

REFERENCES

, 23(5), 541–547. <https://doi.org/10.1016/j.mechatronics.2013.04.004>

AN885. (n.d.).

Alatise, M. B., & Hancke, G. P. (2020). A Review on Challenges of Autonomous Mobile Robot and Sensor Fusion Methods. *IEEE Access*

Ibrahim, D. (2006). Front Matter. In *Microcontroller Based Applied Digital Control* (pp. i–xii). John Wiley & Sons, Ltd. <https://doi.org/10.1002/0470863374.fmatter>

IEEE Staff. (2018). *2018 1st International Scientific Conference of Engineering Sciences 3rd Scientific Conference of Engineering Science (ISCES)*. IEEE.

IEEE Staff, & IEEE Staff. (n.d.). *2012 IEEE International Power Engineering and Optimization Conference*.

Köseoğlu, M., Çelik, O. M., & Pektaş, Ö. (2017). *Design of an autonomous mobile robot based on ROS. IDAP 2017 - International Artificial Intelligence and Data Processing Symposium*. <https://doi.org/10.1109/IDAP.2017.8090199>

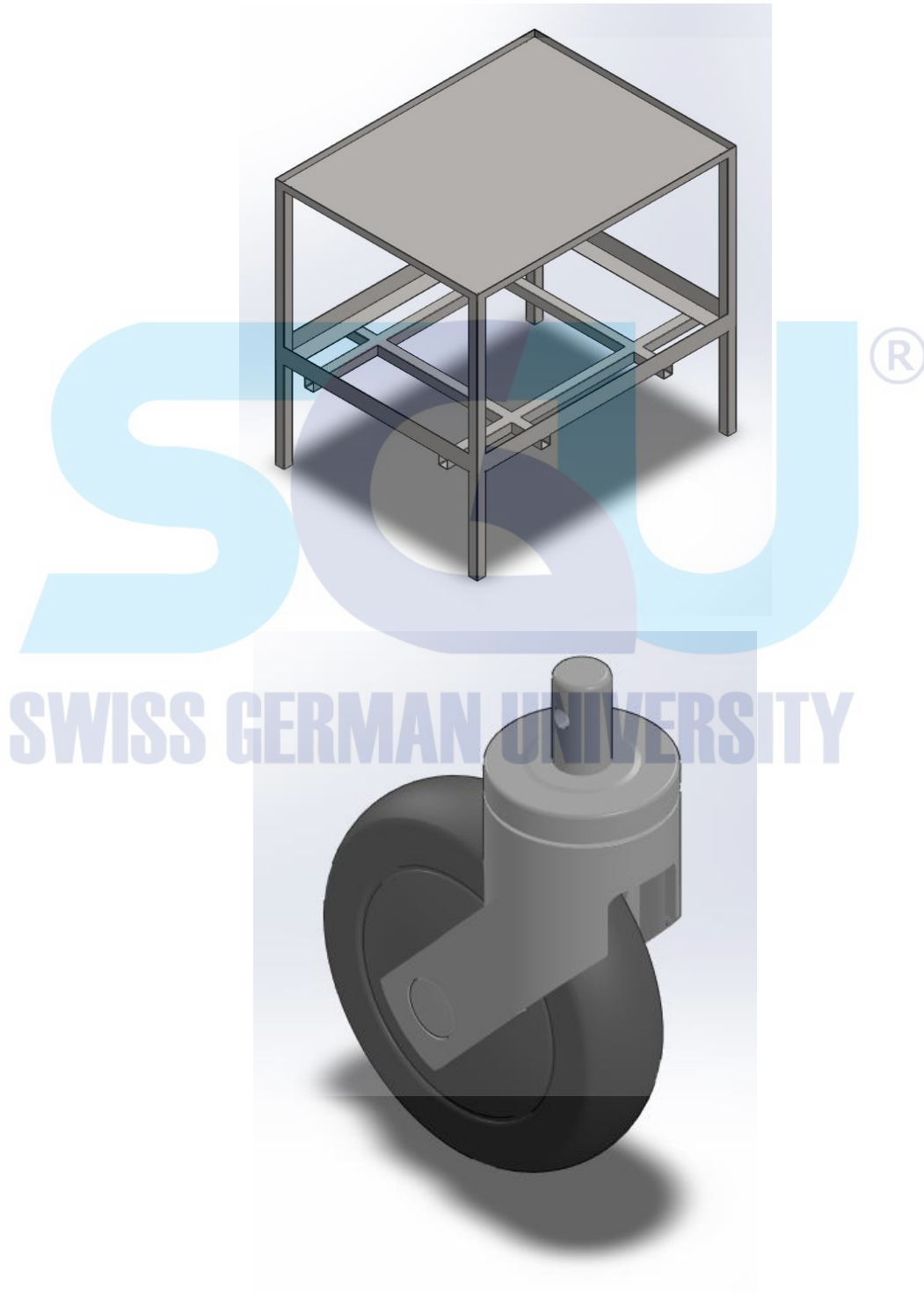
Plooij, M., Mathijssen, G., Cherelle, P., Lefeber, D., & Vanderborght, B. (2015). *Lock your robot: A review of locking devices in robotics*. *IEEE Robotics and Automation Magazine*, 22(1), 106–117. <https://doi.org/10.1109/MRA.2014.2381368>

Siripala, P. J., & Sekercioglu, Y. A. (2013). *A generalised solution for generating stepper motor speed profiles in real time*. *Mechatronics*, 23(5), 541–547. <https://doi.org/10.1016/j.mechatronics.2013.04.004>

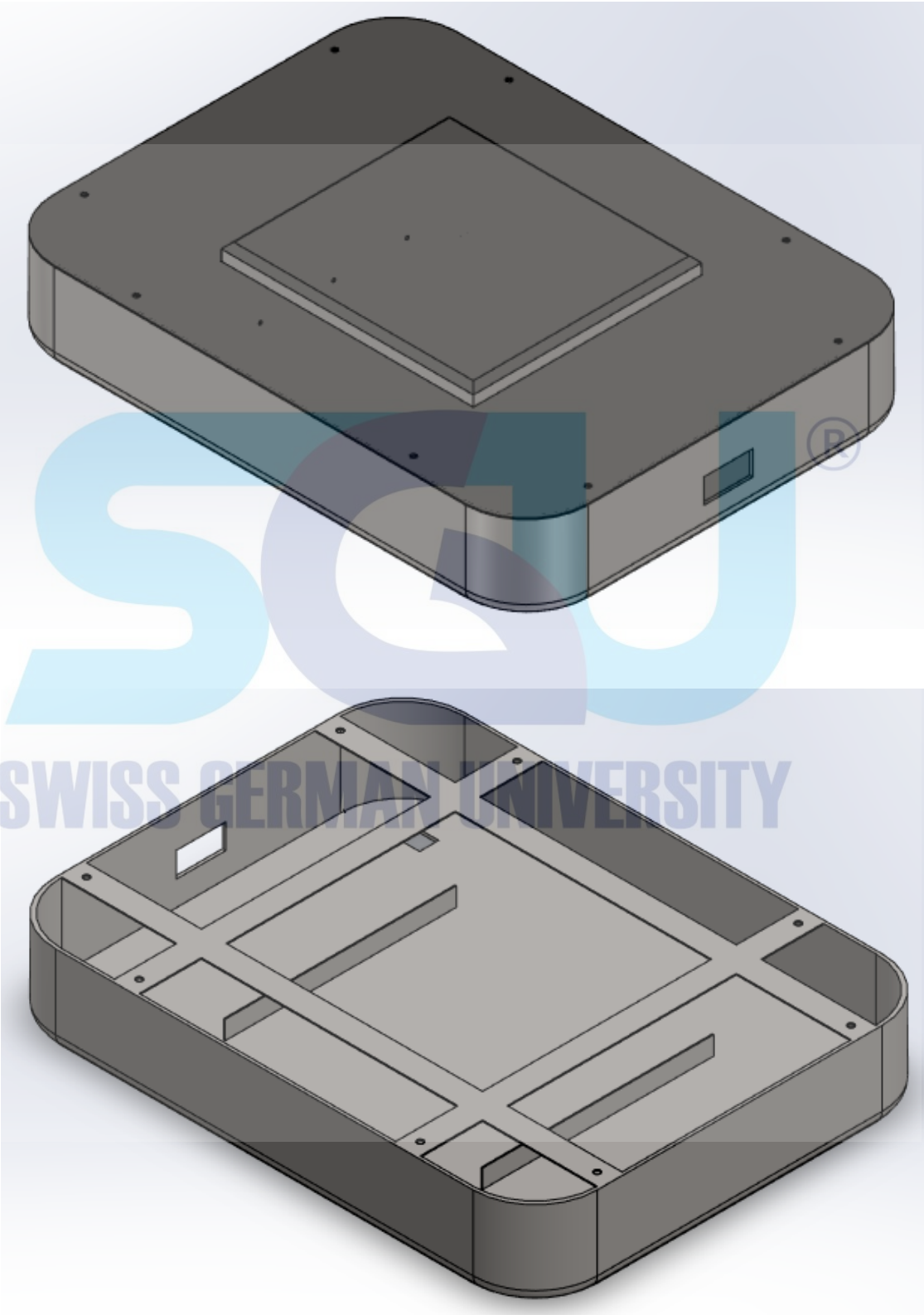
APPENDICES

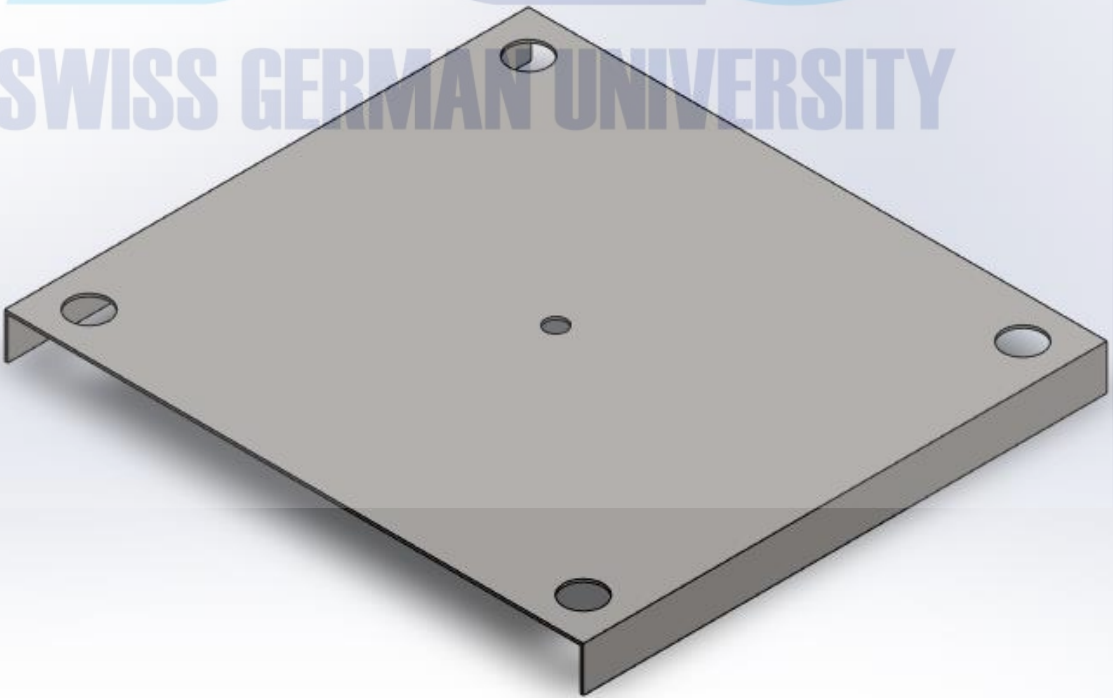
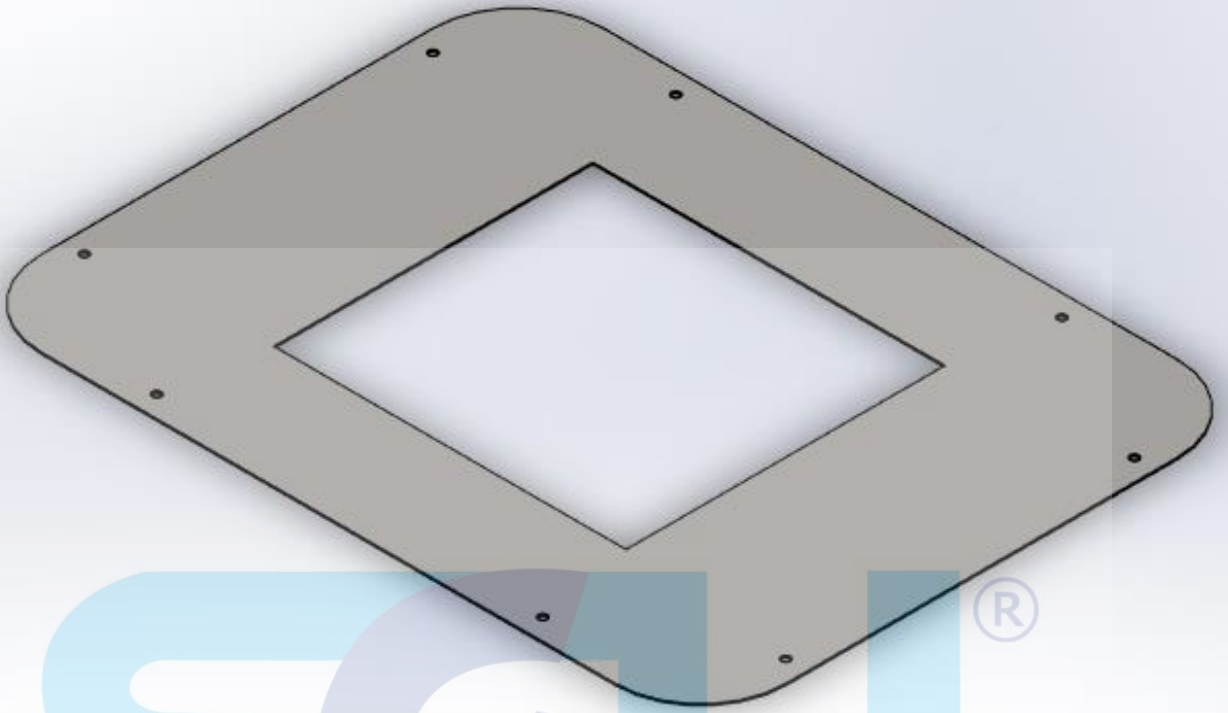
APPENDIX A - 3D DESIGN

