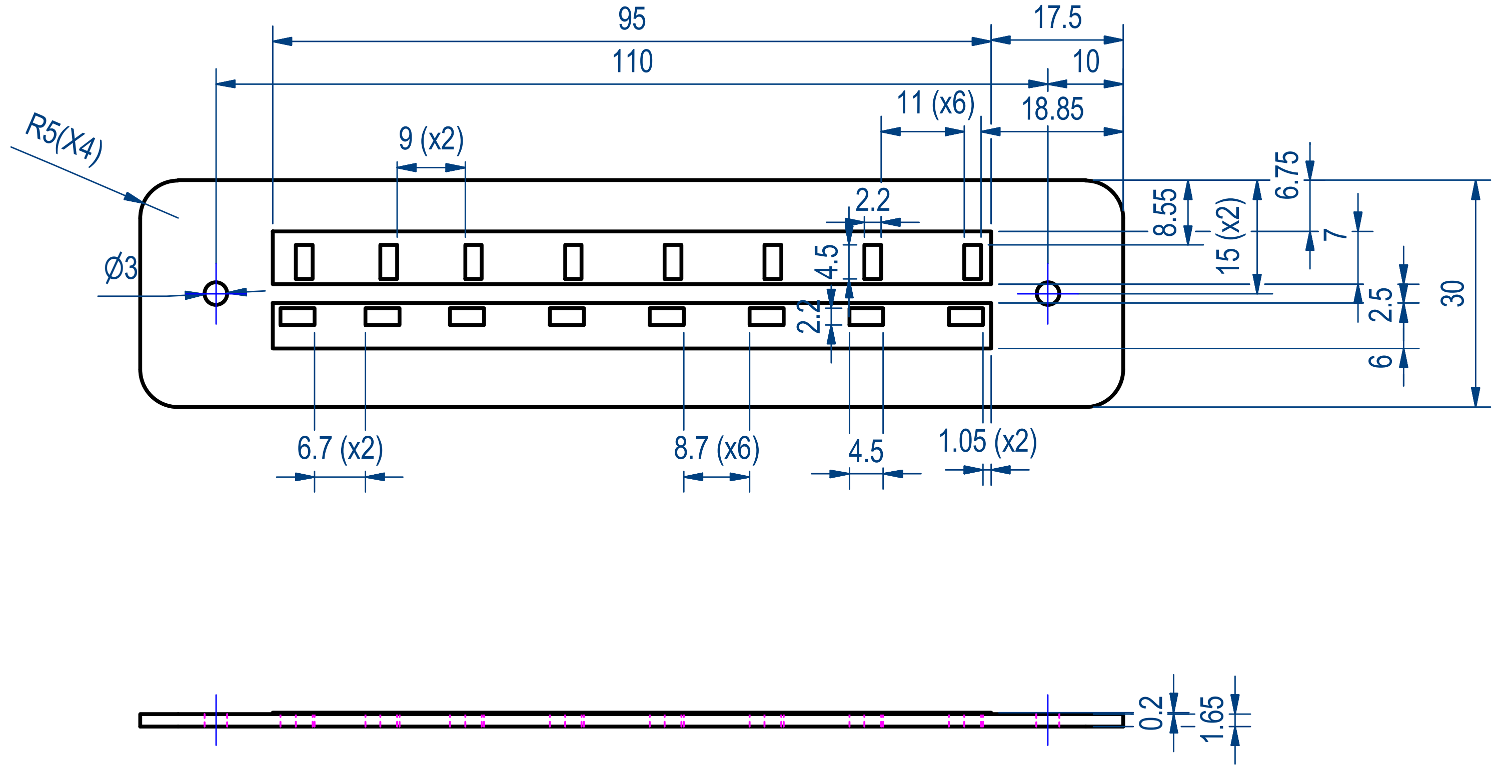
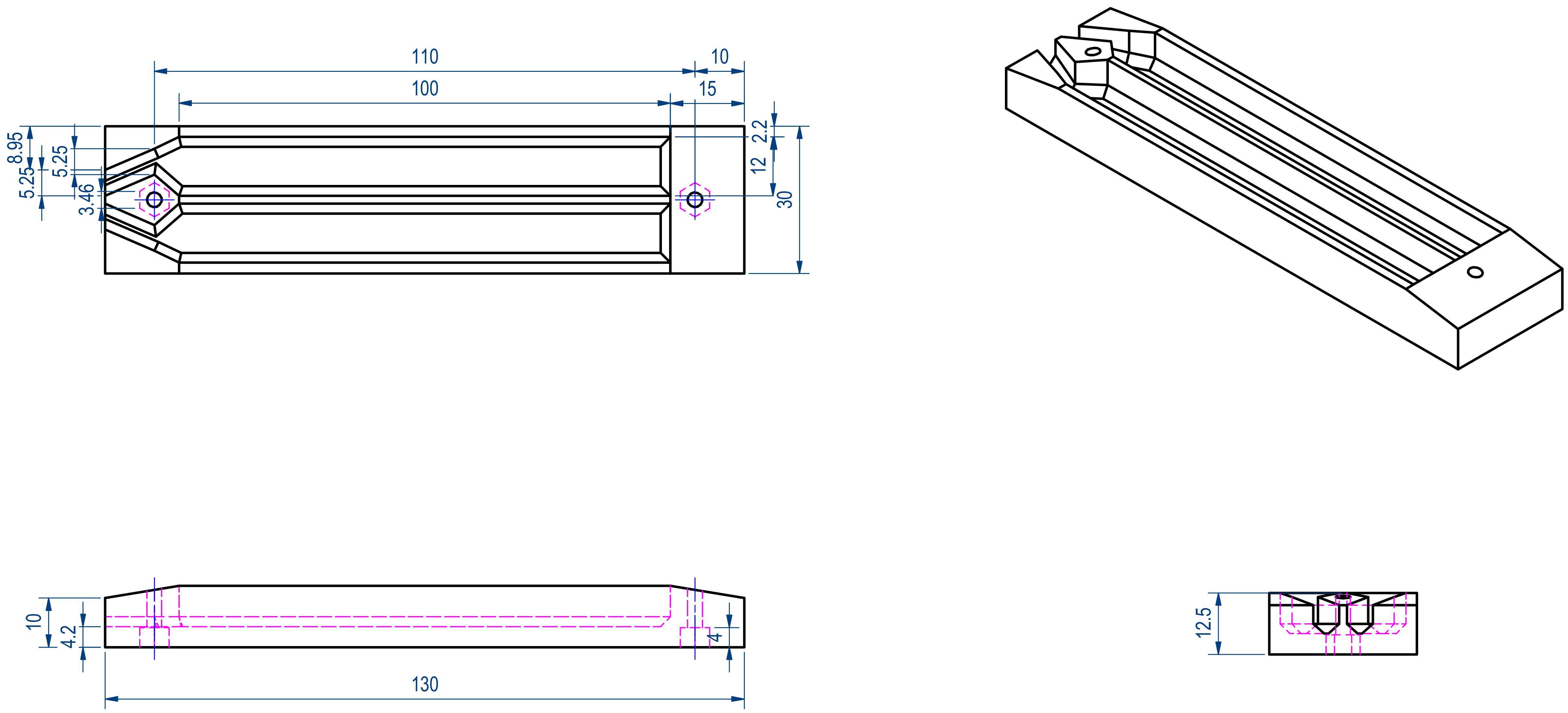
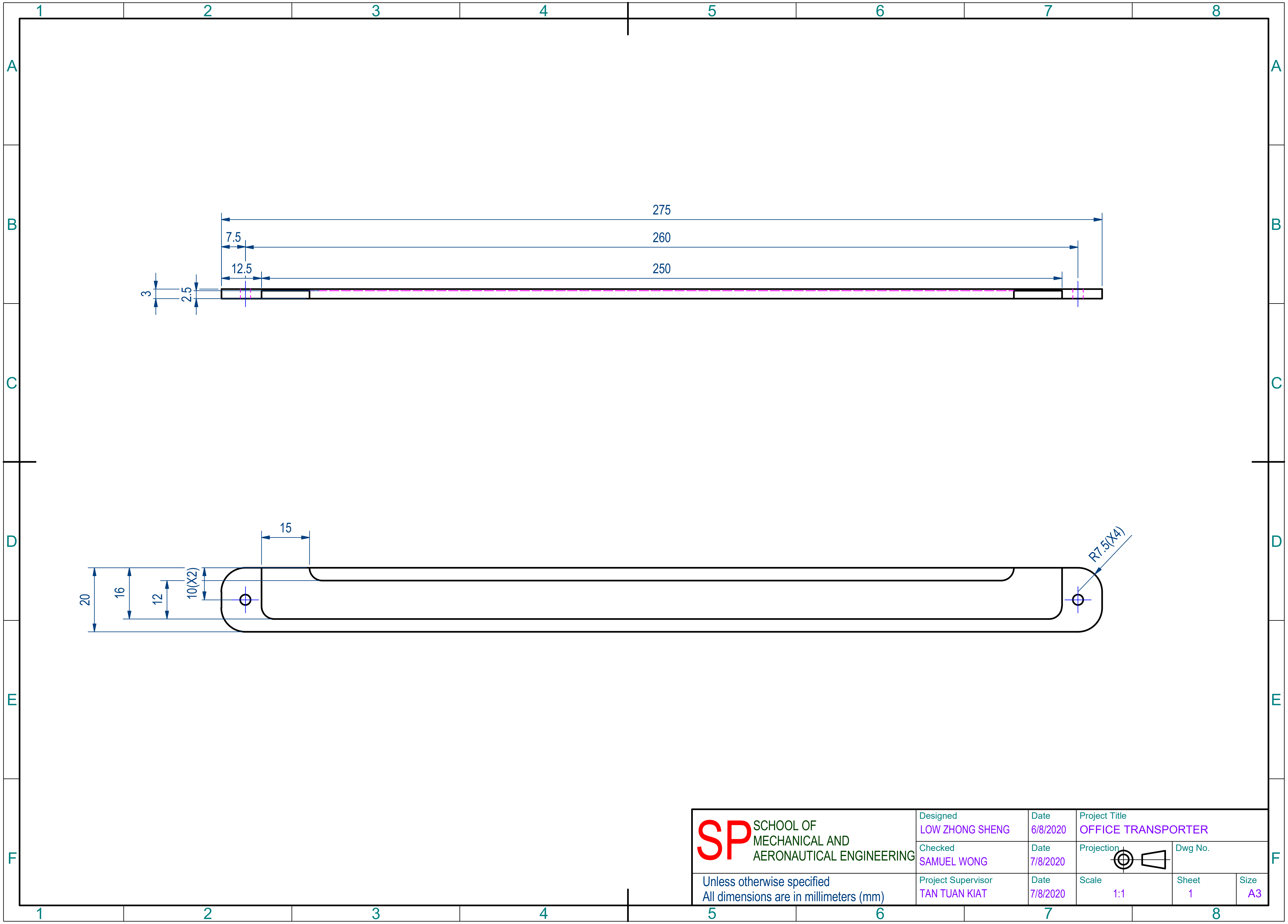


SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed SAMUEL WONG	Date 6/8/2020	Project Title OFFICE TRANSPORTER		
	Checked LOW ZHONG SHENG	Date 7/8/2020	Projection	Dwg No.	
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor TAN TUAN KIAT	Date 7/8/2020	Scale 1:1	Sheet 1	Size A4



SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed: LOW ZHONG SHENG	Date: 6/8/2020	Project Title: OFFICE TRANSPORTER	
	Checked: SAMUEL WONG	Date: 7/8/2020	Projection	Dwg No.
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor: TAN TUAN KIAT	Date: 7/8/2020	Scale: 1:1	Sheet: 1 / Size: A3


275
260
250
7.5
12.5
3
2.5
15
R7.5(X4)
20
16
12
10(X2)
SP
SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING
Designed
LOW ZHONG SHENG
Date
6/8/2020
Project Title
OFFICE TRANSPORTER
Checked
SAMUEL WONG
Date
7/8/2020
Projection
Dwg No.
Unless otherwise specified
All dimensions are in millimeters (mm)
Project Supervisor
TAN TUAN KIAT
Date
7/8/2020
Scale
1:1
Sheet
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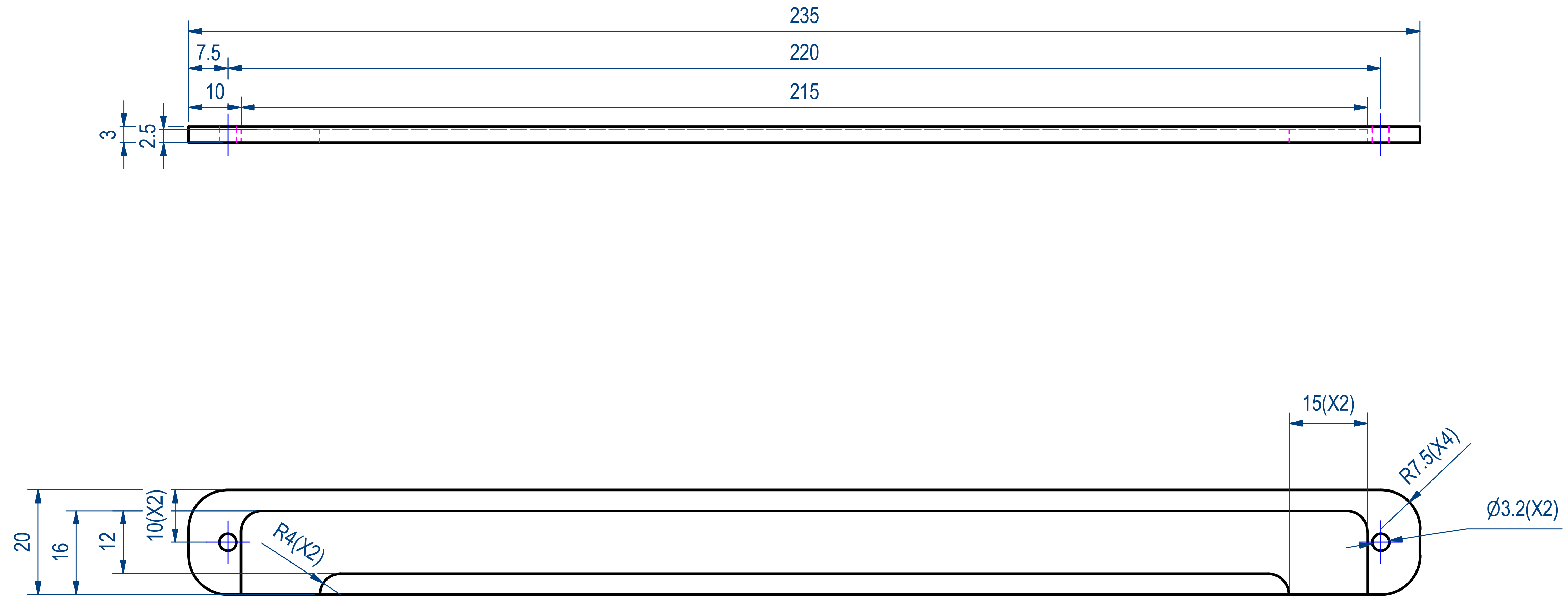
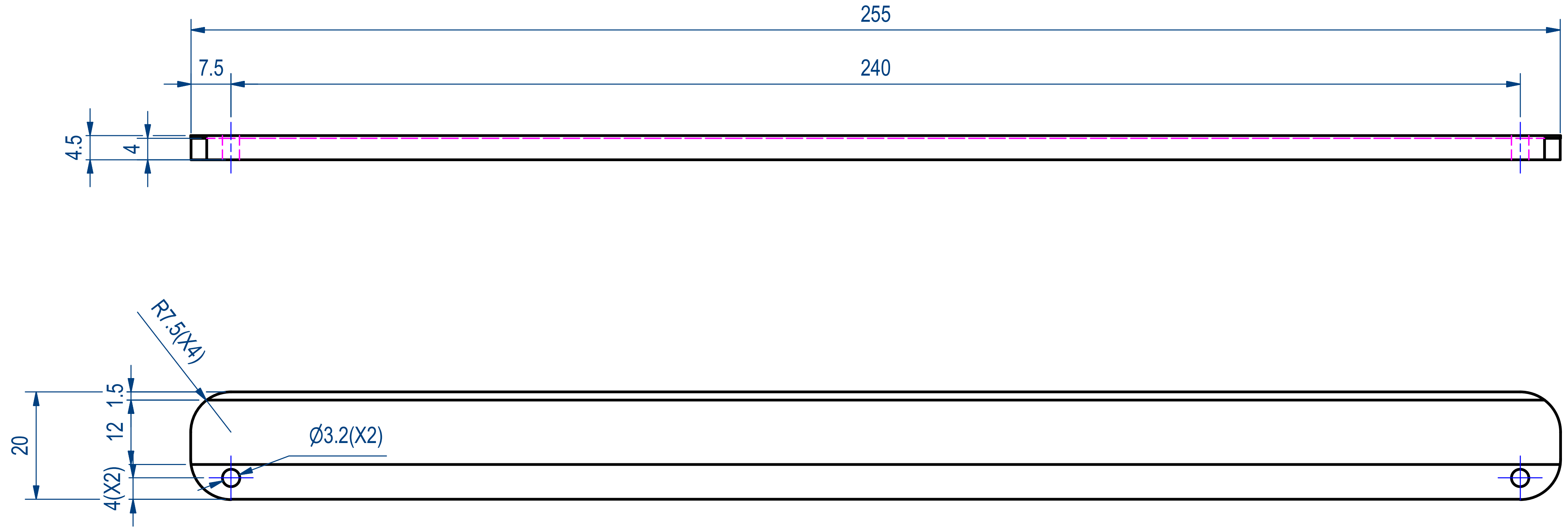
Size
A3

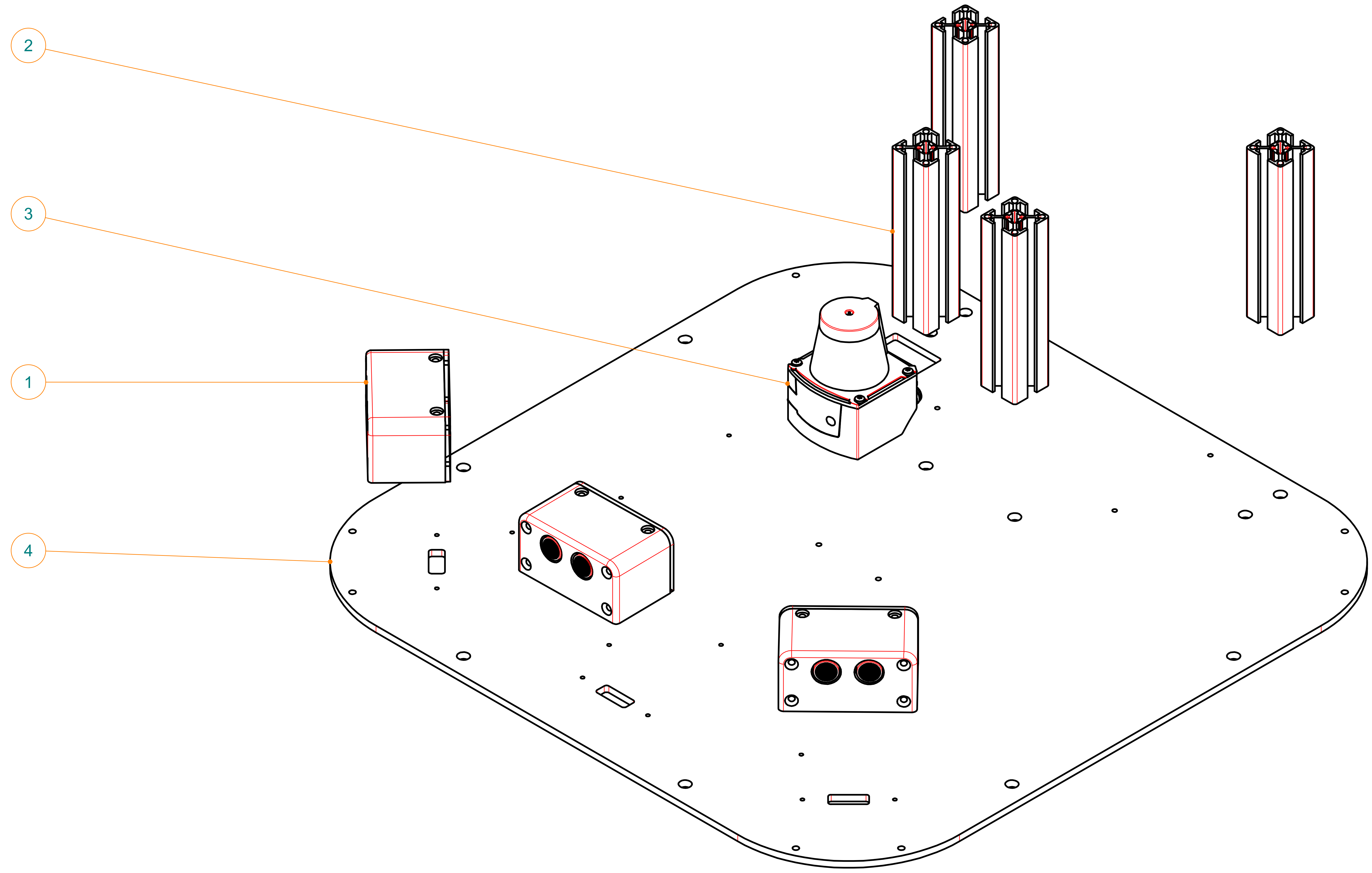


SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed LOW ZHONG SHENG	Date 6/8/2020	Project Title OFFICE TRANSPORTER
	Checked SAMUEL WONG	Date 7/8/2020	Projection / Dwg No.
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor TAN TUAN KIAT	Date 7/8/2020	Scale 1:1 / Sheet 1 / Size A3



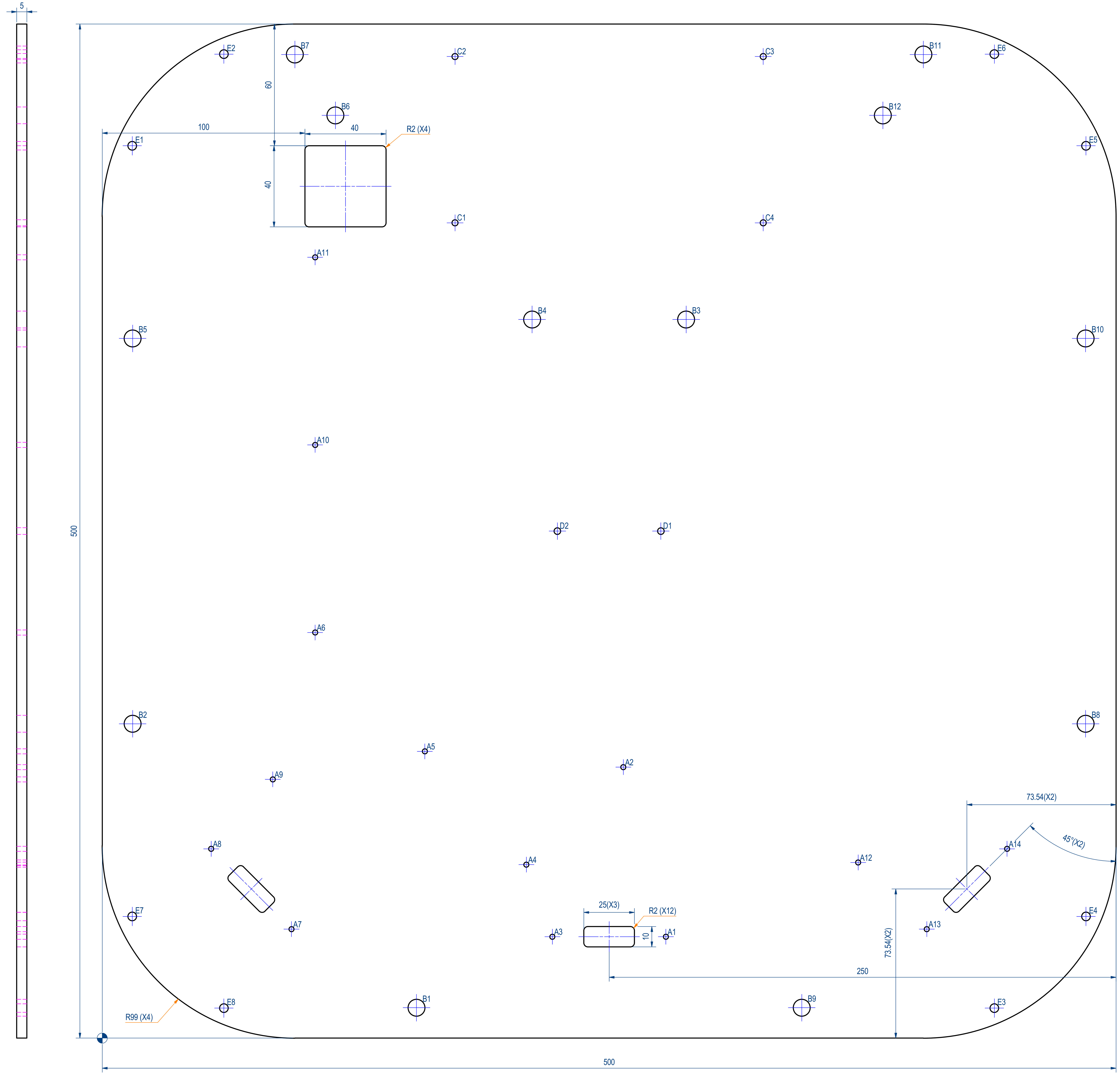
SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed LOW ZHONG SHENG	Date 6/8/2020	Project Title OFFICE TRANSPORTER		
	Checked SAMUEL WONG	Date 7/8/2020	Projection	Dwg No.	
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor TAN TUAN KIAT	Date 7/8/2020	Scale 1:1	Sheet 1	Size A3

Parts List			
ITEM	DESCRIPTION	QTY	MATERIAL
1	Ultrasonic Sensor	3	
2	120mm Profile	4	Aluminum
3	TIM561	1	
4	top base plate	1	Aluminum



SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed: LOW ZHONG SHENG	Date: 6/8/2020	Project Title: OFFICE TRANSPORTER		
	Checked: SILVANUS SNG	Date: 7/8/2020	Projection	Dwg No.	
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor: TAN TUAN KIAT	Date: 7/8/2020	Scale: 1:2	Sheet: 1	Size: A2

Hole Table			
HOLE	XDIM	YDIM	DESCRIPTION
A1	278	50	Ø2.5 THRU
A2	257.01	133.61	Ø2.5 THRU
A3	222	50	Ø2.5 THRU
A4	209.18	85.55	Ø2.5 THRU
A5	159.11	141.4	Ø2.5 THRU
A6	105	200	Ø2.5 THRU
A7	93.34	53.74	Ø2.5 THRU
A8	53.74	93.34	Ø2.5 THRU
A9	84.12	127.58	Ø2.5 THRU
A10	105	292.5	Ø2.5 THRU
A11	105	385	Ø2.5 THRU
A12	372.83	86.61	Ø2.5 THRU
A13	406.66	53.74	Ø2.5 THRU
A14	446.26	93.34	Ø2.5 THRU
B1	155	15	Ø8.3 THRU
B2	15	155	Ø8.3 THRU
B3	288	354.35	Ø8.3 THRU
B4	212	354.35	Ø8.3 THRU
B5	15	345	Ø8.3 THRU
B6	115	455	Ø8.3 THRU
B7	95	485	Ø8.3 THRU
B8	485	155	Ø8.3 THRU
B9	345	15	Ø8.3 THRU
B10	485	345	Ø8.3 THRU
B11	405	485	Ø8.3 THRU
B12	385	455	Ø8.3 THRU
C1	174	402	Ø3 THRU
C2	174	484	Ø3 THRU
C3	326	484	Ø3 THRU
C4	326	402	Ø3 THRU
D1	275.5	250	Ø3.3 THRU
D2	224.5	250	Ø3.3 THRU
E1	14.8	440	Ø4.2 THRU
E2	60	485.2	Ø4.2 THRU
E3	440	14.8	Ø4.2 THRU
E4	485.2	60	Ø4.2 THRU
E5	485.2	440	Ø4.2 THRU
E6	440	485.2	Ø4.2 THRU
E7	14.8	60	Ø4.2 THRU
E8	60	14.8	Ø4.2 THRU

