FC6P01
Final Year Report

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Academic Year	2023-24		

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1. Introduction

This project documents the creation of an all-terrain vehicle. This vehicle will not only have the ability to drive on land and water but also have the capability to fly through the sky. To do this it will be capable of seamlessly transforming between a hovercraft and drone form.

The primary objective of this project is to address the challenge of transporting items from point A to B in locations with limited human accessibility. The robot, named ARTEx (All-terrain Robotic Transportation and Exploration System), is specifically designed for deployment in the medical industry, enabling the swift delivery of medical items to critical areas. Inspired by initiatives like Zipline's operations in Rwanda, ARTEx aims to overcome the limitations of gliding drones, particularly in urban settings such as London with numerous high-rise buildings. Unlike traditional gliding drones, this system avoids dropping medical packages via parachute during flight, minimizing the risk of damage or getting stuck in inaccessible locations such as trees.

1.1 Aims and Objectives

The aims and objectives of the project are as follows:

- To create a working hovercraft.
- To make an embedded solution for the control system, RF Control, and Battery PSU.
- 3D model a drone and hovercraft solution.
- Further develop C programming language skills.
- Further develop CAD skills.
- To create a working drone.
- For the vehicle to be able to hold item(s).
- For the vehicle to be able to switch forms seamlessly.

1.2 Project Deliverables

The deliverables of the project are as follows:

- Research different types of motors for the propellers – pref. Kyrio A2212 Brushless Motor 2200KV.
- Design and research compatible propellers – pref. CESFONJER 10pcs APC Composite Propeller 6x4 E.
- Research and implement different types of Servo Motors for the best result 3D model of different materials for the casing – i.e. the body of the robot.
- Skirt – To allow it to become an airboat.
- Design and implement a PCB solution for the electronics.
- Design and form a concept for item holders.

1.3 Project Plan

The weekly project plan is in the Gantt chart documented in Figure 1. Gantt charts are a vital tool when carrying out projects as it aids in facilitating coordination and meeting deadlines. Gantt charts provide an overview of the necessary tasks that need to be completed along with what should be a relatively accurate estimation of the completion time. Gantt charts help both the client and the organisation when carrying out the project to know if it is possible to complete it within the specified time frame.

In the case of developing ARTEx, the Gantt chart highlights that the project should be completed 2 months before the deadline assuming there are no hiccups throughout the development of the ARTEx. The Gantt Chart specifies that the preparatory phase where research will be conducted should take no longer than a month. While research is being done the building and testing phase will also begin. This was a fair assumption especially considering research would need to be done while the components are in hand. The Gantt chart then ends with the delivery phase, allowing the final product to be tested and cleaned up, removing any kinks. This Gantt chart would also allow time for the further development/expansion of ARTEx.