A.1. The Cart Carrier

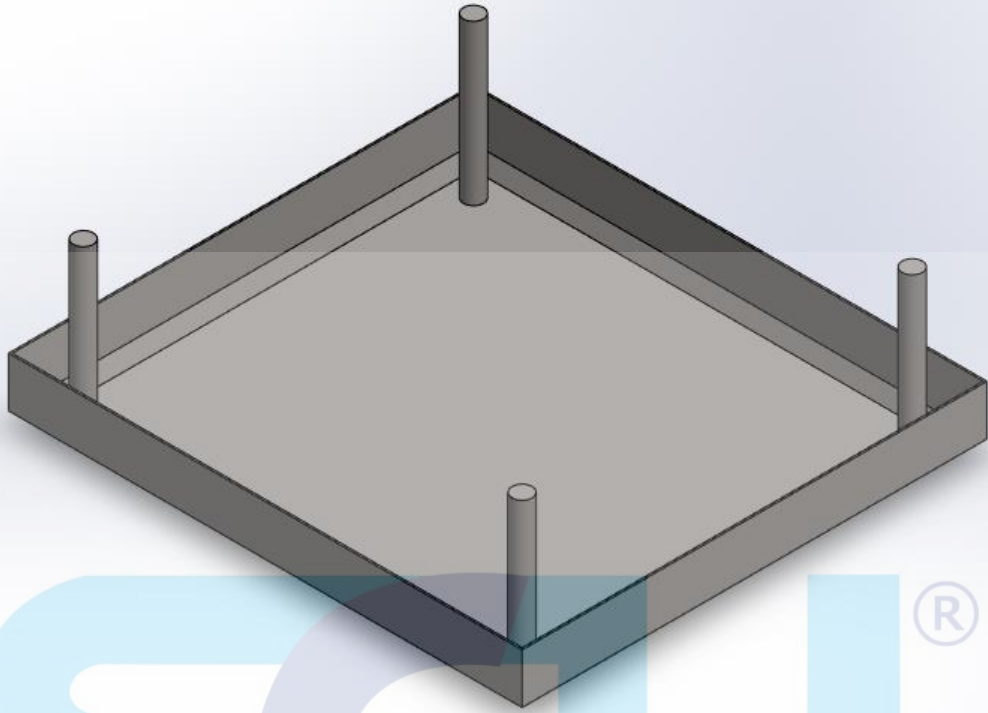


A.2 Locking Pins

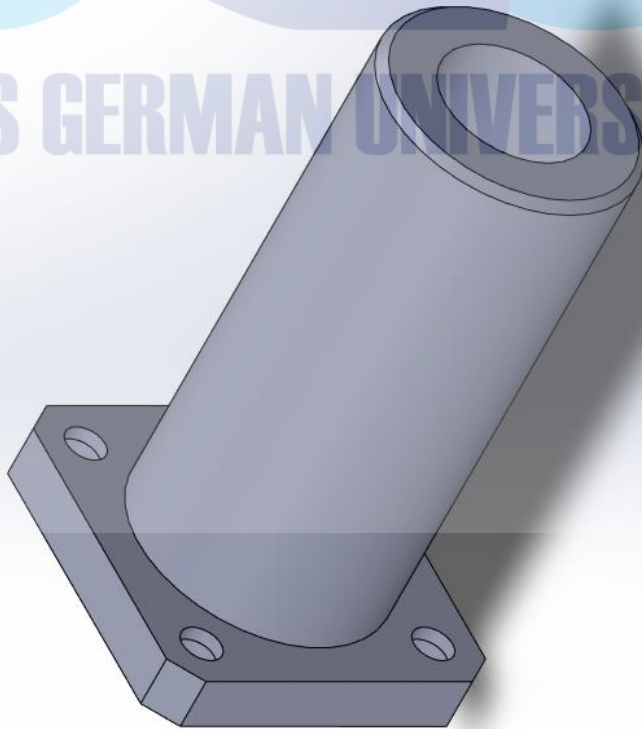


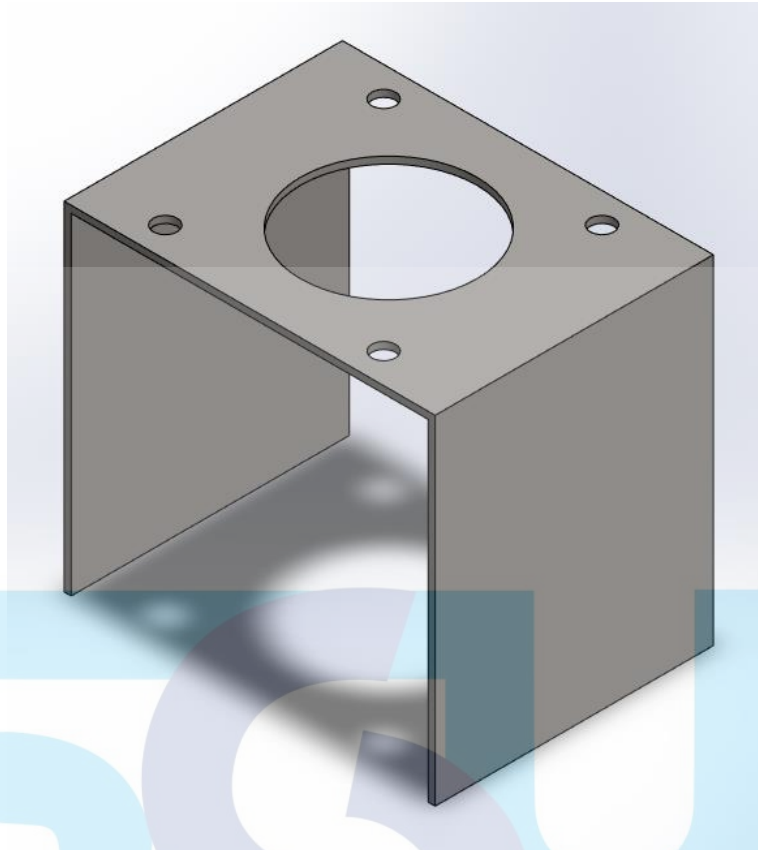


SGU[®]
SWISS GERMAN UNIVERSITY



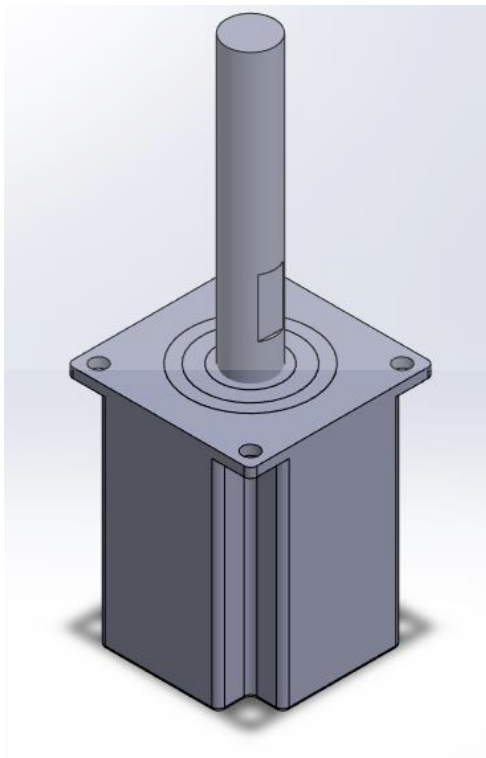
SCU[®]
SWISS GERMAN UNIVERSITY



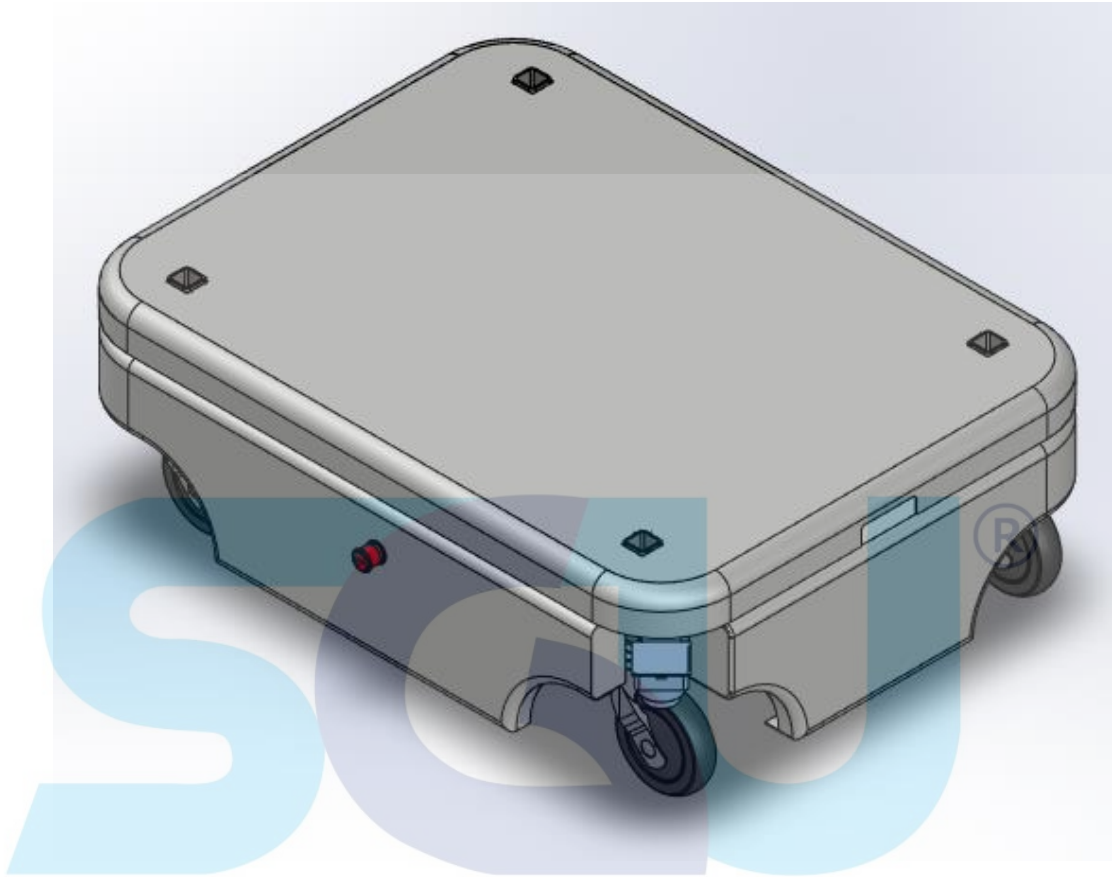


®

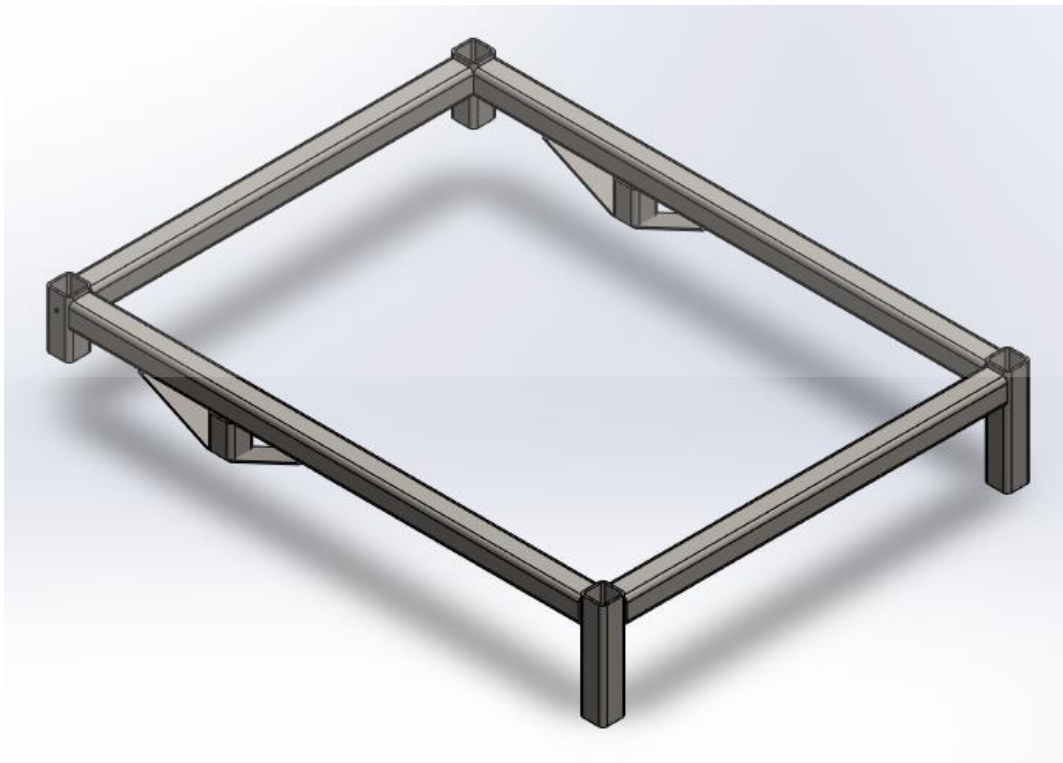
SWISS GERMAN UNIVERSITY

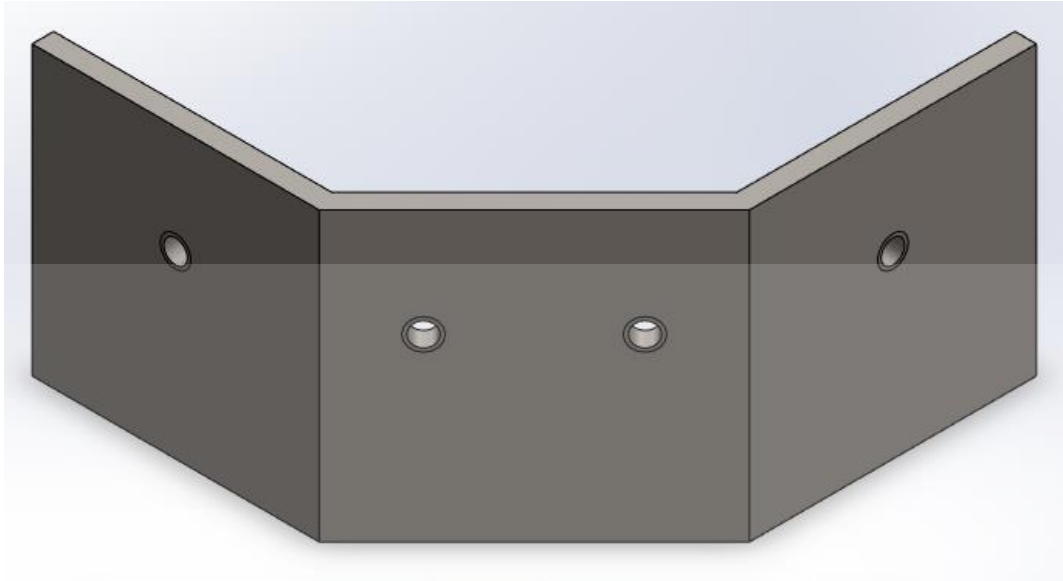


A.3 The AMR Robot



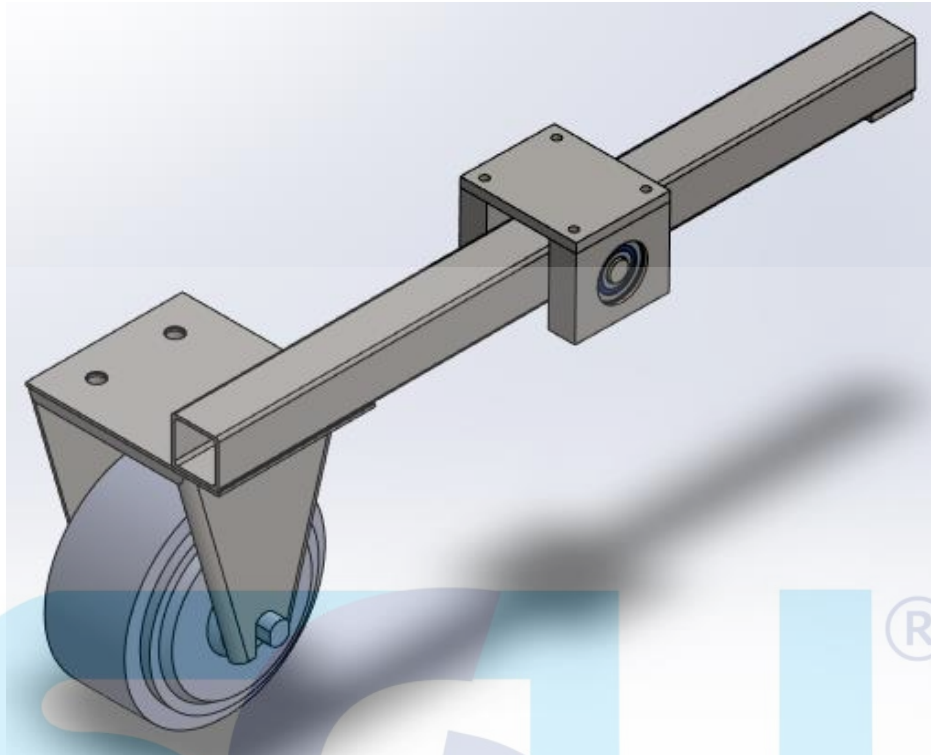
SWISS GERMAN UNIVERSITY



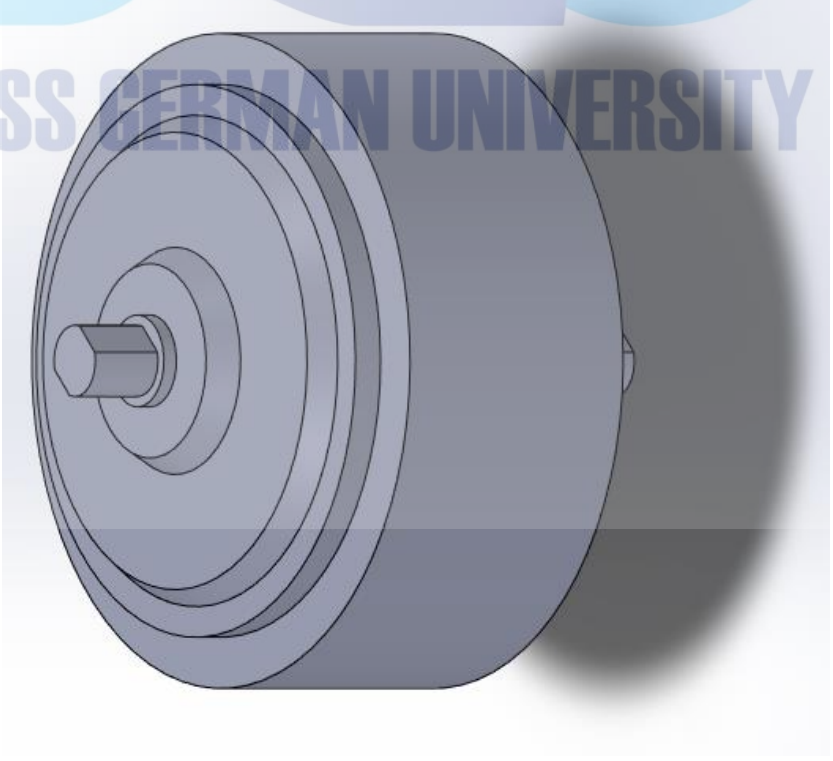


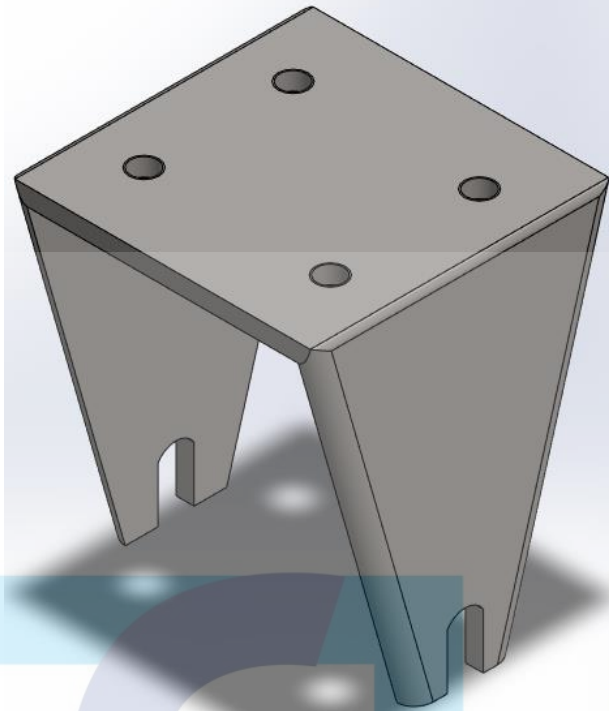
SGU[®]
SWISS GERMAN UNIVERSITY





SGU[®]
SWISS GERMAN UNIVERSITY

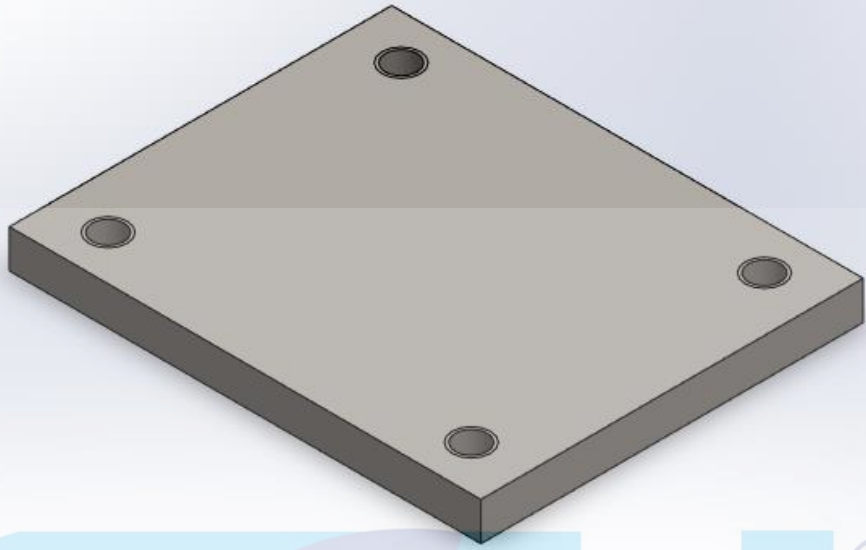




SGU[®]

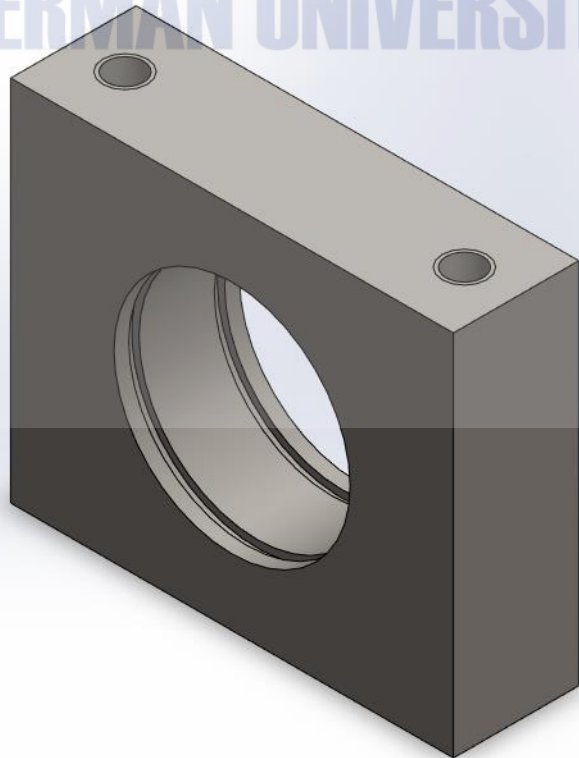
SWISS GERMAN UNIVERSITY

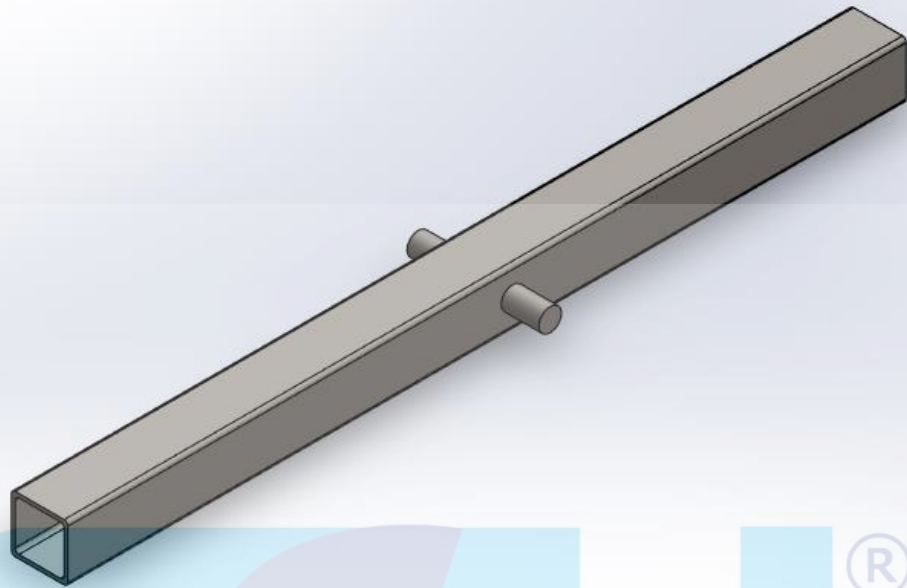




SGU[®]