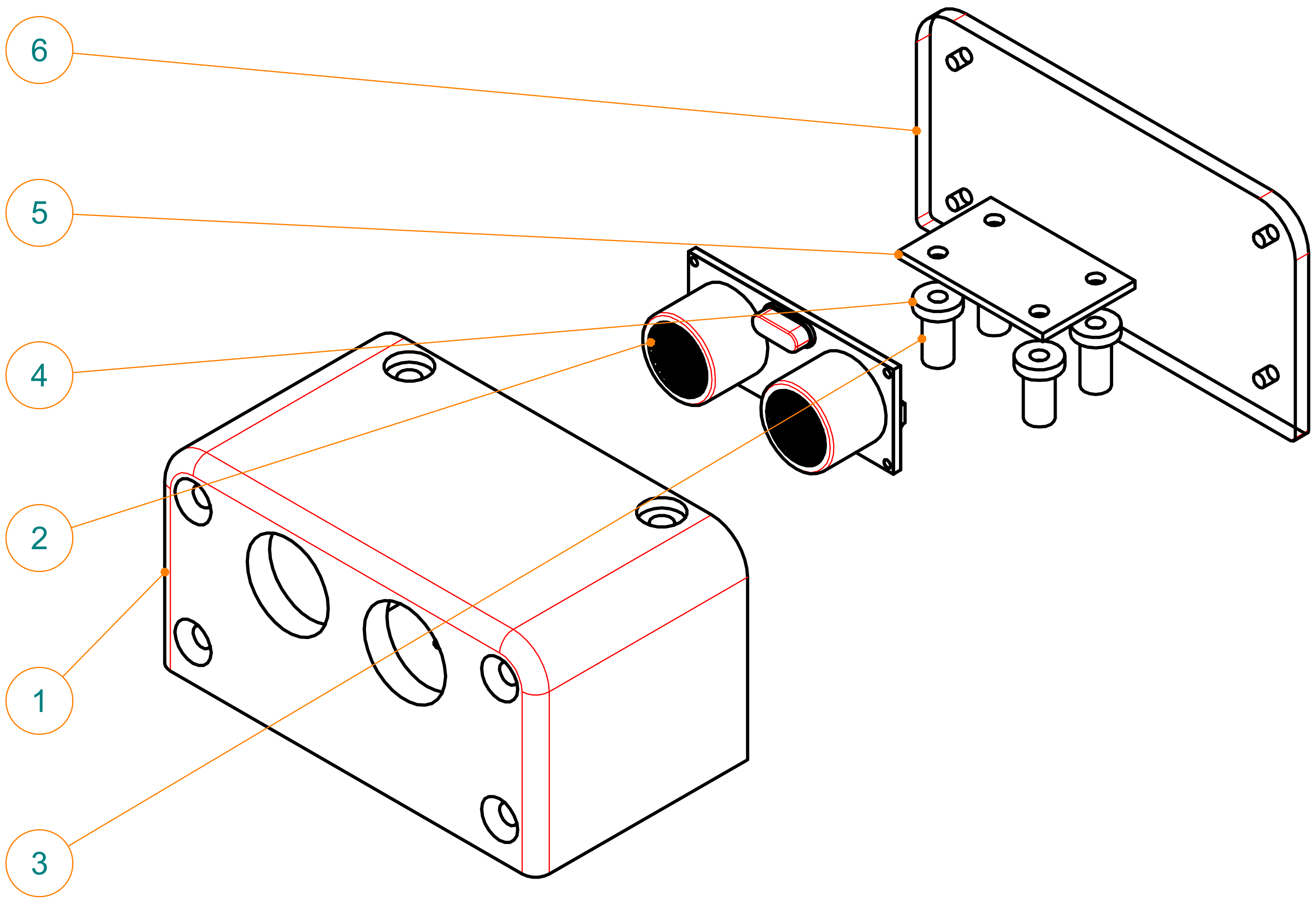


SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING

Unless otherwise specified
All dimensions are in millimeters (mm)

Designed: SILVANUS SNG	Date: 6/8/2020	Project Title: OFFICE TRANSPORTER	
Checked: LOW ZHONG SHENG	Date: 7/8/2020	Projection	Dwg No.
Project Supervisor: TAN TUAN KIAT	Date: 7/8/2020	Scale: 1:1	Sheet: 1 / Size: A1

Parts List			
ITEM	DESCRIPTION	QTY	MATERIAL
1	Front Ultrasound Enclose	1	PLA
2	Ultrasonic Sensor	1	
3	Spacer for Ion	4	
4	Washer	4	
5	Board	1	
6	Back Ultrasound Enclosure	1	Polycarbonate



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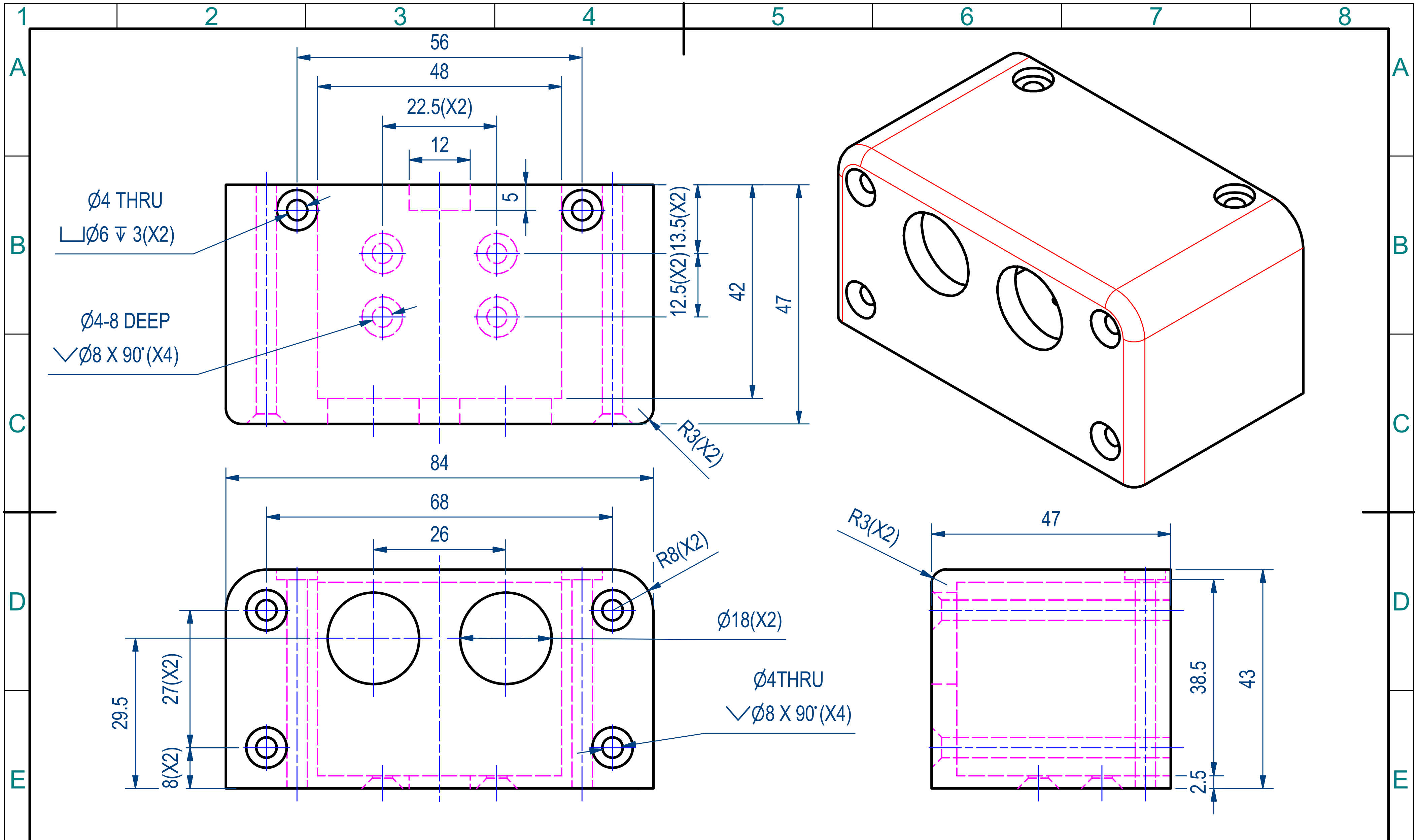
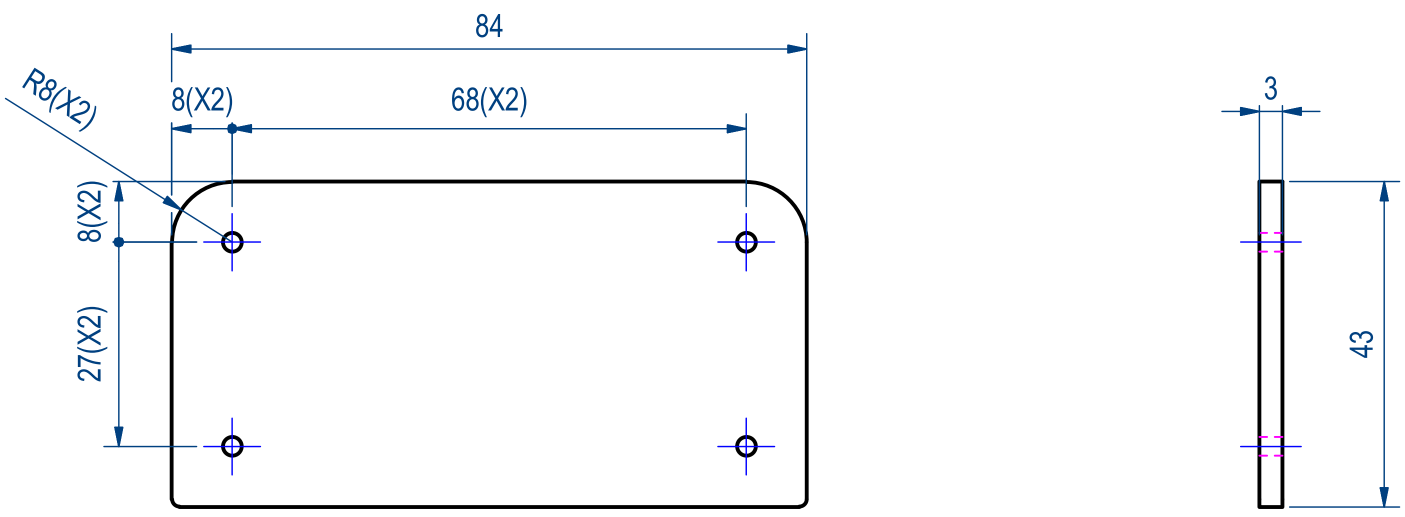
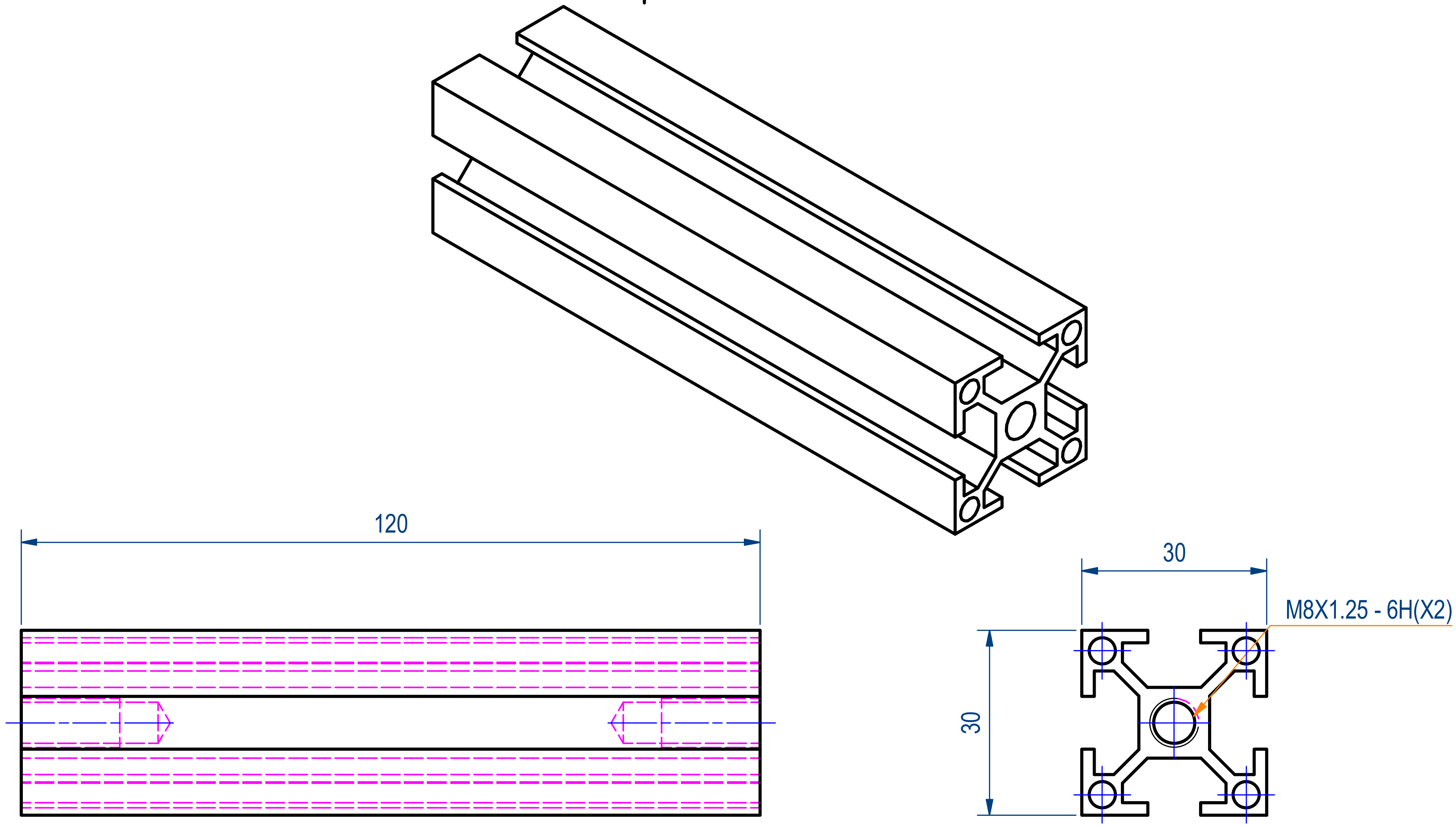
	Checked: SILVANUS SNG	Date: 7/8/2020	Projection	Dwg No.	
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor: TAN TUAN KIAT	Date: 7/8/2020	Scale: 1:1	Sheet: 1	Size: A3



SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed LOW ZHONG SHENG	Date 6/8/2020	Project Title OFFICE TRANSPORTER		
	Checked JARED TAN	Date 7/8/2020	Projection	Dwg No.	
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor TAN TUAN KIAT	Date 7/8/2020	Scale 1:1	Sheet 1	Size A4



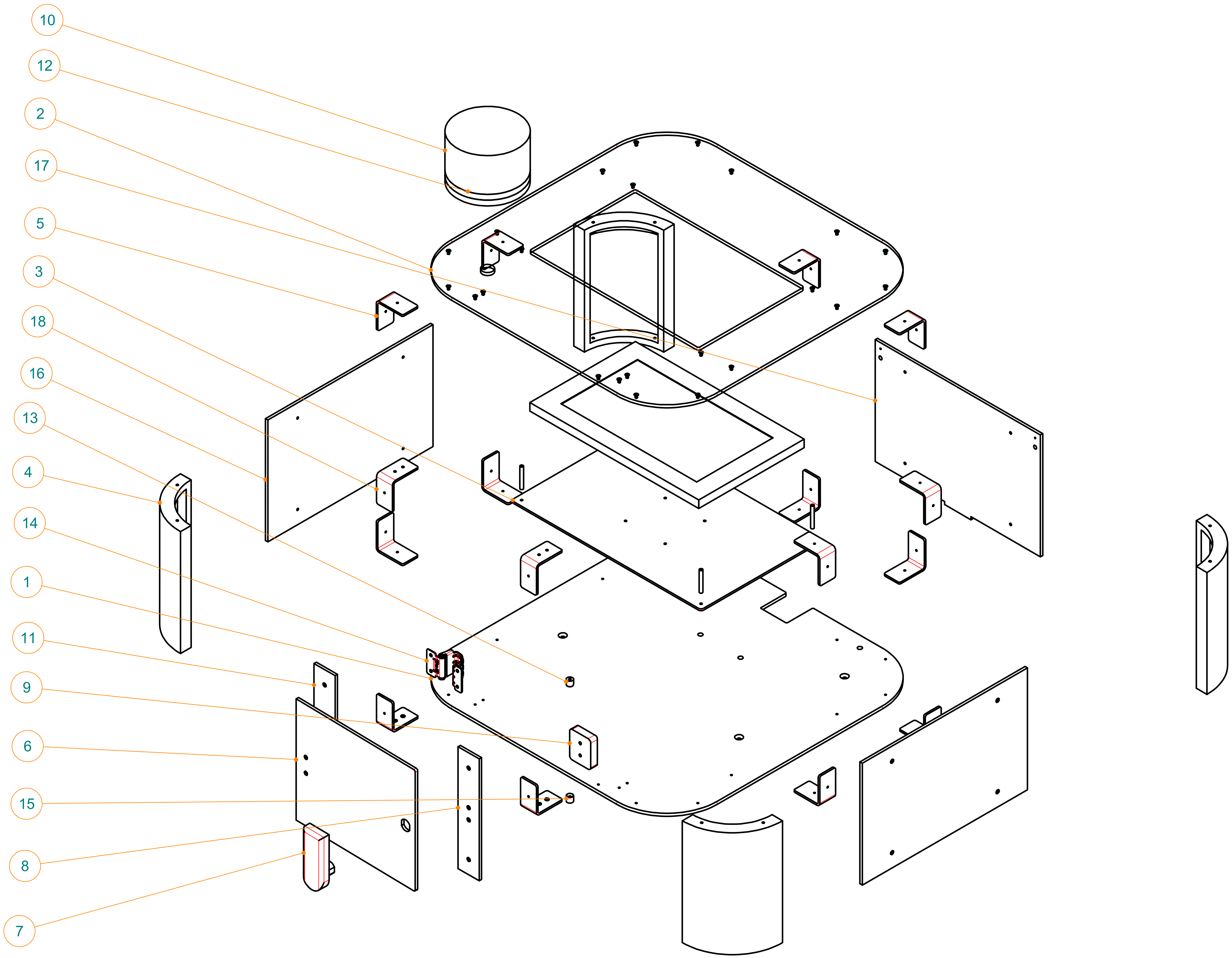
SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed LOW ZHONG SHENG	Date 6/8/2020	Project Title OFFICE TRANSPORTER			
	Checked JARED TAN	Date 7/8/2020	Projection	Dwg No.		
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor TAN TUAN KIAT	Date 7/8/2020	Scale 1:1	Sheet 1	Size A4	



SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed LOW ZHONG SHENG	Date 6/8/2020	Project Title OFFICE TRANSPORTER			
	Checked SILVANUS SNG	Date 7/8/2020	Projection	Dwg No.		
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor TAN TUAN KIAT	Date 7/8/2020	Scale 1:1	Sheet 1	Size A4	

Parts List

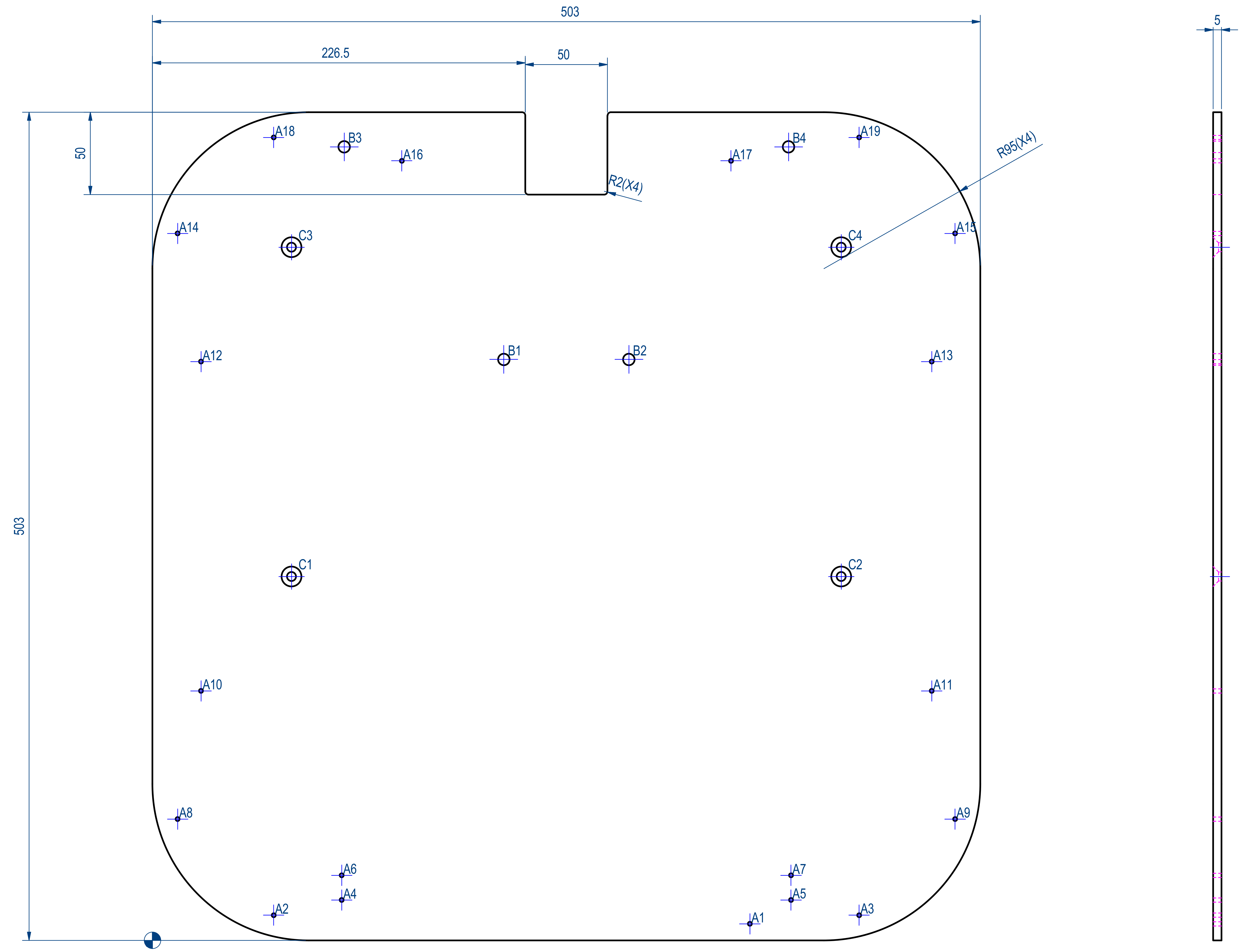
ITEM	DESCRIPTION	QTY	MATERIAL
1	Document Box Base	1	Aluminium
2	Document Box Top	1	Polycarbonate
3	Monitor Mount	1	Aluminium
4	Document Box Corner	4	PLA
5	Lplate Mount for Box	12	Aluminium
6	Document Box Door	1	Polycarbonate
7	Electrical Lock	1	
8	Document Box Lock Holder	1	Polycarbonate
9	Lock	1	PLA
10	Antenna	1	
11	Hinge Holder	1	Polycarbonate
12	Antenna spacer	2	
13	Top Door Bumper	1	PLA
14	Hinge	1	
15	Bottom Door Bumper	1	PLA
16	Document Box Side	2	Polycarbonate
17	Document Box Back	1	Polycarbonate
18	Lplate Mount for Box 2	4	Aluminium



SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed: LOW ZHONG SHENG	Date: 6/8/2020	Project Title: OFFICE TRANSPORTER	
	Checked: SILVANUS SNG	Date: 7/8/2020	Projection	Dwg No.
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor: TAN TUAN KIAT	Date: 7/8/2020	Scale: 1:4	Sheet: 1 Size: A2

Hole Table

HOLE	XDIM	YDIM	DESCRIPTION
A1	363	10	Ø2.5 THRU
A2	73.65	15.31	Ø2.5 THRU
A3	429.35	15.31	Ø2.5 THRU
A4	115	24.5	Ø2.5 THRU
A5	388	24.5	Ø2.5 THRU
A6	115	39.5	Ø2.5 THRU
A7	388	39.5	Ø2.5 THRU
A8	15.31	73.65	Ø2.5 THRU
A9	487.69	73.65	Ø2.5 THRU
A10	29.5	151.5	Ø2.5 THRU
A11	473.5	151.5	Ø2.5 THRU
A12	29.5	351.5	Ø2.5 THRU
A13	473.5	351.5	Ø2.5 THRU
A14	15.31	429.35	Ø2.5 THRU
A15	487.69	429.35	Ø2.5 THRU
A16	151.5	473.5	Ø2.5 THRU
A17	351.5	473.5	Ø2.5 THRU
A18	73.65	487.69	Ø2.5 THRU
A19	429.35	487.69	Ø2.5 THRU
B1	213.5	352.85	Ø7 THRU
B2	289.5	352.85	Ø7 THRU
B3	116.5	481.98	Ø7 THRU
B4	386.5	481.98	Ø7 THRU
C1	84.5	220.99	Ø5.5 THRU ∨ Ø12 X 90°
C2	418.5	220.99	Ø5.5 THRU ∨ Ø12 X 90°
C3	84.5	420.99	Ø5.5 THRU ∨ Ø12 X 90°
C4	418.5	420.99	Ø5.5 THRU ∨ Ø12 X 90°