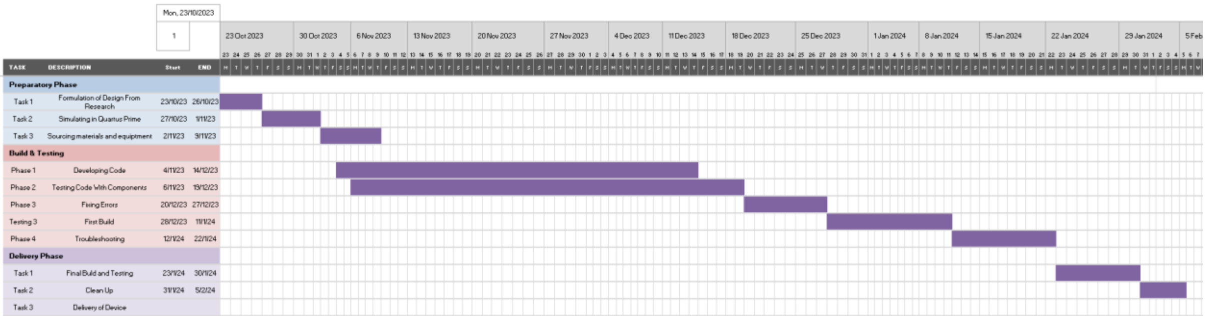

Figure 1 - Project Plan Gant Chart

1.4 Risk Analysis

Considering the time frame that has been allowed to complete this project, the risks that come with developing ARTEx are extremely low. The Gantt chart in Figure 1 clearly shows that there should be more than enough time to develop the ARTEx and make further improvements if needed. The main risks that this project could encounter are budgetary constraints. Drones tend to be quite expensive, and the budget allowed for this project was £50. This limitation in funds makes it quite risky to develop the ARTEx. This risk can be negated with extensive research and diligence when deciding which components to use.

There are also safety concerns that arise. Drones have motors that rotate extremely fast at rates of 45,000 rotations per minute (RPM) and higher. This could be very dangerous to deal with when constructing and testing the ARTEx in public areas.

Vehicles are also very prone to environmental damage, especially ones that fly. The tough terrains on the ground could potentially damage the skirts on the ARTEx and strong winds could send it falling out of the sky. On top of that, heat and rain can easily break many of the components.

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4.2.5 Design 5 – Final Build

Taking into account all of the issues that happened before this build and adjusting accordingly, the following build displayed in Figure 21 is the sprog. This build is smaller in height than and allows for the addition of multiple components such as the BMP280, ADXL345 and even an IR sensor. This version (version 5/v5) is constructed of 6 different major components which can be referred to in their 3 different segments. One segment aids the flight. This segment is made of one piece. Another segment is what allows the hovercraft function to be carried out in the ARTEx. This segment is made of 4 pieces. The final segment which is the most important is the battery holder. Without power, the ARTEx isn't going anywhere. This is only made of one piece. The structure of this build will be segmented into different sections and discussed below.

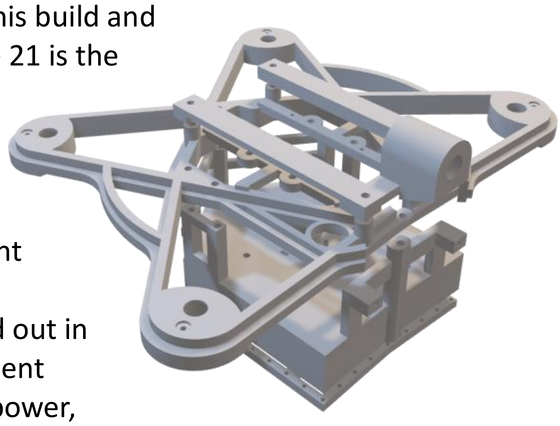

Figure 2 - ARTEx v5 Full Build

4.2.5.1 Top Segment – Drone

The first changes to make note of would be the updated upper frame. A focused view of this part is displayed in Figure 22. The upper frame implements a number of components such as the motors, ESP32, L9110, etc. The implementation of these components will be discussed in section 5 entitled Implementations. The images of how components will be connected to the upper frame can be found in Appendix B1 entitled Upper Segment Implemented Components.

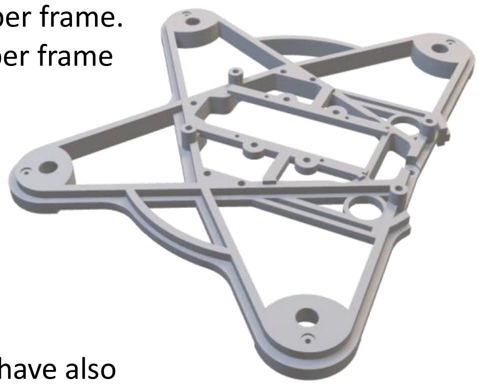

Figure 3 - v5 Upper Frame

The holes which are used to connect to the lower segment have also been altered to allow more stability and firmness when connecting. The rear end depicted in Figure 23 shows how the lower segment connecting the pole joins with the upper frame. This has slightly extruded bezels to help hold the connecting pole from the base stay in place. It also dips in from the top allowing the screw to remain flush with the upper frame and allows a larger surface area of the screw to entrench itself into the pole.