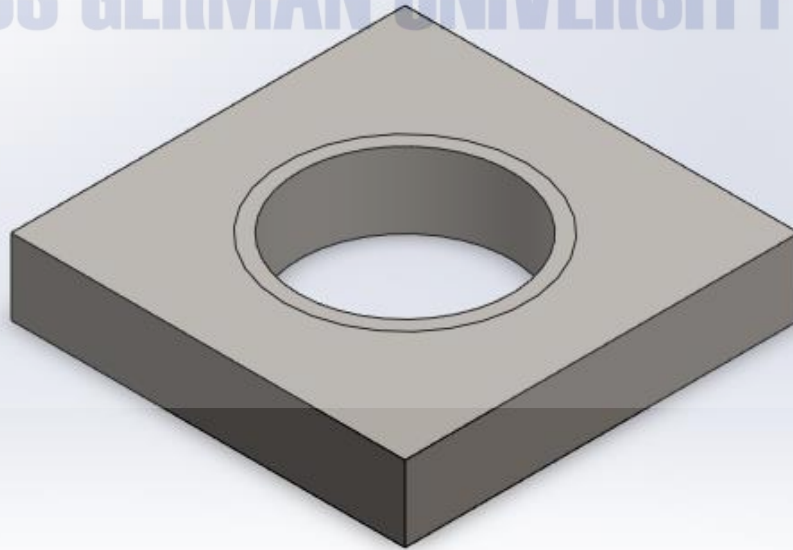
SWISS GERMAN UNIVERSITY

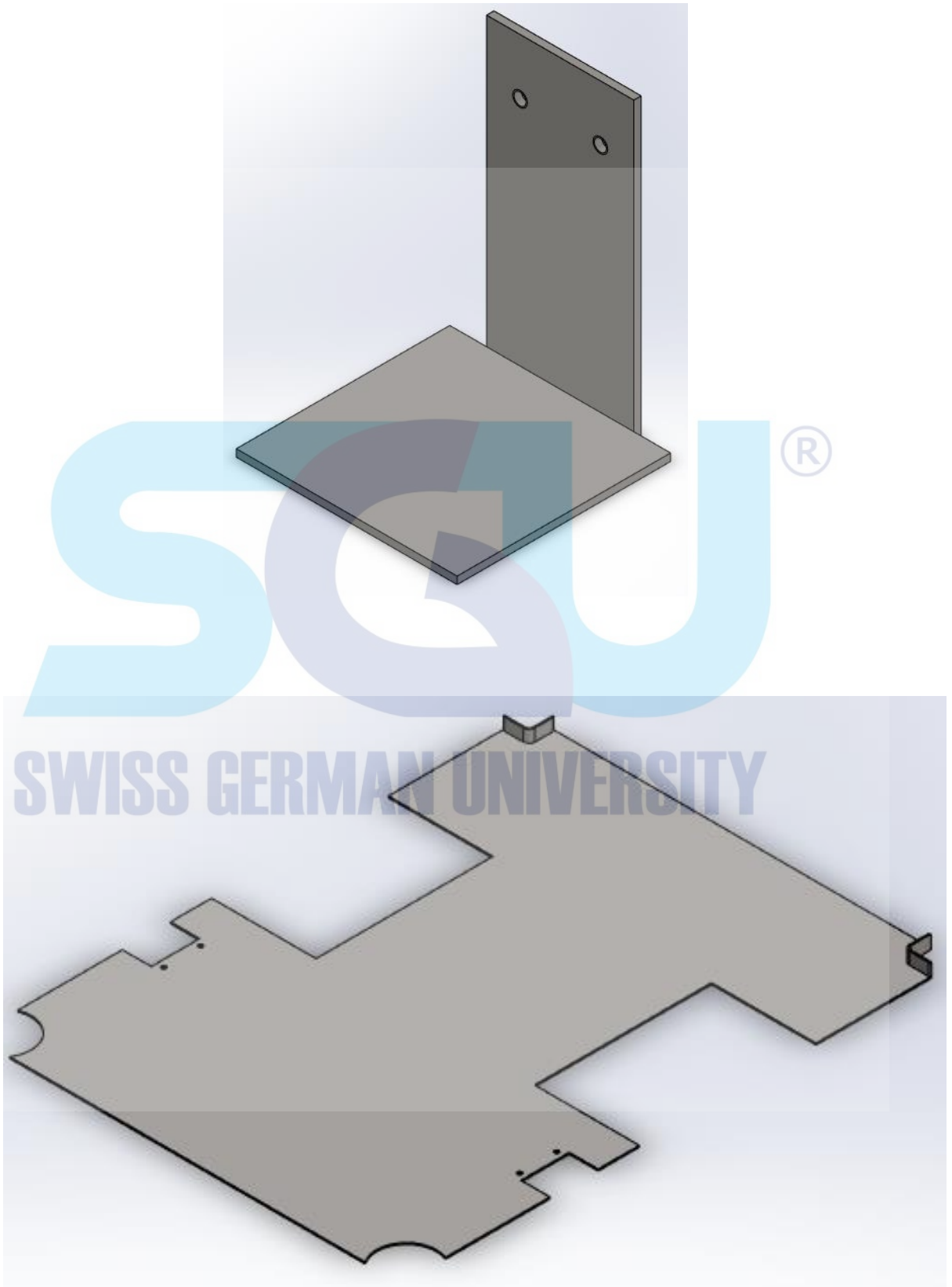


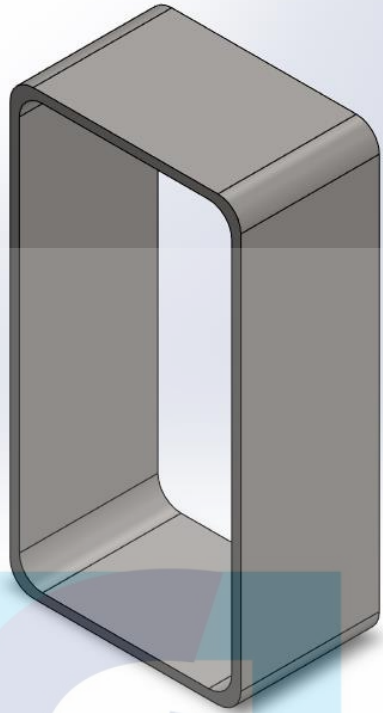


SGU[®]

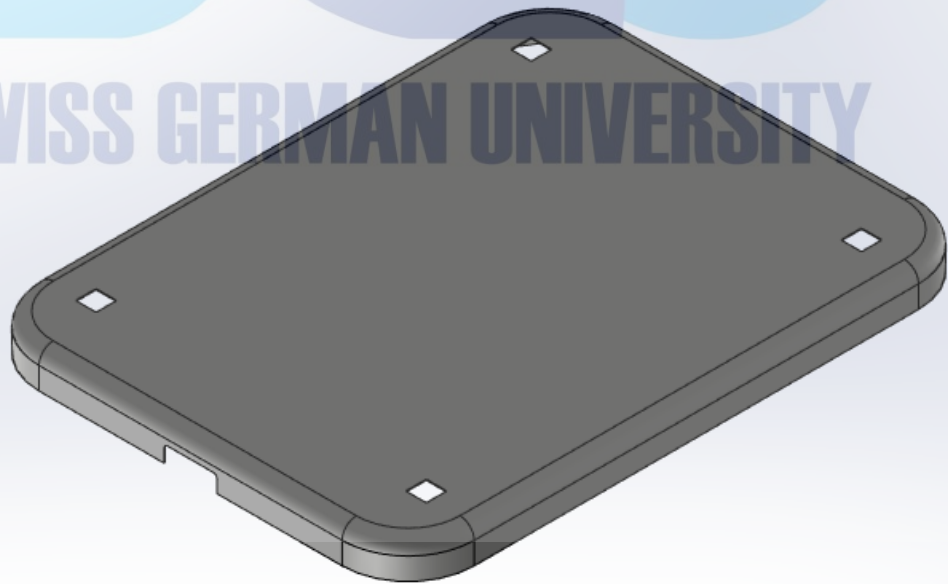
SWISS GERMAN UNIVERSITY

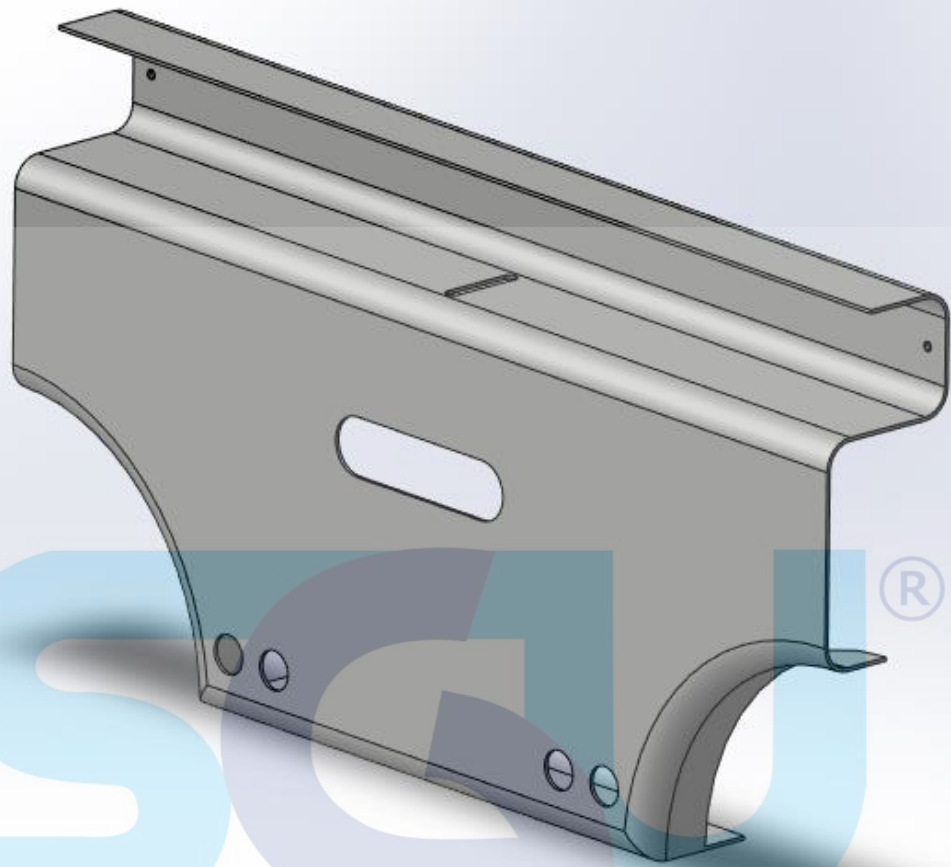




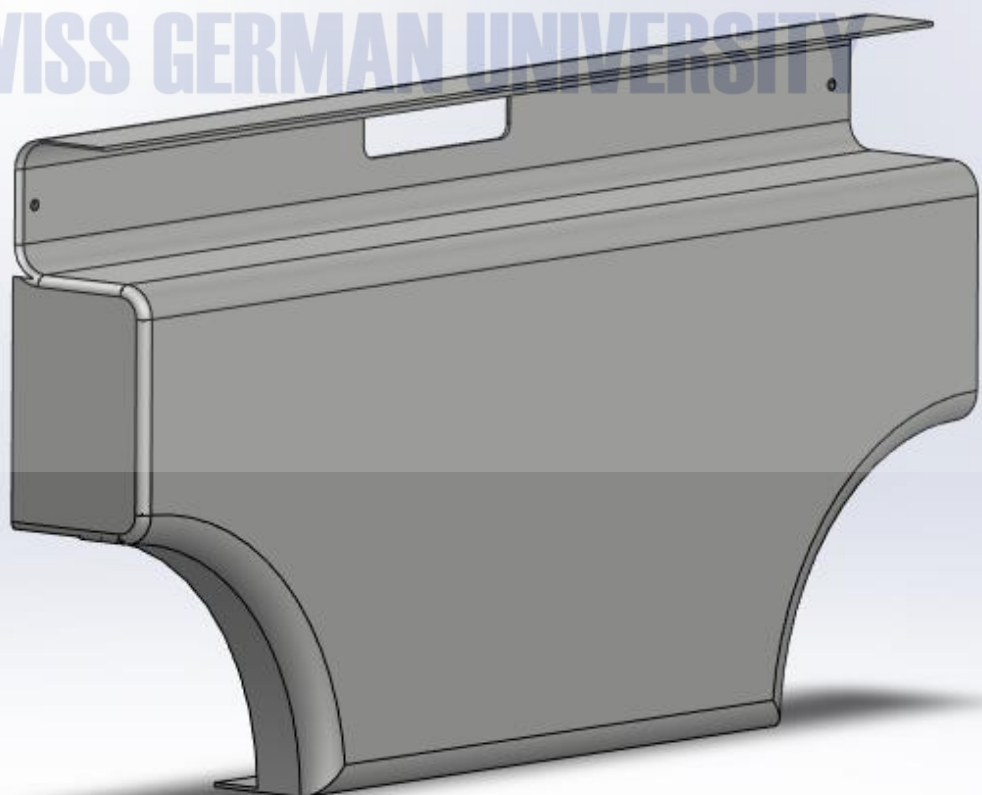


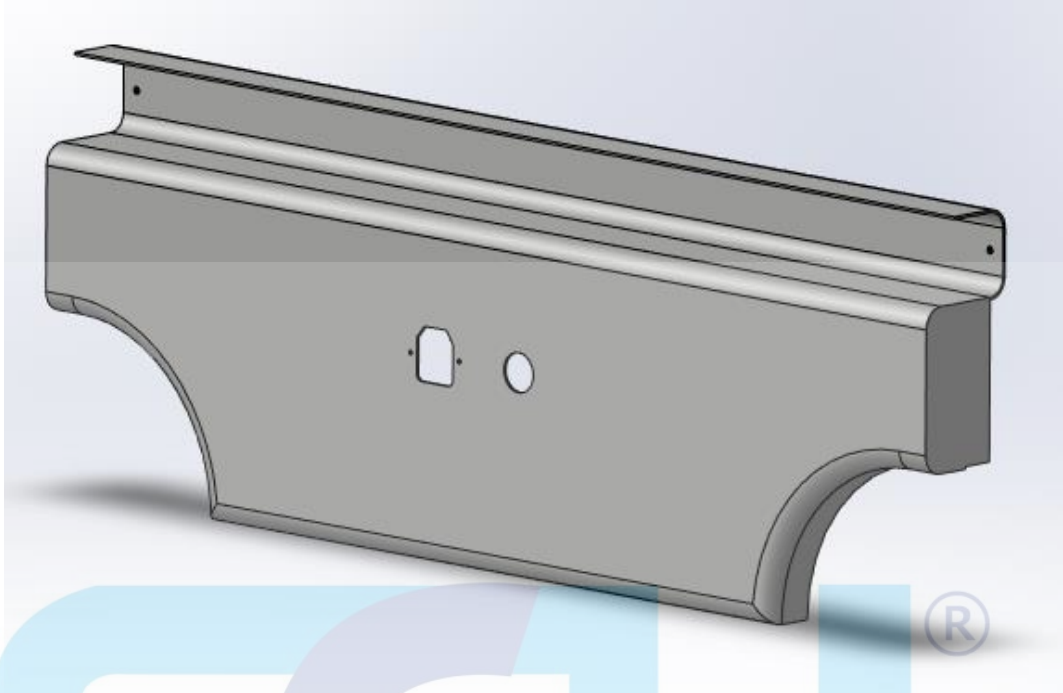
SGU[®]
SWISS GERMAN UNIVERSITY





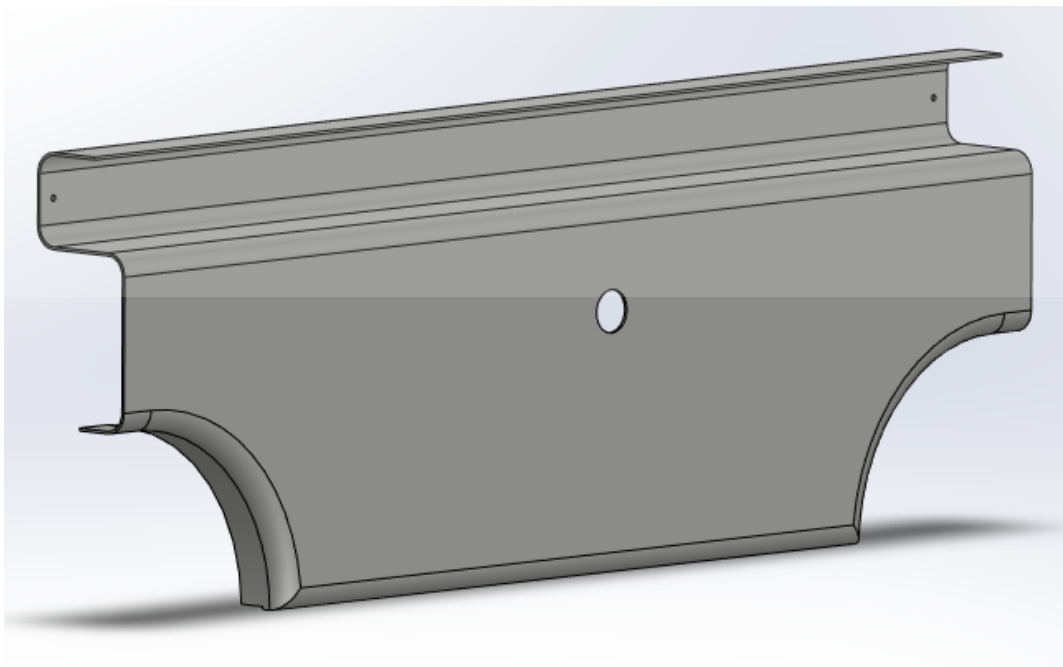
SWISS GERMAN UNIVERSITY

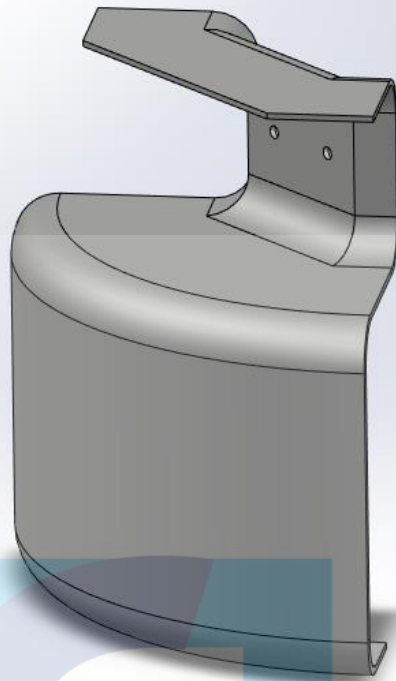




SGU

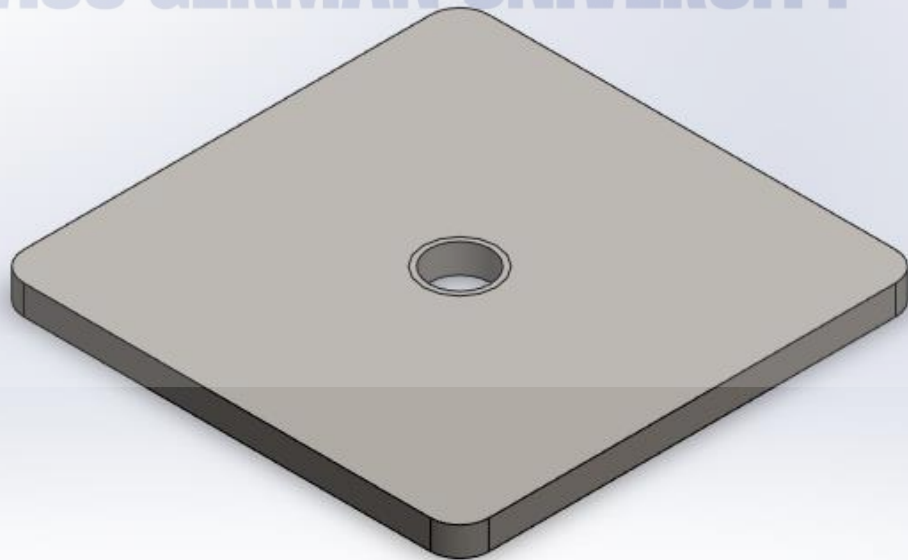
SWISS GERMAN UNIVERSITY





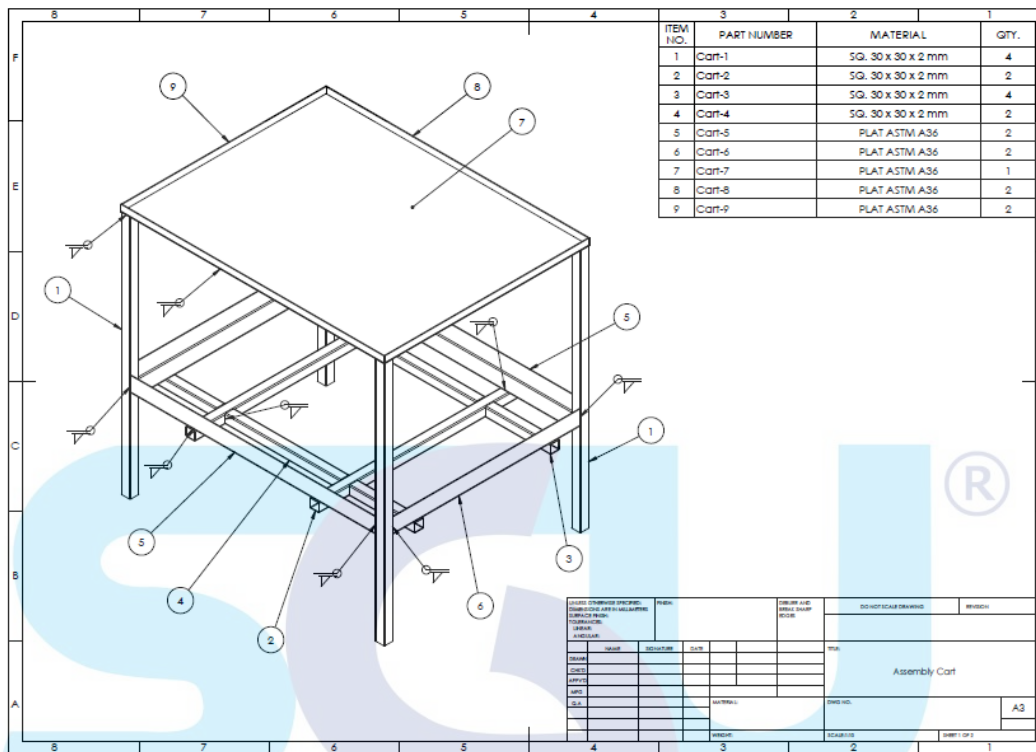
SGU[®]