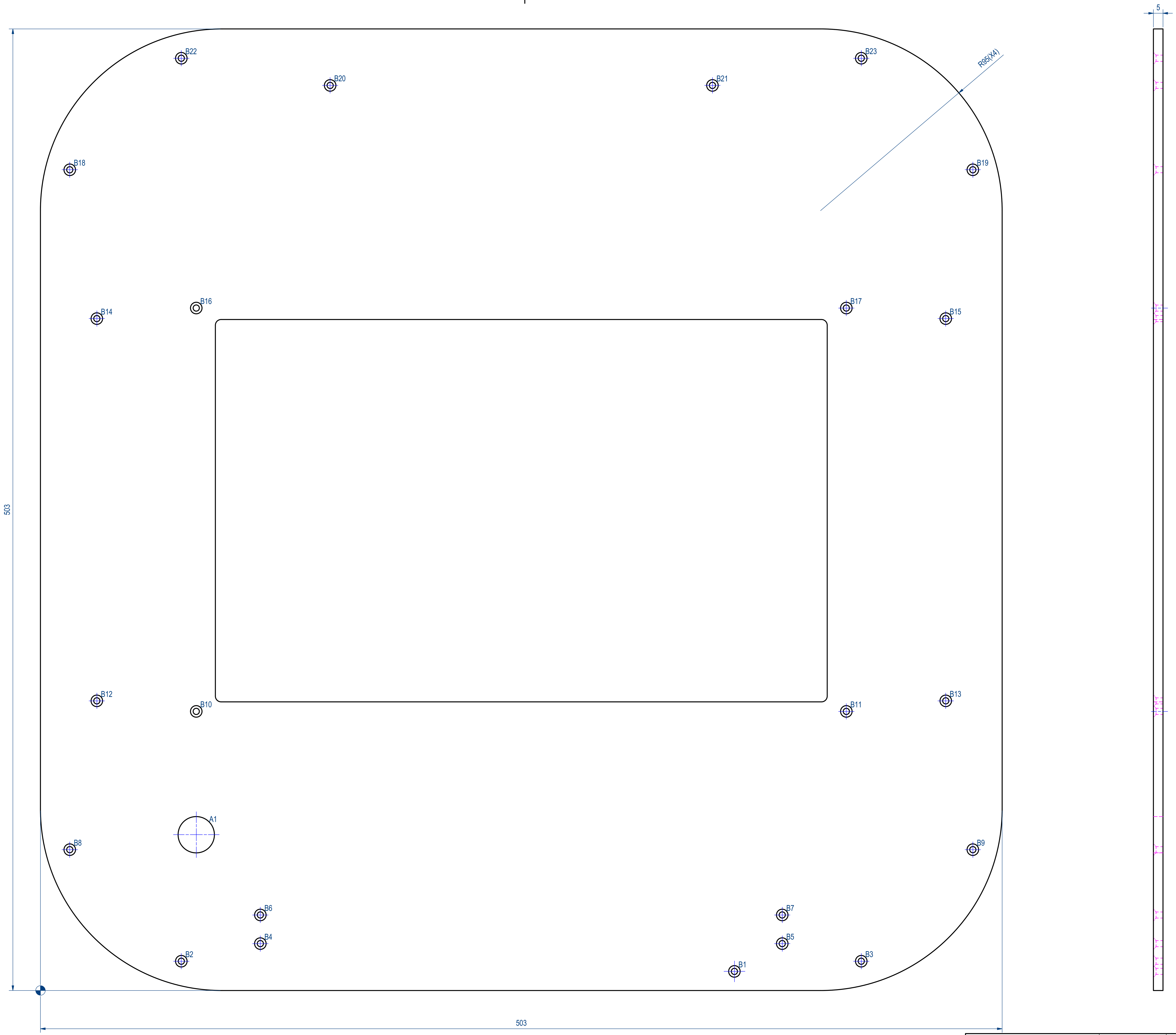


SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING

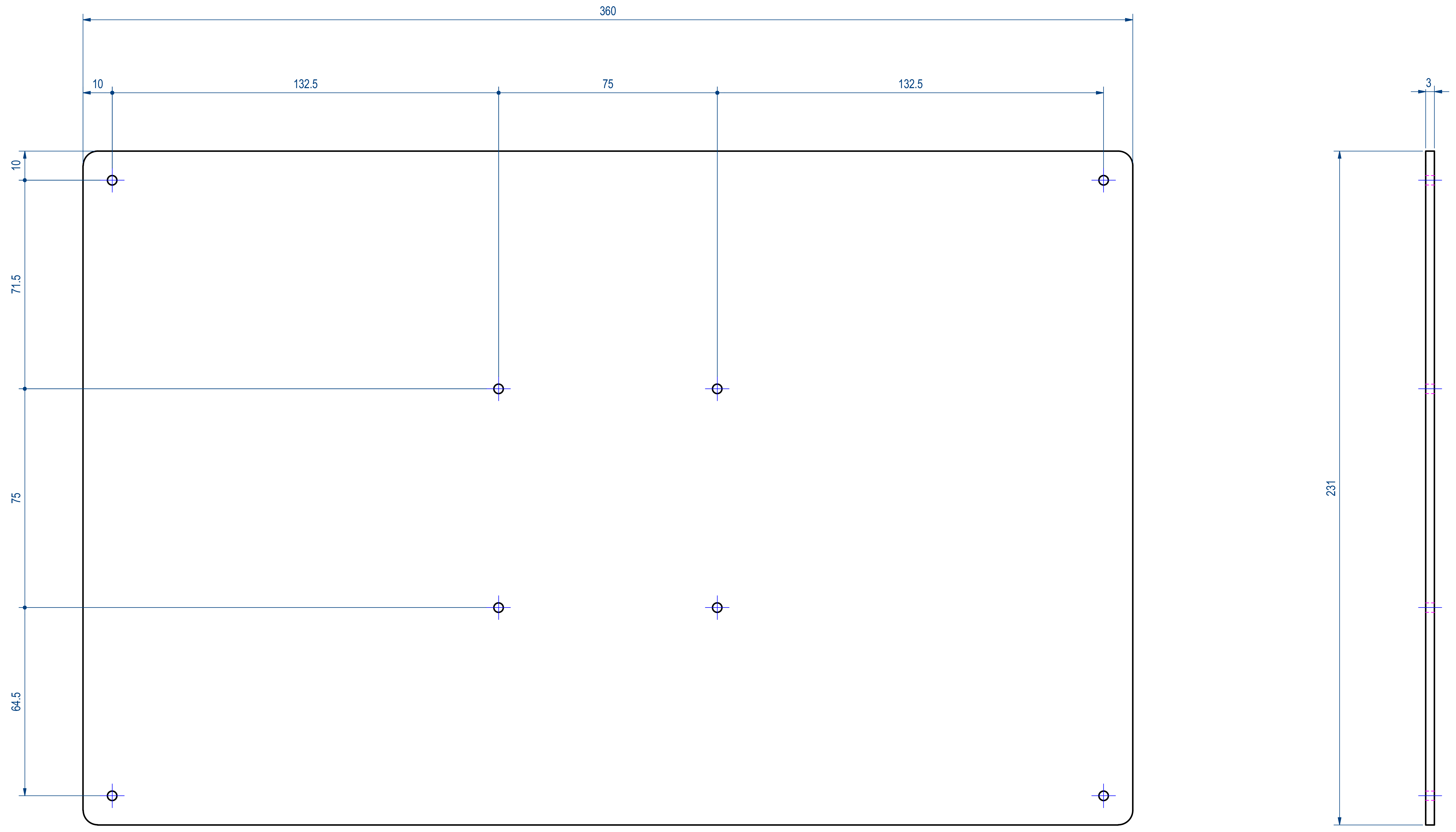
Unless otherwise specified
All dimensions are in millimeters (mm)

Designed: LOW ZHONG SHENG	Date: 6/8/2020	Project Title: OFFICE TRANSPORTER	
Checked: SILVANUS SNG	Date: 7/8/2020	Projection	Dwg No.
Project Supervisor: TAN TUAN KIAT	Date: 7/8/2020	Scale: 1:2	Sheet: 1 · Size: A2

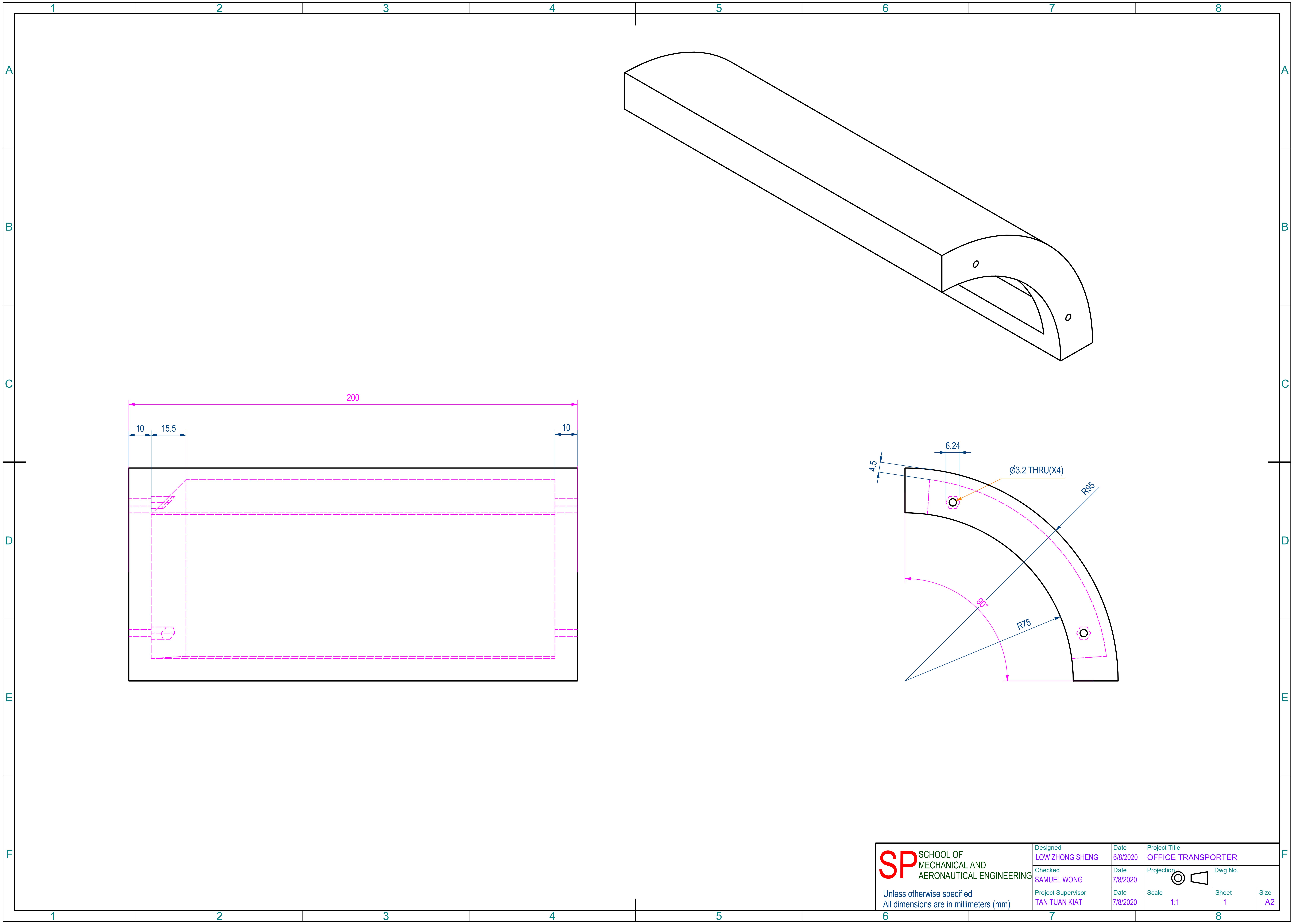
Hole Table			
HOLE	XDIM	YDIM	DESCRIPTION
A1	81.5	81.5	Ø19 THRU
B1	363	10	Ø3.2 THRU ⌵ Ø6 X 90°
B2	73.65	15.31	Ø3.2 THRU ⌵ Ø6 X 90°
B3	429.35	15.31	Ø3.2 THRU ⌵ Ø6 X 90°
B4	115	24.5	Ø3.2 THRU ⌵ Ø6 X 90°
B5	388	24.5	Ø3.2 THRU ⌵ Ø6 X 90°
B6	115	39.5	Ø3.2 THRU ⌵ Ø6 X 90°
B7	388	39.5	Ø3.2 THRU ⌵ Ø6 X 90°
B8	15.31	73.65	Ø3.2 THRU ⌵ Ø6 X 90°
B9	487.69	73.65	Ø3.2 THRU ⌵ Ø6 X 90°
B10	81.5	146	Ø3.2 THRU ⌵ Ø6 X 90°
B11	421.5	146	Ø3.2 THRU ⌵ Ø6 X 90°
B12	29.5	151.5	Ø3.2 THRU ⌵ Ø6 X 90°
B13	473.5	151.5	Ø3.2 THRU ⌵ Ø6 X 90°
B14	29.5	351.5	Ø3.2 THRU ⌵ Ø6 X 90°
B15	473.5	351.5	Ø3.2 THRU ⌵ Ø6 X 90°
B16	81.5	357	Ø3.2 THRU ⌵ Ø6 X 90°
B17	421.5	357	Ø3.2 THRU ⌵ Ø6 X 90°
B18	15.31	429.35	Ø3.2 THRU ⌵ Ø6 X 90°
B19	487.69	429.35	Ø3.2 THRU ⌵ Ø6 X 90°
B20	151.5	473.5	Ø3.2 THRU ⌵ Ø6 X 90°
B21	351.5	473.5	Ø3.2 THRU ⌵ Ø6 X 90°
B22	73.65	487.69	Ø3.2 THRU ⌵ Ø6 X 90°
B23	429.35	487.69	Ø3.2 THRU ⌵ Ø6 X 90°



SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed LOW ZHONG SHENG	Date 6/8/2020	Project Title OFFICE TRANSPORTER
	Checked SILVANUS SNG	Date 7/8/2020	Projection / Dwg No.
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor TAN TUAN KIAT	Date 7/8/2020	Scale 1:1 / Sheet 1 / Size A1



SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed LOW ZHONG SHENG	Date 6/8/2020	Project Title OFFICE TRANSPORTER		
	Checked SILVANUS SNG	Date 7/8/2020	Projection	Dwg No.	
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor TAN TUAN KIAT	Date 7/8/2020	Scale 1:1	Sheet 1	Size A2


200
10
15.5
10
6.24
4.5
Ø3.2 THRU(X4)
R95
90°
R75
SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING
Designed
LOW ZHONG SHENG
Date
6/8/2020
Project Title
OFFICE TRANSPORTER
Checked
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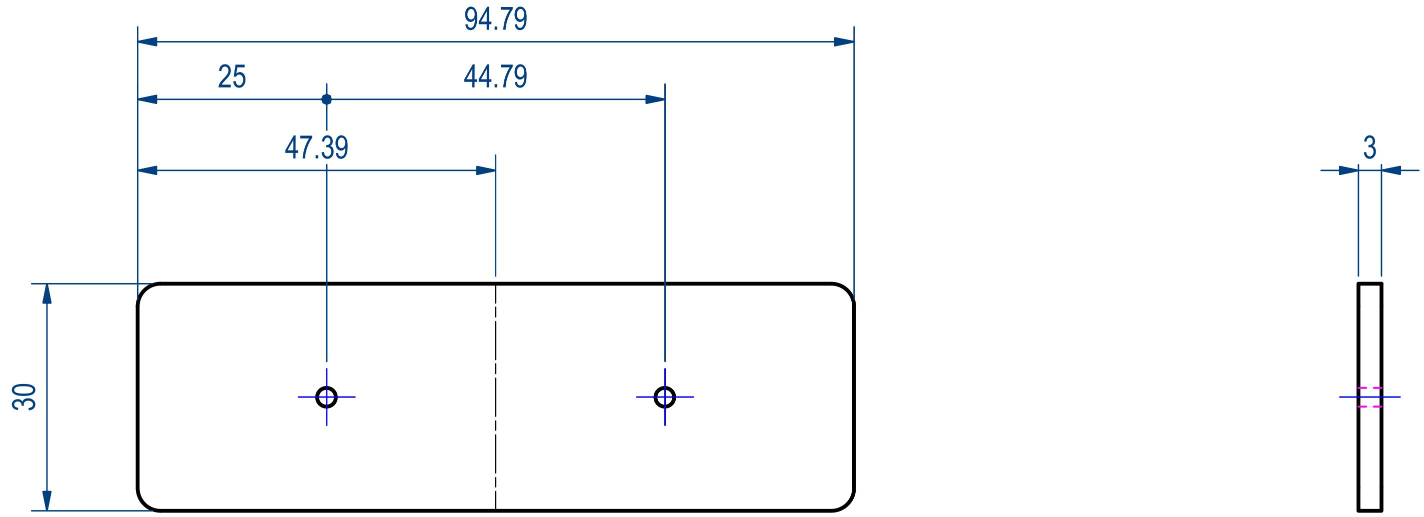
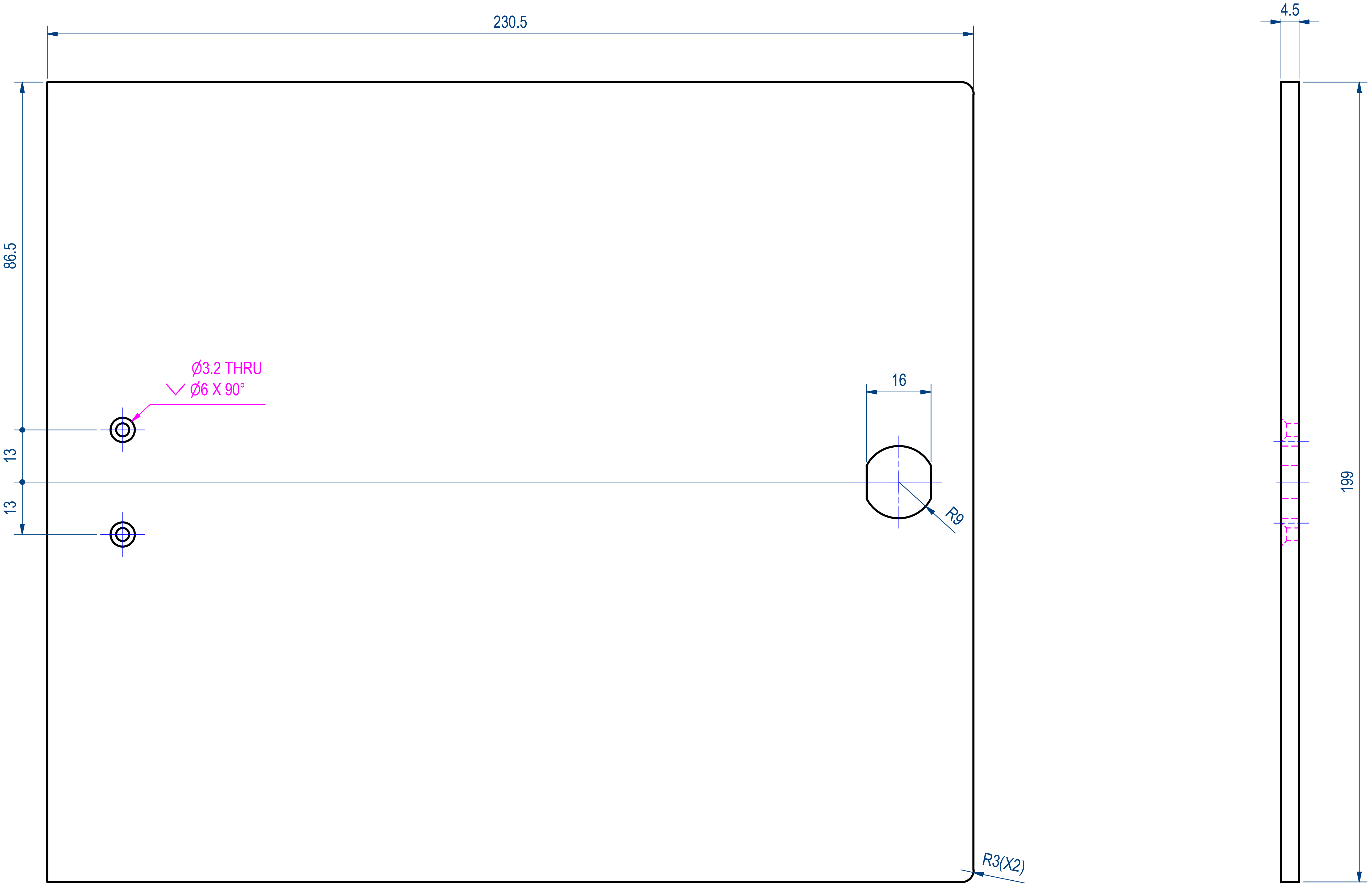
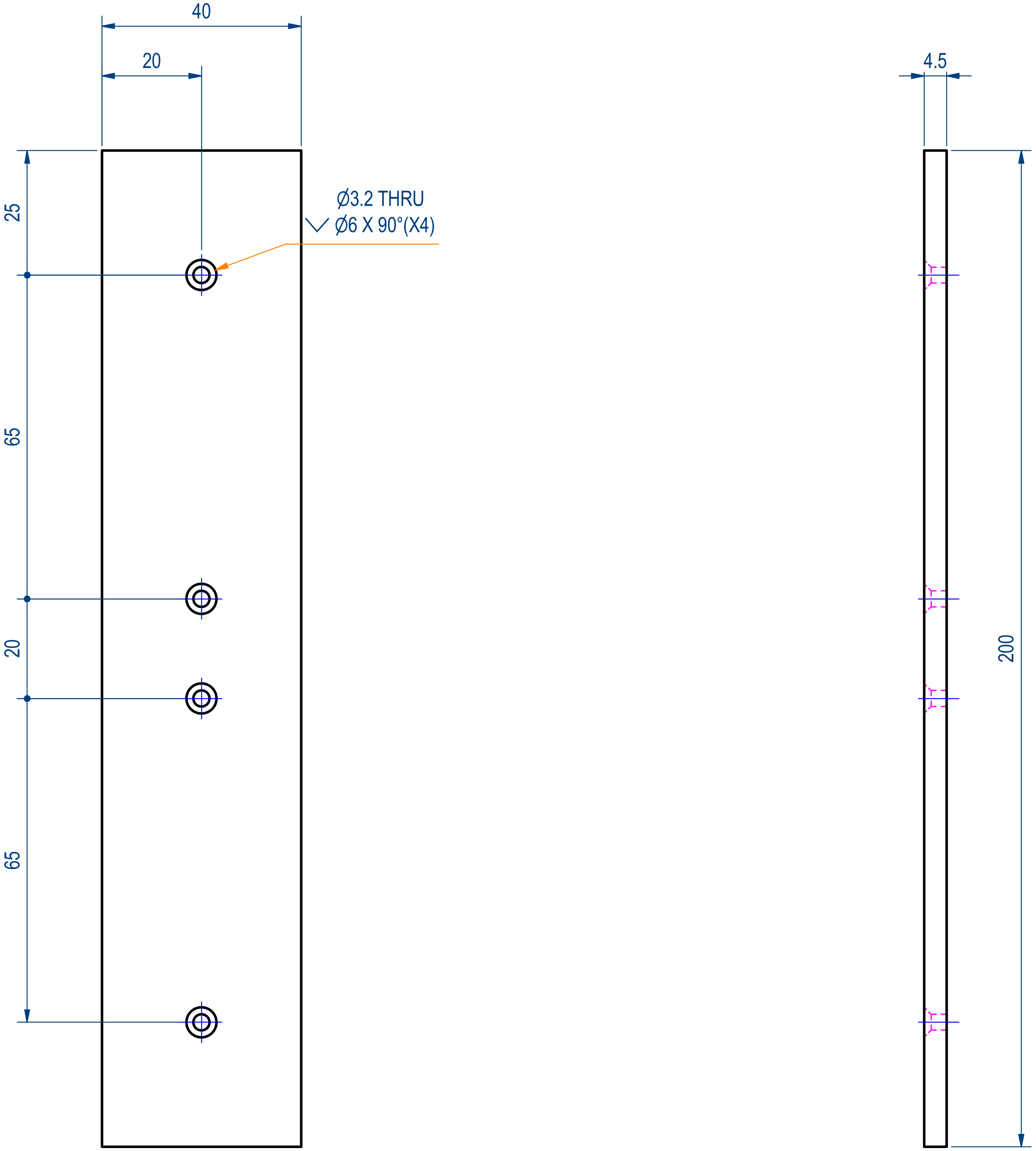
Date
7/8/2020
Projection
Dwg No.
Unless otherwise specified
All dimensions are in millimeters (mm)
Project Supervisor
TAN TUAN KIAT
Date
7/8/2020
Scale
1:1
Sheet
1
Size
A2



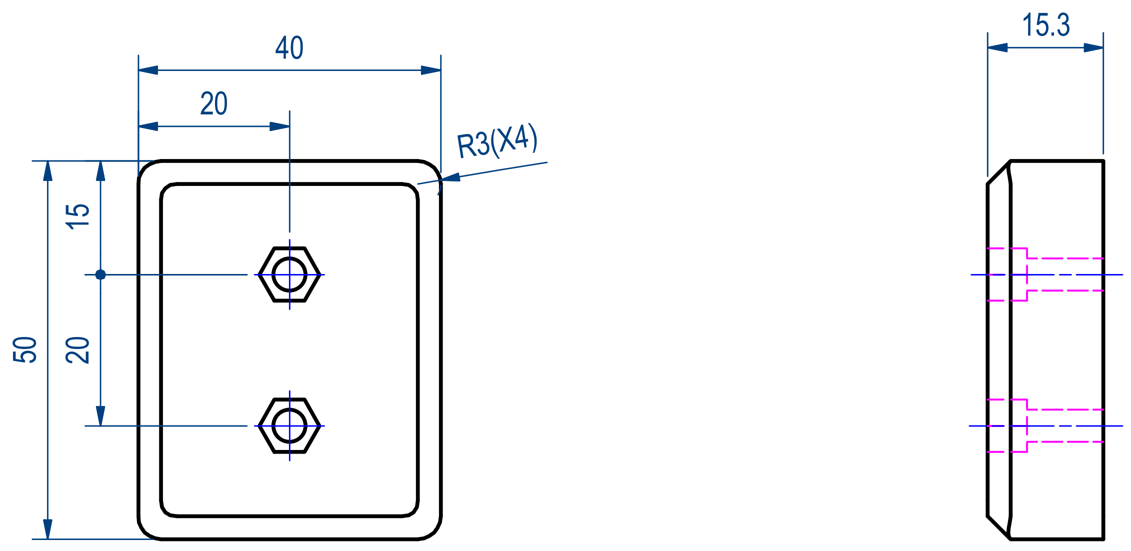
SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed LOW ZHONG SHENG	Date 6/8/2020	Project Title OFFICE TRANSPORTER		
	Checked SILVANUS SNG	Date 7/8/2020	Projection	Dwg No.	
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor TAN TUAN KIAT	Date 7/8/2020	Scale 1:1	Sheet 1	Size A4



SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed: LOW ZHONG SHENG	Date: 6/8/2020	Project Title: OFFICE TRANSPORTER		
	Checked: SILVANUS SNG	Date: 7/8/2020	Projection	Dwg No.	
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor: TAN TUAN KIAT	Date: 7/8/2020	Scale: 1:1	Sheet: 1	Size: A3



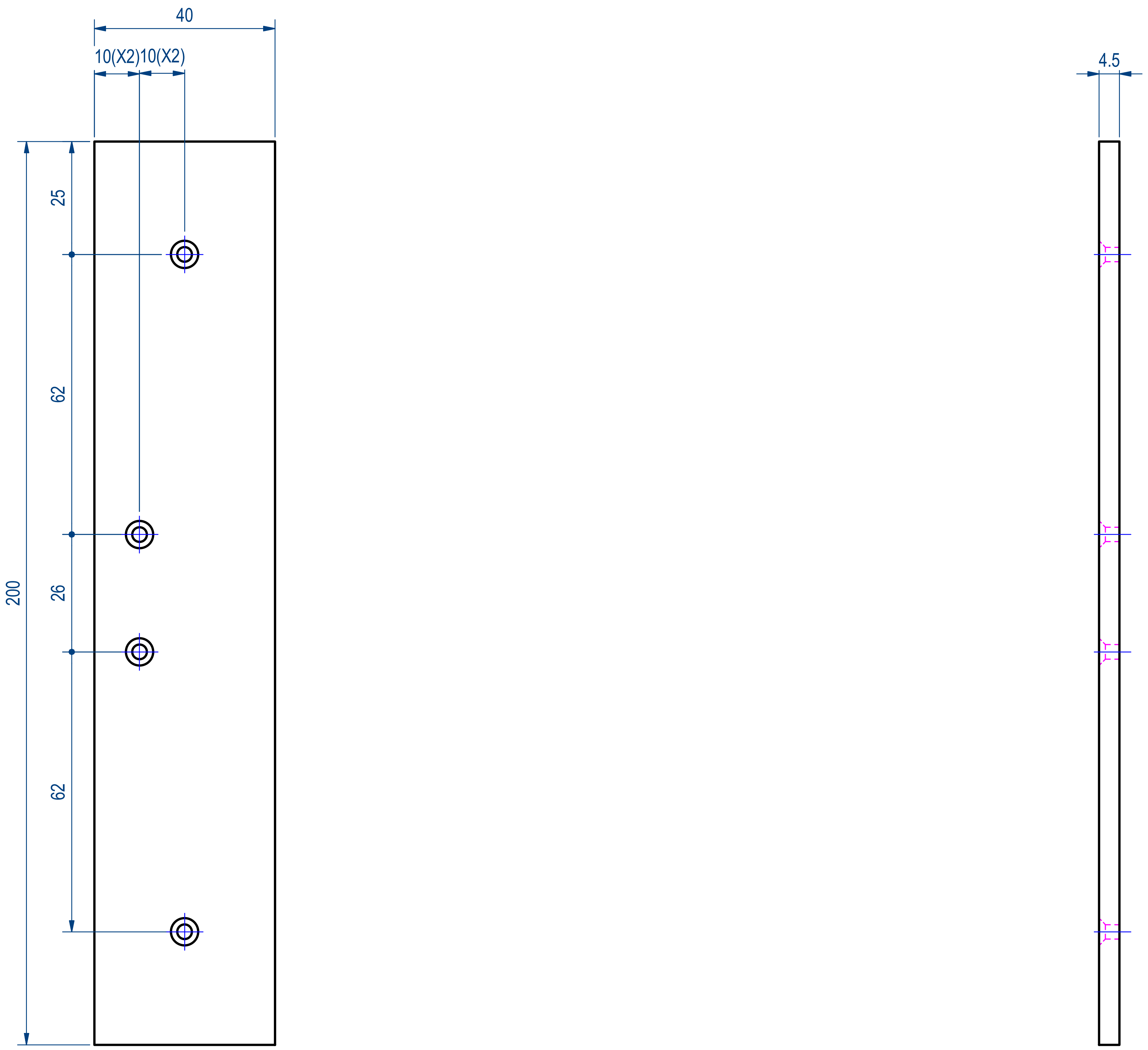
SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed: LOW ZHONG SHENG	Date: 6/8/2020	Project Title: OFFICE TRANSPORTER		
	Checked: SAMUEL WONG	Date: 7/8/2020	Projection	Dwg No.	
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor: TAN TUAN KIAT	Date: 7/8/2020	Scale: 1:1	Sheet: 1	Size: A3



SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING

Designed	Date	Project Title	
LOW ZHONG SHENG	6/8/2020	OFFICE TRANSPORTER	
Checked	Date	Projection	Dwg No.
SAMUEL WONG	7/8/2020		
Project Supervisor	Date	Scale	Sheet / Size
TAN TUAN KIAT	7/8/2020	1:1	1 / A4

Unless otherwise specified
All dimensions are in millimeters (mm)



SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed: LOW ZHONG SHENG	Date: 6/8/2020	Project Title: OFFICE TRANSPORTER		
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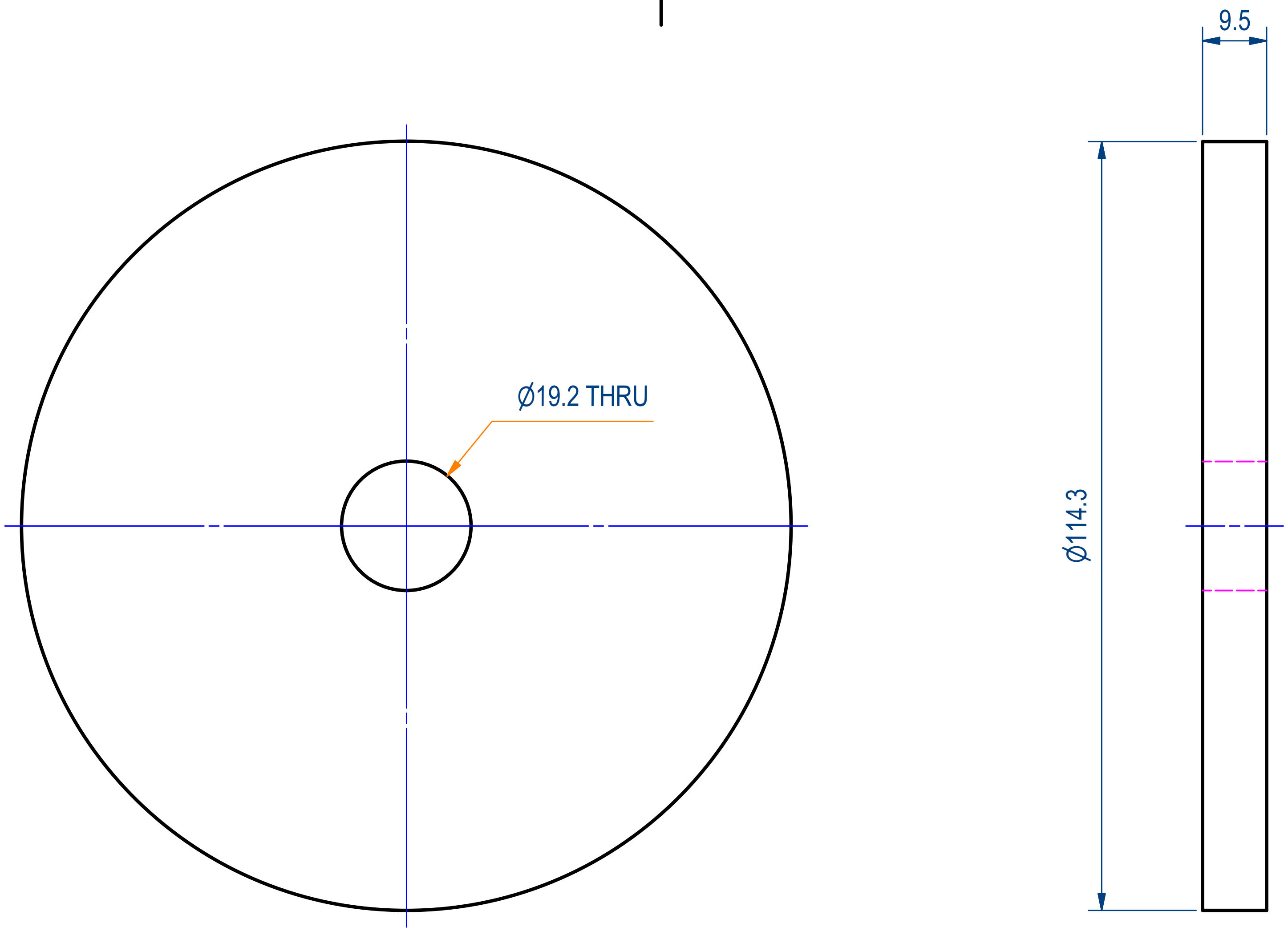

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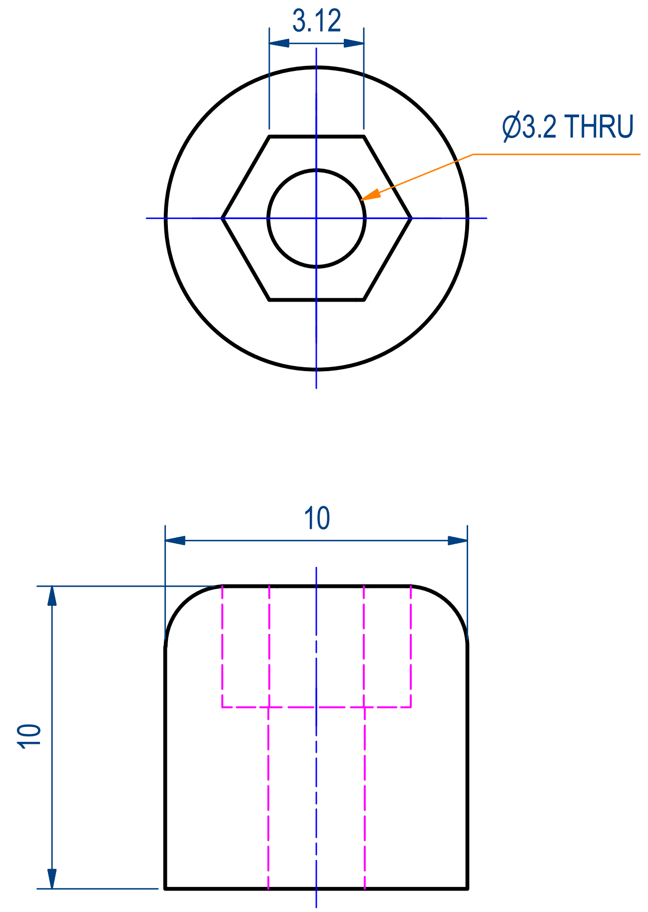

SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed LOW ZHONG SHENG	Date 6/8/2020	Project Title OFFICE TRANSPORTER		
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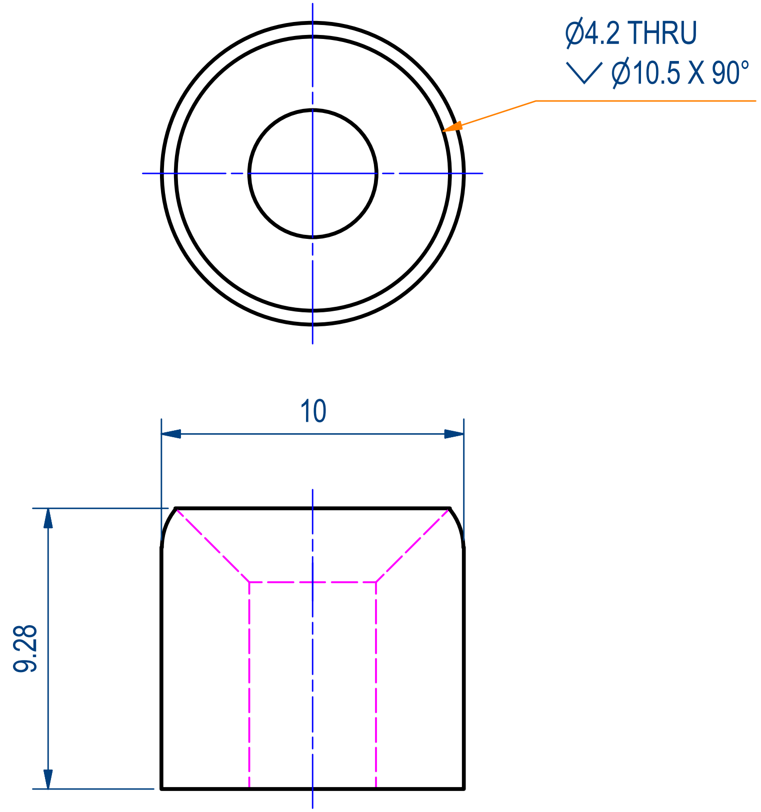

SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed LOW ZHONG SHENG	Date 6/8/2020	Project Title OFFICE TRANSPORTER		
	Checked SILVANUS SNG	Date 7/8/2020	Projection	Dwg No.	
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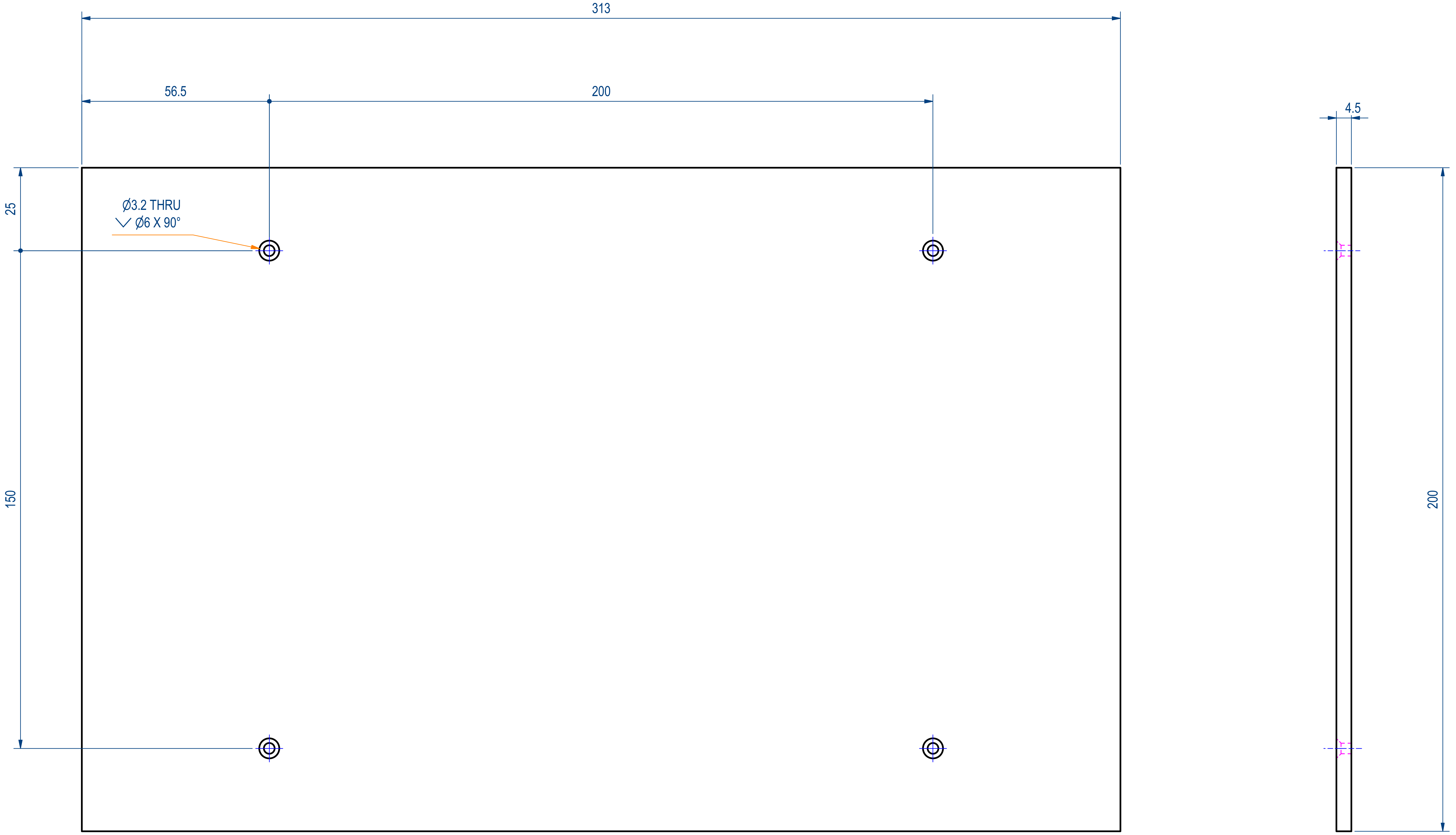
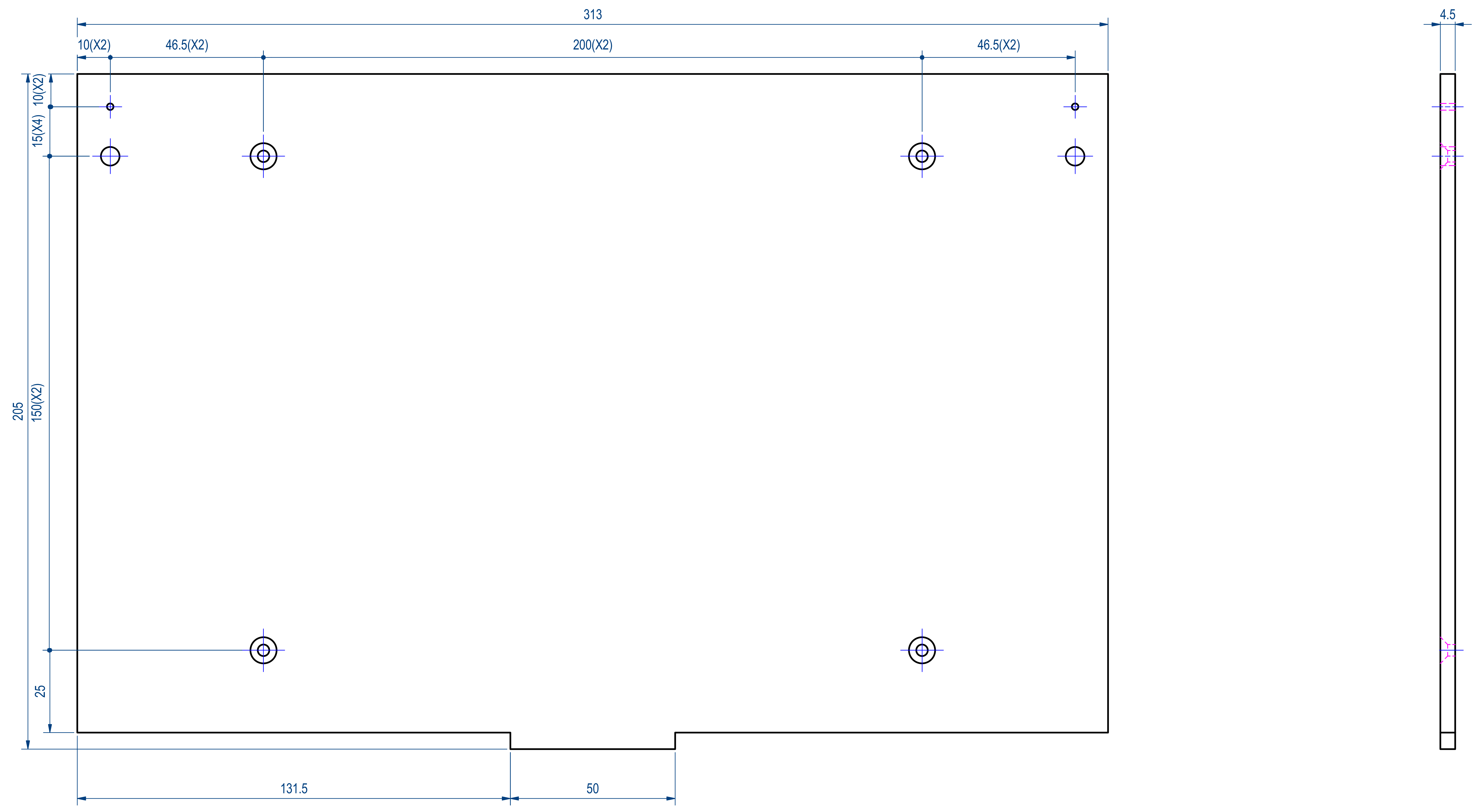
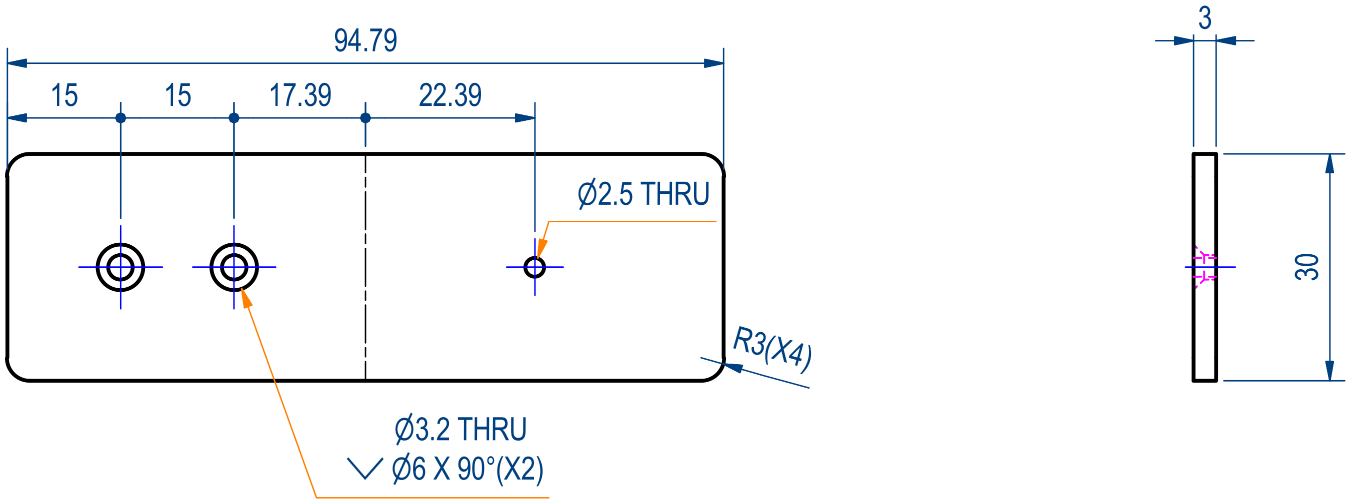


SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed LOW ZHONG SHENG	Date 6/8/2020	Project Title OFFICE TRANSPORTER			
	Checked SILVANUS SNG	Date 7/8/2020	Projection	Dwg No.		
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor TAN TUAN KIAT	Date 7/8/2020	Scale 1:1	Sheet 1	Size A2	



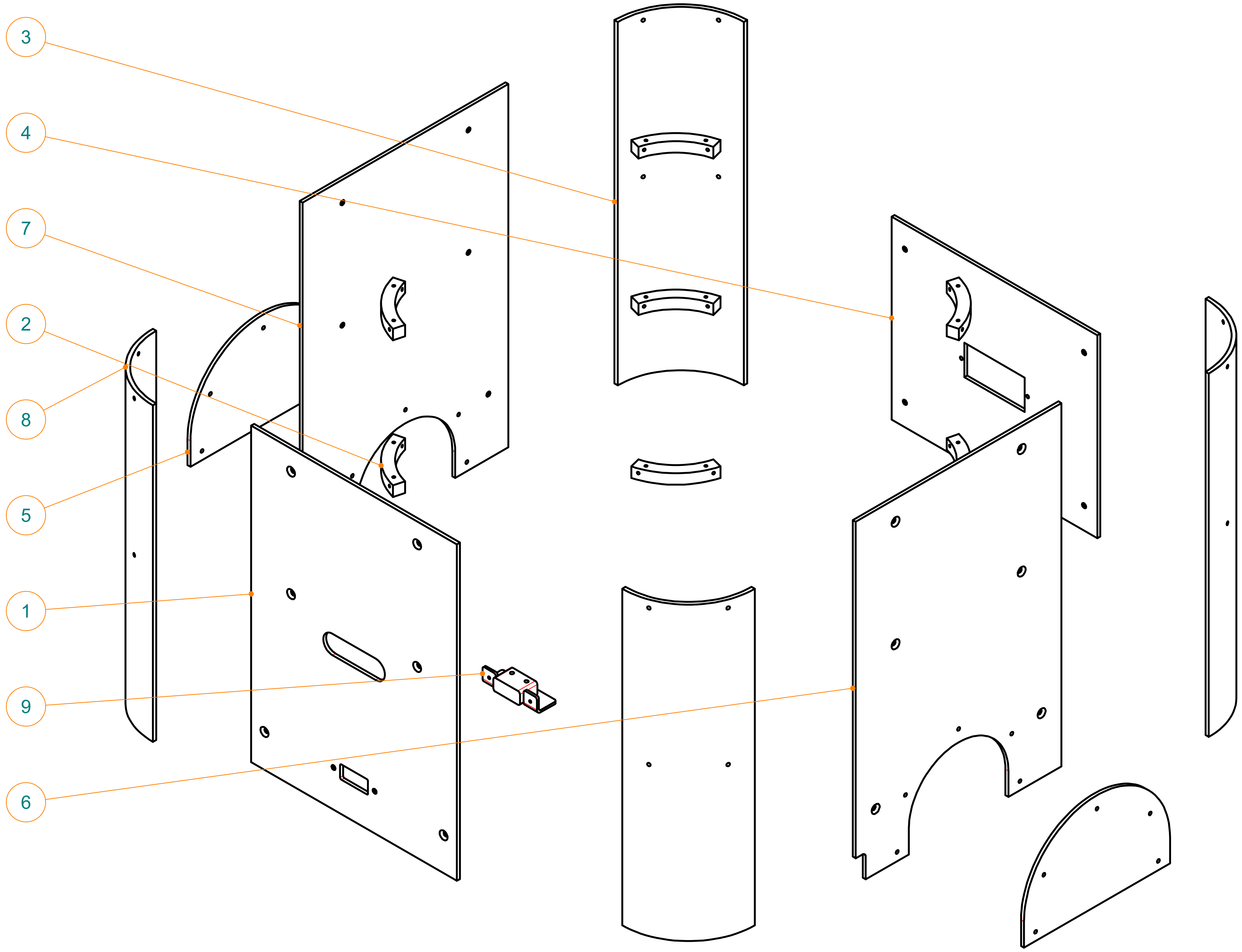
SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed: LOW ZHONG SHENG	Date: 6/8/2020	Project Title: OFFICE TRANSPORTER			
	Checked: SAMUEL WONG	Date: 7/8/2020	Projection		Dwg No.	
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor: TAN TUAN KIAT	Date: 7/8/2020	Scale: 1:1		Sheet: 1	Size: A2



SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed LOW ZHONG SHENG	Date 6/8/2020	Project Title OFFICE TRANSPORTER		
	Checked SILVANUS SNG	Date 7/8/2020	Projection	Dwg No.	
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor TAN TUAN KIAT	Date 7/8/2020	Scale 1:1	Sheet 1	Size A4

Parts List

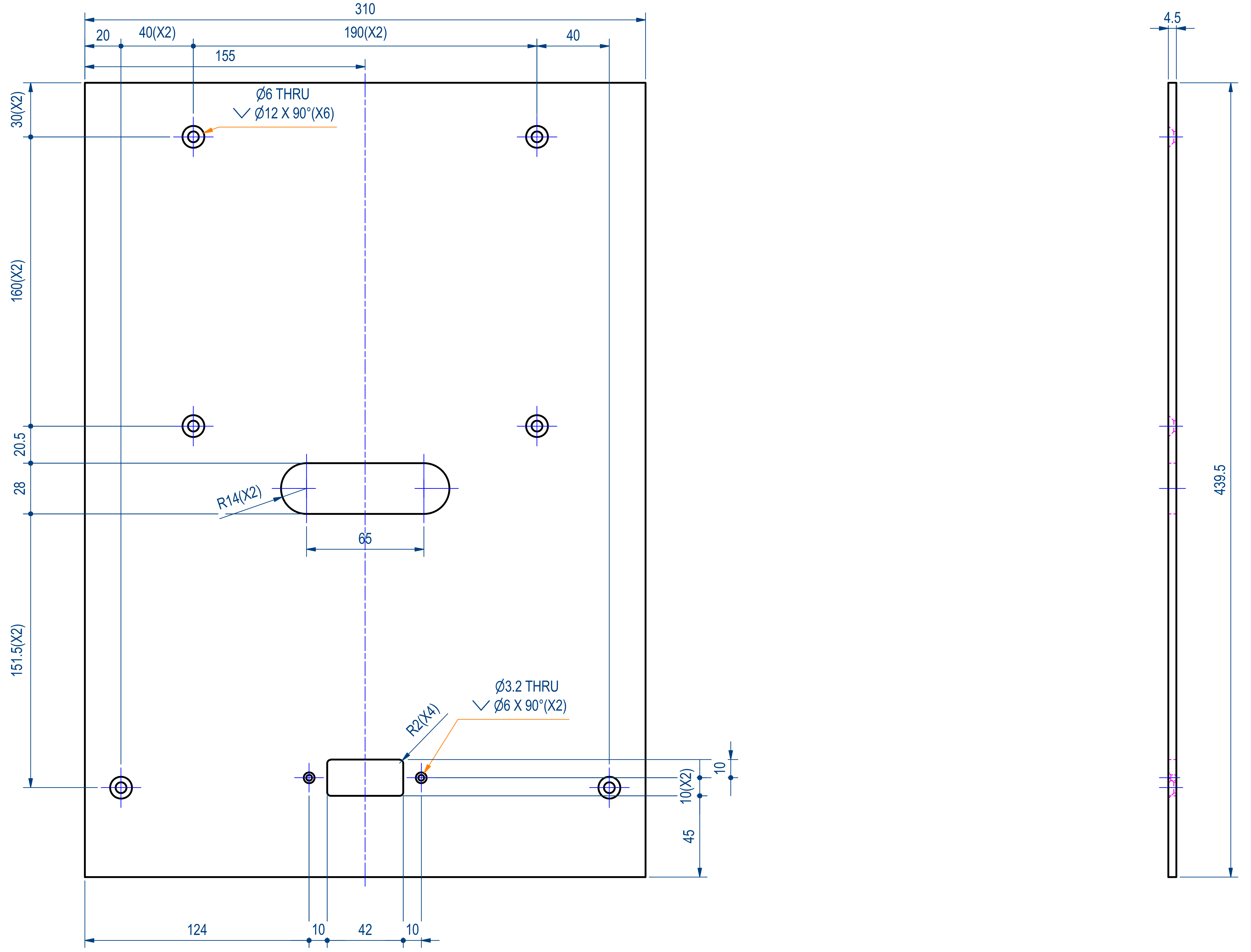
ITEM	DESCRIPTION	QTY	MATERIAL
1	Front Panel	1	Polycarbonate
2	Corner Panel Mounts	8	Aluminium
3	Back Corner Panel	2	PVC
4	Back Panel	1	Polycarbonate
5	Wheel Guard	2	Polycarbonate
6	Left Side Panels	1	Polycarbonate
7	Right Side Panels	1	Polycarbonate
8	Front Corner Panel	2	Polycarbonate
9	RFID Mount	1	Aluminium



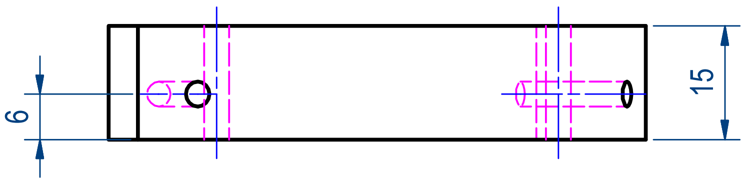
SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING

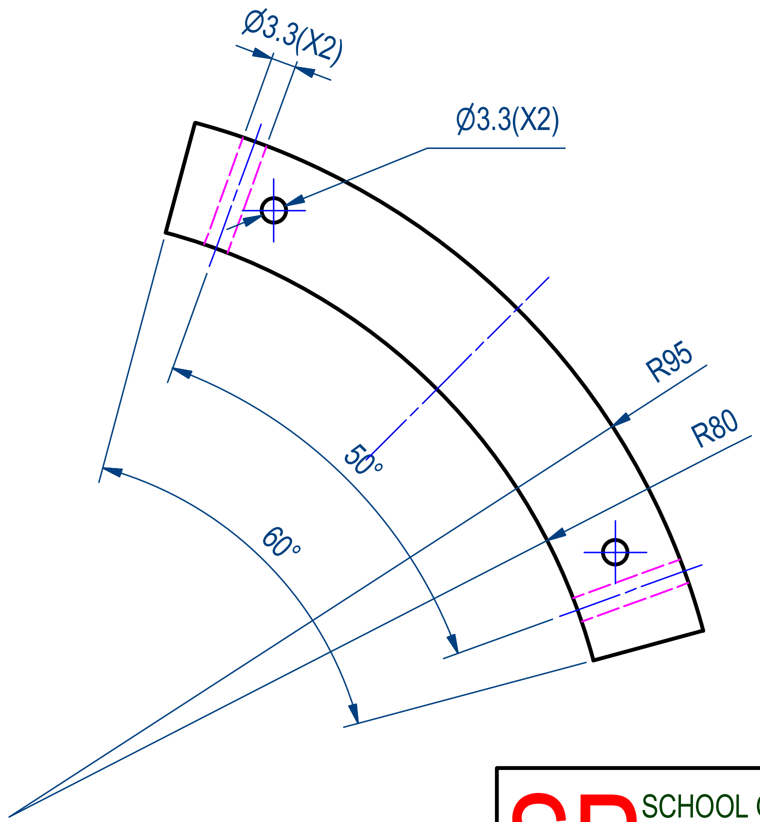
Designed	LOW ZHONG SHENG	Date	6/8/2020	Project Title	OFFICE TRANSPORTER
Checked	SILVANUS SNG	Date	7/8/2020	Projection	Dwg No.
Project Supervisor	TAN TUAN KIAT	Date	7/8/2020	Scale 1:4	Sheet 1 / Size A2