Furthermore, the motor holders on this design no longer protrude out as it was deemed unnecessary and would only add to the weight of the vehicle. These motor holders support larger propellers which have now been implemented from the Wipkviey T16 Drone. These larger propellers heavily aid thrust and efficiency. Larger propellers generate more thrust making them more efficient. Although they may weigh more than smaller propellers, the increased efficiency means more thrust for the same power or alternatively the same thrust at a lower power output.

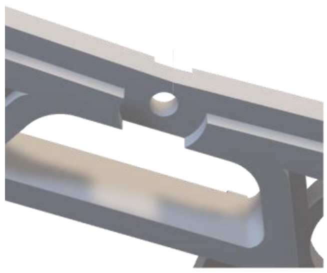

Figure 4 - v5 Upper Frame Connection Example

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down the ESP32, as long as the screws are too tight, the ESP32 will be able to rest at a good height securely while also being able to be pushed down to activate the button below it and turns on drone. The design of the top segment also has a wire holder which can be seen in figure 33. This segment was purposely added but works perfectly in the ARTEx's favour.

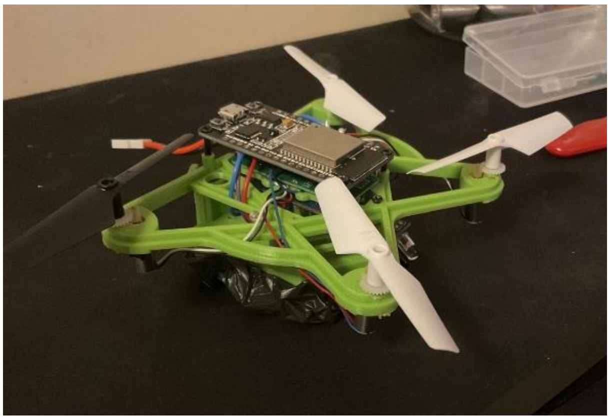

Figure 5 - Full Build

4.5 Code

All code is documented in Appendix C for ease of viewing. All code is pertaining to the functionality of the ESP32. Appendix C1 shows the Arduino code used for the onboard functions. Appendix C2 - C4 Document the code used for the webpage. This section will serve as an explanation for the different codes and their uses in the functionality of the ARTEx.

SPLIFFS was implemented to allow the use of separate HTML, Java, and CSS code. When the ESP32 is turned on data is sent to the webpage depicted in Figure 34. Buttons on the webpage also become useable so that the user can manually turn on and off the ARTEx's motor which is used to inflate the skirt. The functionality of the code is the control the inflation and deflation of the skirts on the hovercraft. An IR sensor is used to detect if the ARTEx is close to the ground. If the ARTEx is close to the ground within the IR sensor's specified range, then the light on the sensor will turn on and the motor will begin to push air down to the skirts. When the IR sensor doesn't detect anything, the motors will spin in the opposite direction to retract the skirts. The motors will only spin in the opposite direction for a few seconds and then turn off.

The code also enables the ESP32 to send data from the various microcontrollers and sensors back to the webpage. This way the user can have a reading on the specific temperature, pressure, and altitude of the ARTEx. The camera was also supposed to be implemented to enable better visualisation and computer vision capabilities like obstacle detection, but the camera could not be used. The web server also allows the user to see if the skirts are inflated or not and manually change whether it should be on or off.

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6 Results and Discussion

6.1 Discussion of Results

Even though the ARTEx inflates its skirts, it struggles. More powerful motors would need to be implemented to make the ARTEx work at full performance. The implementations of powerful motors on a vehicle of this size will simply not be possible. Therefore, the whole build needs to be scaled up significantly to accommodate. This build was still a good prototype. The build is also heavy. Making the ARTEx bigger would help but the addition of a PCB would also make the entire system cleaner and lighter.