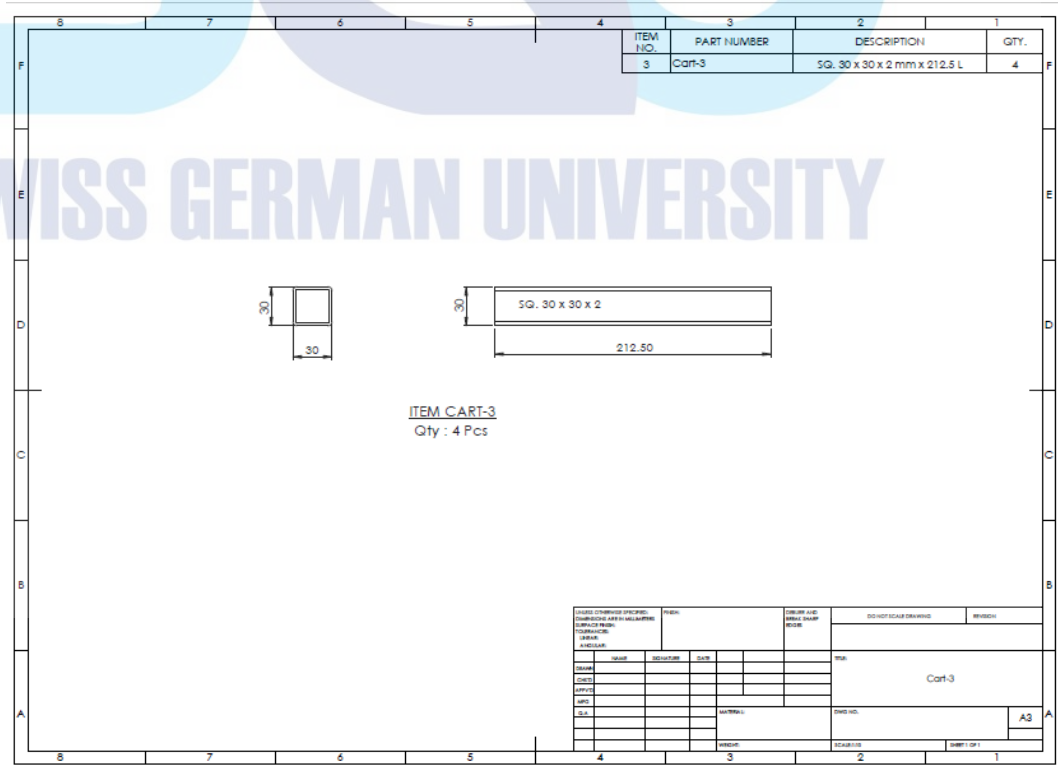
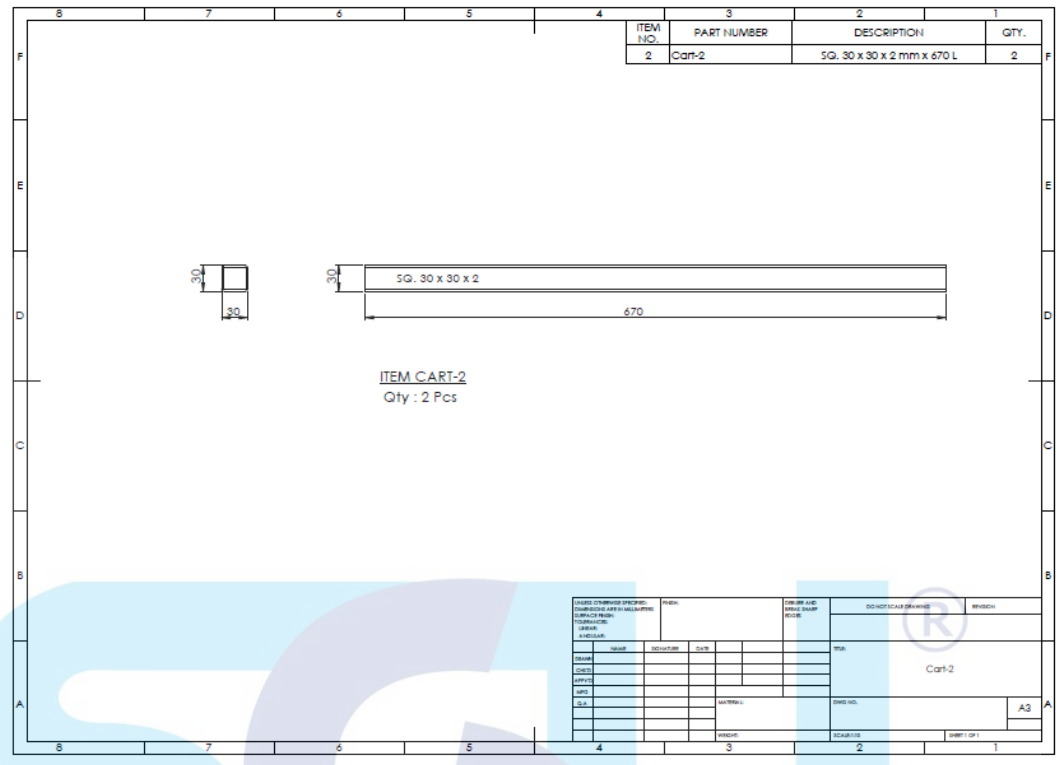
SWISS GERMAN UNIVERSITY

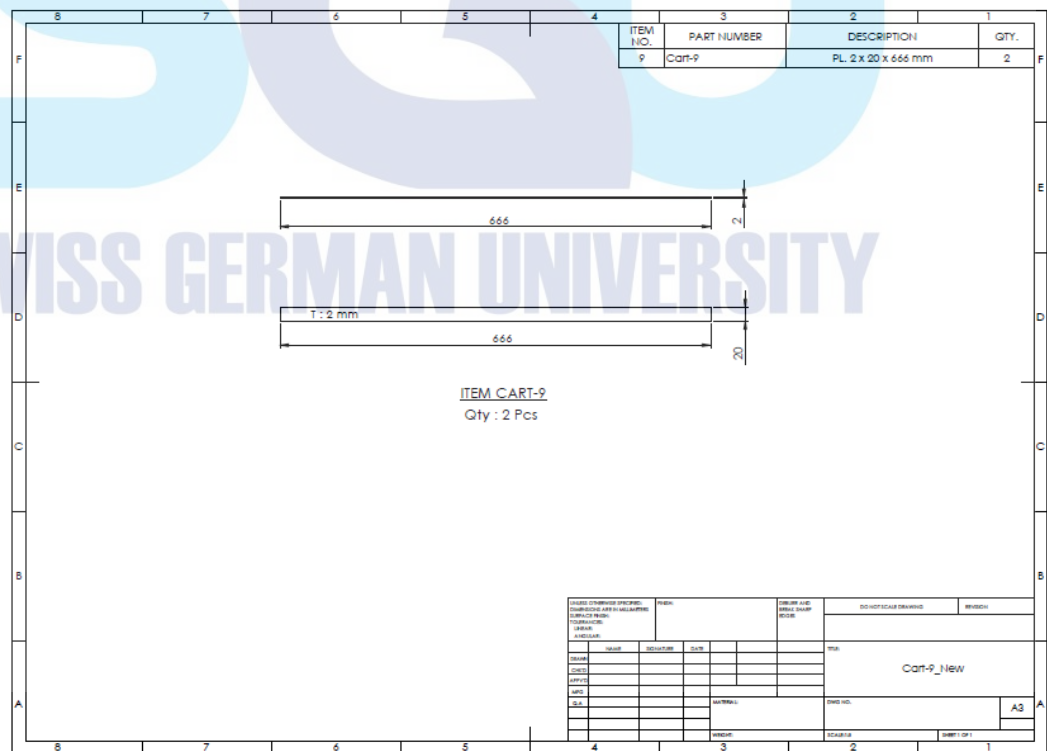
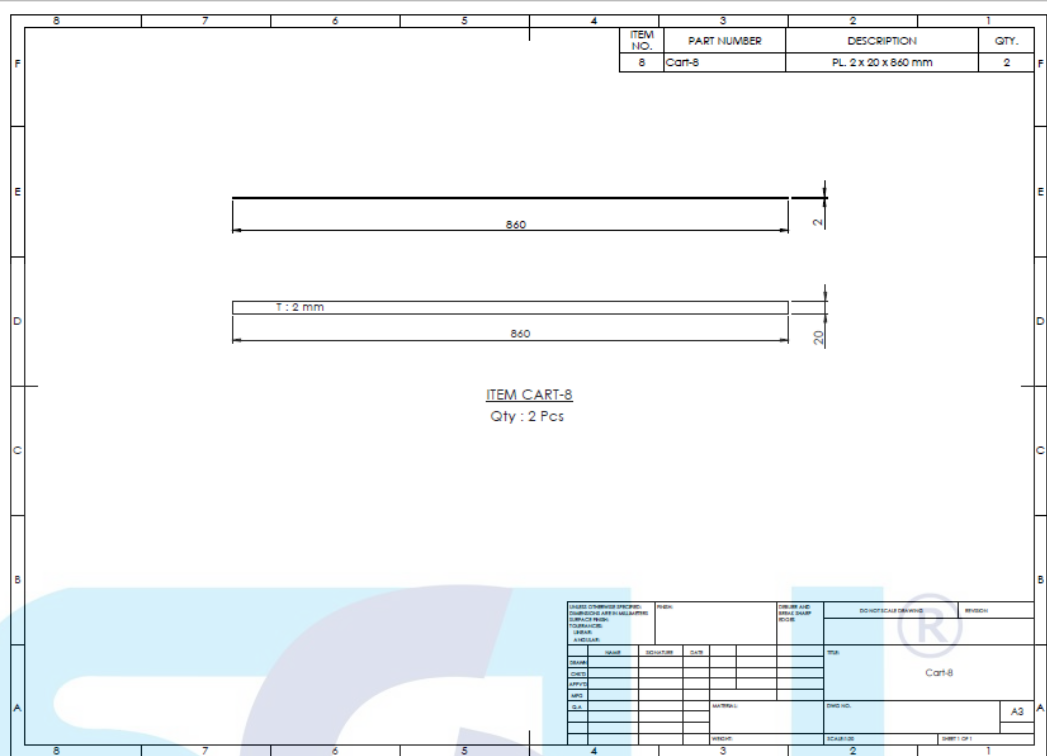


APPENDIX B - MECHANICAL DRAWING

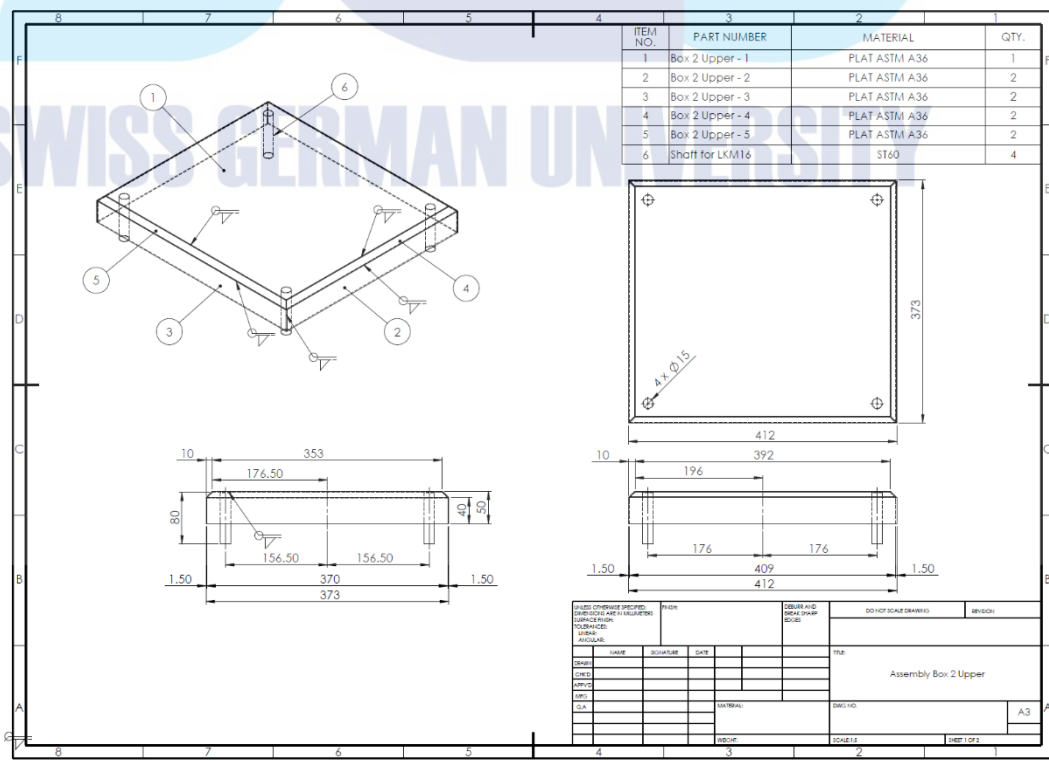
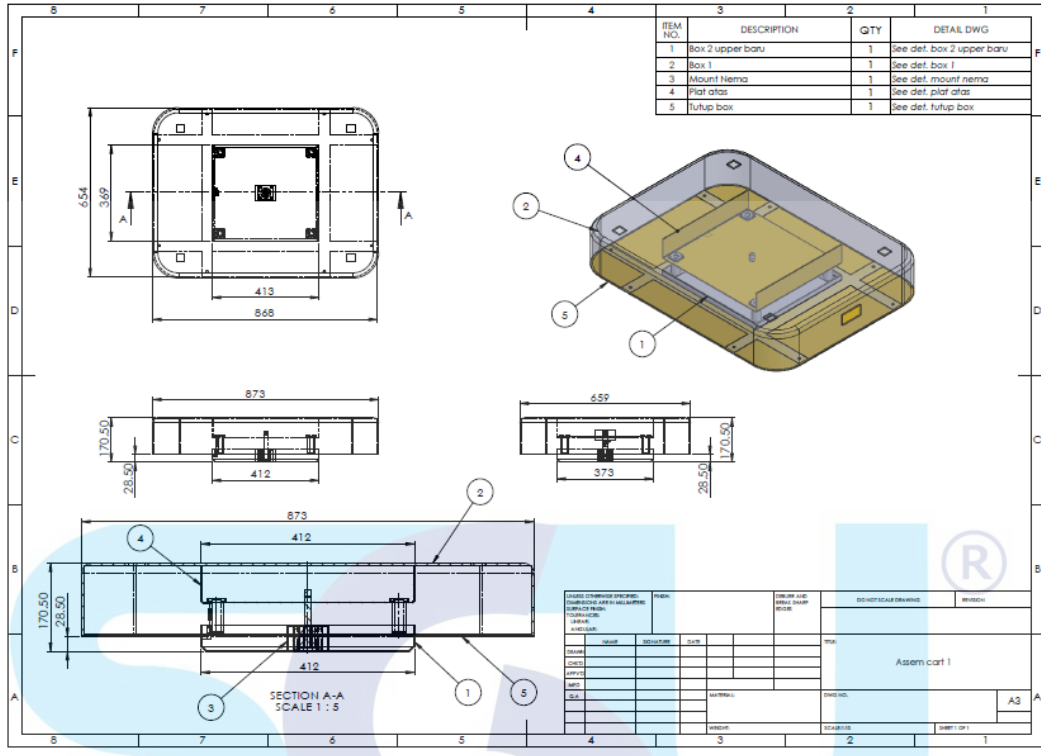
The Cart

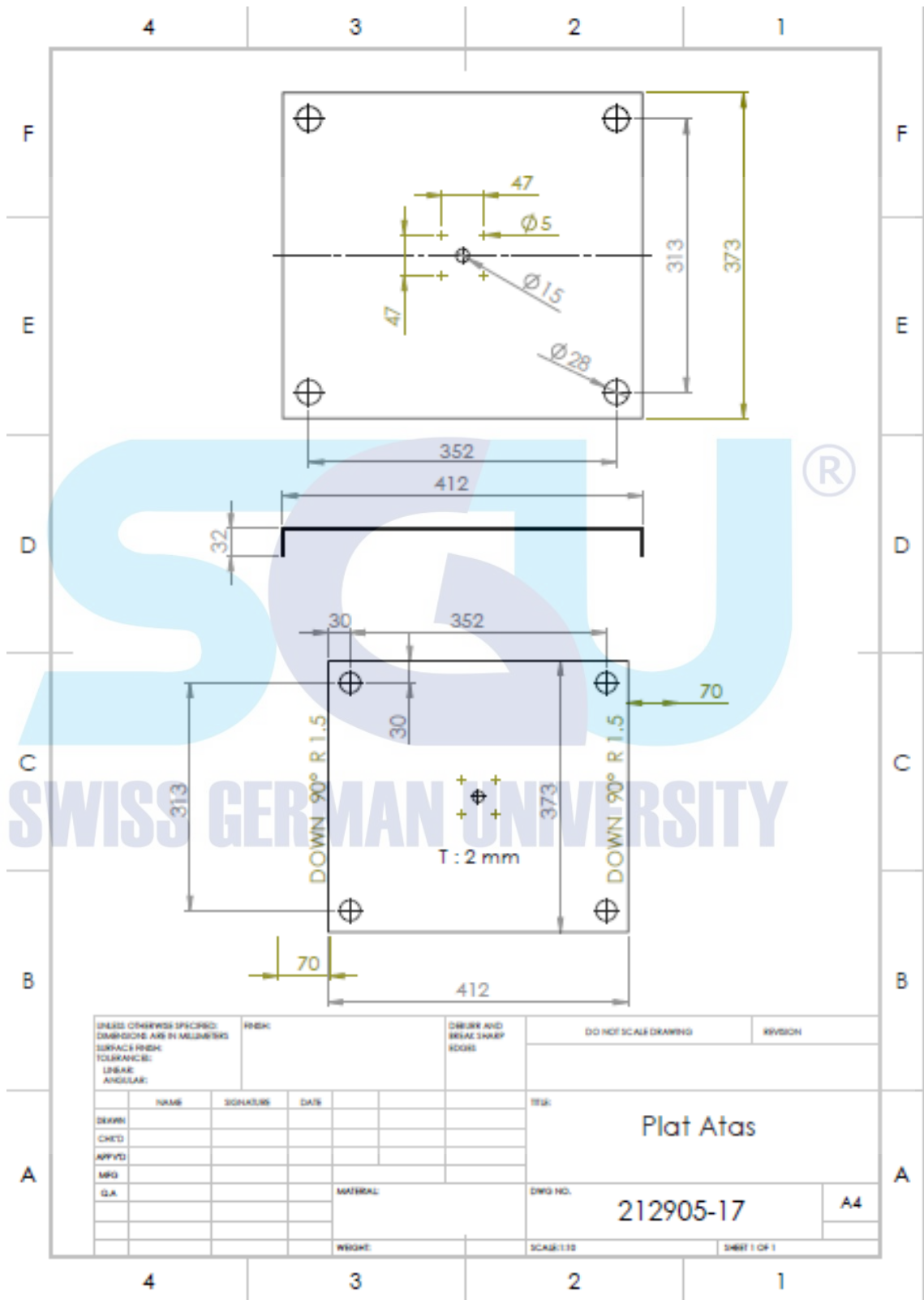






Locking Cart





UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH
TOLERANCES:
LINEAR
ANGULAR:

FINISH

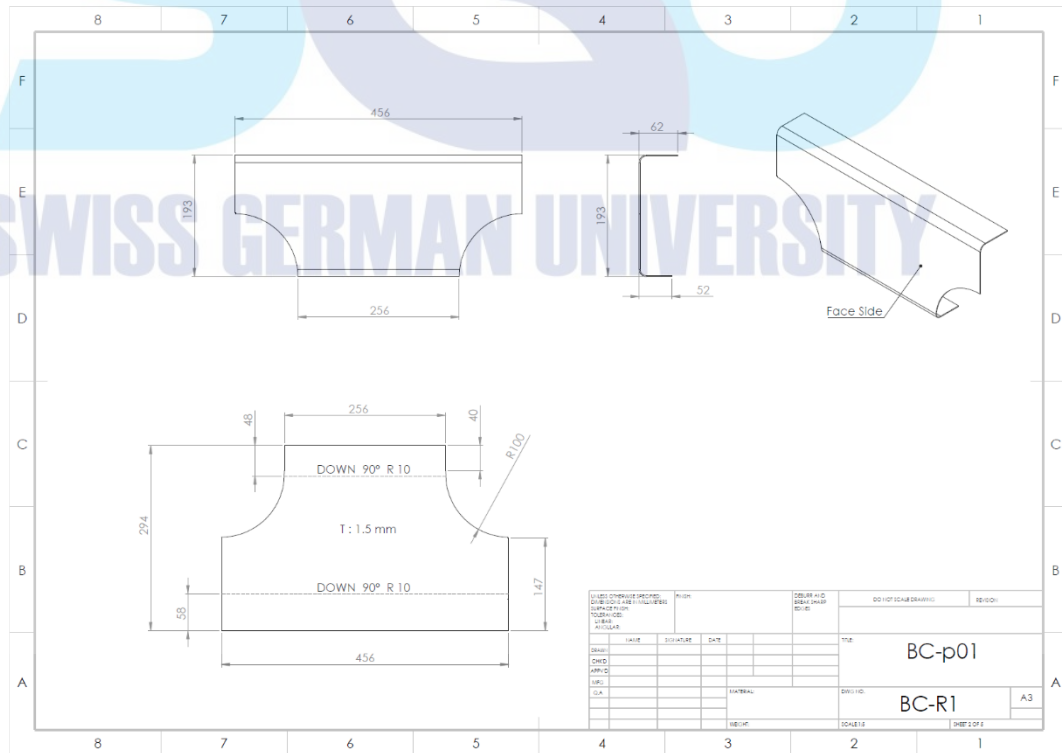
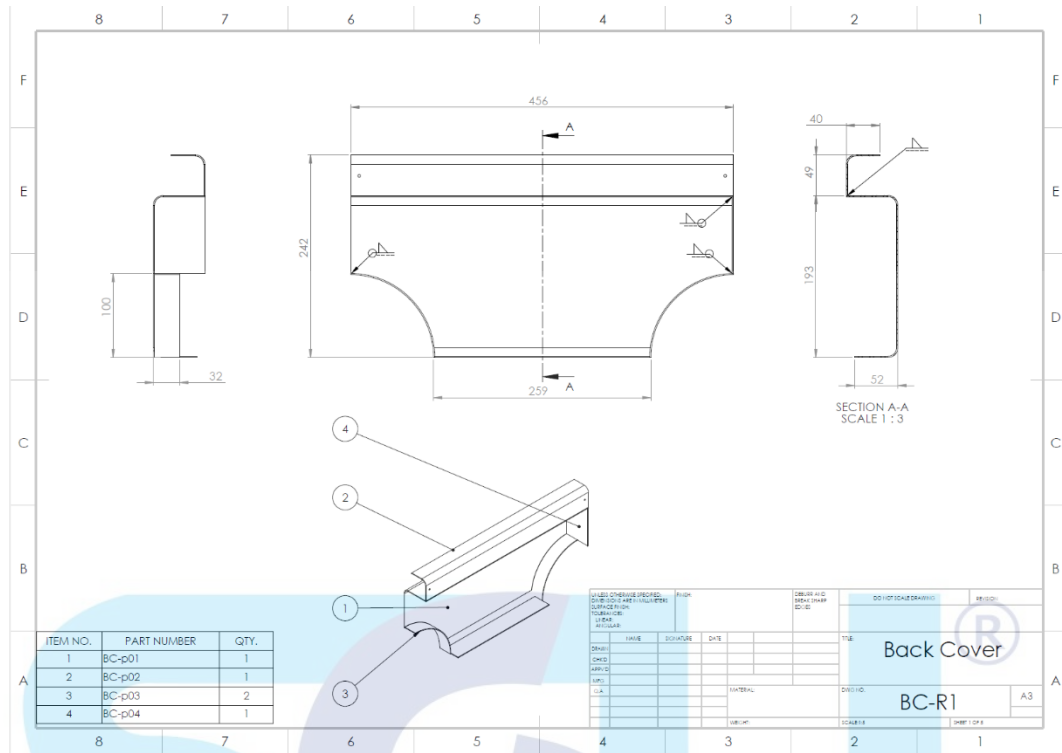
CHAMFER AND
BREAK SHARP
EDGES

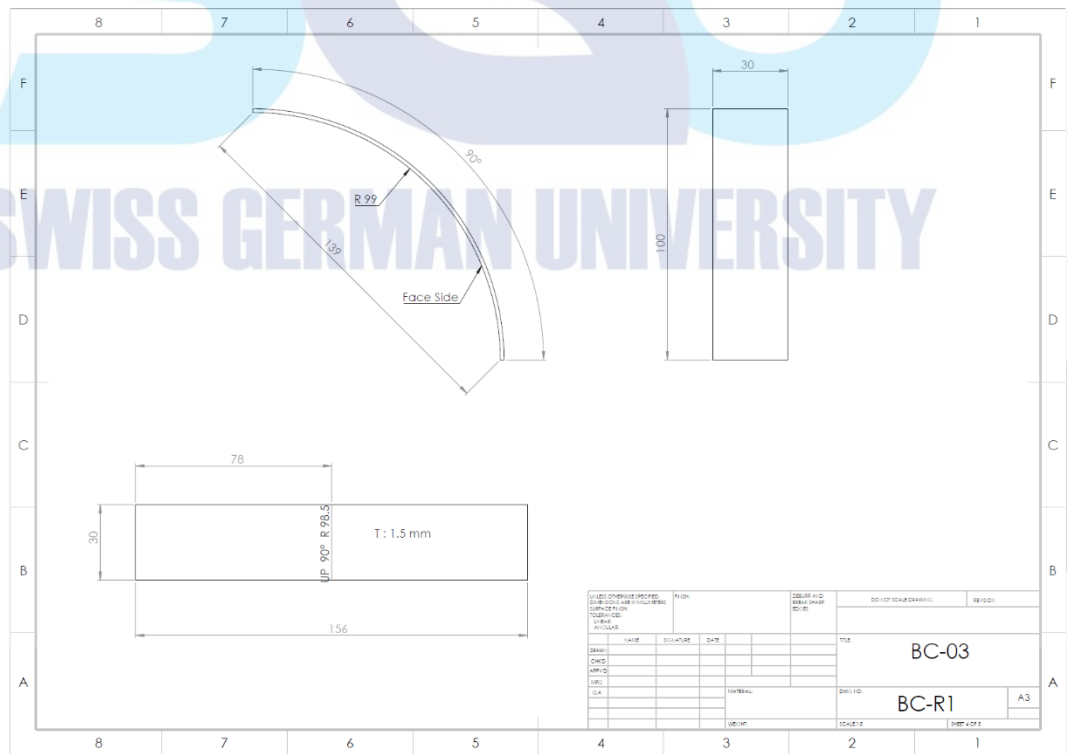
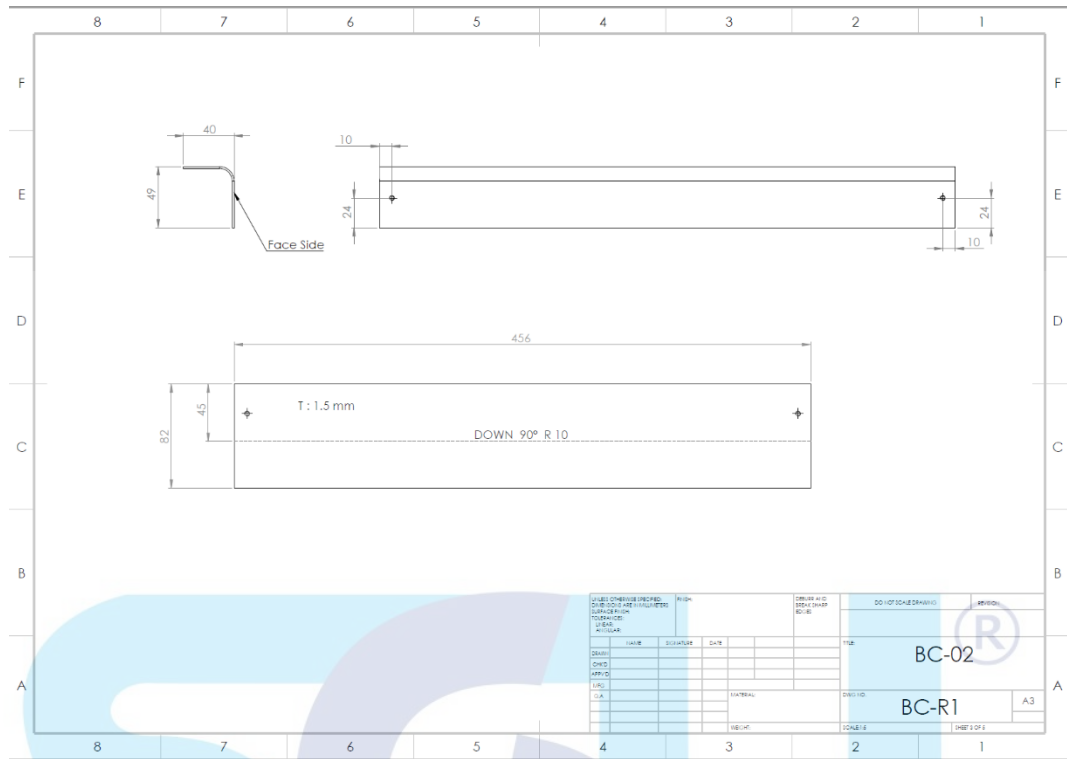
DO NOT SCALE DRAWING

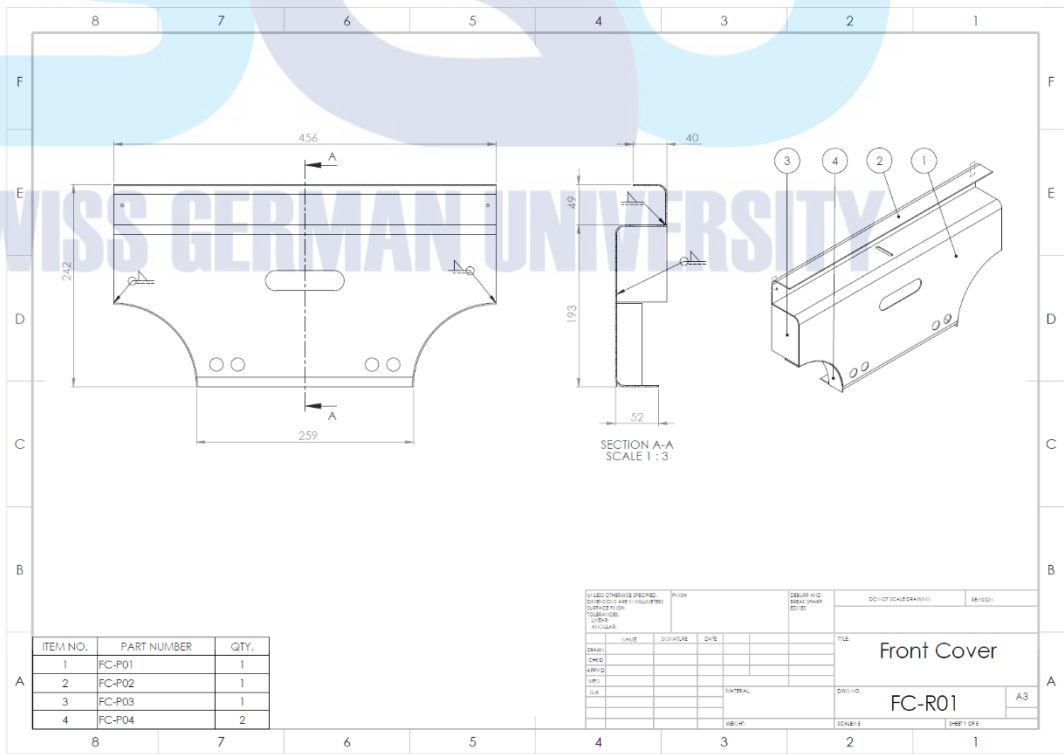
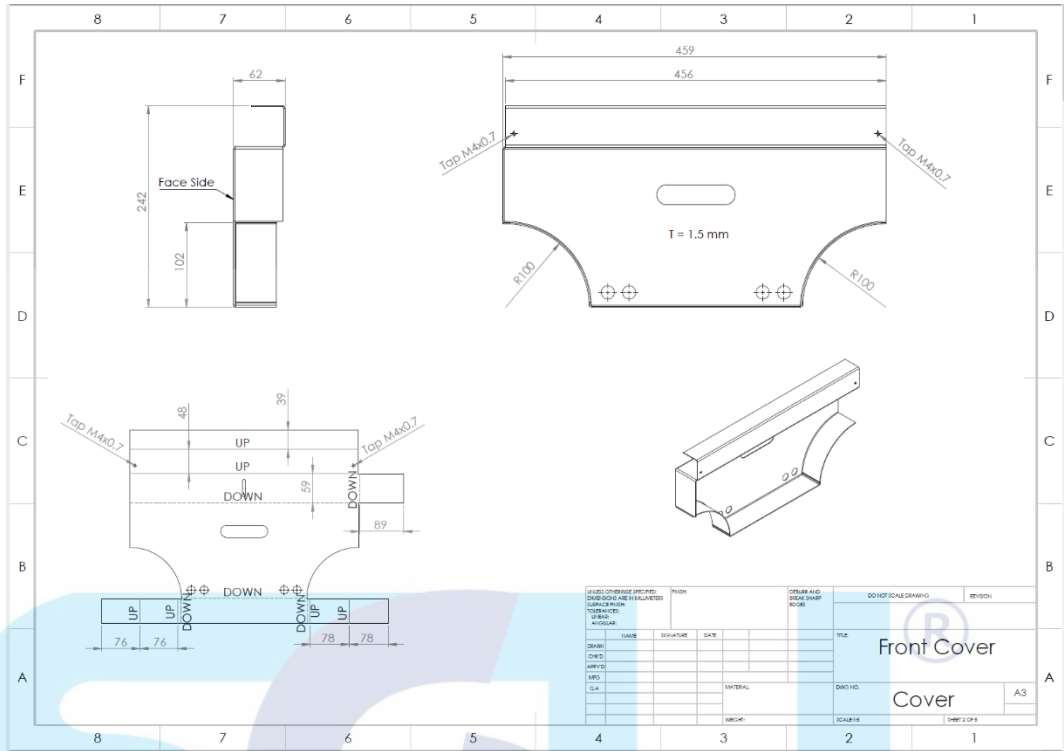
REVISION

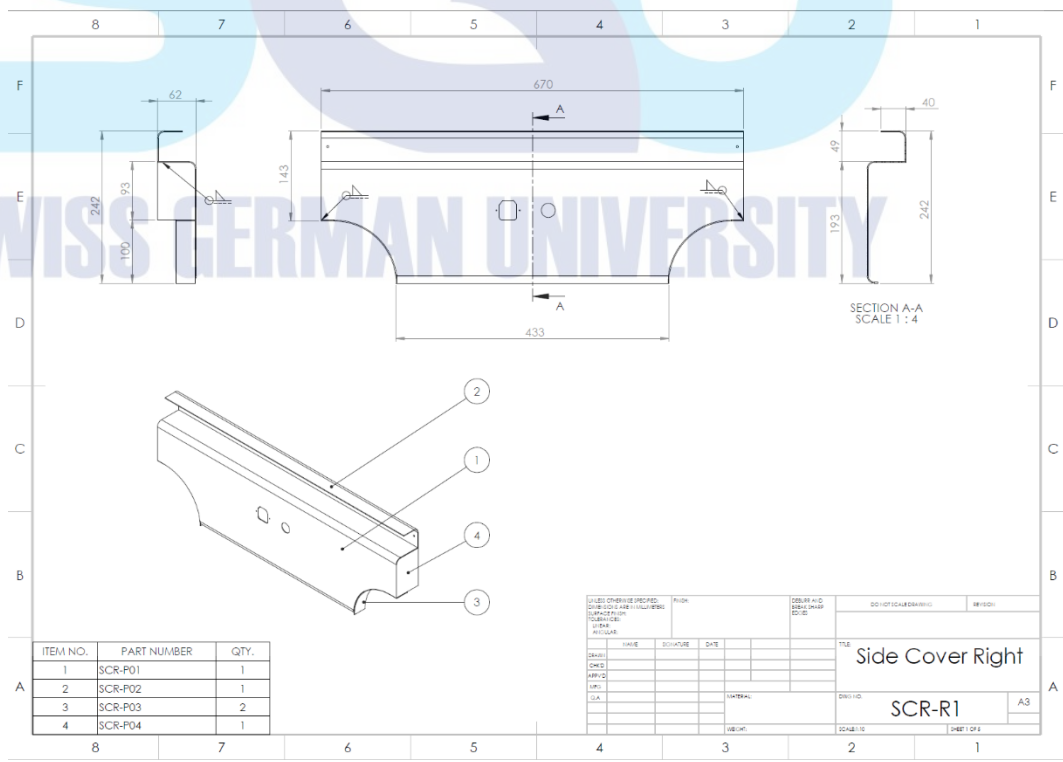
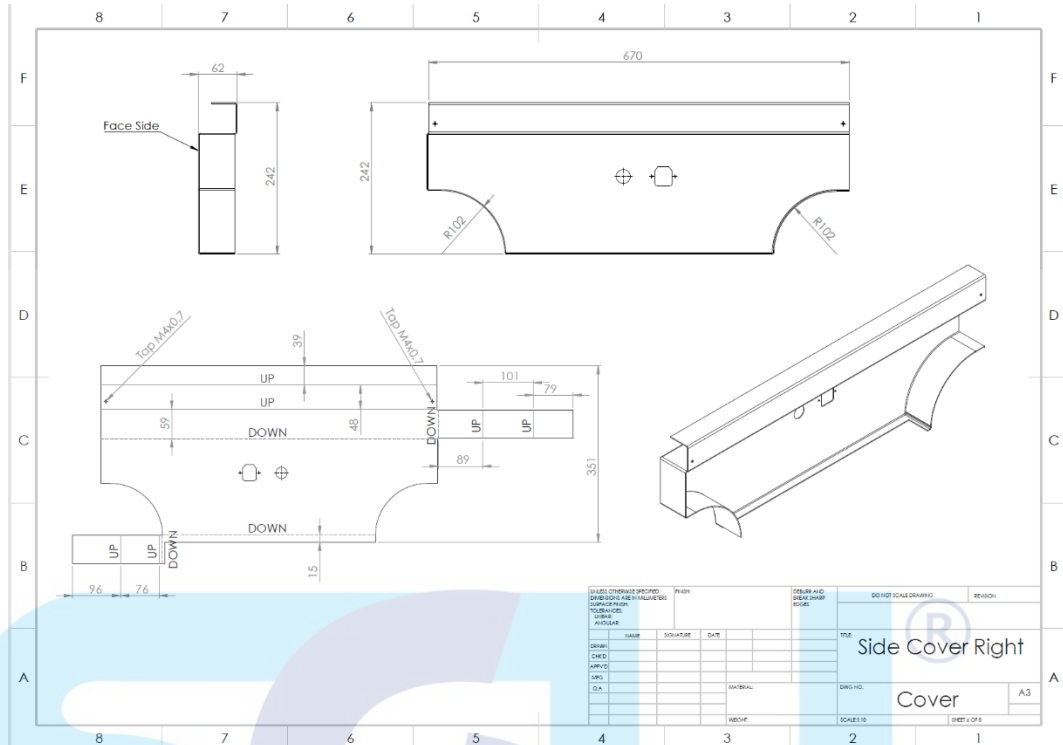
	NAME	SIGNATURE	DATE		
DESIGN					
CHECK					
APPROV					
MFG					
D.A.				MATERIAL:	
				WEIGHT:	