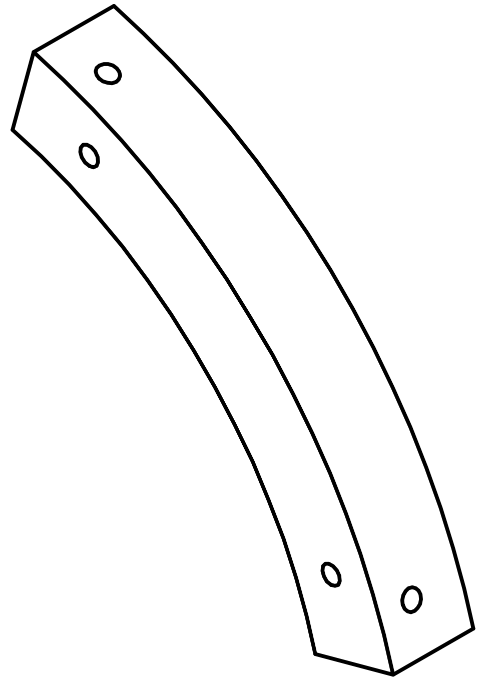
Unless otherwise specified
All dimensions are in millimeters (mm)



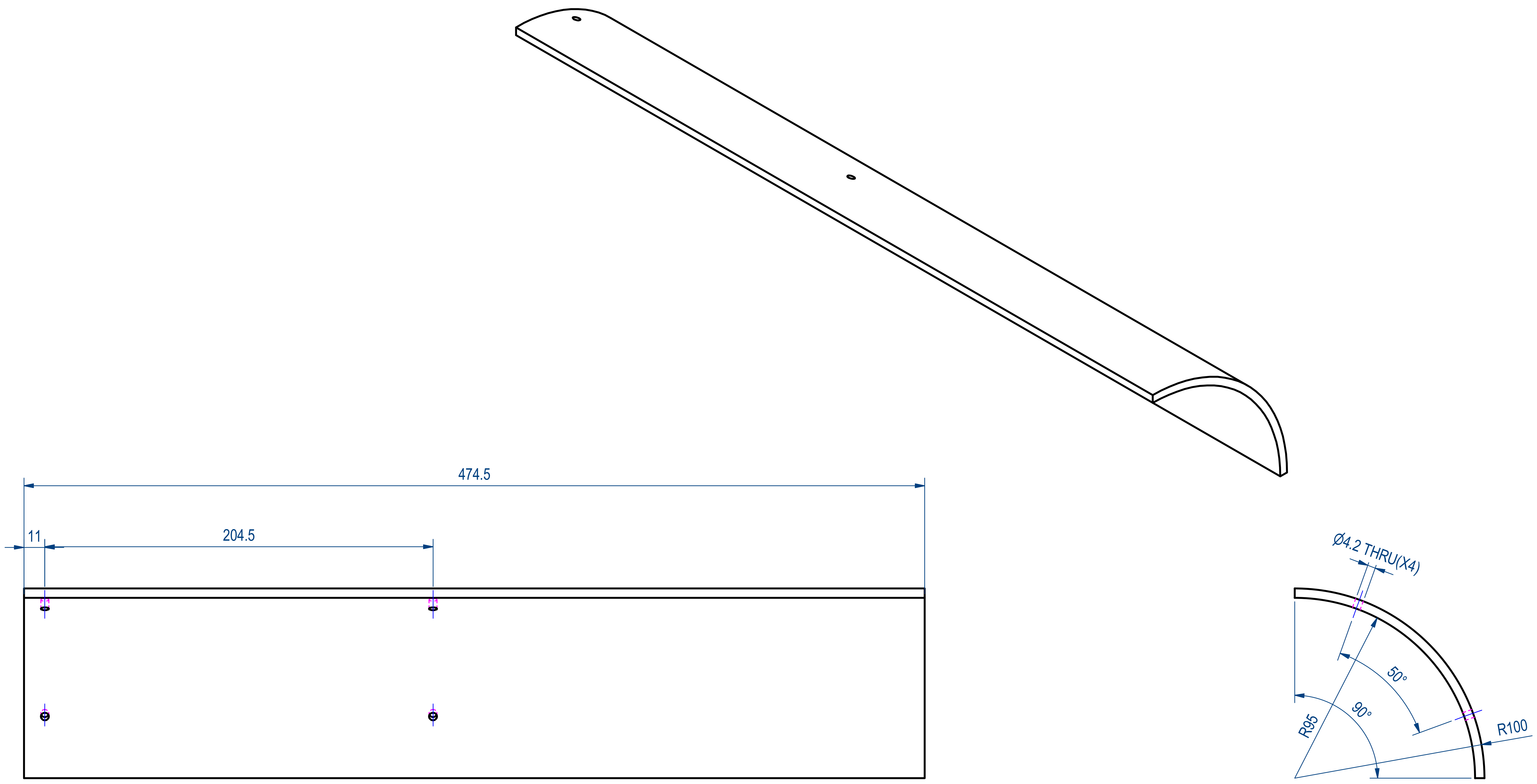
SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed LOW ZHONG SHENG	Date 6/8/2020	Project Title OFFICE TRANSPORTER	
	Checked SAMUEL WONG	Date 7/8/2020	Projection	Dwg No.
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor TAN TUAN KIAT	Date 7/8/2020	Scale 1:2	Sheet 1 / Size A2



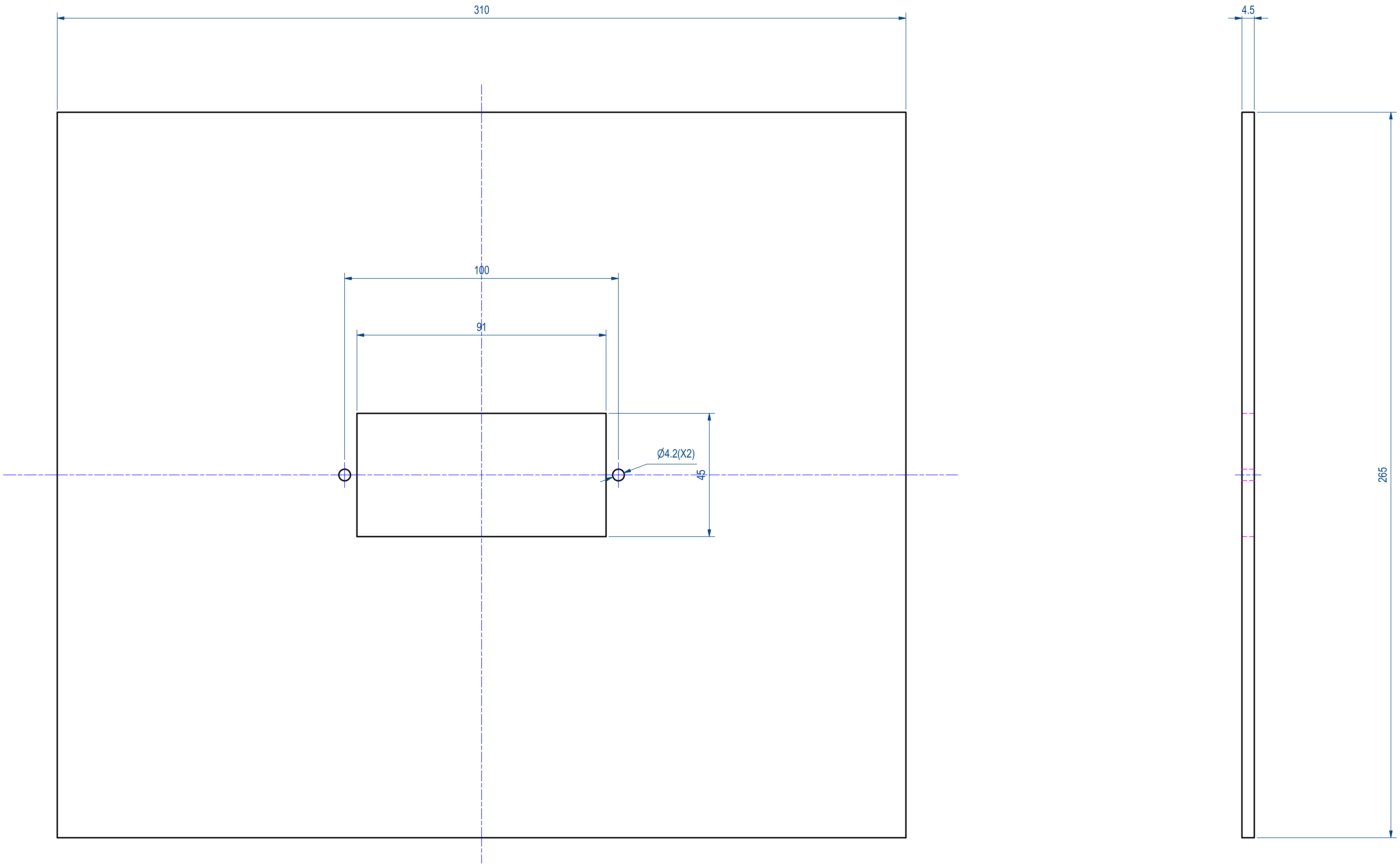




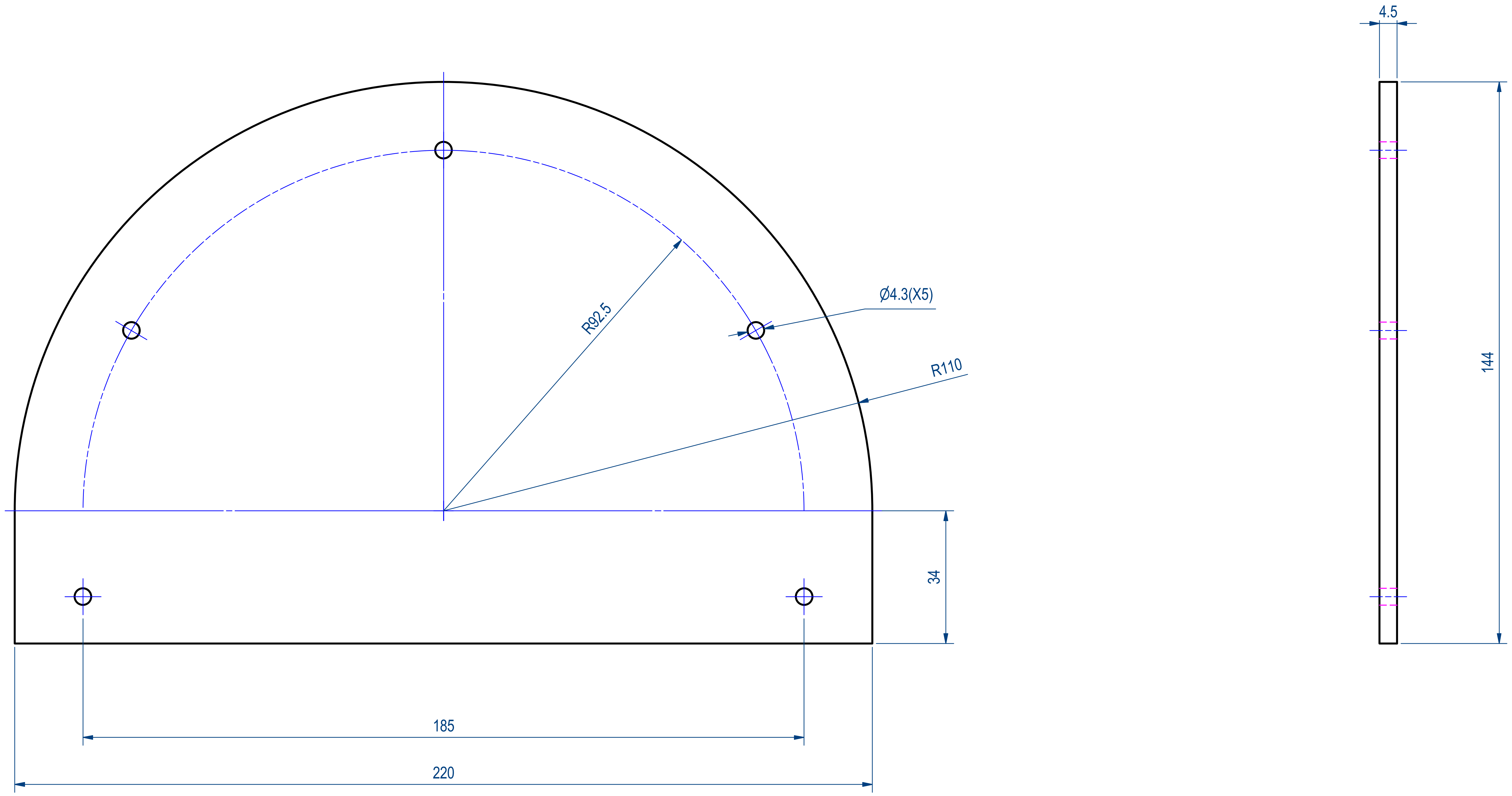
SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed SAMUEL WONG	Date 6/8/2020	Project Title OFFICE TRANSPORTER		
	Checked LOW ZHONG SHENG	Date 7/8/2020	Projection	Dwg No.	
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor TAN TUAN KIAT	Date 7/8/2020	Scale 1:1	Sheet 1	Size A4



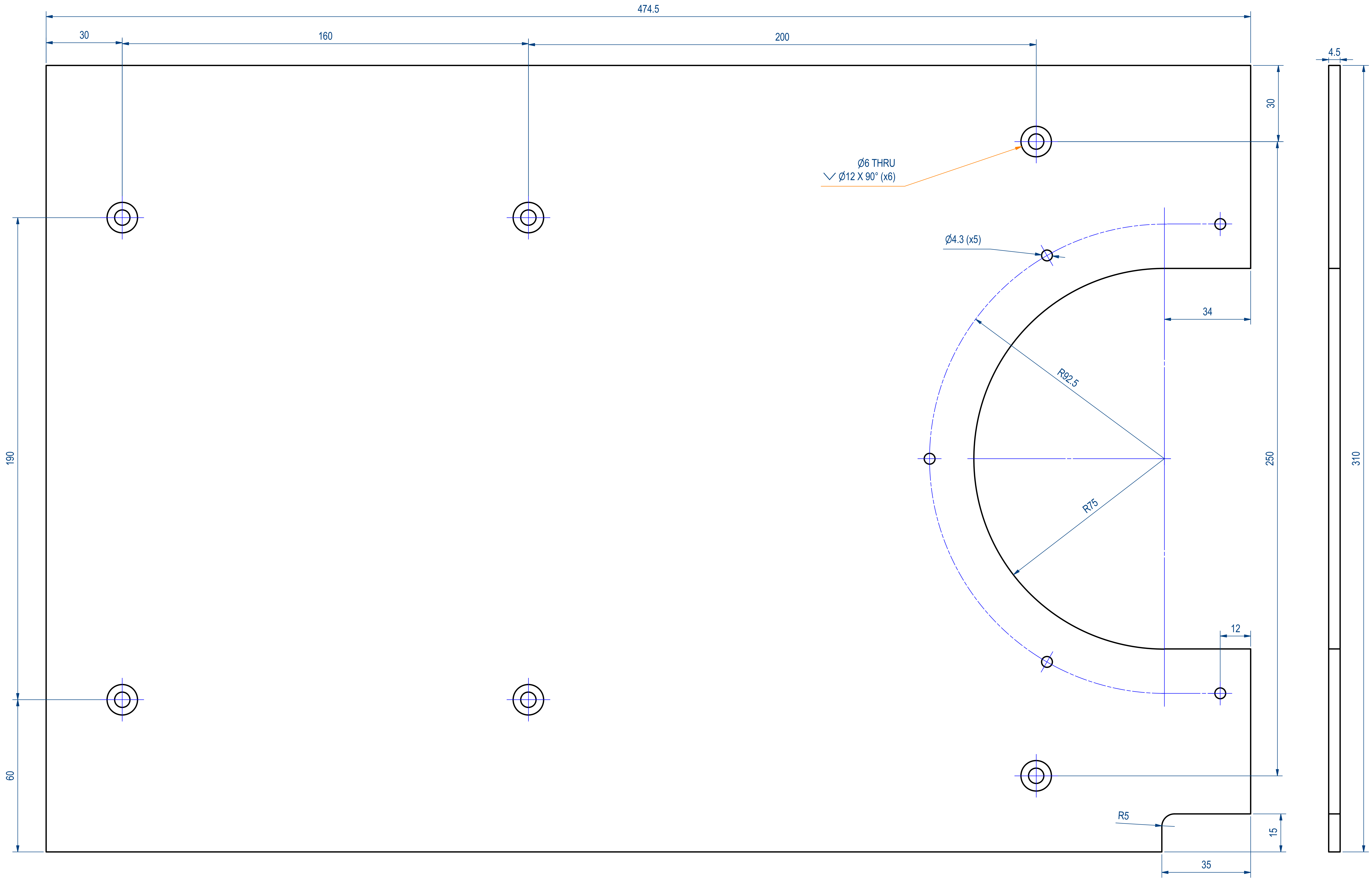
SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed: LOW ZHONG SHENG	Date: 6/8/2020	Project Title: OFFICE TRANSPORTER		
	Checked: SAMUEL WONG	Date: 7/8/2020	Projection	Dwg No.	
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor: TAN TUAN KIAT	Date: 7/8/2020	Scale: 1:2	Sheet: 1	Size: A2



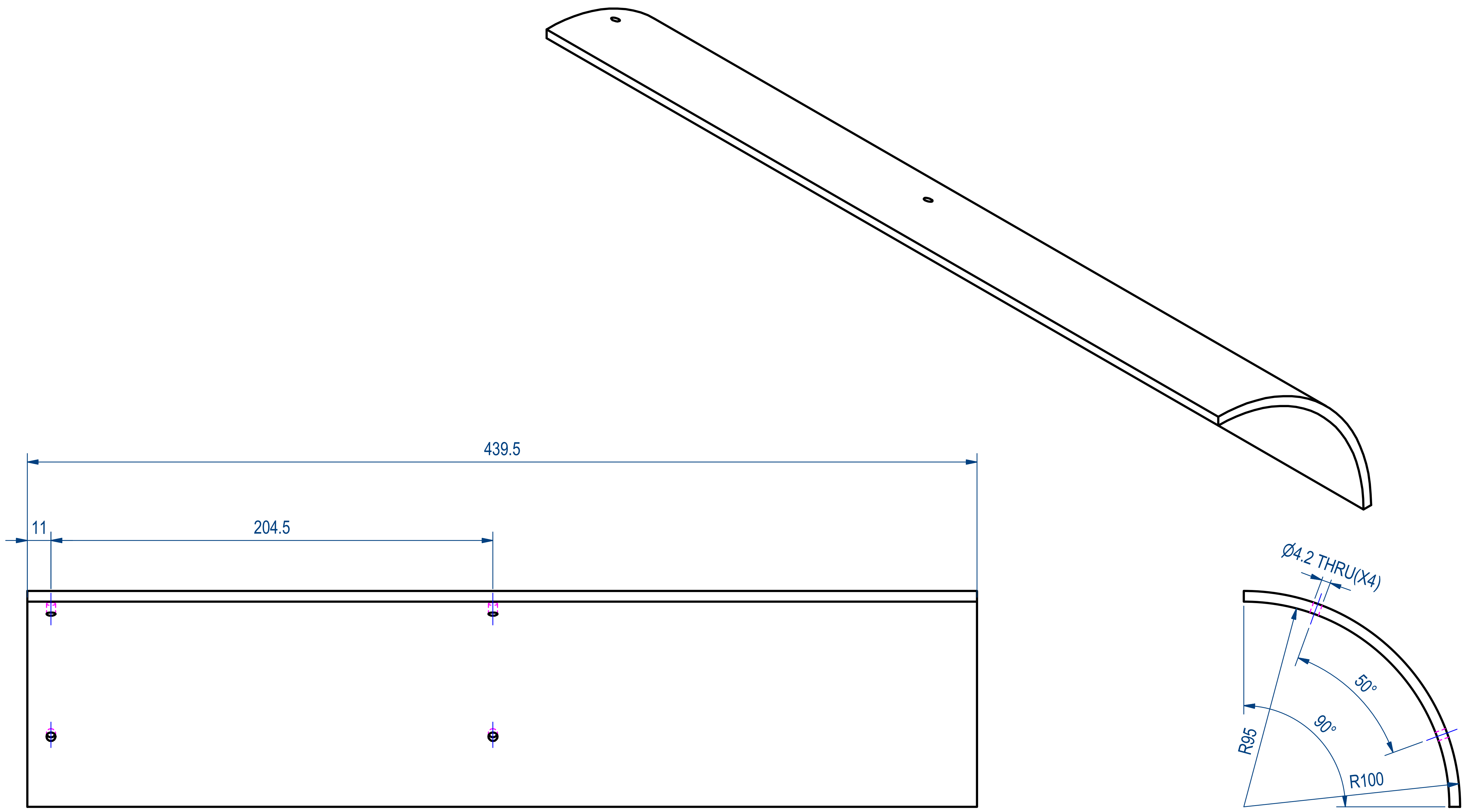
SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed SAMUEL WONG	Date 6/8/2020	Project Title OFFICE TRANSPORTER		
	Checked LOW ZHONG SHENG	Date 7/8/2020	Projection	Dwg No.	
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor TAN TUAN KIAT	Date 7/8/2020	Scale 1:1	Sheet 1	Size A2



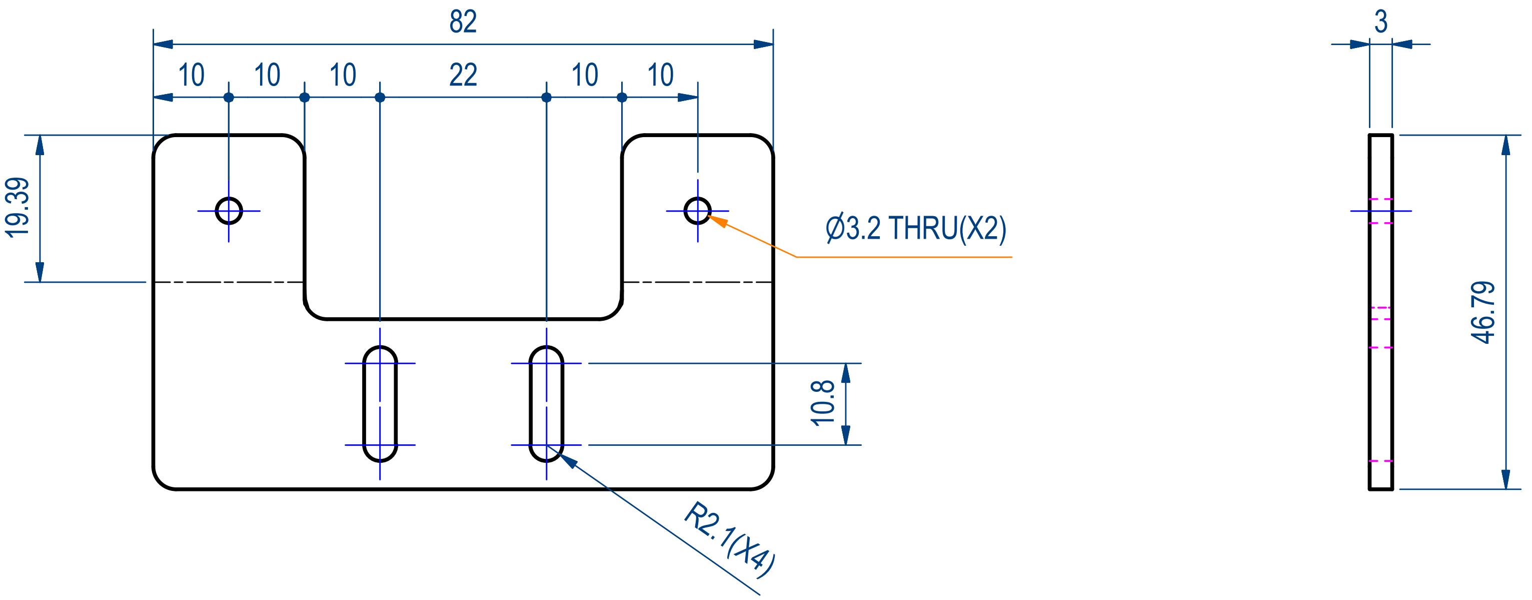
SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed: LOW ZHONG SHENG	Date: 6/8/2020	Project Title: OFFICE TRANSPORTER		
	Checked: SAMUEL WONG	Date: 7/8/2020	Projection	Dwg No.	
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor: TAN TUAN KIAT	Date: 7/8/2020	Scale: 1:1	Sheet: 1	Size: A2



SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed LOW ZHONG SHENG	Date 6/8/2020	Project Title OFFICE TRANSPORTER	
	Checked SAMUEL WONG	Date 7/8/2020	Projection	Dwg No.
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor TAN TUAN KIAT	Date 7/8/2020	Scale 1:1	Sheet 1 / Size A2



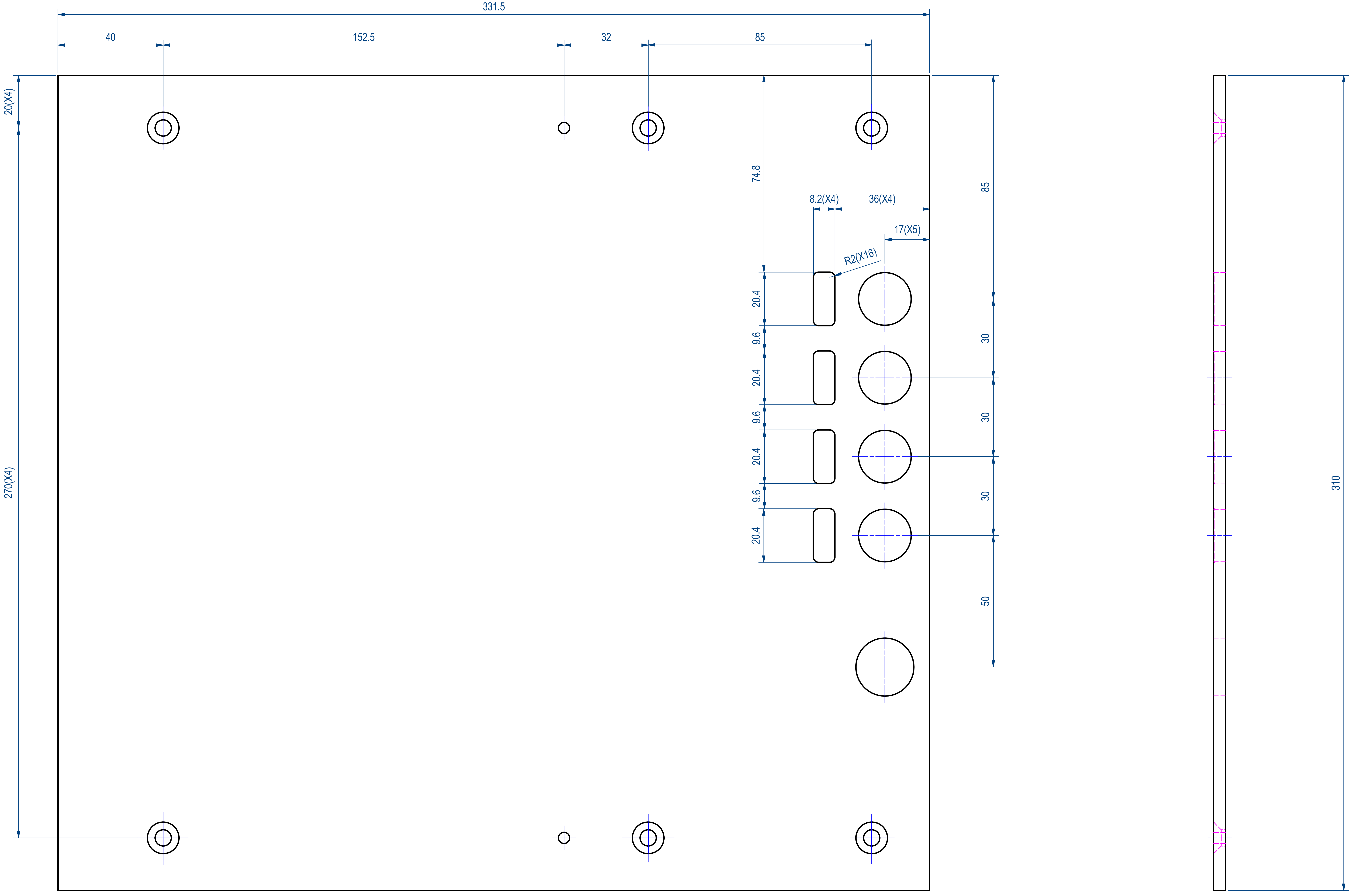
SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed SAMUEL WONG	Date 6/8/2020	Project Title OFFICE TRANSPORTER		
	Checked LOW ZHONG SHENG	Date 7/8/2020	Projection	Dwg No.	
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor TAN TUAN KIAT	Date 7/8/2020	Scale 1:2	Sheet 1	Size A3



SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING

Unless otherwise specified
All dimensions are in millimeters (mm)

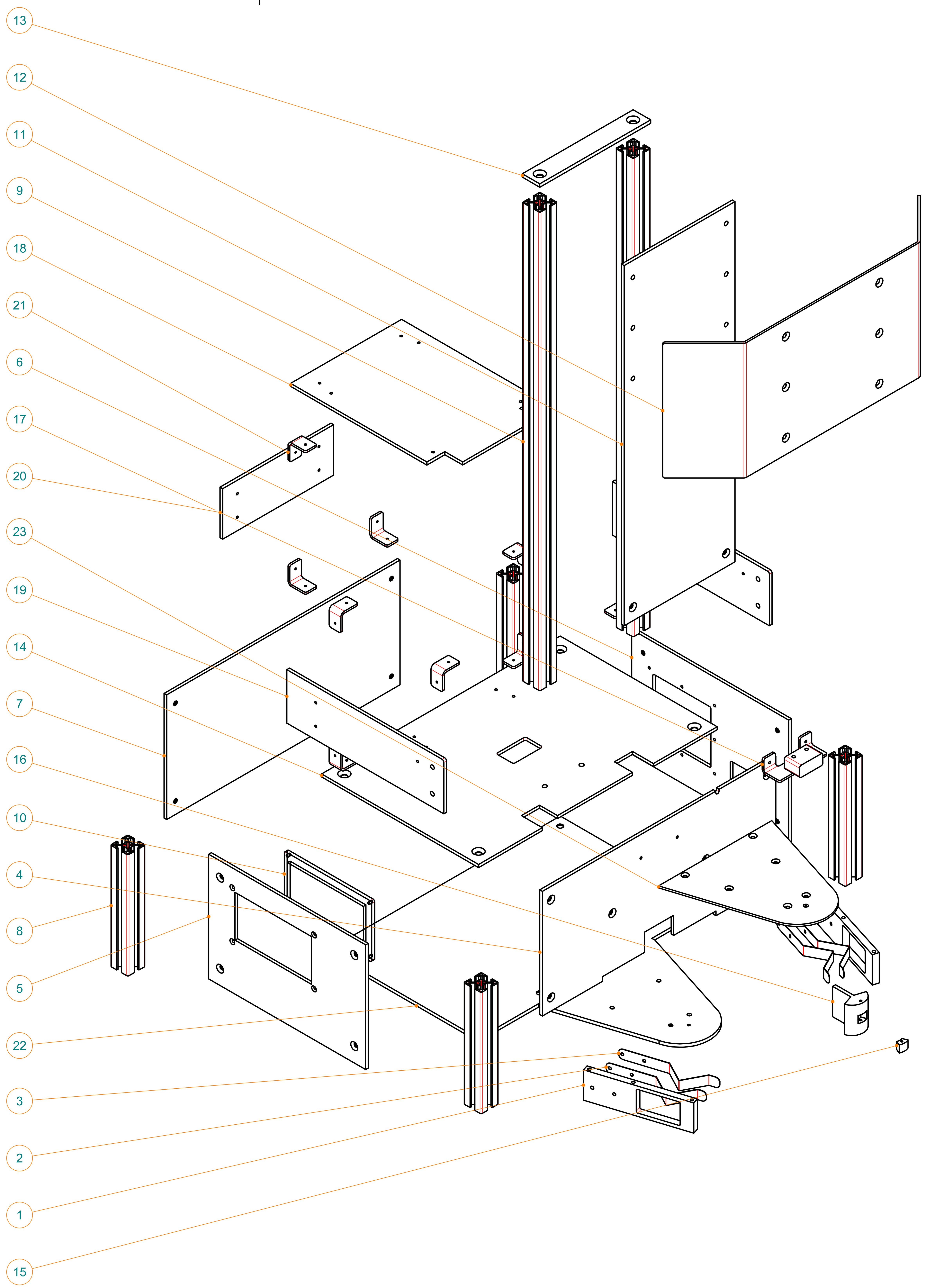
Designed	LOW ZHONG SHENG	Date	6/8/2020	Project Title	OFFICE TRANSPORTER
Checked	SILVAUNS SNG	Date	7/8/2020	Projection	Dwg No.
Project Supervisor	TAN TUAN KIAT	Date	7/8/2020	Scale 1:1	Sheet 1 / Size A4



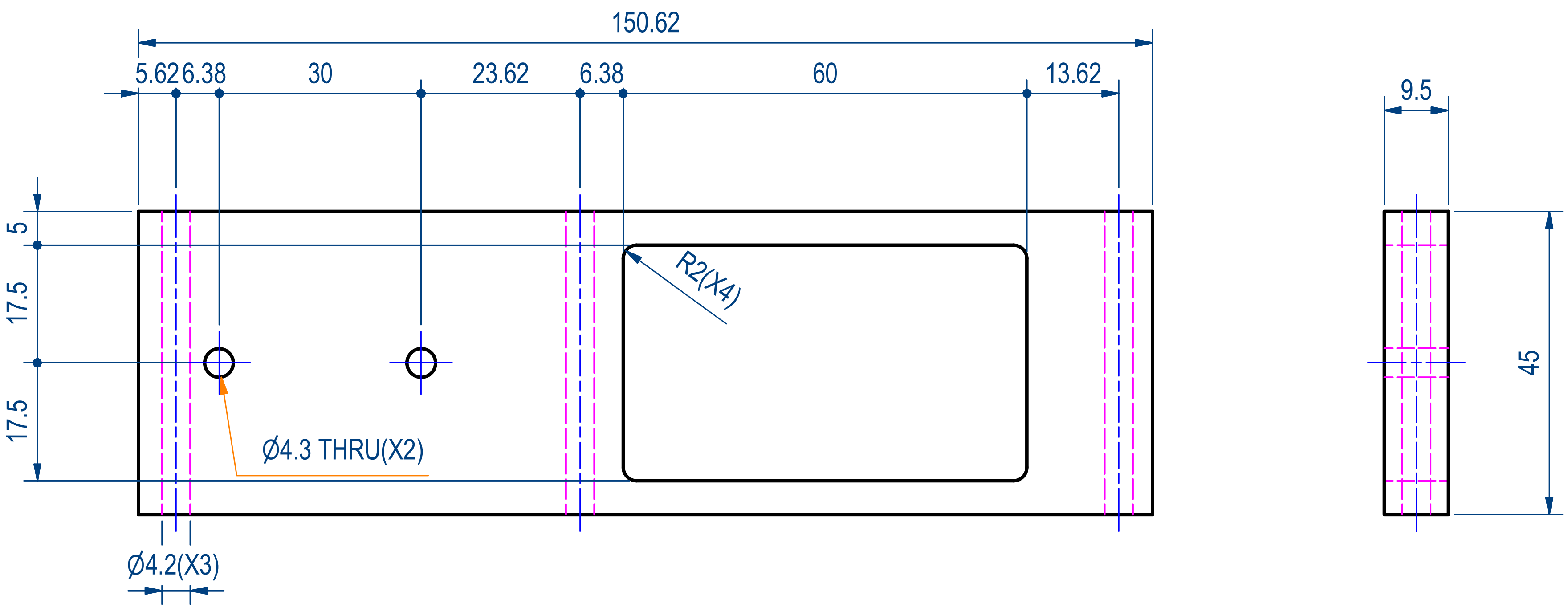
SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed LOW ZHONG SHENG	Date 6/8/2020	Project Title OFFICE TRANSPORTER		
	Checked SILVANUS SNG	Date 7/8/2020	Projection	Dwg No.	
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor TAN TUAN KIAT	Date 7/8/2020	Scale 1:1	Sheet 1	Size A2

Parts List

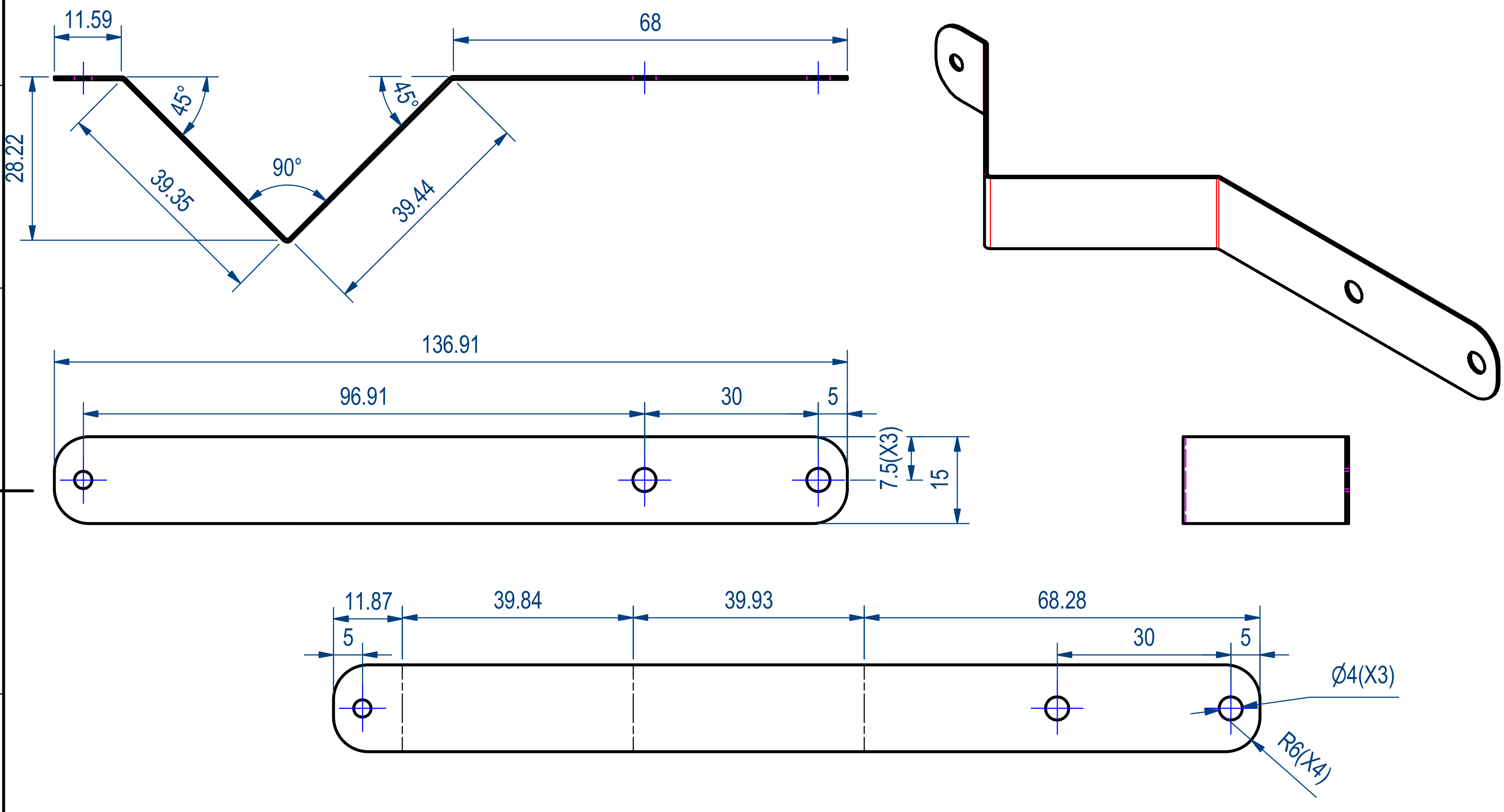
ITEM	DESCRIPTION	QTY	MATERIAL
1	Copper Contact Mount	2	Polycarbonate
2	Copper Contact	2	Copper
3	Spring Steel Support	2	Spring Steel
4	Charging Station Front Panel	1	Polycarbonate
5	Charging Station Left Panel	1	Polycarbonate
6	Charging Station Right Panel	1	Polycarbonate
7	Charging Station Back Panel	1	Polycarbonate
8	182mm Profile	4	Aluminium
9	712mm Profile	2	Aluminium
10	Display Window	1	Polycarbonate
11	Stand Panel	1	Polycarbonate
12	Lidar Dock Shape	1	Aluminium
13	Charging Station Handle	1	Aluminium
14	Charging Station Lid	1	Polycarbonate
15	Metal for 3D print	1	Aluminium
16	3D Printed Corner Piece	1	PLA
17	RFID Mount	1	Aluminium
18	Top Panel for Contactor Box	1	Polycarbonate
19	Side Panel for Contactor Box	2	Polycarbonate
20	Back Panel for Contactor Box	1	Polycarbonate
21	Lplate for Contactor Box	10	Aluminium
22	Charging Station Base Plate	1	Fiberglass
23	Charging Station Dock Top Plate	1	Polycarbonate



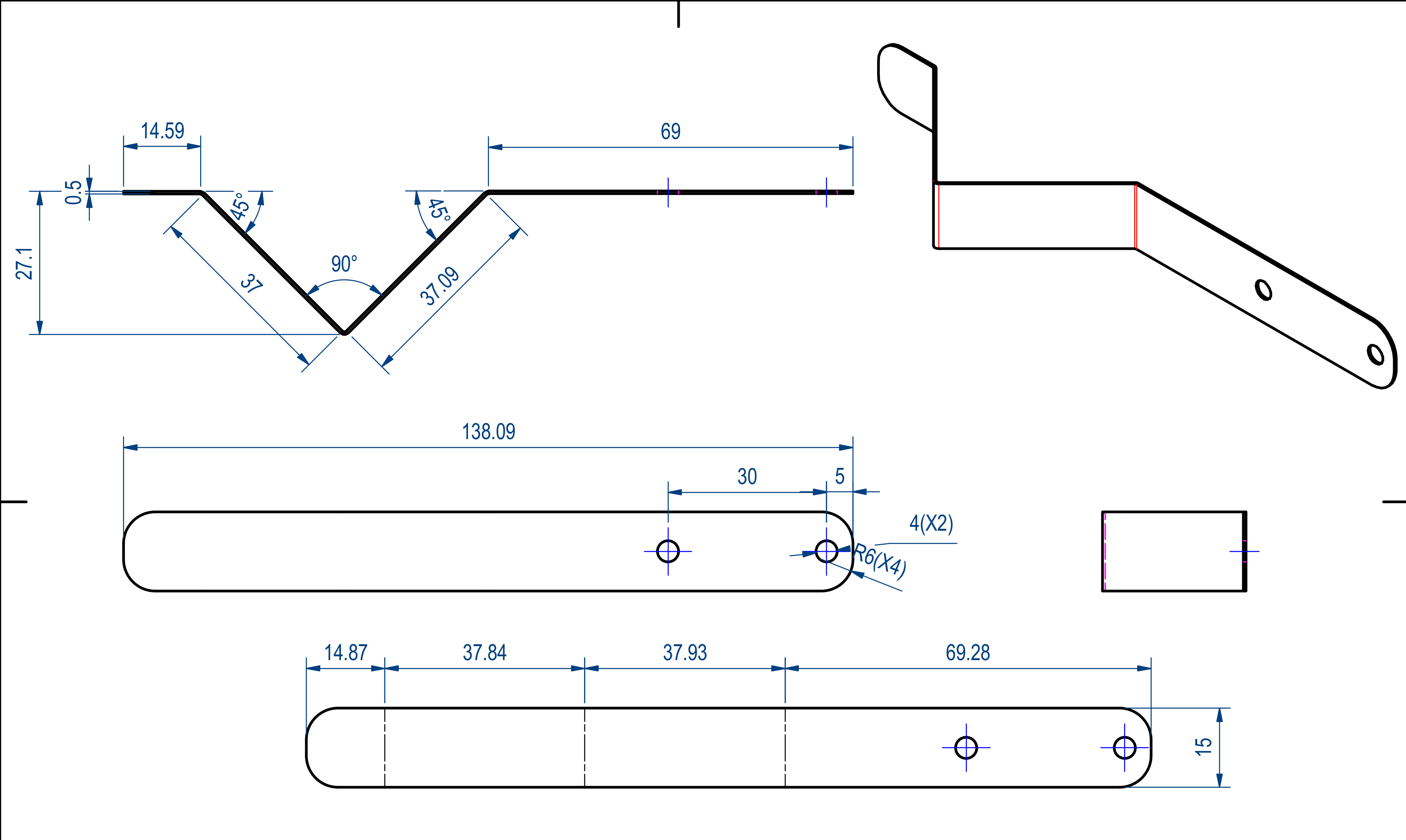
SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed LOW ZHONG SHENG	Date 6/8/2020	Project Title OFFICE TRANSPORTER		
	Checked SILVANUS SNG	Date 7/8/2020	Projection	Dwg No.	
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor TAN TUAN KIAT	Date 7/8/2020	Scale 1:3	Sheet 1	Size A1



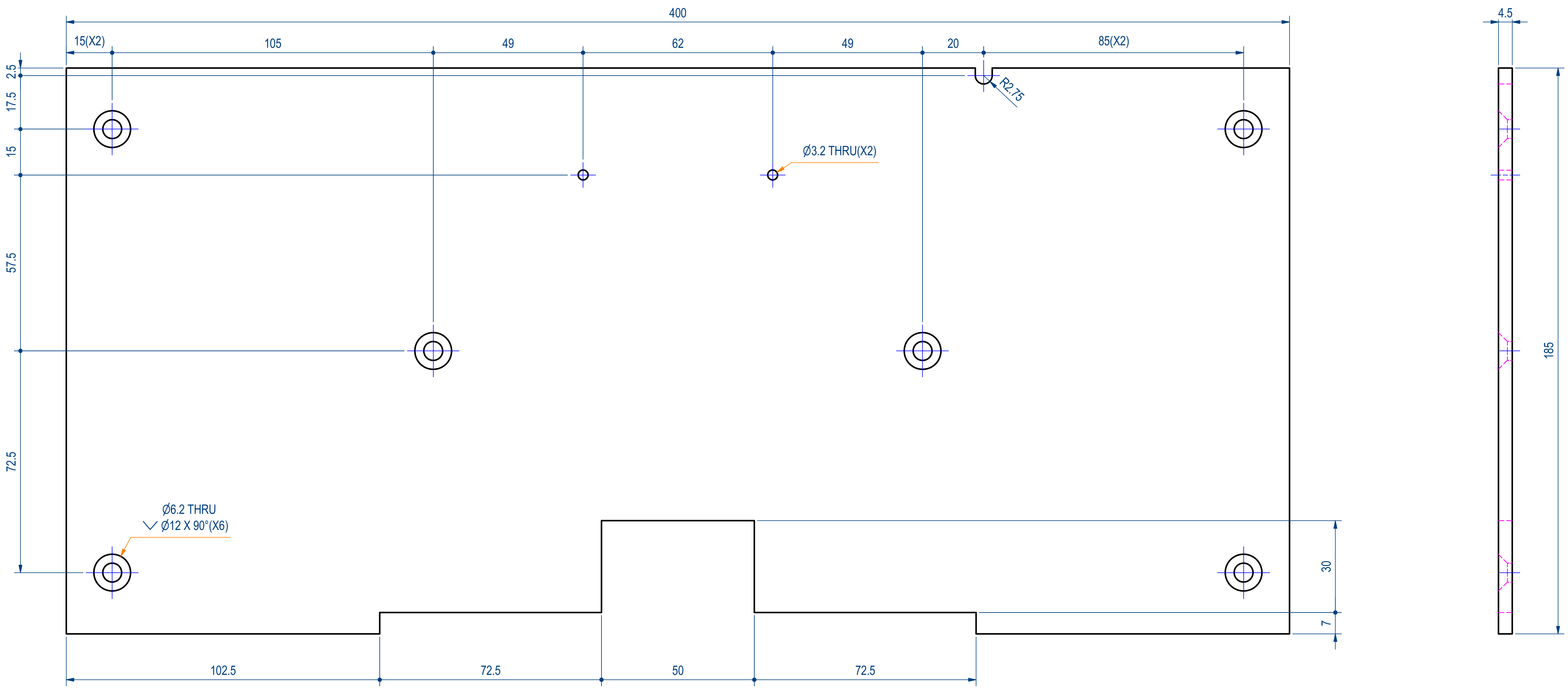
SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed SAMUEL WONG	Date 6/8/2020	Project Title OFFICE TRANSPORTER	
	Checked LOW ZHONG SHENG	Date 7/8/2020	Projection	Dwg No.
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor TAN TUAN KIAT	Date 7/8/2020	Scale 1:1	Sheet 1	Size A4



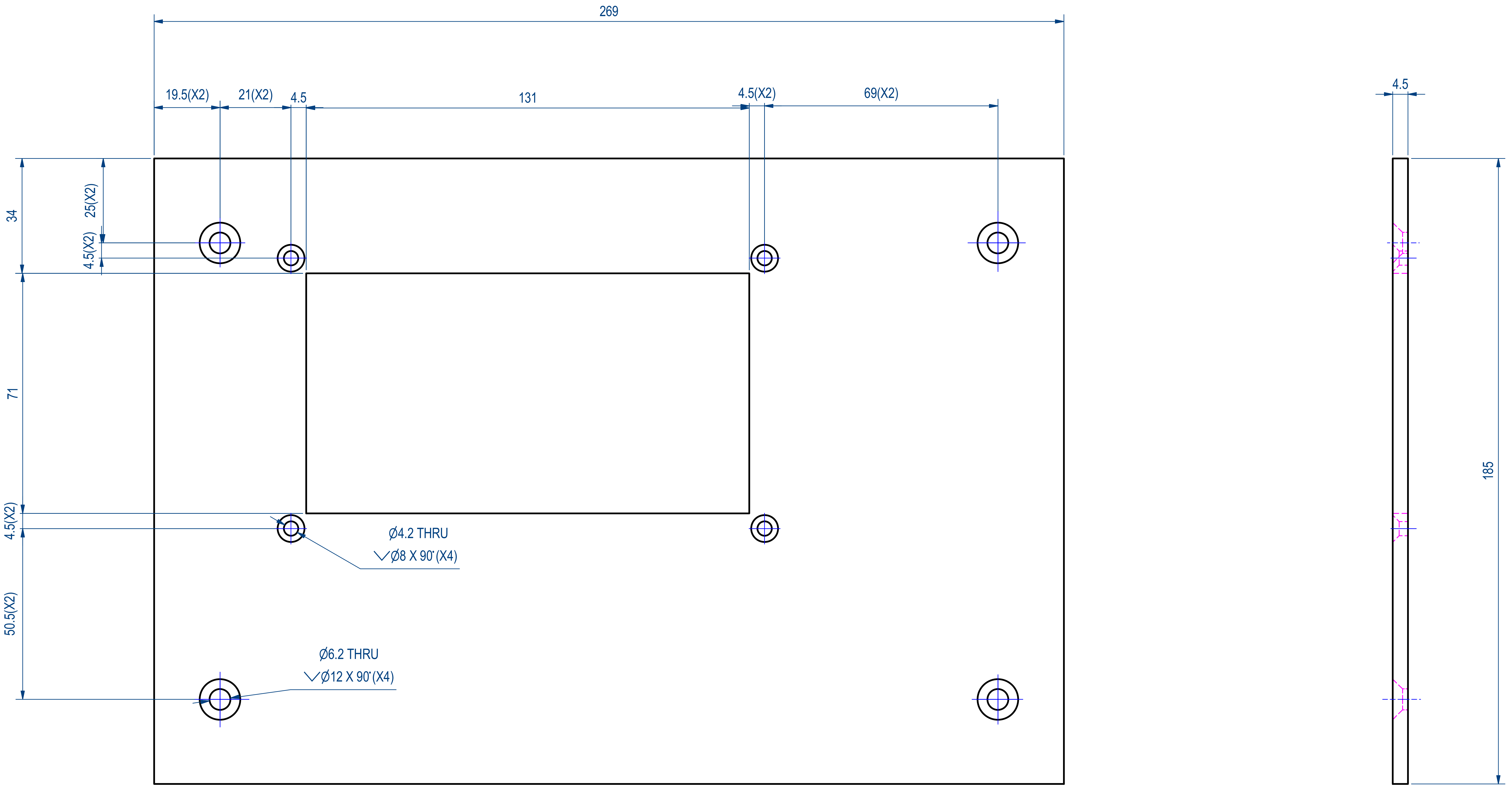
SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed: LOW ZHONG SHENG	Date: 6/8/2020	Project Title: OFFICE TRANSPORTER	
	Checked: SAMUEL WONG	Date: 7/8/2020	Projection	Dwg No.
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor: TAN TUAN KIAT	Date: 7/8/2020	Scale: 1:1	Sheet: 1 / Size: A4



SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed LOW ZHONG SHENG	Date 6/8/2020	Project Title OFFICE TRANSPORTER		
	Checked SAMUEL WONG	Date 7/8/2020	Projection	Dwg No.	
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor TAN TUAN KIAT	Date 7/8/2020	Scale 1:1	Sheet 1	Size A4



SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed LOW ZHONG SHENG	Date 6/8/2020	Project Title OFFICE TRANSPORTER			
	Checked JARED TAN	Date 7/8/2020	Projection		Dwg No.	
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor TAN TUAN KIAT	Date 7/8/2020	Scale 1:1		Sheet 1	Size A2



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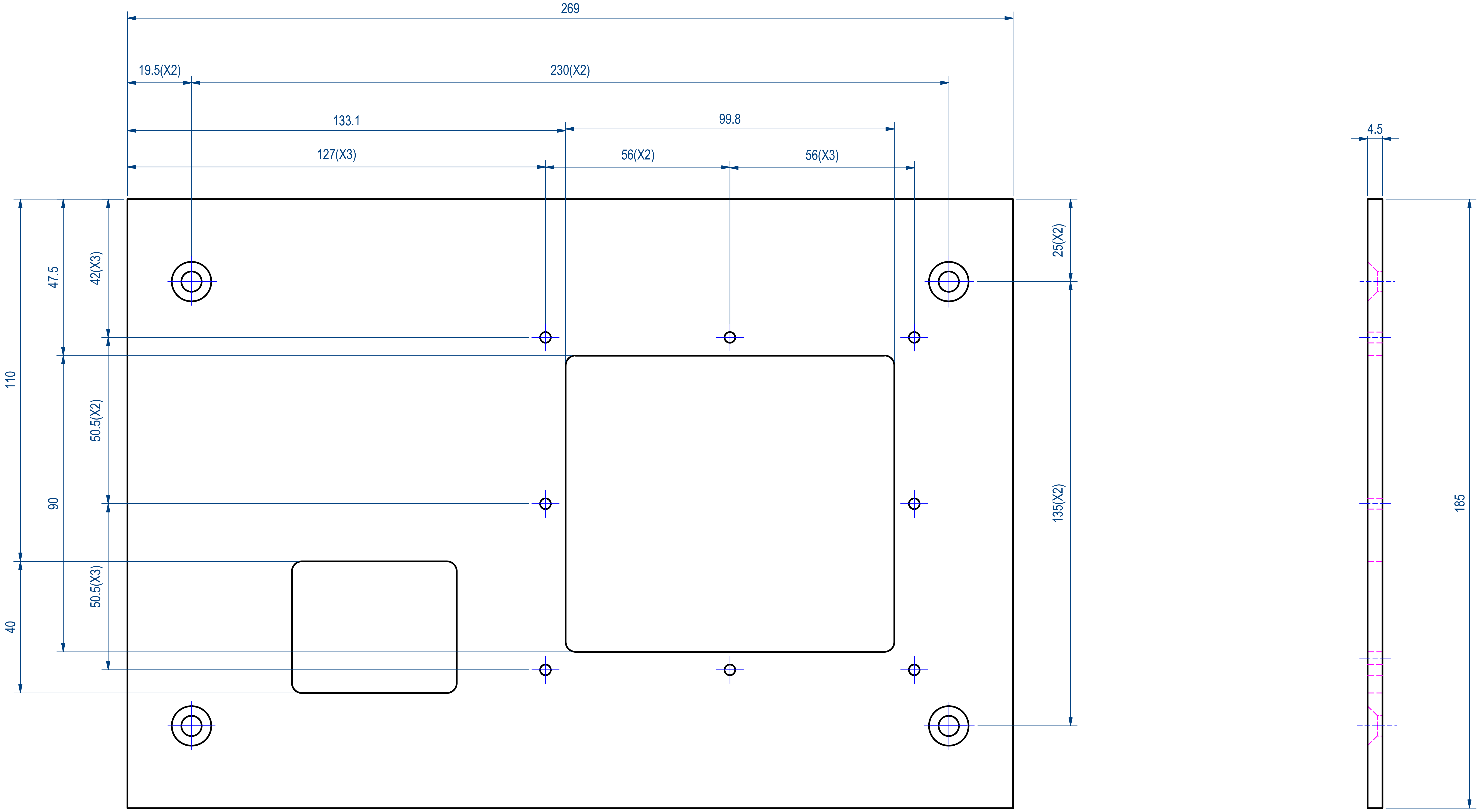
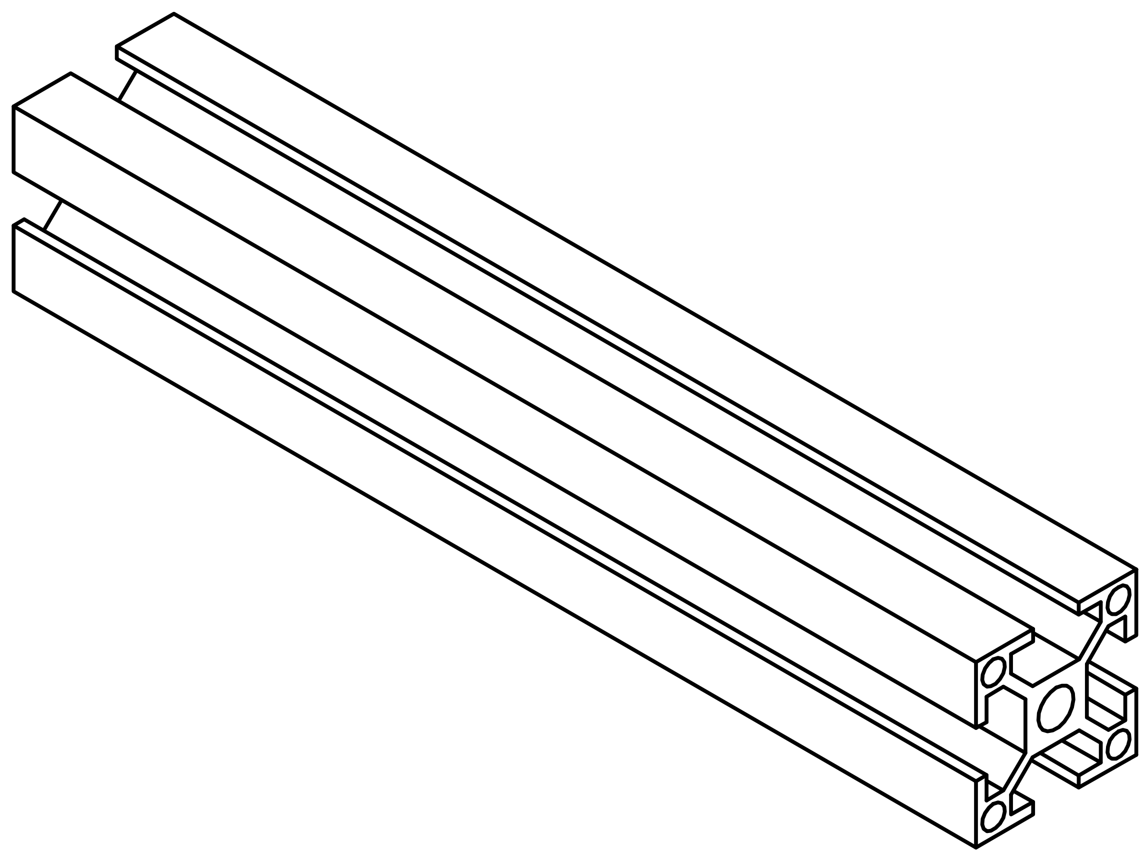
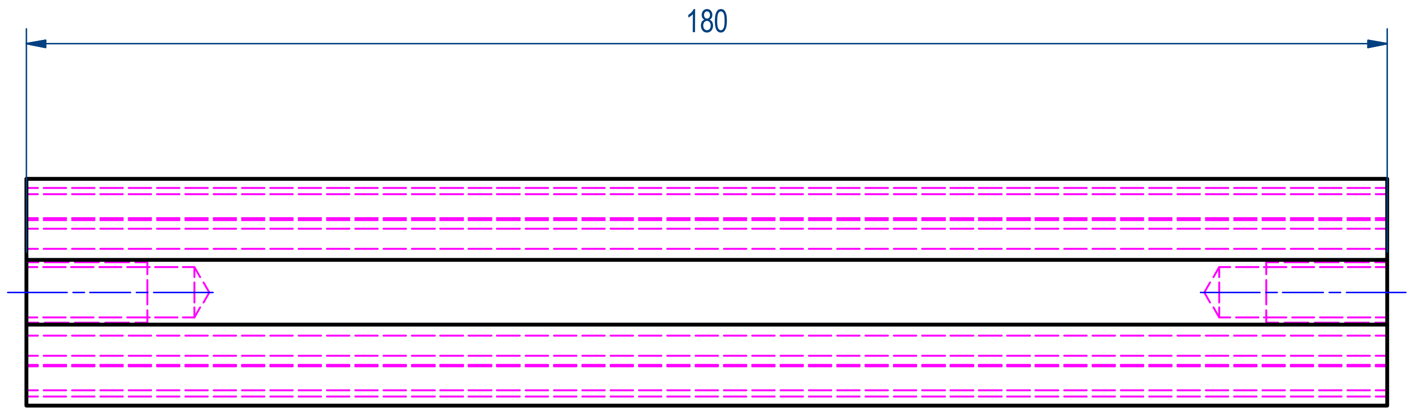
	Checked JARED TAN	Date 7/8/2020	Projection	Dwg No.		
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor TAN TUAN KIAT	Date 7/8/2020	Scale 1:1	Sheet 1	Size A2	

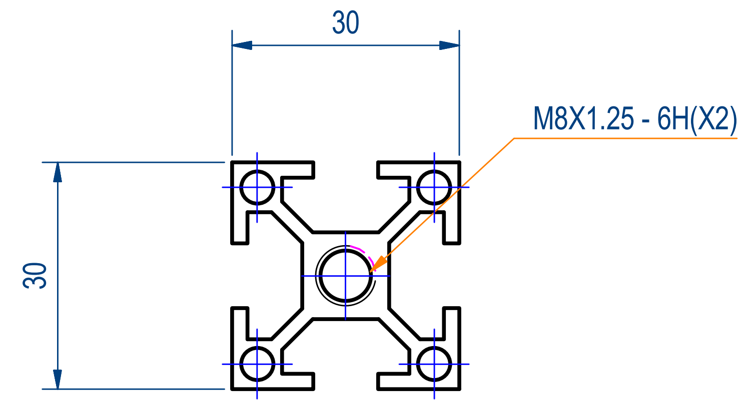


SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed: LOW ZHONG SHENG	Date: 6/8/2020	Project Title: OFFICE TRANSPORTER	
	Checked: JARED TAN	Date: 7/8/2020	Projection	Dwg No.
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor: TAN TUAN KIAT	Date: 7/8/2020	Scale: 1:1	Sheet: 1 / Size: A2

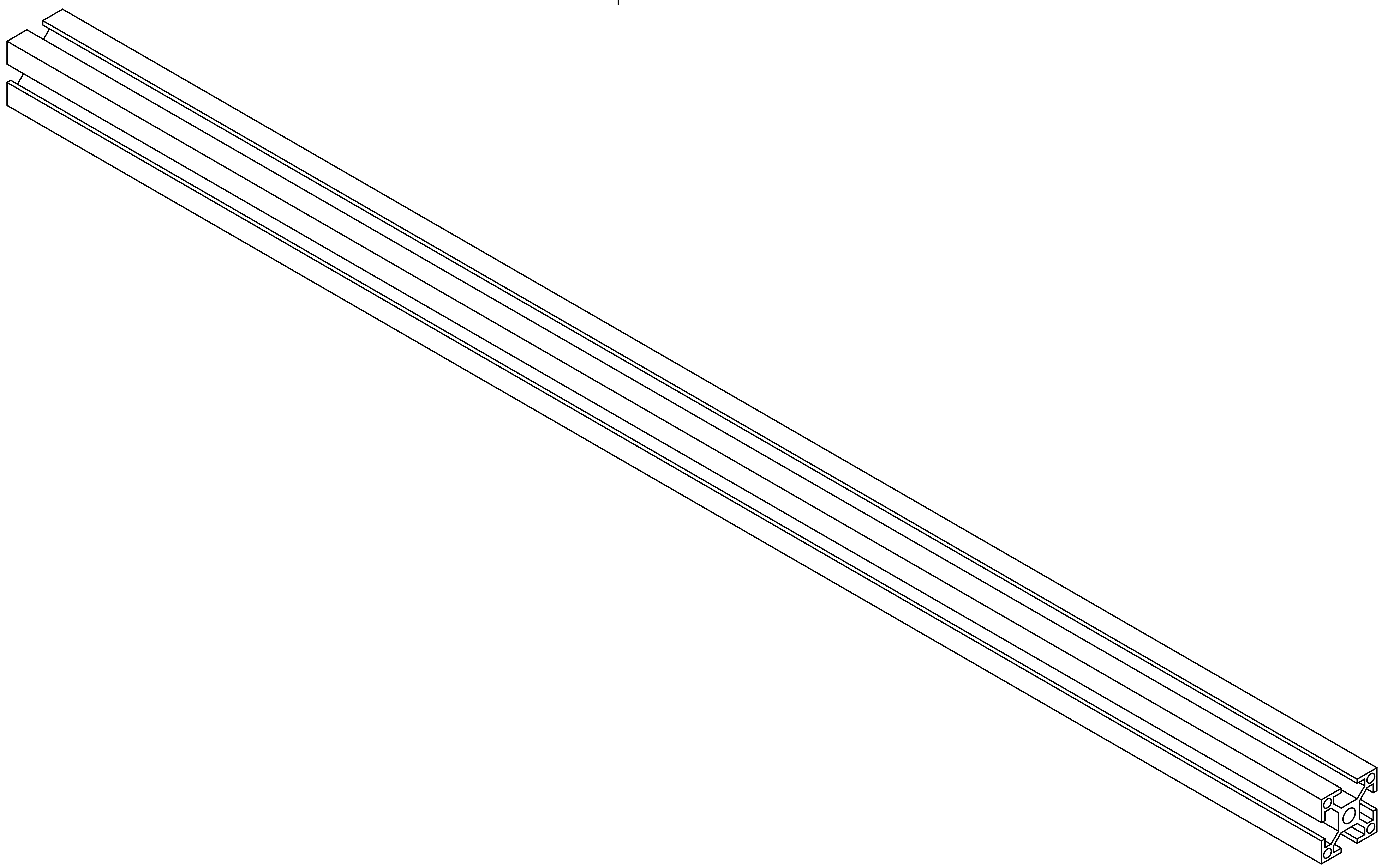
SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed: LOW ZHONG SHENG	Date: 6/8/2020	Project Title: OFFICE TRANSPORTER	
	Checked: JARED TAN	Date: 7/8/2020	Projection	Dwg No.
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor: TAN TUAN KIAT	Date: 7/8/2020	Scale: 1:1	Sheet: 1 / Size: A2

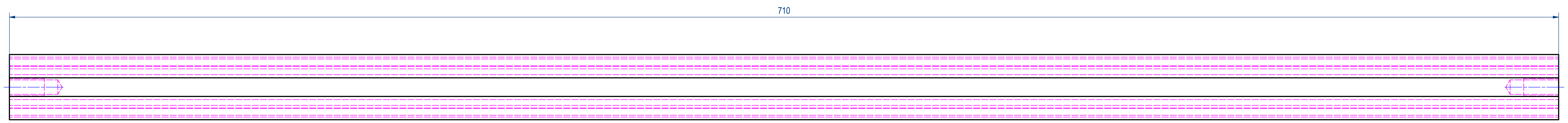


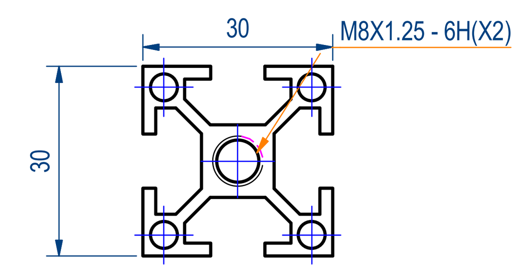




SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed LOW ZHONG SHENG	Date 6/8/2020	Project Title OFFICE TRANSPORTER		
	Checked SILVANUS SNG	Date 7/8/2020	Projection	Dwg No.	
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor TAN TUAN KIAT	Date 7/8/2020	Scale 1:1	Sheet 1	Size A3







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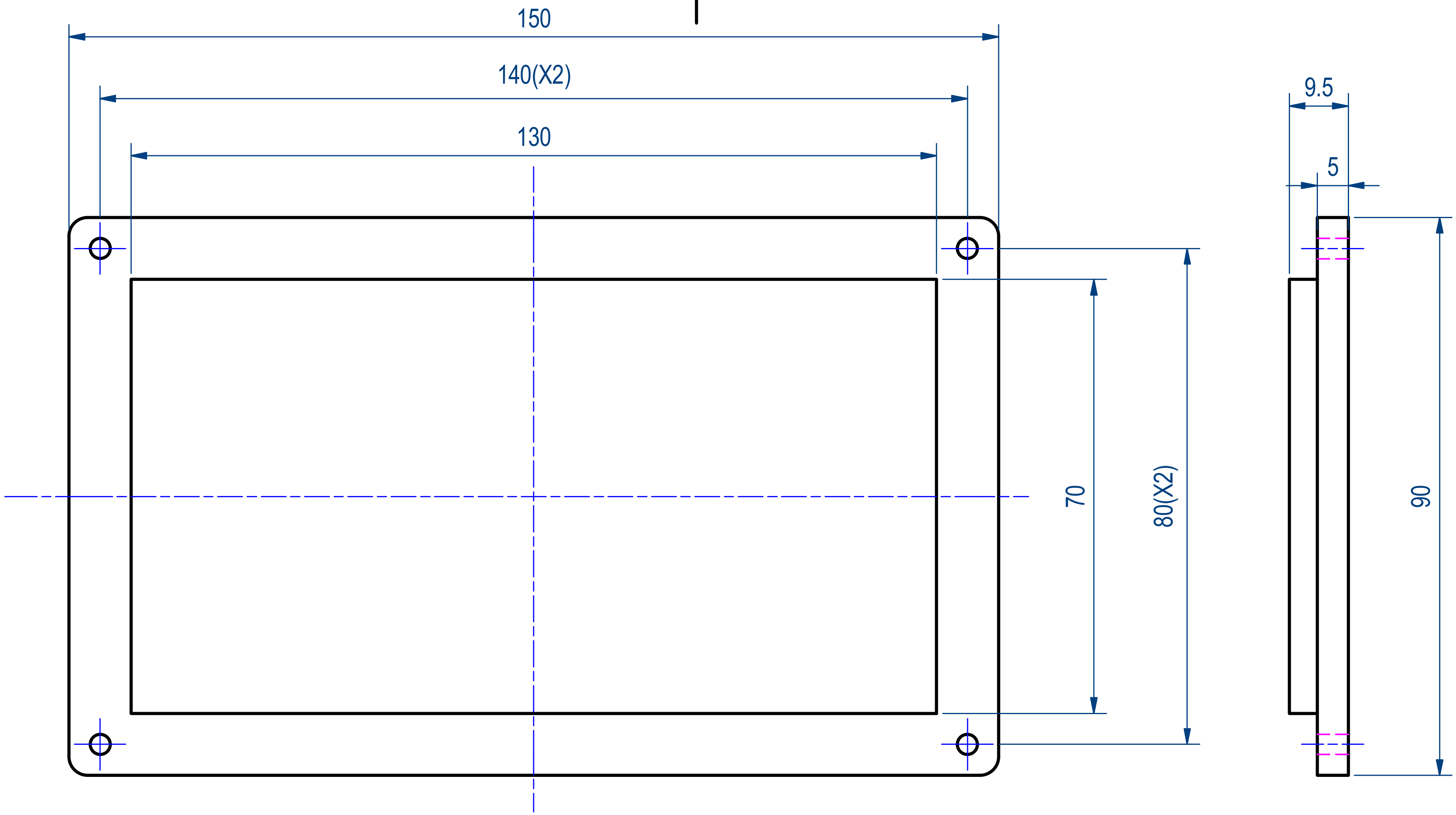
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor: TAN TUAN KIAT	Date: 7/8/2020	Scale: 1:1 / Sheet: 1 / Size: A1



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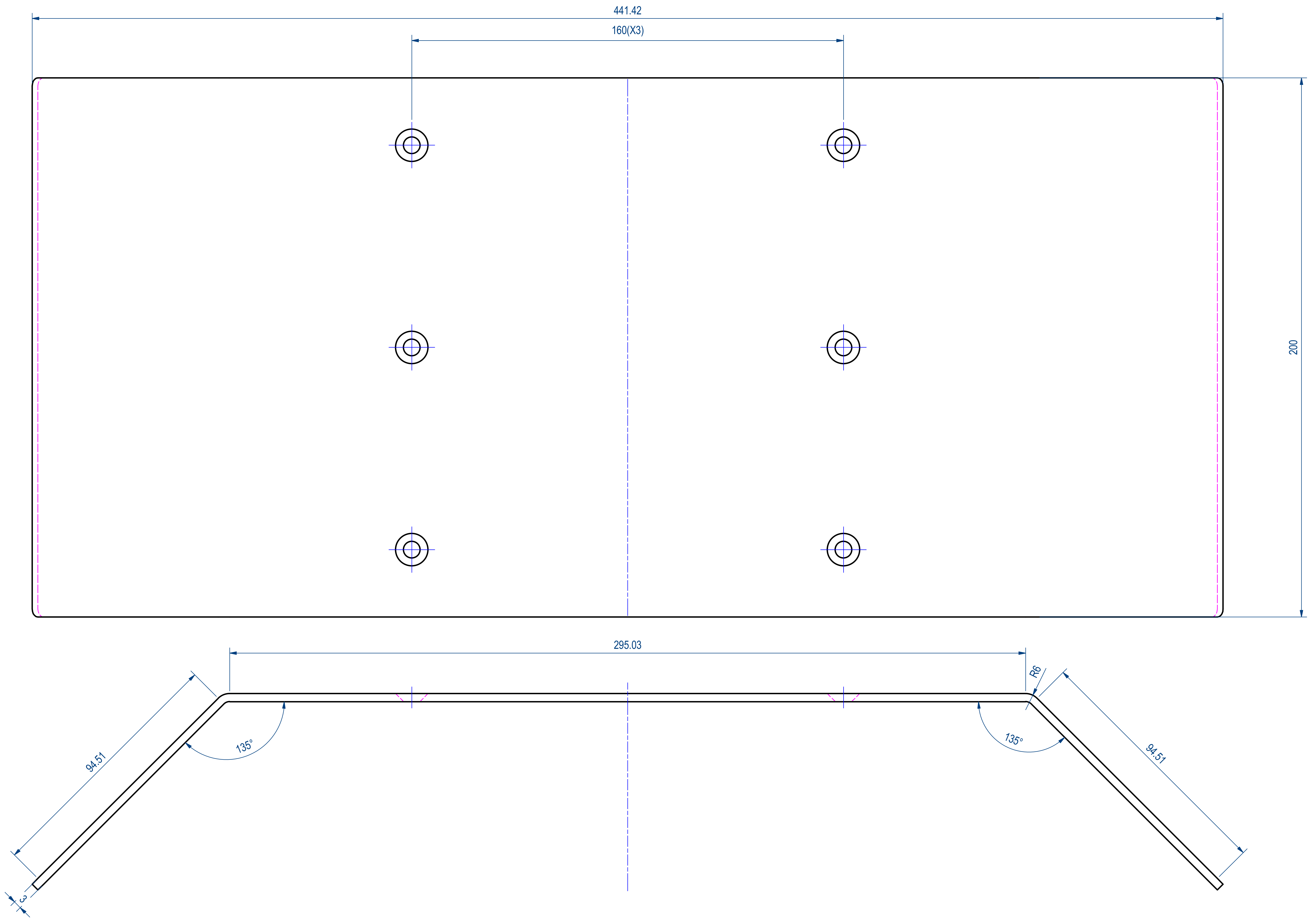
	Checked: JARED TAN	Date: 7/8/2020	Projection	Dwg No.	
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor: TAN TUAN KIAT	Date: 7/8/2020	Scale: 1:1	Sheet: 1	Size: A4

SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed LOW ZHONG SHENG	Date 6/8/2020	Project Title OFFICE TRANSPORTER
	Checked SILVANUS SNG	Date 7/8/2020	Projection / Dwg No.
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor TAN TUAN KIAT	Date 7/8/2020	Scale 1:1 / Sheet 1 / Size A2



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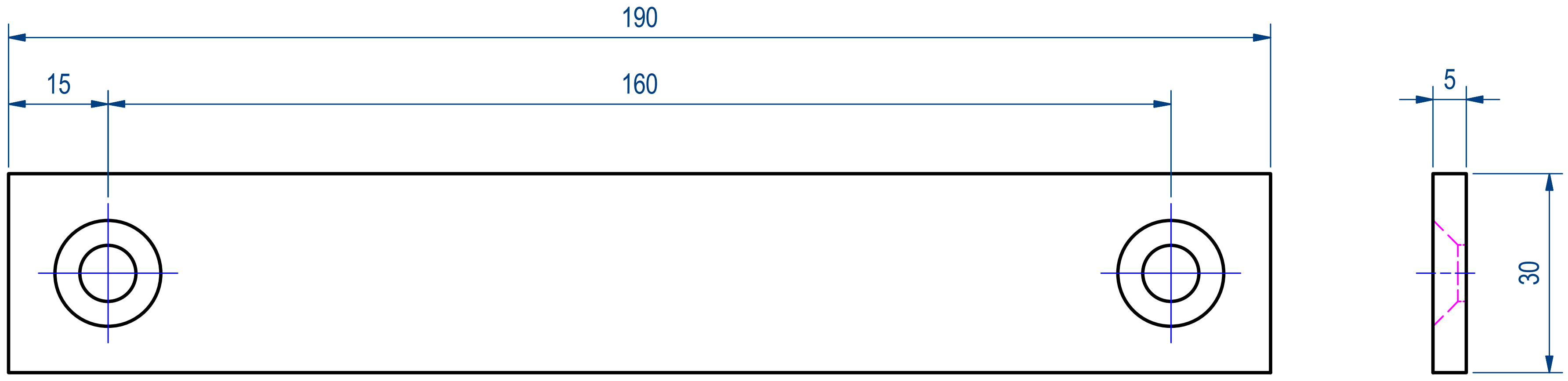
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor: TAN TUAN KIAT	Date: 7/8/2020	Scale: 1:1	Sheet: 1	Size: A2



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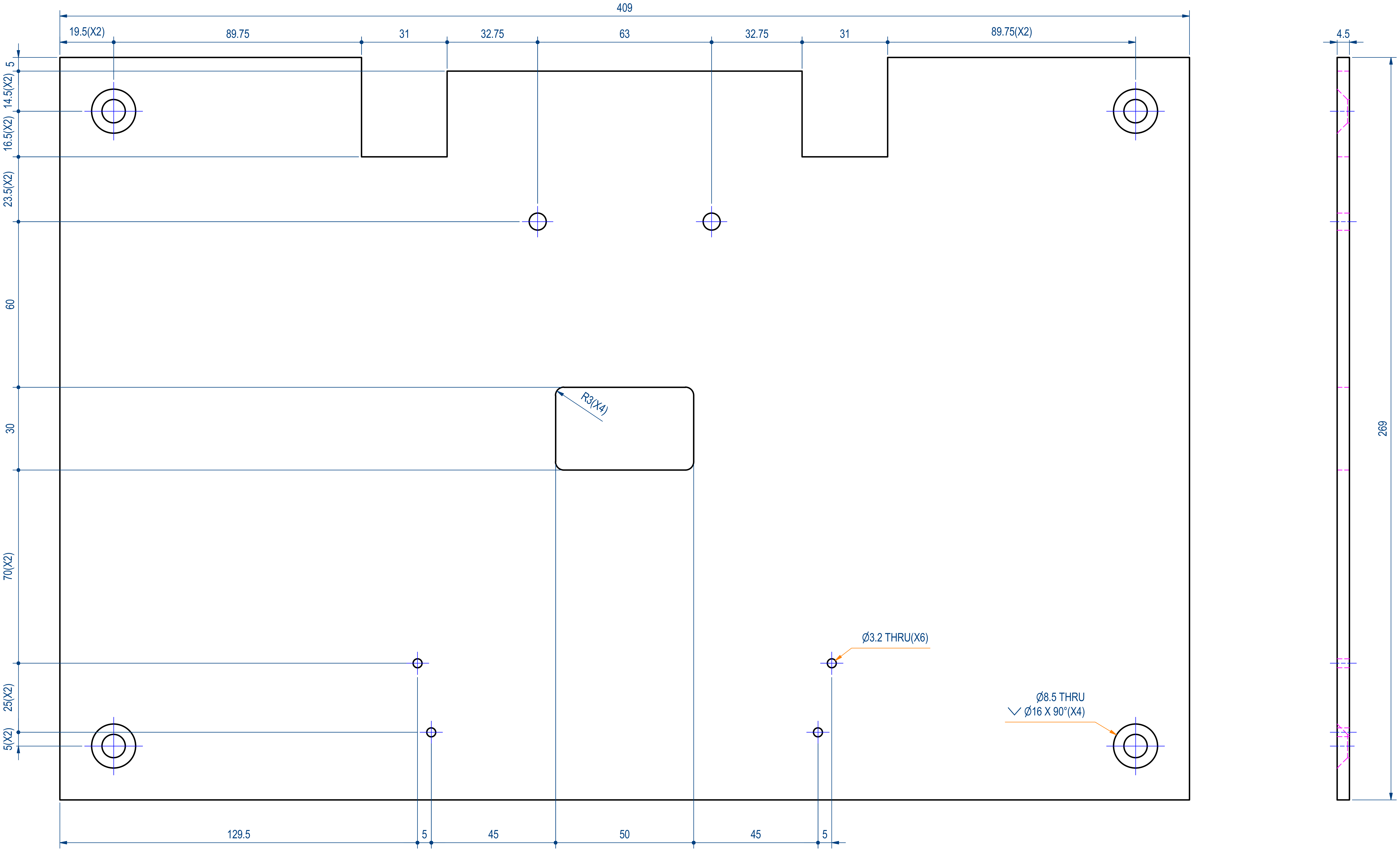
	Checked JARED TAN	Date 7/8/2020	Projection	Dwg No.	
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor TAN TUAN KIAT	Date 7/8/2020	Scale 1:1	Sheet 1	Size A4