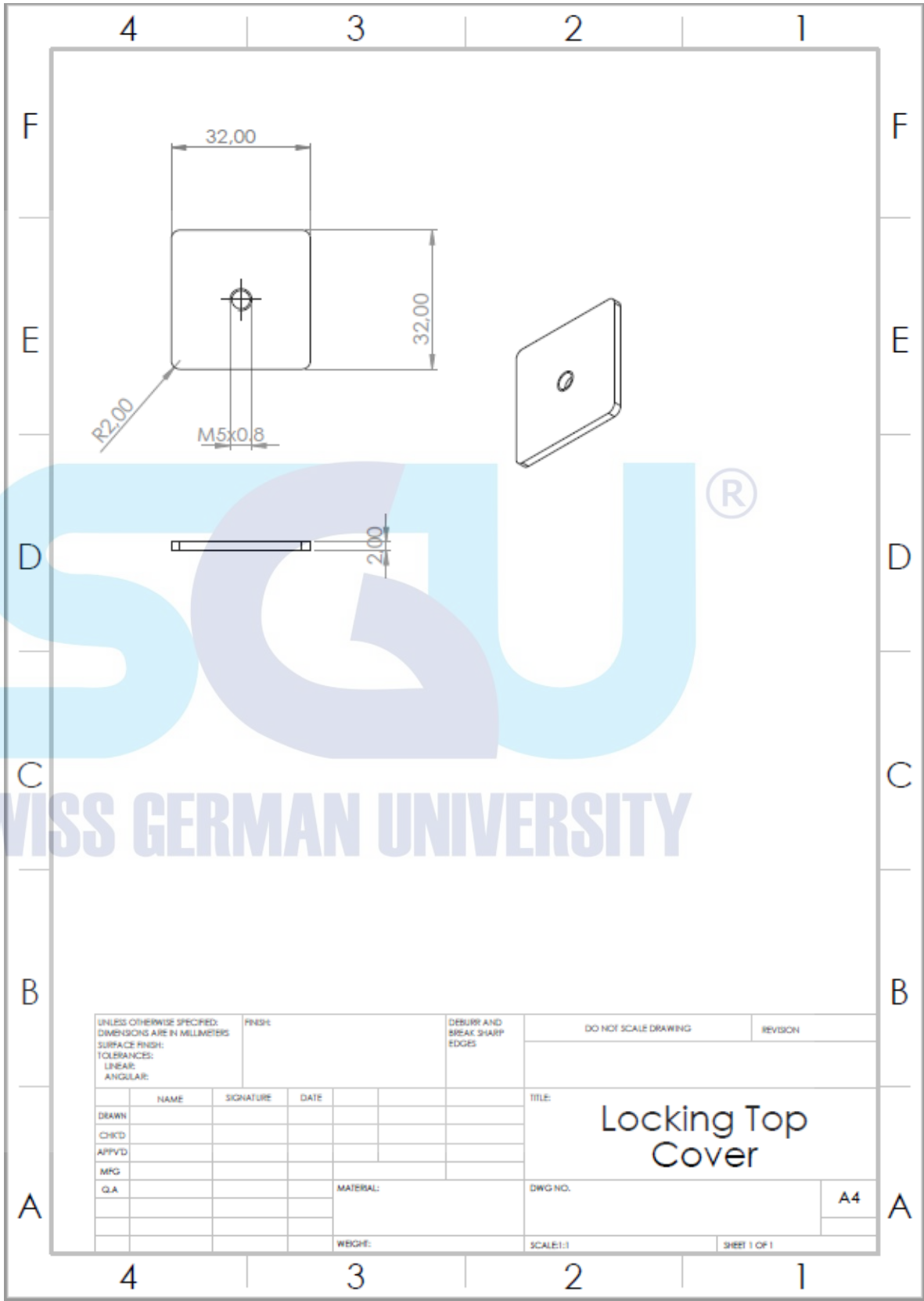
TITLE:		Plat Atas	
DWG NO.		212905-17	
SCALE: 1:10		SHEET 1 OF 1	
		A4	





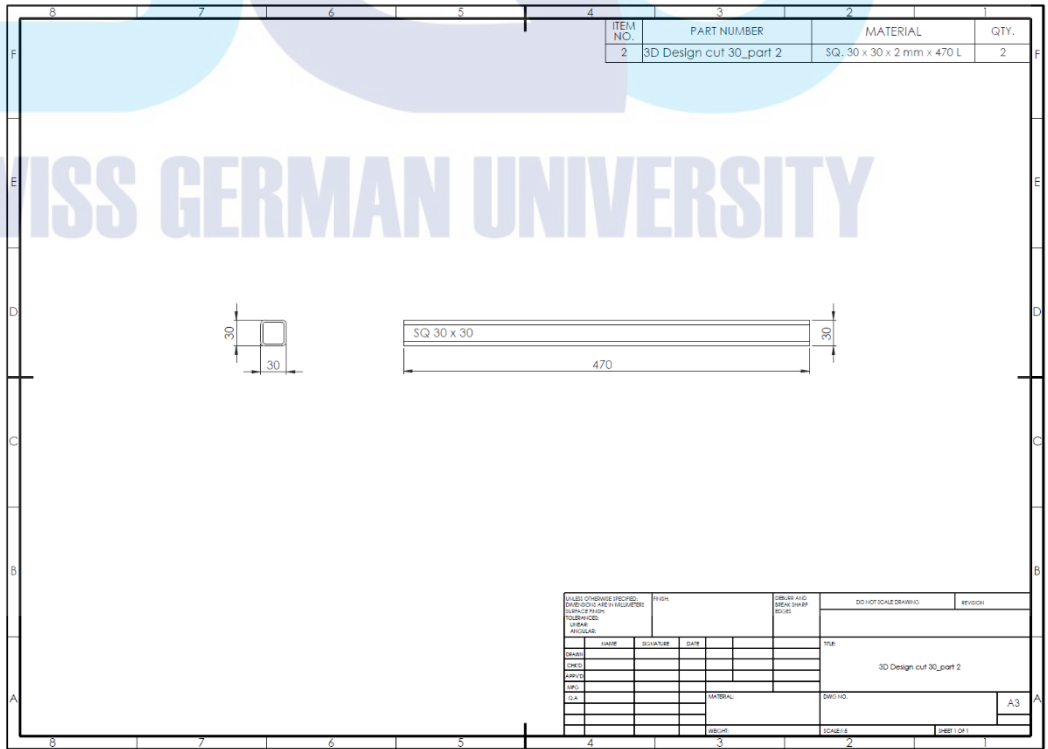
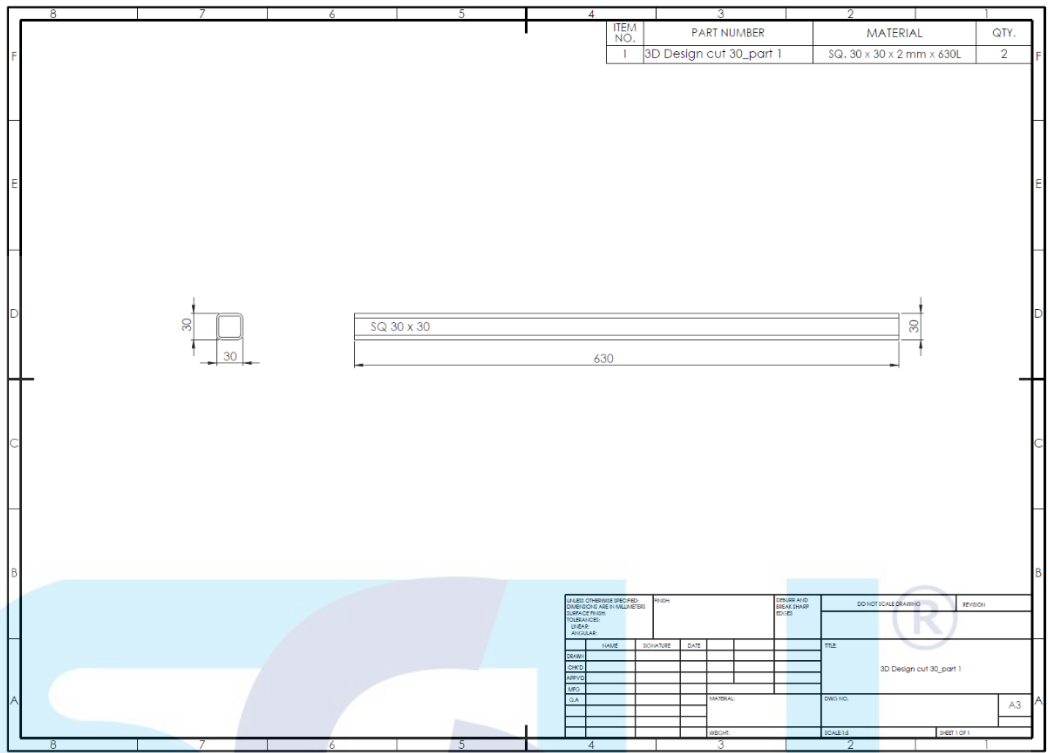




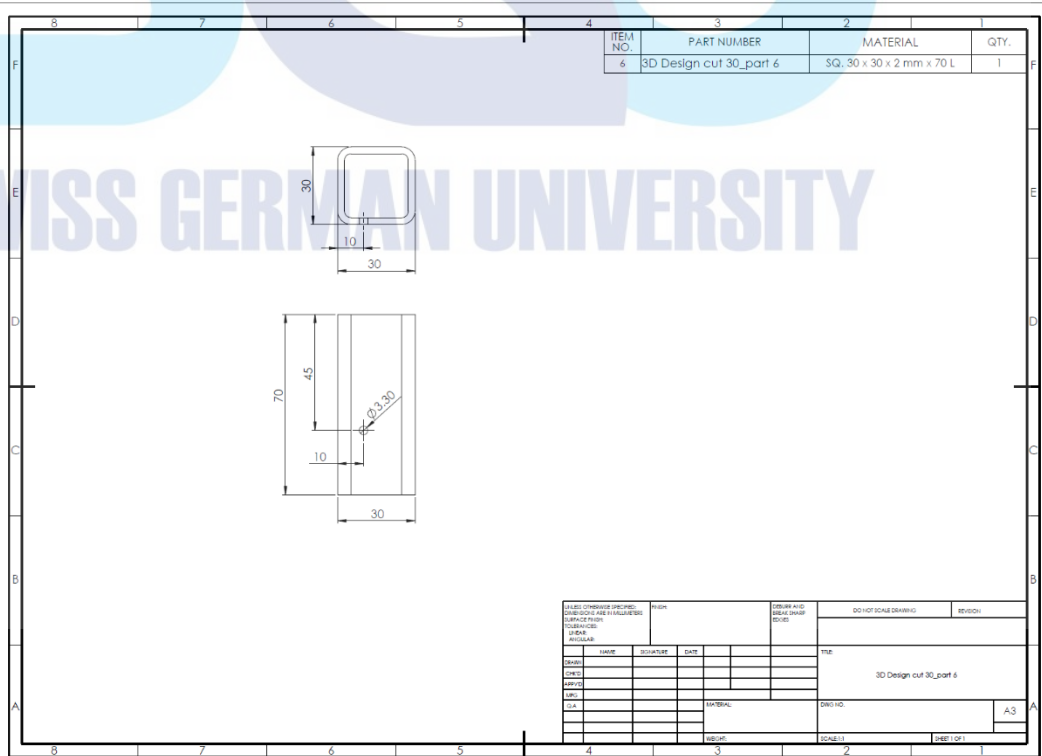
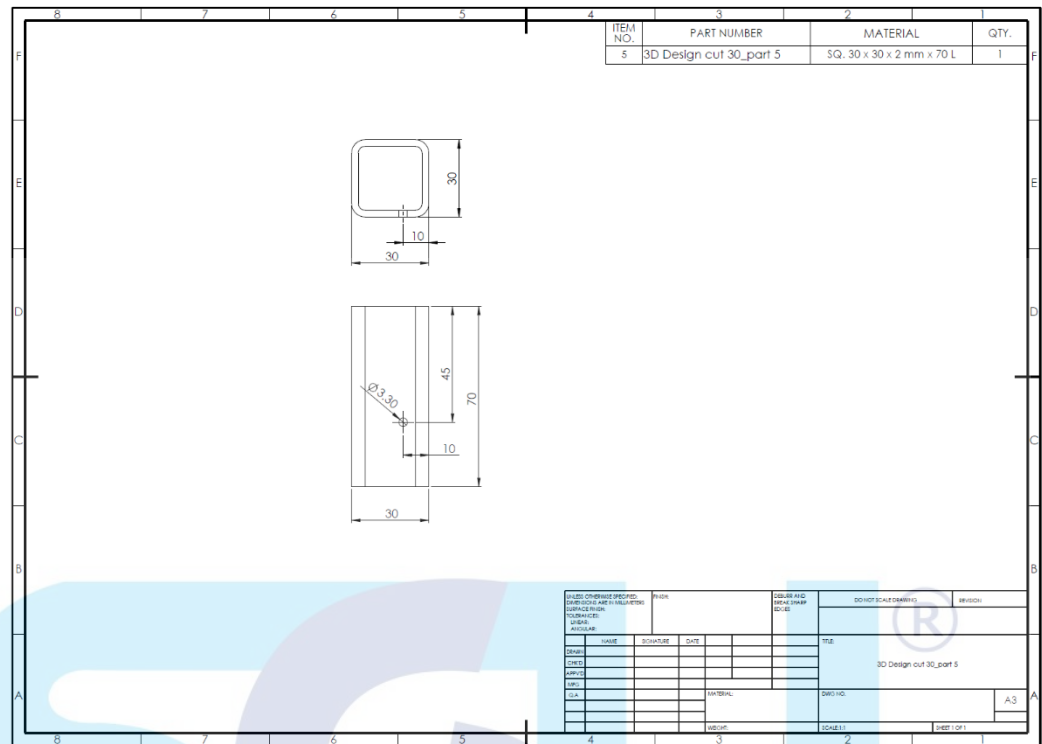


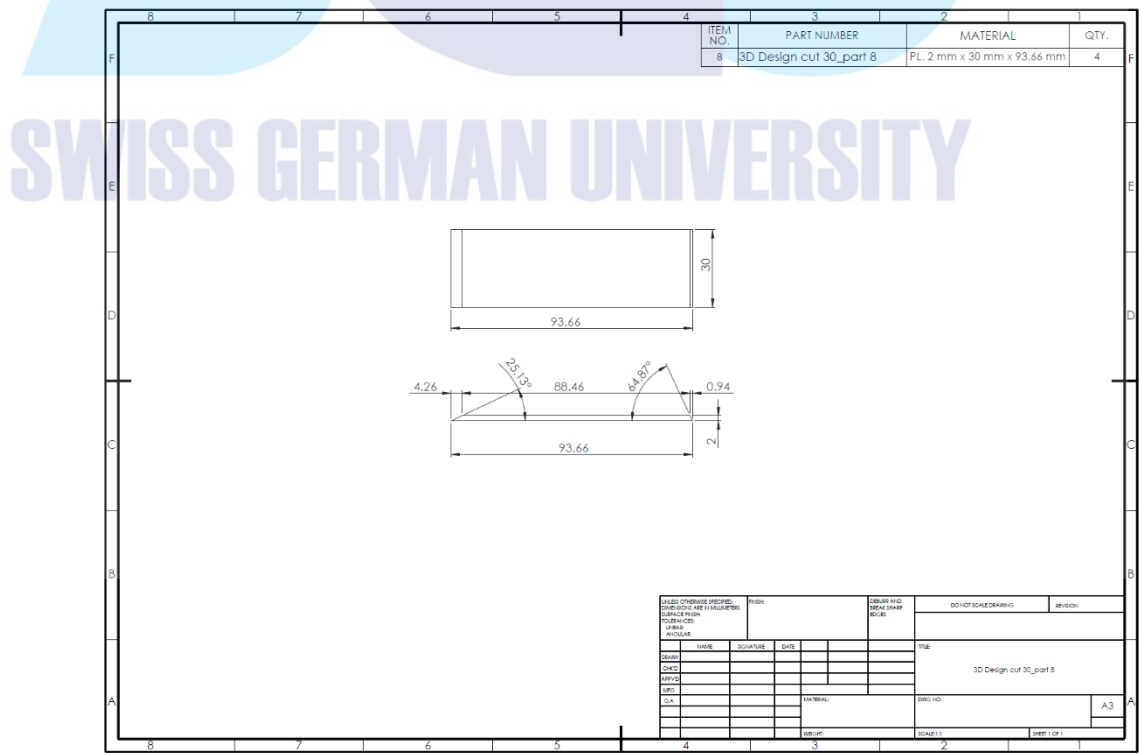
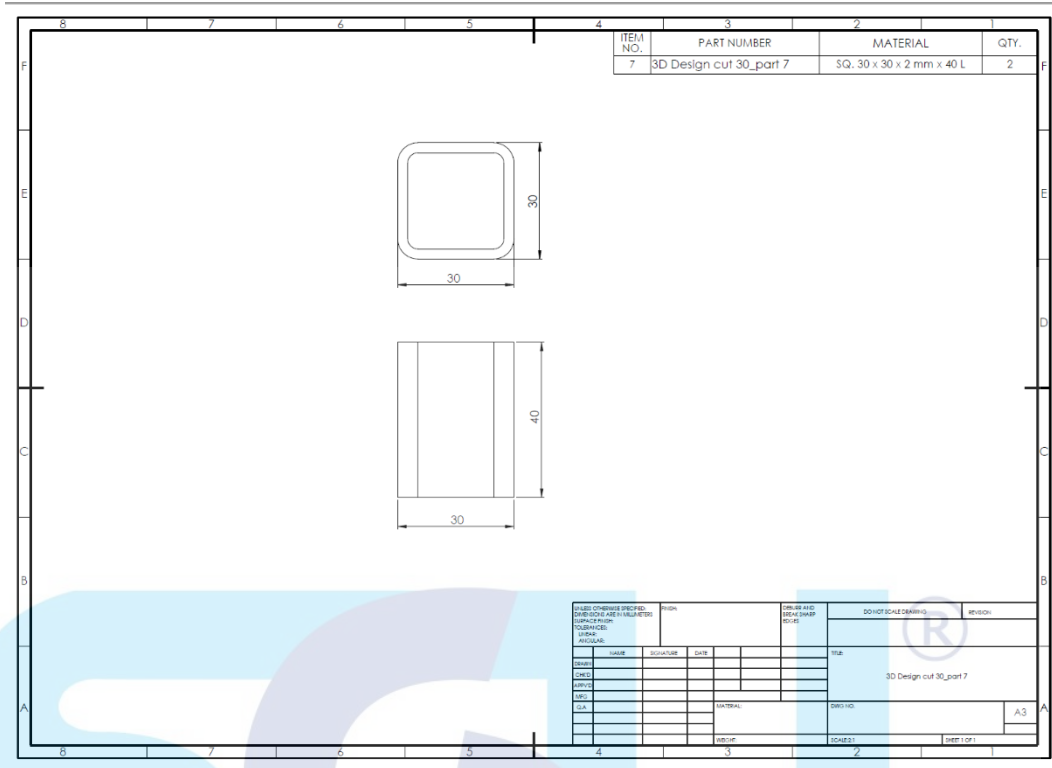
SGU
 SWISS GERMAN UNIVERSITY

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:			FINISH:		DEBURR AND BREAK SHARP EDGES		DO NOT SCALE DRAWING		REVISION	
							TITLE: <h2 style="margin: 0;">Locking Top Cover</h2>			
							DWG NO.		A4	
							SCALE: 1:1		SHEET 1 OF 1	

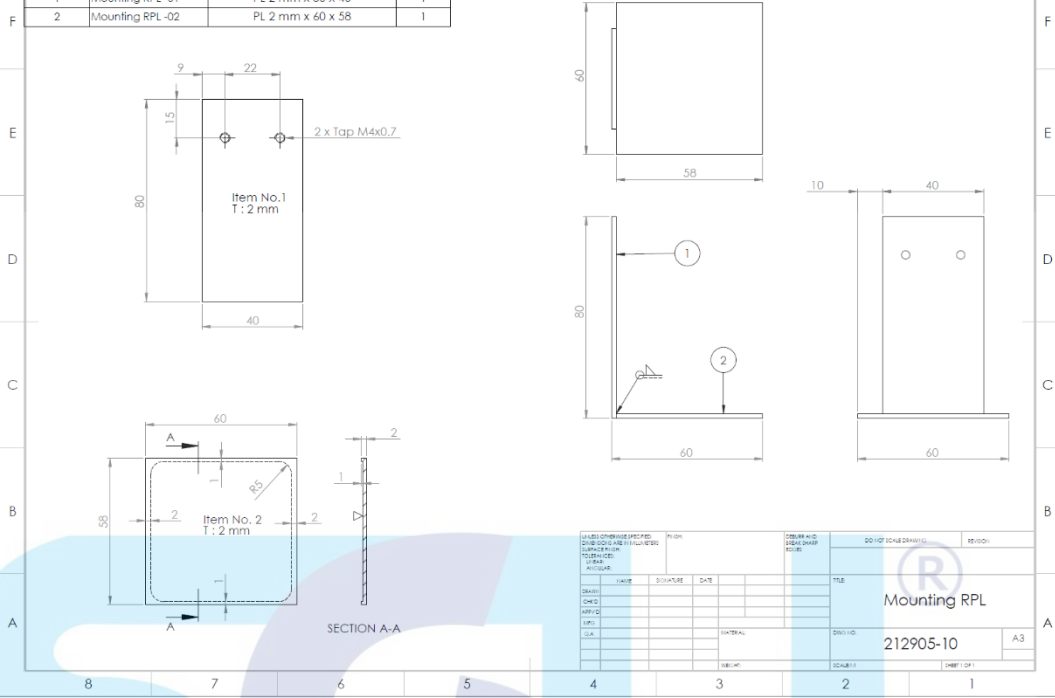


SWISS GERMAN UNIVERSITY

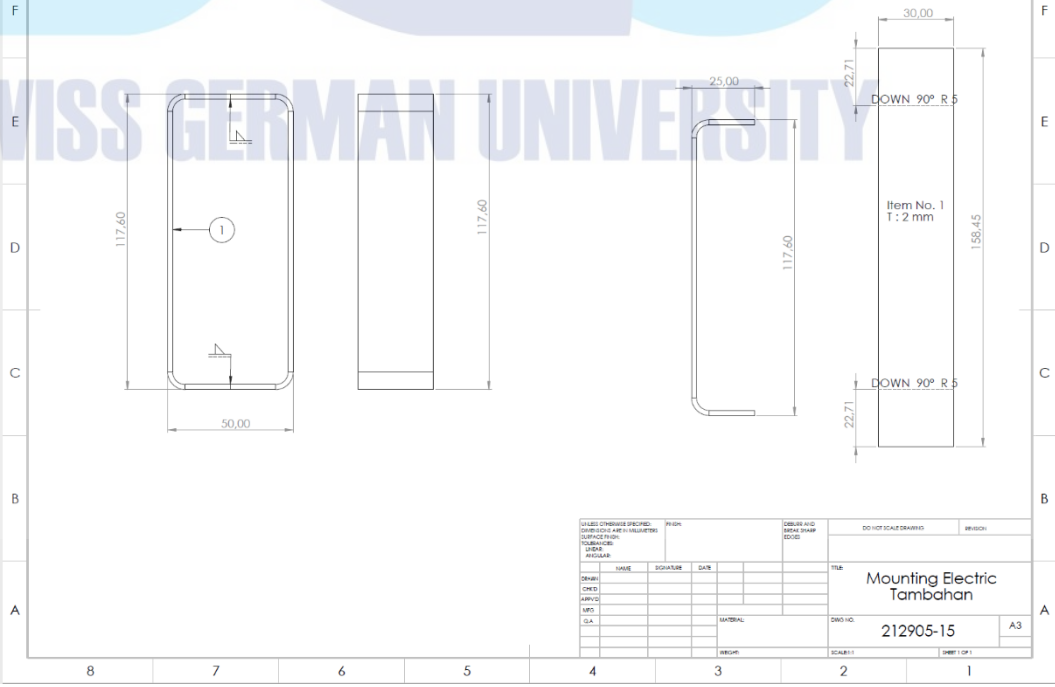


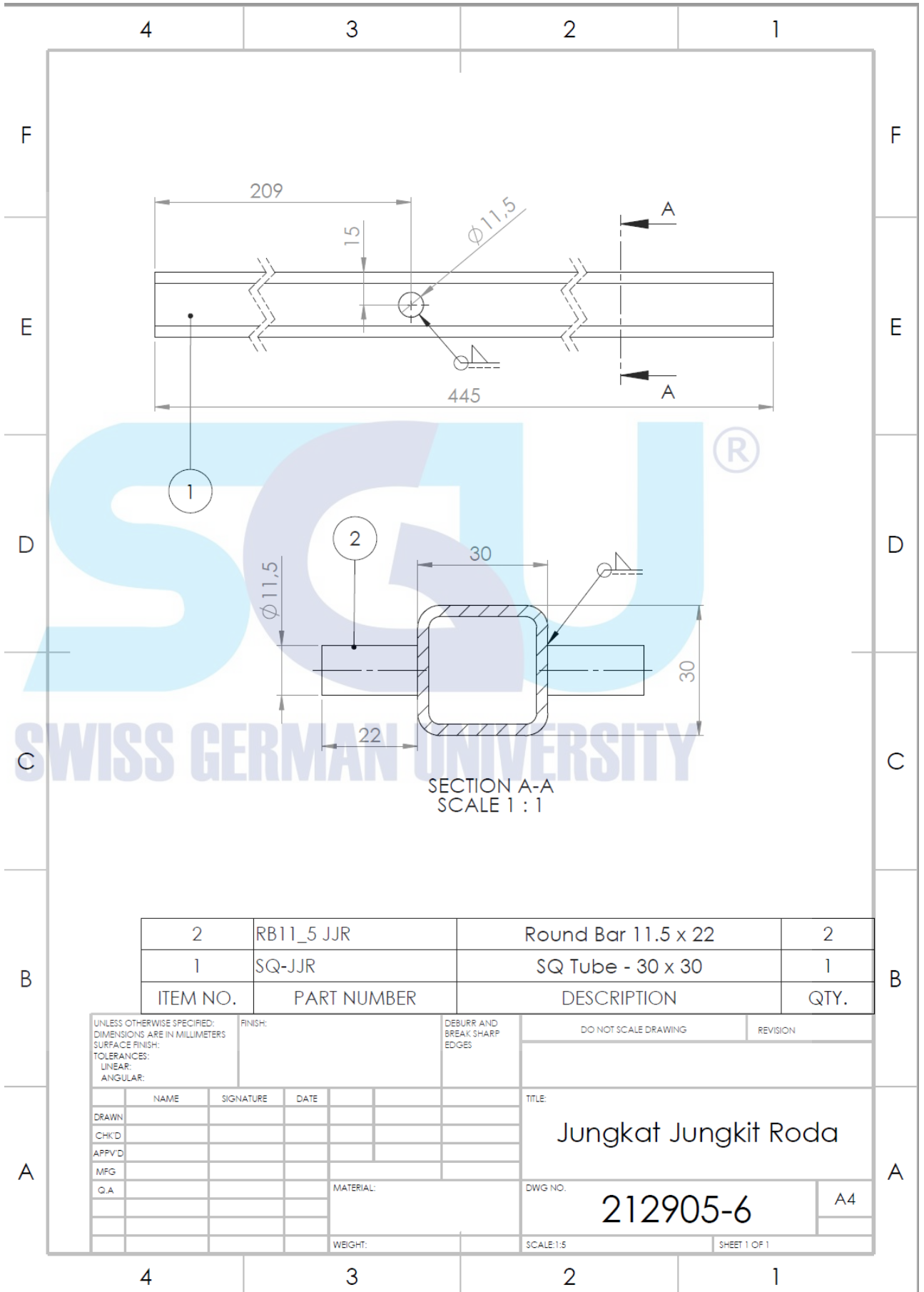


ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Mounting RPL-01	PL 2 mm x 80 x 40	1
2	Mounting RPL-02	PL 2 mm x 60 x 58	1



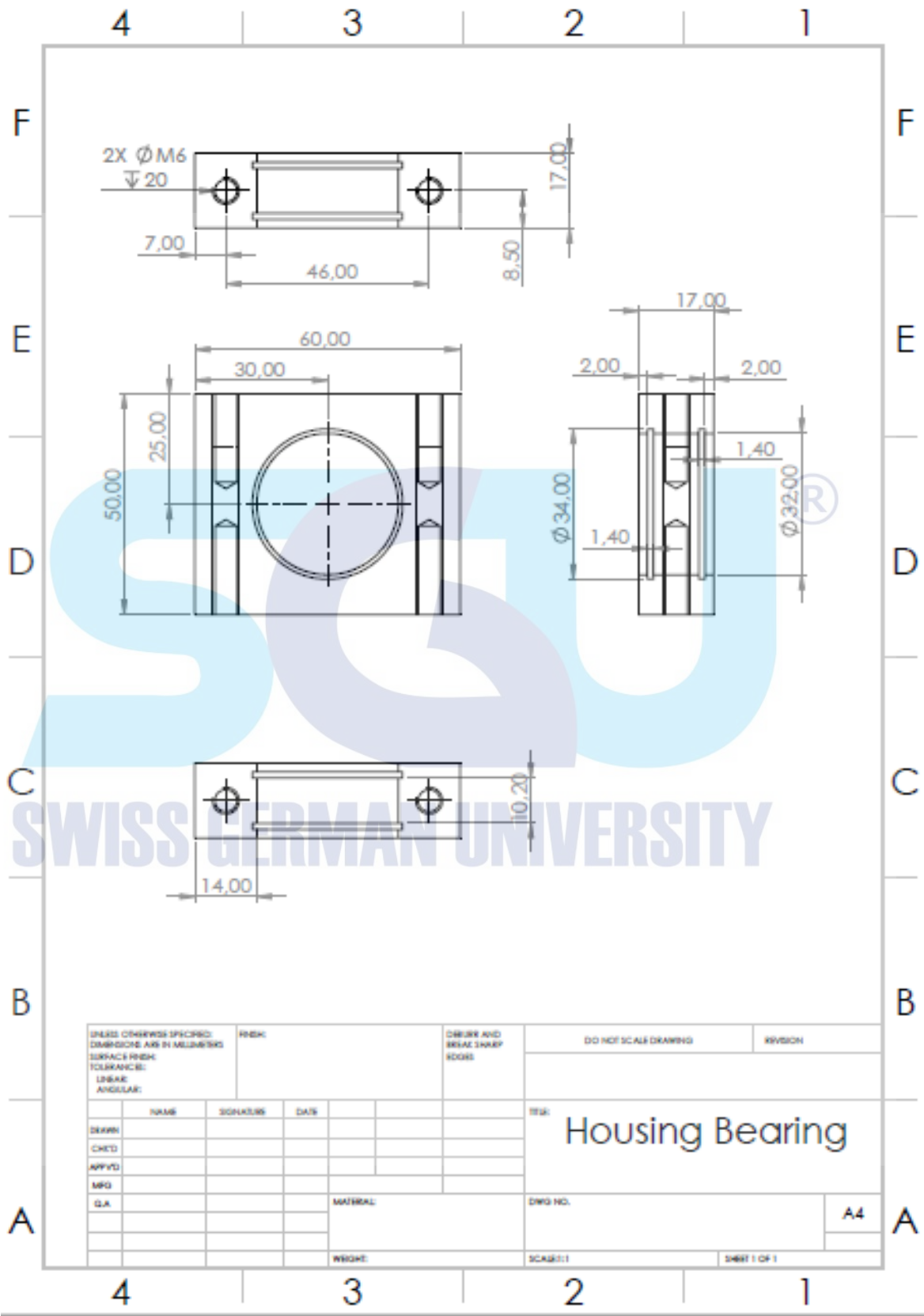
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	ME-p01	PL 2 mm x 158 x 30	2



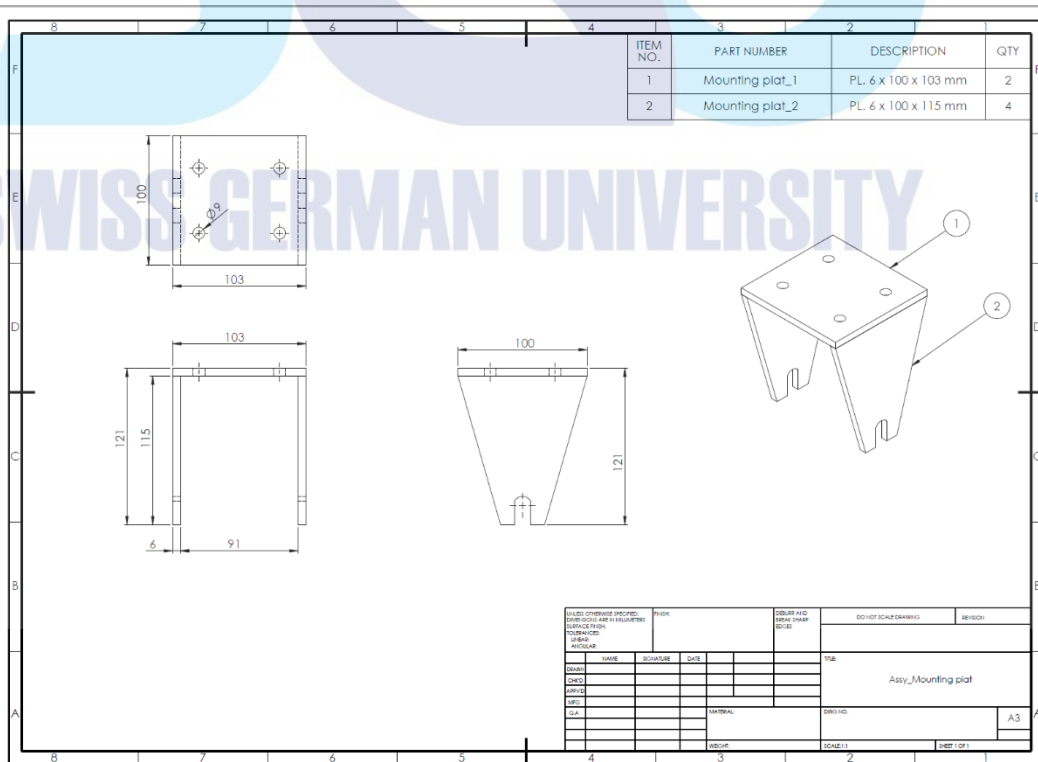
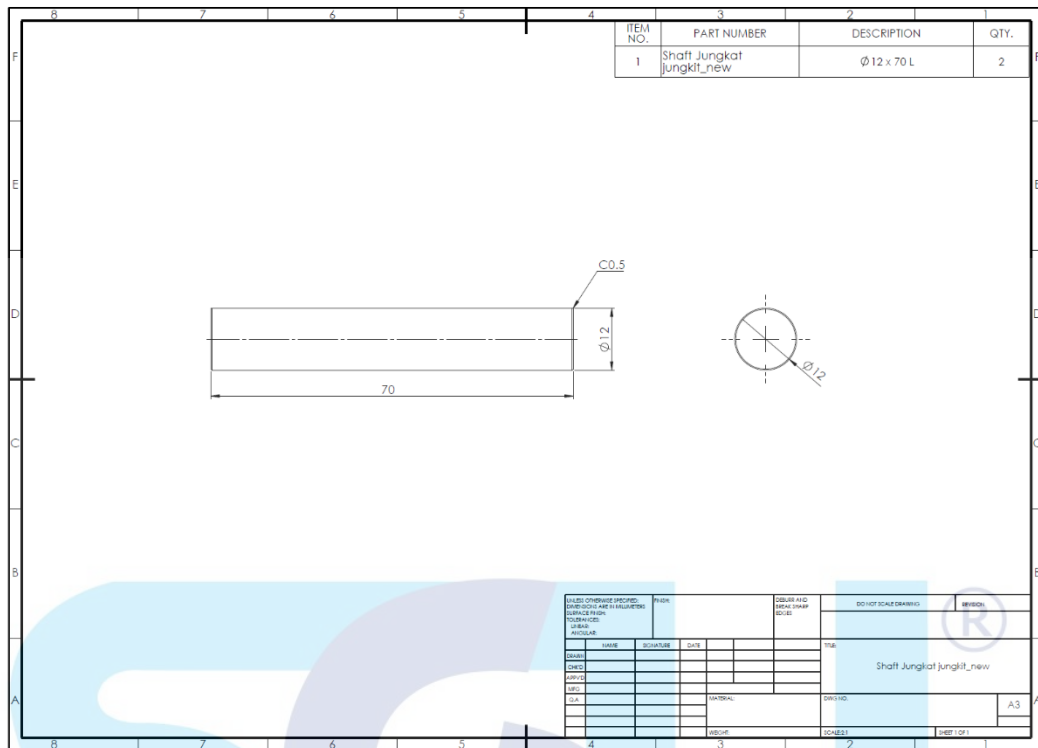


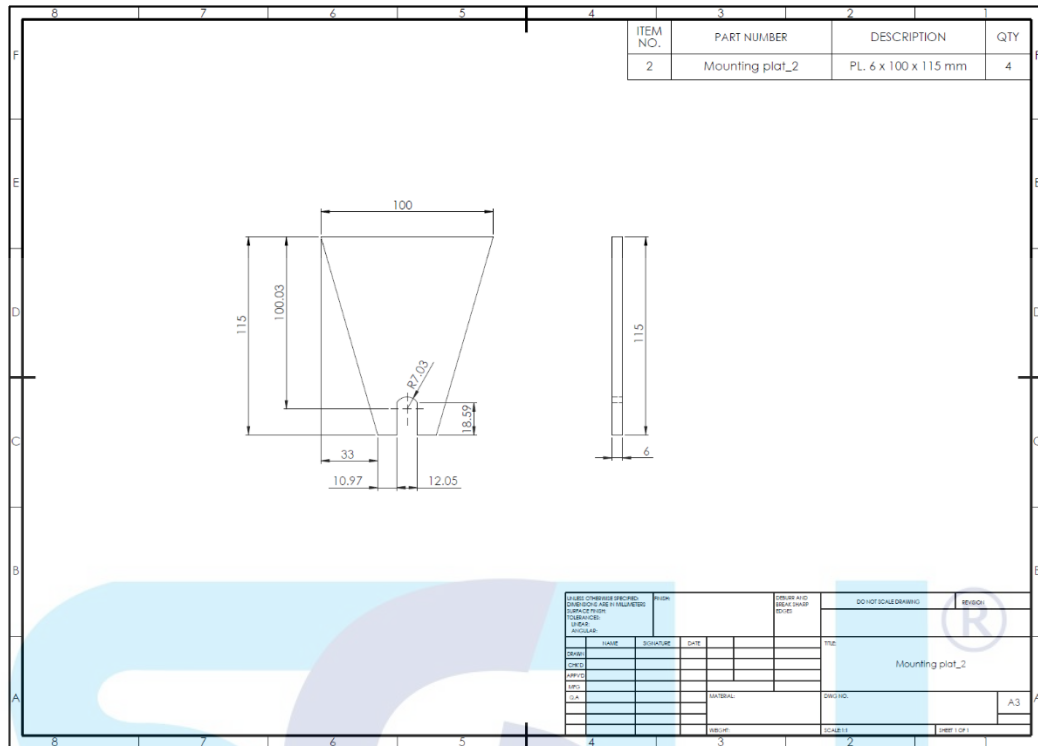
2	RB11_5 JJR	Round Bar 11.5 x 22	2
1	SQ-JJR	SQ Tube - 30 x 30	1
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:		FINISH:	DEBURR AND BREAK SHARP EDGES		DO NOT SCALE DRAWING	REVISION
DRAWN	NAME	SIGNATURE	DATE		TITLE: Jungkat Jungkit Roda	
CHK'D					DWG. NO. 212905-6	
APPV'D					A4	
MFG				MATERIAL:	SCALE:1:5	
Q.A.				WEIGHT:	SHEET 1 OF 1	



UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:			FINISH:		DRAWN AND CHECKED DATE:		DO NOT SCALE DRAWING		REVISION	
DESIGN	NAME	SIGNATURE	DATE			TITLE: <h2 style="text-align: center;">Housing Bearing</h2>				
CHECKED										
APPROVED										
MFG										
Q.A.				MATERIAL:		DWG NO.		A4		
				WEIGHT:		SCALE: 1:1				SHEET 1 OF 1





SGU

SWISS GERMAN UNIVERSITY

APPENDIX C – DATASHEETS

Arduino Mega

Technical Specification

EAGLE files: [arduino-mega2560-reference-design.zip](#) Schematic: [arduino-mega2560-schematic.pdf](#)

Summary

Microcontroller	ATmega2560
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	54 (of which 14 provide PWM output)
Analog Input Pins	16
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	256 KB of which 8 KB used by bootloader
SRAM	8 KB
EEPROM	4 KB
Clock Speed	16 MHz

the board

The image shows a top-down view of an Arduino Mega 2560 board. Various components are highlighted with colored boxes and labels:

- TX/RX Leds** (blue box): Located near the USB interface.
- "Test" Led 13** (yellow box): Located near the digital pins header.
- digital pins** (green box): Points to the digital pins header.
- Power Led** (yellow box): Located near the I2C header.
- I2C** (green box): Points to the I2C header.
- USB Interface** (red box): Points to the USB Type-B connector.
- ICSP Header** (red box): Points to the ICSP header.
- ATmega 2560** (red box): Points to the microcontroller chip.
- Reset Button** (purple box): Points to the reset button.
- External Power Supply** (red box): Points to the DC power jack.
- power pins** (red box): Points to the power pins header.
- analog pins** (yellow box): Points to the analog pins header.

Power

The Arduino Mega2560 can be powered via the USB connection or with an external power supply. The power source is selected automatically. External (non-USB) power can come either from an AC-to-DC adapter (wall-wart) or battery. The adapter can be connected by plugging a 2.1mm center-positive plug into the board's power jack. Leads from a battery can be inserted in the Gnd and Vin pin headers of the POWER connector.

The board can operate on an external supply of 6 to 20 volts. If supplied with less than 7V, however, the 5V pin may supply less than five volts and the board may be unstable. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts.

The Mega2560 differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the ATmega8U2 programmed as a USB-to-serial converter.

The power pins are as follows:

- **VIN.** The input voltage to the Arduino board when it's using an external power source (as opposed to 5 volts from the USB connection or other regulated power source). You can supply voltage through this pin, or, if supplying voltage via the power jack, access it through this pin.
- **5V.** The regulated power supply used to power the microcontroller and other components on the board. This can come either from VIN via an on-board regulator, or be supplied by USB or another regulated 5V supply.
- **3V3.** A 3.3 volt supply generated by the on-board regulator. Maximum current draw is 50 mA.
- **GND.** Ground pins.