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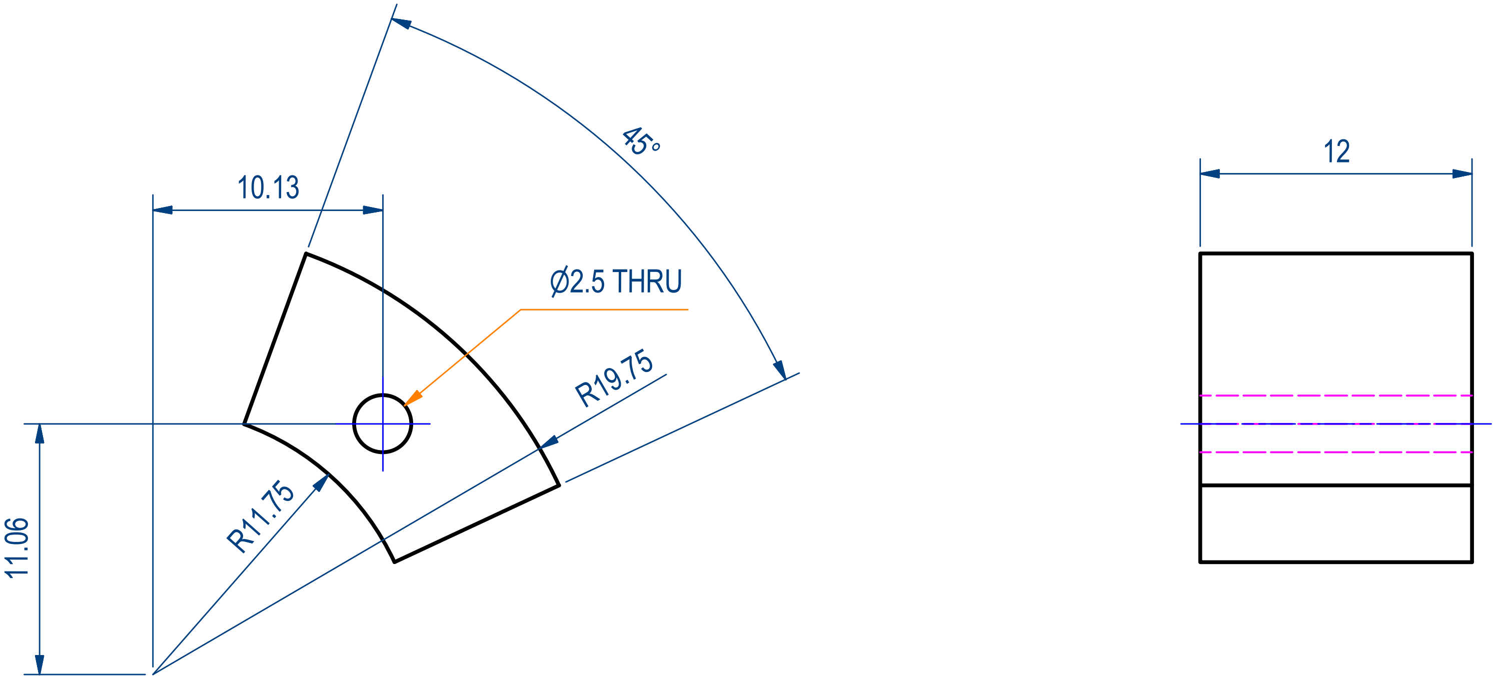
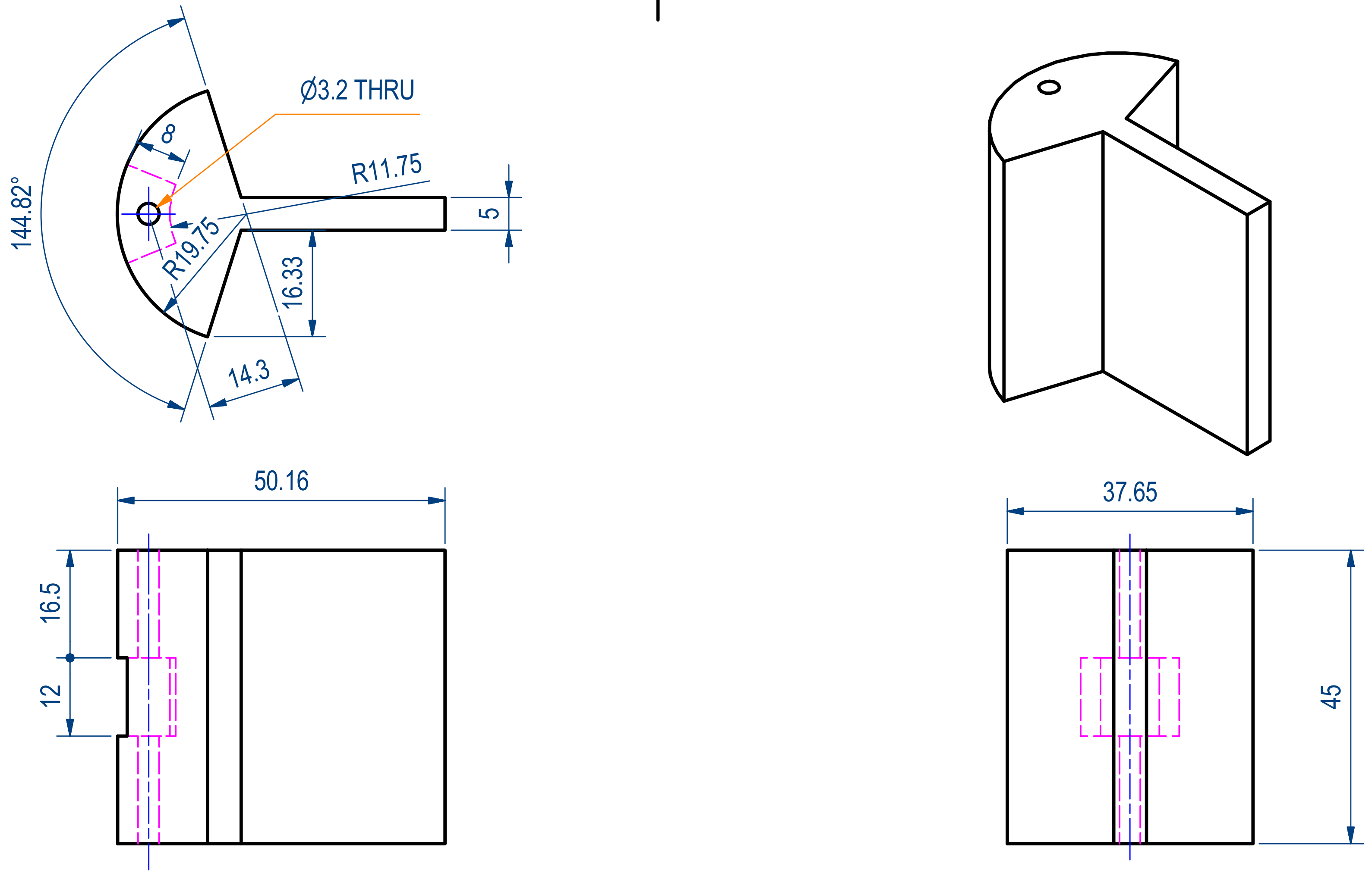
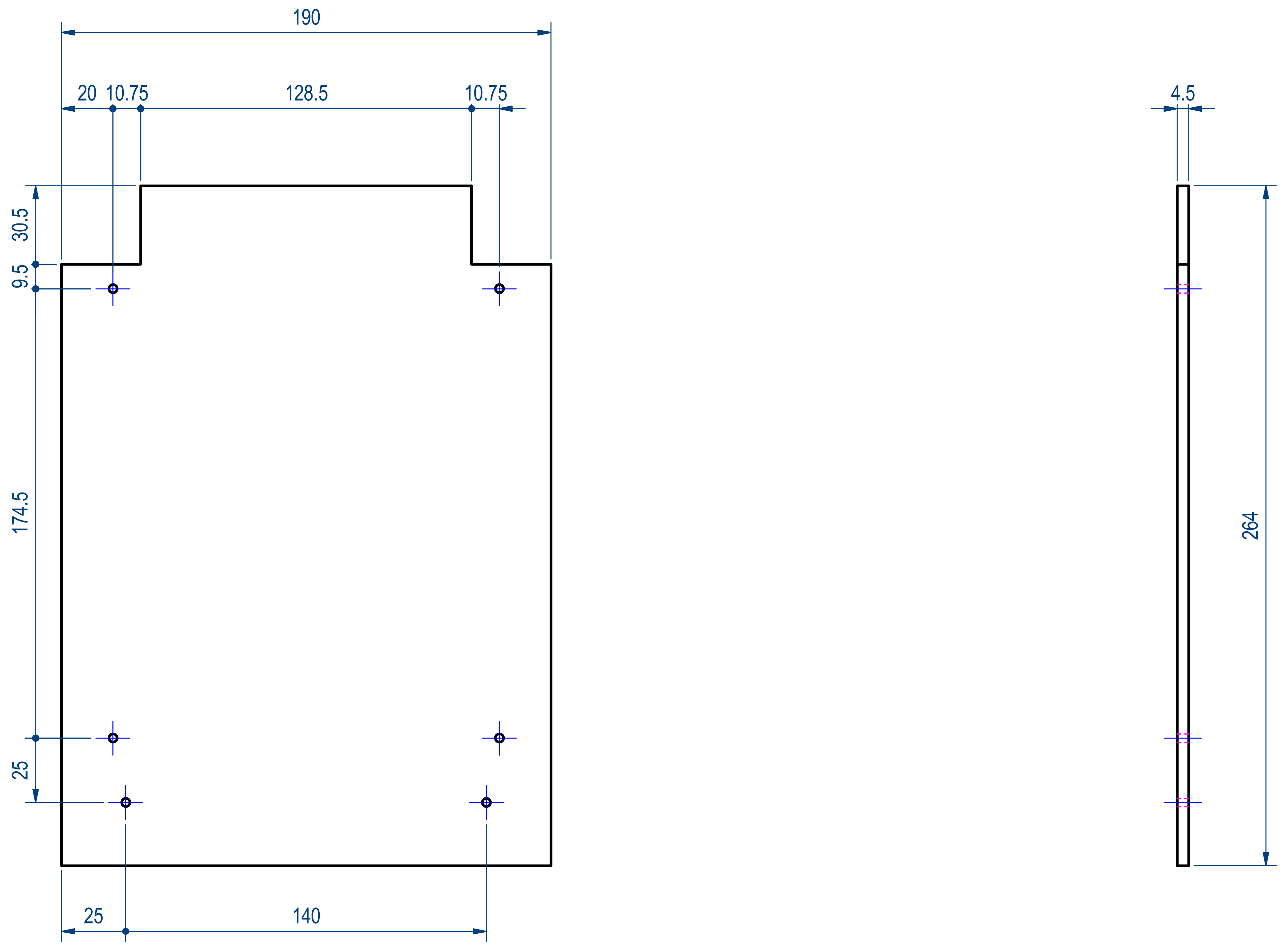
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor: TAN TUAN KIAT	Date: 7/8/2020	Scale: 1:1	Sheet: 1	Size: A2



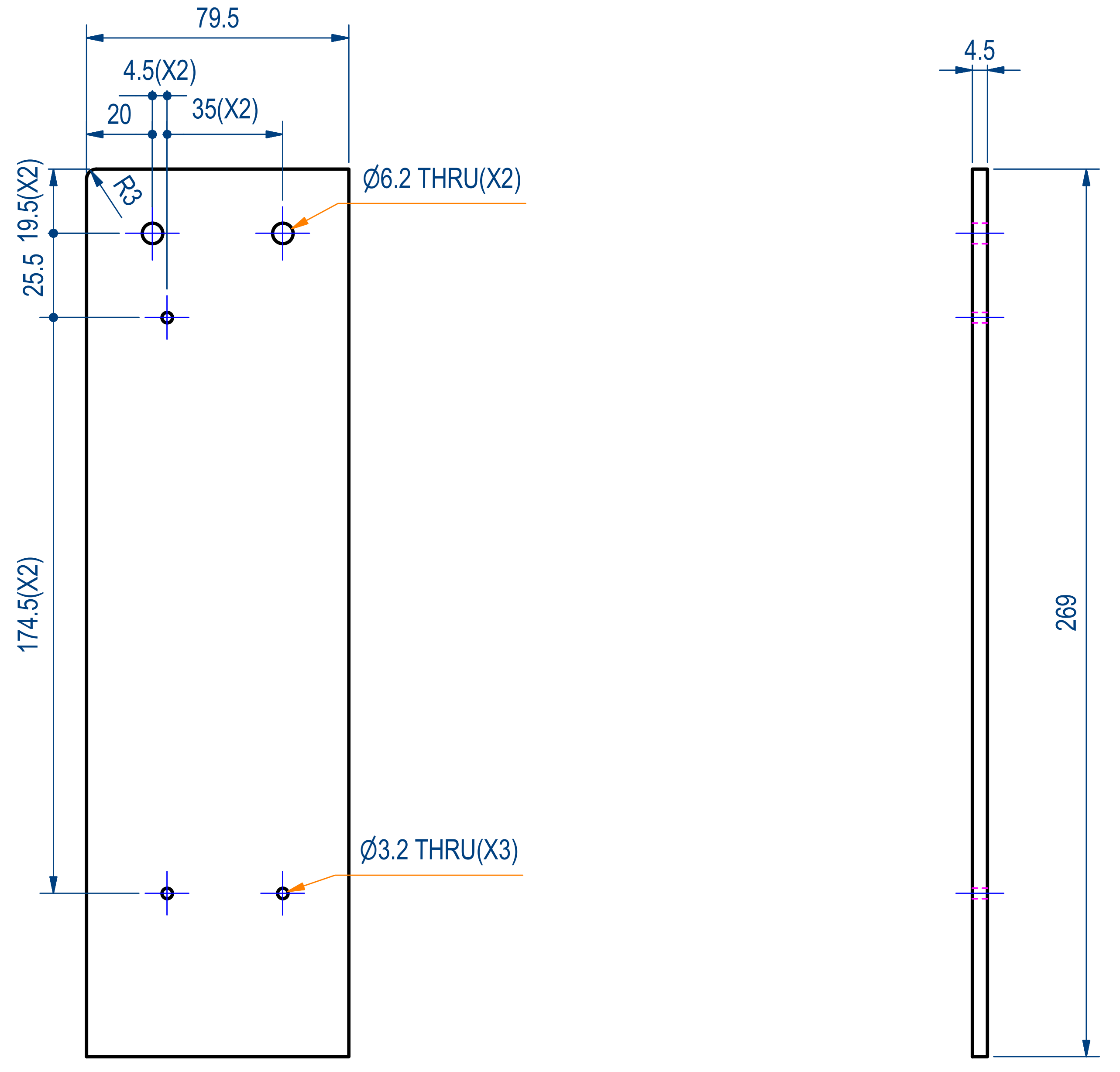
SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed LOW ZHONG SHENG	Date 6/8/2020	Project Title OFFICE TRANSPORTER			
	Checked SAMUEL WONG	Date 7/8/2020	Projection	Dwg No.		
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor TAN TUAN KIAT	Date 7/8/2020	Scale 3:1	Sheet 1	Size A4	



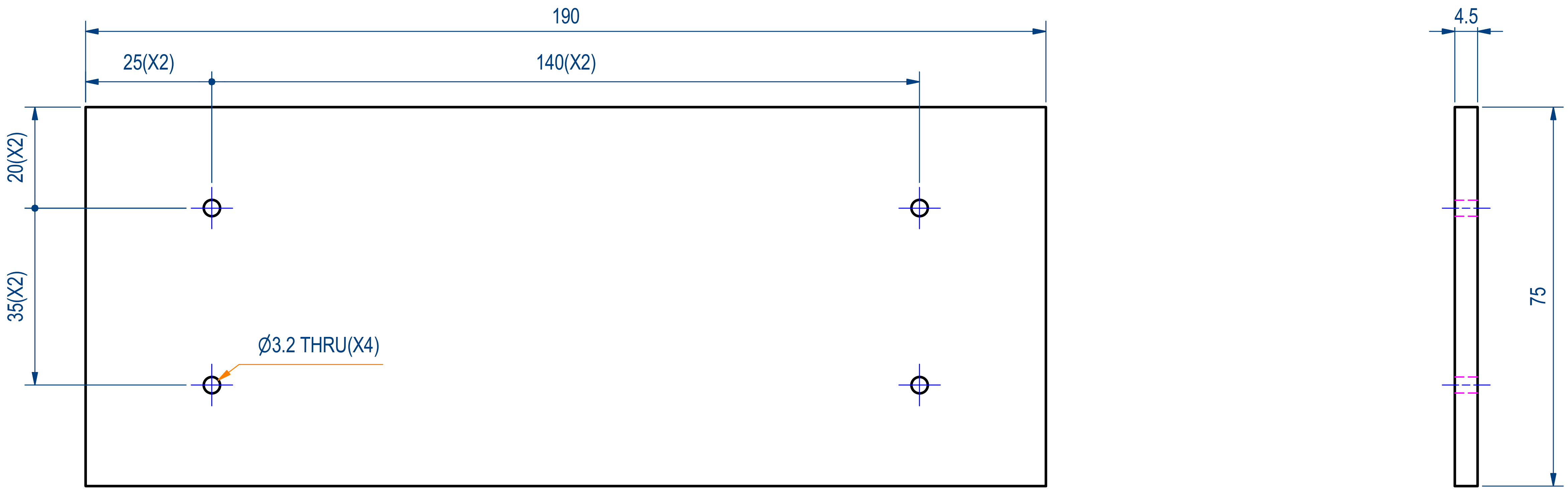
SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed LOW ZHONG SHENG	Date 6/8/2020	Project Title OFFICE TRANSPORTER			
	Checked JARED TAN	Date 7/8/2020	Projection		Dwg No.	
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor TAN TUAN KIAT	Date 7/8/2020	Scale 1:1		Sheet 1	Size A4



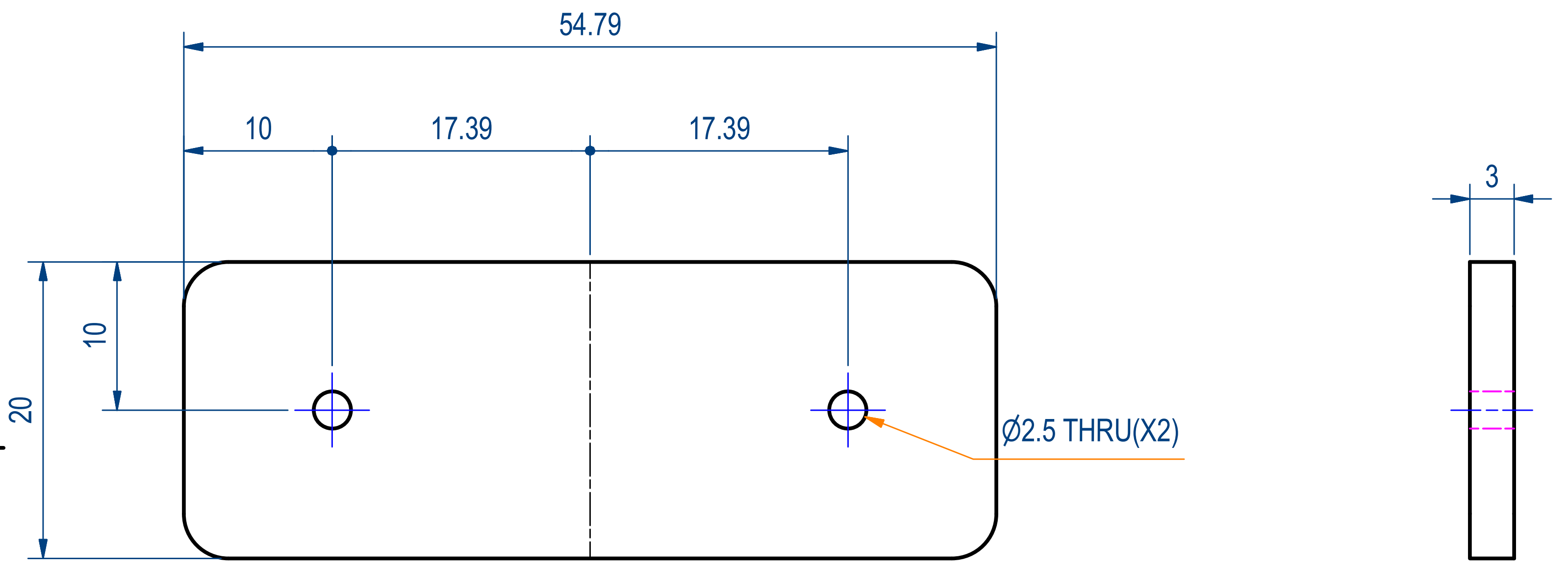
SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed LOW ZHONG SHENG	Date 6/8/2020	Project Title OFFICE TRANSPORTER			
	Checked SAMUEL WONG	Date 7/8/2020	Projection		Dwg No.	
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor TAN TUAN KIAT	Date 7/8/2020	Scale 1:2	Sheet 1	Size A3	



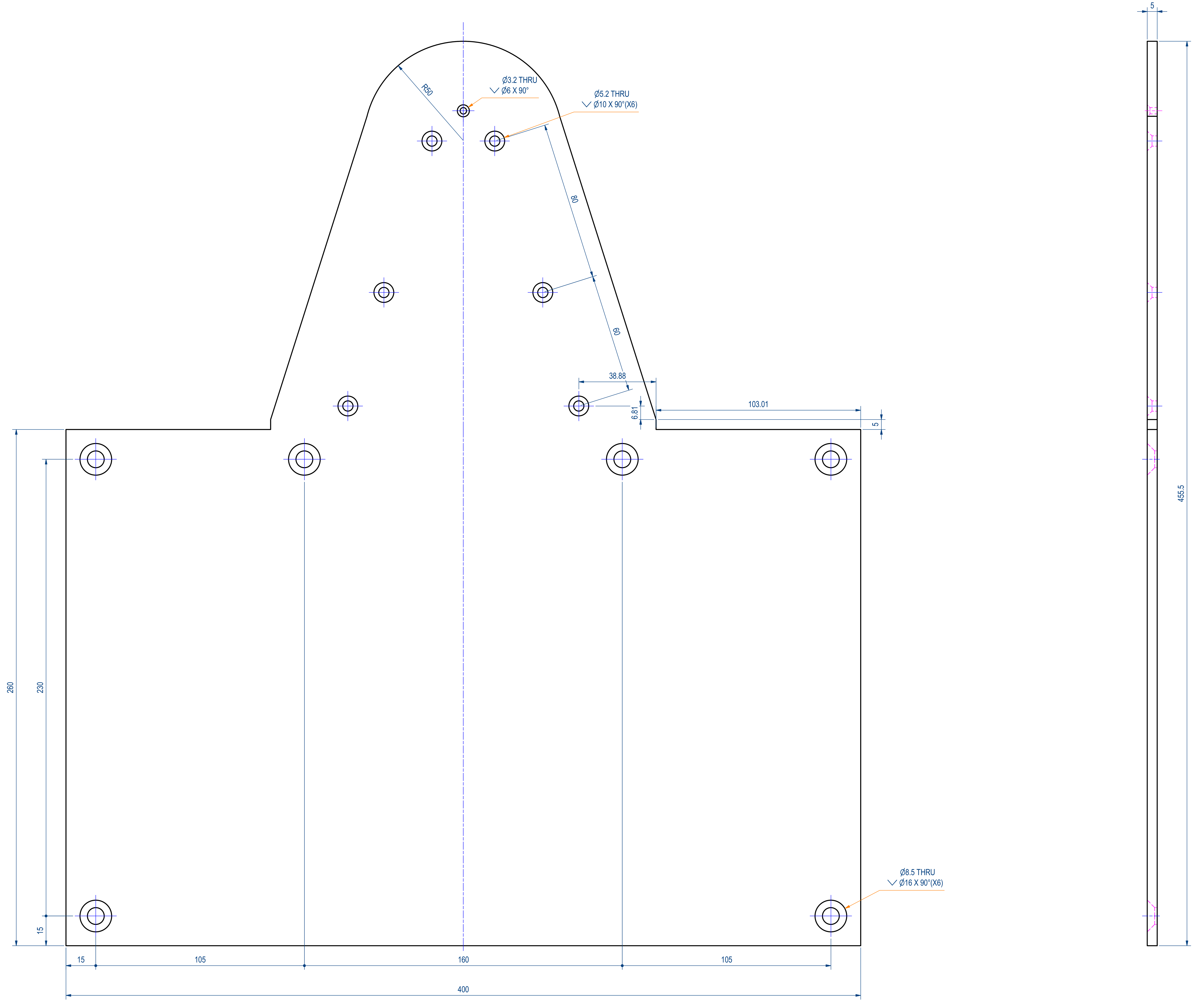
SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed: LOW ZHONG SHENG	Date: 6/8/2020	Project Title: OFFICE TRANSPORTER	
	Checked: SAMUEL WONG	Date: 7/8/2020	Projection	Dwg No.
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor: TAN TUAN KIAT	Date: 7/8/2020	Scale: 1:2	Sheet: 1 / Size: A3



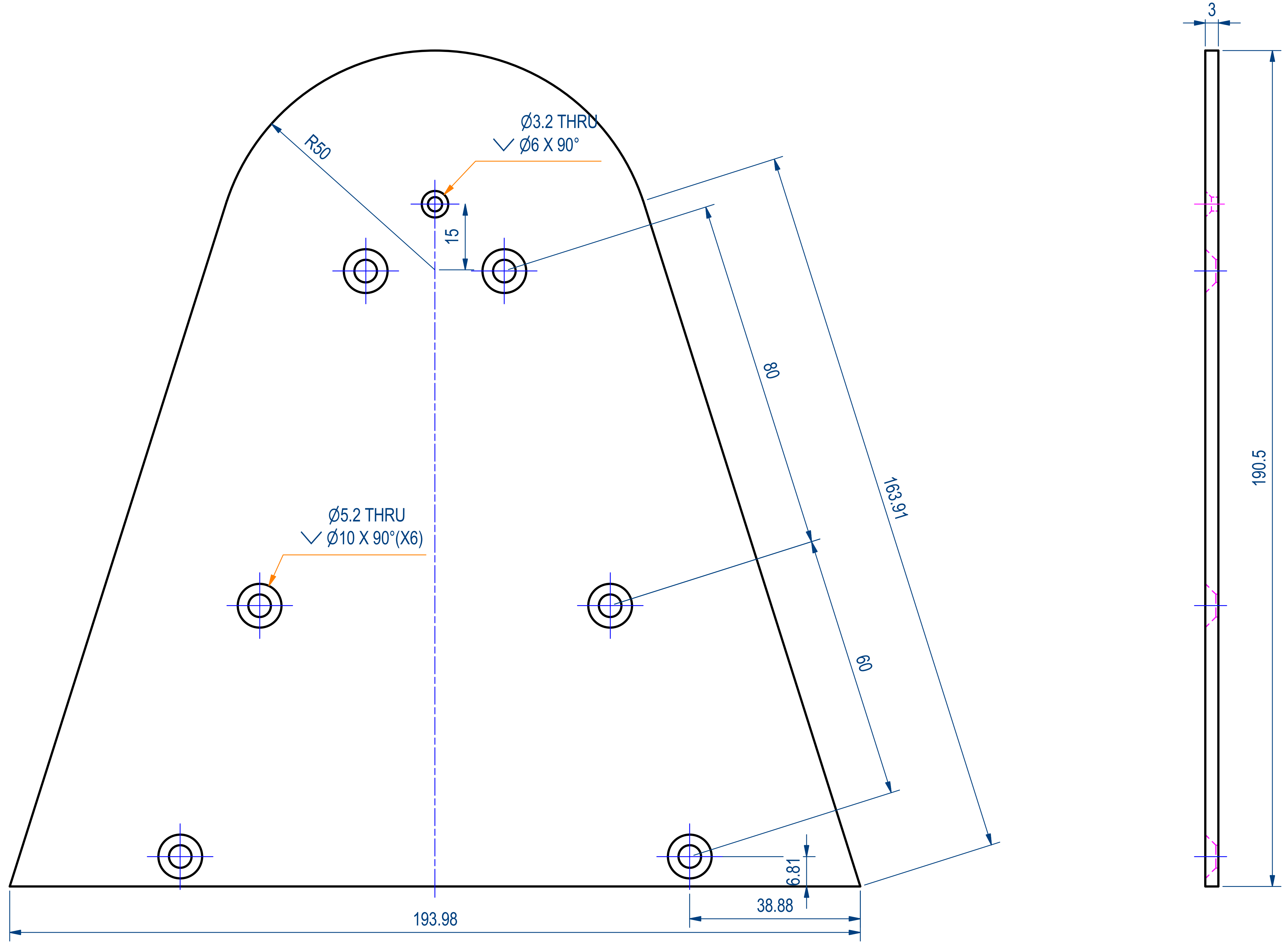
SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed LOW ZHONG SHENG	Date 6/8/2020	Project Title OFFICE TRANSPORTER		
	Checked SAMUEL WONG	Date 7/8/2020	Projection	Dwg No.	
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor TAN TUAN KIAT	Date 7/8/2020	Scale 1:1	Sheet 1	Size A3



SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed: LOW ZHONG SHENG	Date: 6/8/2020	Project Title: OFFICE TRANSPORTER		
	Checked: SILVANUS SNG	Date: 7/8/2020	Projection	Dwg No.	
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor: TAN TUAN KIAT	Date: 7/8/2020	Scale: 2:1	Sheet: 1	Size: A4



SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed LOW ZHONG SHENG	Date 6/8/2020	Project Title OFFICE TRANSPORTER		
	Checked SAMUEL WONG	Date 7/8/2020	Projection	Dwg No.	
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor TAN TUAN KIAT	Date 7/8/2020	Scale 1:1	Sheet 1	Size A1



SP SCHOOL OF MECHANICAL AND AERONAUTICAL ENGINEERING	Designed: LOW ZHONG SHENG	Date: 6/8/2020	Project Title: OFFICE TRANSPORTER	
	Checked: JARED TAN	Date: 7/8/2020	Projection	Dwg No.
Unless otherwise specified All dimensions are in millimeters (mm)	Project Supervisor: TAN TUAN KIAT	Date: 7/8/2020	Scale: 1:1	Sheet: 1 / Size: A3