Memory

The ATmega2560 has 256 KB of flash memory for storing code (of which 8 KB is used for the bootloader), 8 KB of SRAM and 4 KB of EEPROM (which can be read and written with the [EEPROM library](#)).

Input and Output

Each of the 54 digital pins on the Mega can be used as an input or output, using `pinMode()`, `digitalWrite()`, and `digitalRead()` functions. They operate at 5 volts. Each pin can provide or receive a maximum of 40 mA and has an internal pull-up resistor (disconnected by default) of 20-50 kOhms. In addition, some pins have specialized functions:

- **Serial: 0 (RX) and 1 (TX); Serial 1: 19 (RX) and 18 (TX); Serial 2: 17 (RX) and 16 (TX); Serial 3: 15 (RX) and 14 (TX).** Used to receive (RX) and transmit (TX) TTL serial data. Pins 0 and 1 are also connected to the corresponding pins of the ATmega8U2 USB-to-TTL Serial chip.
- **External Interrupts: 2 (interrupt 0), 3 (interrupt 1), 18 (interrupt 5), 19 (interrupt 4), 20 (interrupt 3), and 21 (interrupt 2).** These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value. See the `attachInterrupt()` function for details.
- **PWM: 0 to 13.** Provide 8-bit PWM output with the `analogWrite()` function.
- **SPI: 50 (MISO), 51 (MOSI), 52 (SCK), 53 (SS).** These pins support SPI communication, which, although provided by the underlying hardware, is not currently included in the Arduino language. The SPI pins are also broken out on the ICSP header, which is physically compatible with the Duemilanove and Diecimila.
- **LED: 13.** There is a built-in LED connected to digital pin 13. When the pin is HIGH value, the LED is on, when the pin is LOW, it's off.
- **I²C: 20 (SDA) and 21 (SCL).** Support I²C (TWI) communication using the [Wire library](#) (documentation on the Wiring website). Note that these pins are not in the same location as the I²C pins on the Duemilanove.

The Mega2560 has 16 analog inputs, each of which provide 10 bits of resolution (i.e. 1024 different values). By default they measure from ground to 5 volts, though is it possible to change the upper end of their range using the AREF pin and `analogReference()` function.

There are a couple of other pins on the board:

- **AREF.** Reference voltage for the analog inputs. Used with `analogReference()`.
- **Reset.** Bring this line LOW to reset the microcontroller. Typically used to add a reset button to shields which block the one on the board.



radiospares RADIONICS



Communication

The Arduino Mega2560 has a number of facilities for communicating with a computer, another Arduino, or other microcontrollers. The ATmega2560 provides four hardware UARTs for TTL (5V) serial communication. An ATmega8U2 on the board channels one of these over USB and provides a virtual com port to software on the computer (Windows machines will need a .inf file, but OSX and Linux machines will recognize the board as a COM port automatically). The Arduino software includes a serial monitor which allows simple textual data to be sent to and from the board. The RX and TX LEDs on the board will flash when data is being transmitted via the ATmega8U2 chip and USB connection to the computer (but not for serial communication on pins 0 and 1).

A [SoftwareSerial library](#) allows for serial communication on any of the Mega's digital pins.

The ATmega2560 also supports I2C (TWI) and SPI communication. The Arduino software includes a Wire library to simplify use of the I2C bus; see the [documentation on the Wiring website](#) for details. To use the SPI communication, please see the ATmega2560 datasheet.

Programming

The Arduino Mega2560 can be programmed with the Arduino software ([download](#)). For details, see the [reference](#) and [tutorials](#).

The ATmega2560 on the Arduino Mega comes preburned with a [bootloader](#) that allows you to upload new code to it without the use of an external hardware programmer. It communicates using the original STK500 protocol ([reference](#), [C header files](#)).

You can also bypass the bootloader and program the microcontroller through the ICSP (In-Circuit Serial Programming) header; see [these instructions](#) for details.



radiospares

RADIONICS

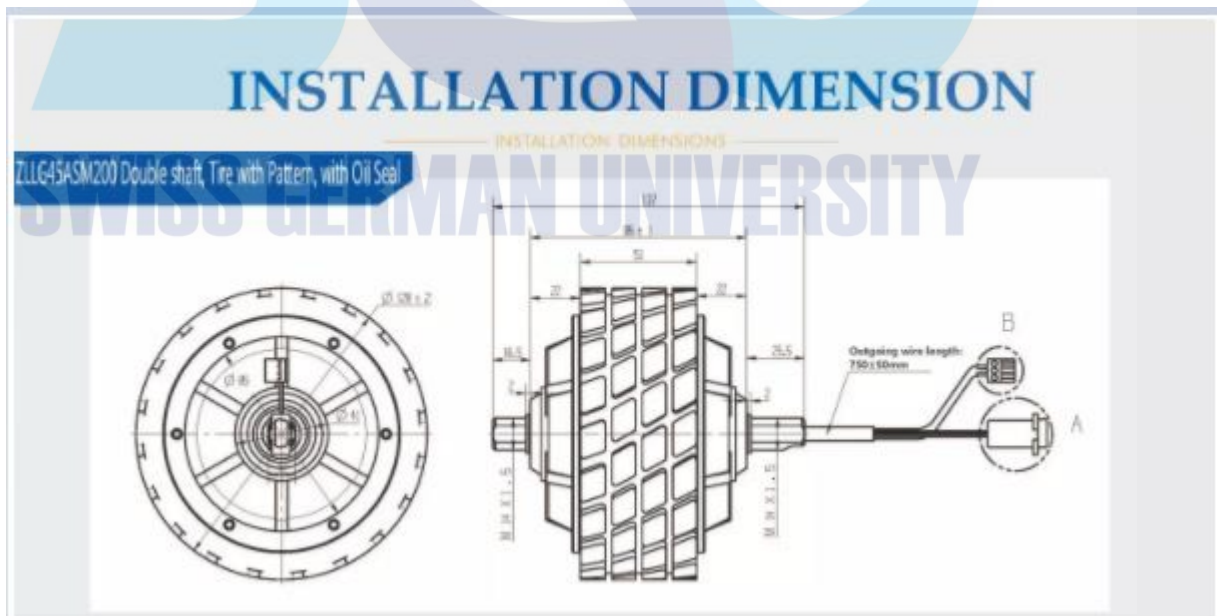


Zltech BLDC Motor and Driver

Overview

Quick Details

Warranty:	3months-1year	Place of Origin:	Guangdong, China
Brand Name:	ZLTECH	Model Number:	ZLLG45ASM200+ZLAC8015
Usage:	AGV, Delivery Robot, Service Robot	Type:	SERVO MOTOR
Torque:	6N.m	Construction:	Permanent Magnet
Commutation:	Brushless	Protect Feature:	Waterproof
Speed(RPM):	300RPM	Continuous Current(A):	5-15A
Efficiency:	le 3	Motor Diameter:	128mm
Motor Voltage:	24V-48V DC	Motor Power:	200W
Peak torque:	12N.m	Motor shaft type:	Double shaft
Tire:	Rubber	Protection class:	IP65
Motor Poles:	10 Pairs	Suggested Load:	150kg/2pcs
Driver Control Method:	CANOPEN, RS485 communication	Certification:	ce, RoHS, ISO9001



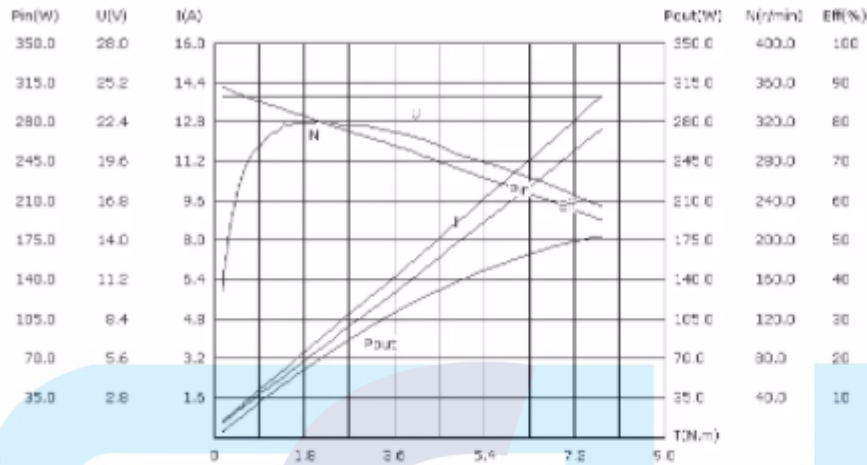
ZhongLing Technology Co.,Ltd.
Motor Load Characteristic Curve

Motor P/N: ZLLG4SASM200
 Mode: Torque Mode

Rated Voltage: 24.0V

Rated Current: 15.0A

No.: FA1909190002
 Rated Power: 150.0W
 Test Date: 09/19/2019



Voltage: 24.24V

No load point: 0.16N.m
 Speed: 356.5r/min
 Current: 0.660A
 The highest efficiency point:
 80.4%
 Torque: 2.10N.m
 Speed: 321.7r/min
 Current: 3.626A
 Output power: 70.62W
 Maximum torque point:
 7.76N.m
 Speed: 220.5r/min
 Current: 12.590A
 Output power: 179.26W
 Maximum output power point:
 179.26W
 Torque: 7.76N.m
 Speed: 220.5r/min
 Current: 12.590A

Tester: Xiang Cheng

MultiTest V3.27

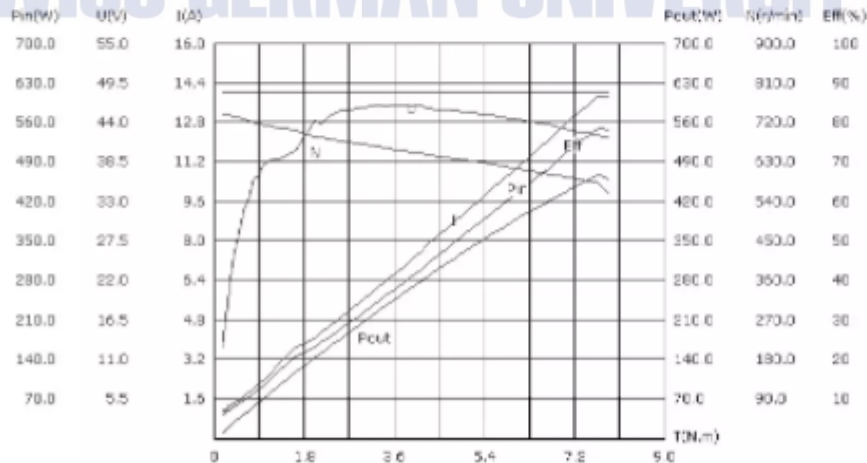
ZhongLing Technology Co.,Ltd.
Motor Load Characteristic Curve

Motor P/N: ZLLG4SASM200
 Mode: Torque Mode

Rated Voltage: 24.0V

Rated Current: 15.0A

No.: FA1909190002
 Rated Power: 150.0W
 Test Date: 09/19/2019



Voltage: 48.32(V)

No load point: 0.15(N.m)
 Speed: 742.4(r/min)
 Current: 1.046(A)
 Highest efficiency point:
 84.8(%)
 Torque: 3.76(N.m)
 Speed: 657.8(r/min)
 Current: 6.327(A)
 Output Power: 259.10(W)
 Max torque point: 7.87(N.m)
 Speed: 560.4(r/min)
 Current: 12.538(A)
 Output Power: 462.07(W)
 Max output power point:
 468.92(W)
 Torque: 7.65(N.m)
 Speed: 585.1(r/min)
 Current: 12.592(A)

测试员: Administrator

PARAMETER

PRODUCT PARAMETERS

BRAND	ZLTECH		
PRODUCT NAME	HUB SERVO MOTOR FOR ROBOT, AGV		
P/N	ZLLG45ASM200 Double Shaft, Tire without Pattern	ZLLG45ASM200 Double Shaft, Tire with Pattern	ZLLG45ASM200 Double Shaft, Tire with Pattern, with Oil Seal
WHEEL DIAMETER	123MM	128MM	128MM
WEIGHT	2.9KG	2.9KG	3.0KG
VOLTAGE	24V DC	24V DC	24V DC
OUTPUT POWER	200W	200W	200W
RATED TORQUE	6N.m	6N.m	6N.m
MAX TORQUE	12N.m	12N.m	12N.m
RATED SPEED	300RPM	300RPM	300RPM
MAX SPEED	400RPM	400RPM	400RPM
RATED PHASE CURRENT	5A-15A	5A-15A	5A-15A
MAX PHASE CURRENT	30A	30A	30A
POLES NO.	10 Pairs Polo	10 Pairs Polo	10 Pairs Polo
ENCODER	1024-wire Optical	1024-wire Optical	1024-wire Optical
TIRE	Rubber without Pattern	Rubber with Pattern	Rubber with Pattern
BRAKE	Electric Brake	Electric Brake	Electric Brake
PROTECTION LEVEL	IP54	IP54	IP65
LOAD	150KG/2 Motors	150KG/2 Motors	150KG/2 Motors
ADAPTED DRIVER	ZLAC706, ZLAC706-CAN, ZLAC706-RC, ZLAC8015		

Overview

Quick Details

Warranty:	3months-1year	Place of Origin:	Guangdong, China
Brand Name:	ZLTECH	Model Number:	ZLAC8015D
Dimension:	150x97x31mm	Adapted motor:	Hub servo motor with power \leq 500W
Input voltage:	24V-48V DC	Output current:	15A-30A
Input signal voltage:	5V DC	Control signal input current:	10mA
Control method:	CANOPEN, RS485	Operation modes:	Position Mode, Velocity Mode, Torque Mode
Channel:	Dual channel	Weight:	0.3kg

DRIVER PARAMETERS

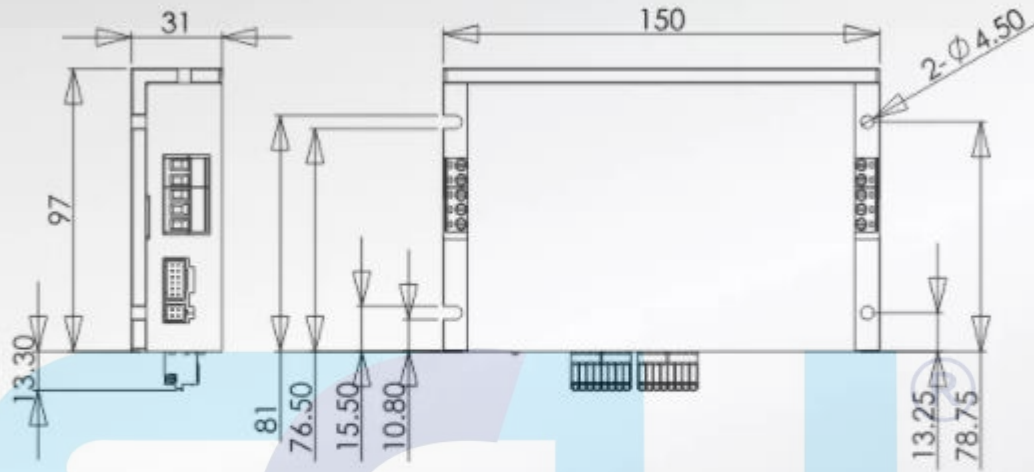
DRIVE PARAMETERS



Brand	Shenzhen ZhongLing Technology Co., Ltd.
Product Name	Hub Servo Motor Driver
P/N	ZLAC8015D
Dimension	150x97x31mm
Working Voltage	24V~48V DC
Output Current	Rated 15A, Peak 30A
Control Method	CANOPEN, RS485
Adapted Motor	Hub motor with power less than 500W
Use Environment	Application Occasion: avoid dust, oil mist and corrosive gases
	Operation Temperature: 0~50°C
	Ambient Humidity: 90% Rh (no condensation)
	Storage Temperature: -10~70°C
	Vibration: 10~55Hz/0.15mm

INSTALLATION DIMENSIONS

INSTALLATION DIMENSIONS



ZLAC8015D

Unit: mm

SWISS GERMAN UNIVERSITY

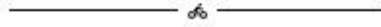
Battery

DESCRIPTION

HIGH QUALITY RELIABLE BATTERY 3C-20C High discharge rate. High Energy density and stable discharge platform. 1000 cycles, durable for lasting usage. Pass GB/T31415&UL1642&GB31241.

Battery Model	SP-36V 10Ah	SP-36V 12Ah	SP-48V 10Ah	SP-48V 12Ah
Material System	NCM	NCM	NCM	NCM
Normal Voltage(V)	36	36	48	48
Normal Capacity(Ah)	10	12	10	12
Battery Dimension(L*W*H) (mm)	310*107*76	350*107*76	365*107*76	420*107*76
Battery Weight(Kg)	2.8	3.1	3.25	3.6
Continuous Charge Current(A)	2~4	2~4	2~4	2~4
Charge Period (hr.)	3~6	3~6	3~6	3~6
Discharge Cut-off Voltage(V)	28	28	36	36
Continuous Discharge Current(A)	≤10	≤10	≤10	≤10
Peak Discharge Current(A)	≤20	≤20	≤20	≤20
Cycle Life (100% DOD) (Times)	≥800	≥800	≥800	≥800
Capacity Retention Rate at °C	≤90%	≤90%	≤90%	≤90%
Self-discharge Ratio	≤5%	≤5%	≤5%	≤5%
Temperature Characteristic	Charge	0°C ~ 45°C	0°C ~ 45°C	0°C ~ 45°C
	Discharge	-20°C ~ 55°C	-20°C ~ 55°C	-20°C ~ 55°C
	Storage	-20°C ~ 45°C	-20°C ~ 45°C	-20°C ~ 45°C

Water Bottle Type Ebike Lithium Battery Details



PRODUCT DETAILS



Appendix D - Program

Arduino Code for Locking System

```
const int pinPUL = 7;
const int pinDIR = 6;
int buttUP = 21;
int buttDN = 20;
int exeButt = 19;

int buttStateCW;
int buttStateCCW;
int buttStateCCCW;

void setup() {
  pinMode(pinPUL, OUTPUT);
  pinMode(pinDIR, OUTPUT);
  pinMode(buttUP, INPUT_PULLUP);
  pinMode(buttDN, INPUT_PULLUP);
  pinMode(exeButt, INPUT_PULLUP);
}

void loop() {
  buttStateCW = digitalRead(buttUP);
  buttStateCCW = digitalRead(buttDN);
  buttStateCCCW = digitalRead(exeButt);

  if(buttStateCW == LOW && buttStateCCCW == LOW){
```

```
digitalWrite(pinDIR, HIGH);
{
while(buttStateCCW == HIGH) {
digitalWrite(pinPUL, HIGH);
delayMicroseconds(500);
digitalWrite(pinPUL, LOW);
delayMicroseconds(500);
buttStateCCW = digitalRead(buttDN);
}

}

else if(buttStateCCW == LOW && buttStateCCCW == LOW){
digitalWrite(pinDIR, LOW);
//for(int i = 0; i < 5000; i++){
while(buttStateCW == HIGH) {
digitalWrite(pinPUL, HIGH);
delayMicroseconds(500);
digitalWrite(pinPUL, LOW);
delayMicroseconds(500);
buttStateCW = digitalRead(buttUP);
}

}

}
```

CURRICULUM VITAE

PERSONAL DETAILS

Name : Muhammad Ichsan
Residential Address : Jl. Bontang Blok B7 No.3,
: Jatiwaringin Asri,
: Pondok Gede, Bekasi
Mobile : (+62) 811-1764-000
E-mail : ichsan2119@gmail.com
Nationality : Indonesian



EDUCATION HISTORY

Aug 2015 – Current **Swiss German University**, BSD City, Mechatronics Engineering
June 2012 – June 2015 **GLOBAL PRESTASI SCHOOL**, Bekasi, West Java
National-Based Certificate of Senior High School
June 2009 – June 2012 **SMP PUTRA 1 JAKARTA**, East Jakarta, Jakarta
Semi-National-Based Certificate of Junior High School

TRAINING AND INTERSHIP

Mar 2016 – Mei 2016 **Practical Training at Akademi Teknik Mesin Industri Cikarang**,
Jawa Barat, Indonesia
Des 2016 – Jan 2017 **PT Bestindo Car Utama (BMW)**, Bintaro, Tangerang Selatan,
Banten, Indonesia
Mar 2019 – Jul 2019 **RK Autowelt Soest**, Soest, Jerman

SKILLS

Computer Skills:

- o Microsoft Office
- o Electronic-Machine Operating
- o Solidworks

Language Skills:

- o Bahasa Indonesia – Mother Language
- o English – Intermediate
- o German – Basic