6.2 Project Management and Progress

The time taken for the project to be completed was a lot longer than initially expected. Unfortunately, due to a number of unforeseen challenges during the course of the project, the scope of changes, availability of resources such as funds and components that could fit the project, the time to complete the project was hindered.

Project was managed well. Making sure that everything was complete before the deadline was possible due to the Gantt chart. If it seemed like a section was going to continue for a long amount of time, the Gantt chart would be adjusted accordingly so that the remaining time could easily be identified. This meant extending sections and even removing some phases in the Gantt chart. This helped especially when it came to deciding which components to still implement. For example, testing and trying to get the camera module to work with the ESP32 was taking far longer than expected. The Gantt chart helped when deciding not to progress with using it due to the number of problems it was causing and the uncertainty with when the issues could be solved. Several steps during the development of the ARTEx have been taken to mitigate the impact of these delays.

7 Conclusions and Further Work

7.1 Conclusions

For application in the medical industry, whereby the ARTEx carries and delivers products to people's homes or (in third world countries) to the hospitals themselves, the ARTEx would need to be scaled up significantly. This is to allow the use of stronger motors and the ability to carry a lot more weight in an area of the body where it won't affect the functionality of the drone or hovercraft. For third world countries where the ground is very tough, the implementation of wheels over a hovercraft skirt would most likely be better. So the implementation of movable wheels could be used. The second reference displays examples of these manoeuvrable wheels.

To conclude, the ARTEx is an amazing prototype. It can currently be implemented in smaller applications such as taking readings in the environment such as temperature, altitude etc. With the use of different components it will also be able to read different values.

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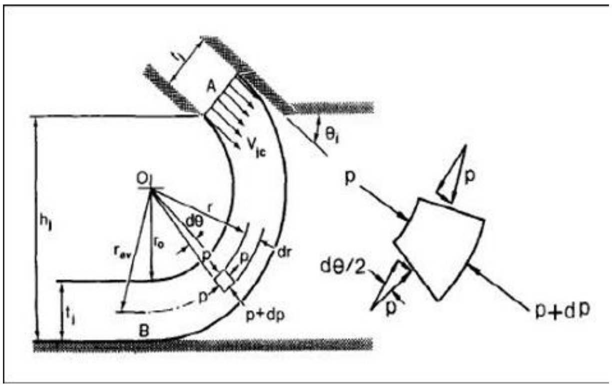
Appendix A

A1 – Hovercraft Equations



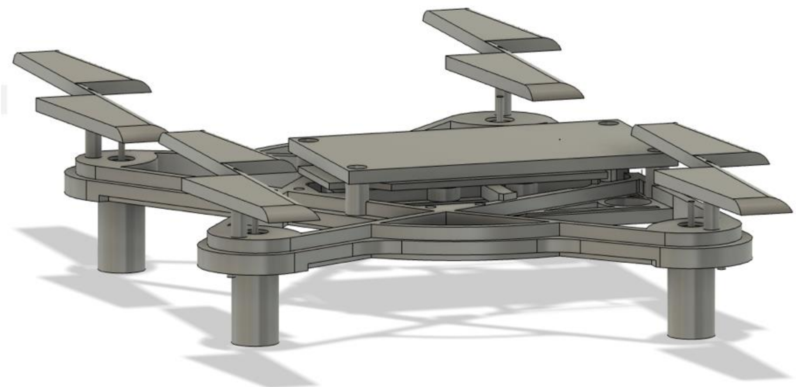
General Equations:

$Fc = W = Pc\ Ac + Jj * Lj * Sin\ \theta j$

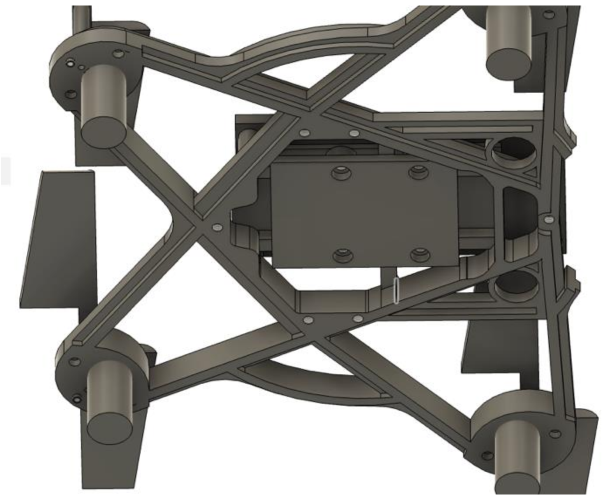
- *Fc* = Lift force (N)
- W = Weight of the model (N)
  - $W = \text{Mass} * \text{Gravity}$
  - *W* = Pc Ac + Jj Lj sinθj
  - *W* = Pc Ac + r * Pc (Lj) sin 45º = Pc (Ac + (r * Lj * sinθ))
- Ac = Area of cushion (m²)
  - Ac = Length * Width
- Jj = Momentum flux of air jet per unit length of the nozzle (Kg/s²)
- Lj = Nozzle perimeter (m)
  - *Lj* = π x tj
- θj = Angle of the nozzle from the horizontal (º)
- *r* = The average radius of the curvature of the length (m)
  - *r* = hj / (1 + cos θj)
- *Pc* = Cushion pressure (Pa)
- *hj* = The lift height (m)
- *Paj* = Power required (W)
  - *Paj = Pj Qj*
- *Qj* = Total volume flow per second into the skirt
  - $Qj = \frac{\text{Ljhj}}{1+\cos\theta\text{j}}\left(\frac{2\text{Pj}}{\rho}\right)^{\frac{1}{2}}(1-(\frac{Pc}{Pj})^{\frac{1}{2}})$

Appendix B

B1 – Upper Segment Implemented Components



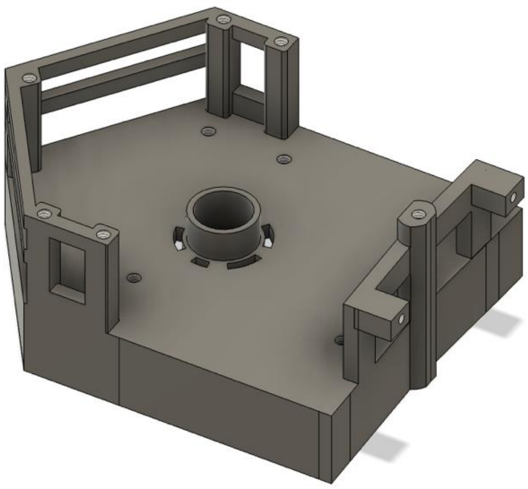
This image displays the full body from a top-view angle. The motors and propellers can be seen on the four corners of the upper frame. The ESP32 can be seen secured into place above the PCB used for the motors.



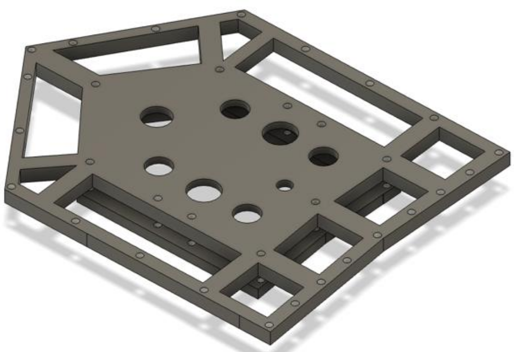
This image depicts the bottom angle of the body having its main focus on the central components. On the bottom is the L9110 microcontroller which is being used as a speed controller for the central motor which inflates the skirt in the base.

B2 – Lower Segment Body View

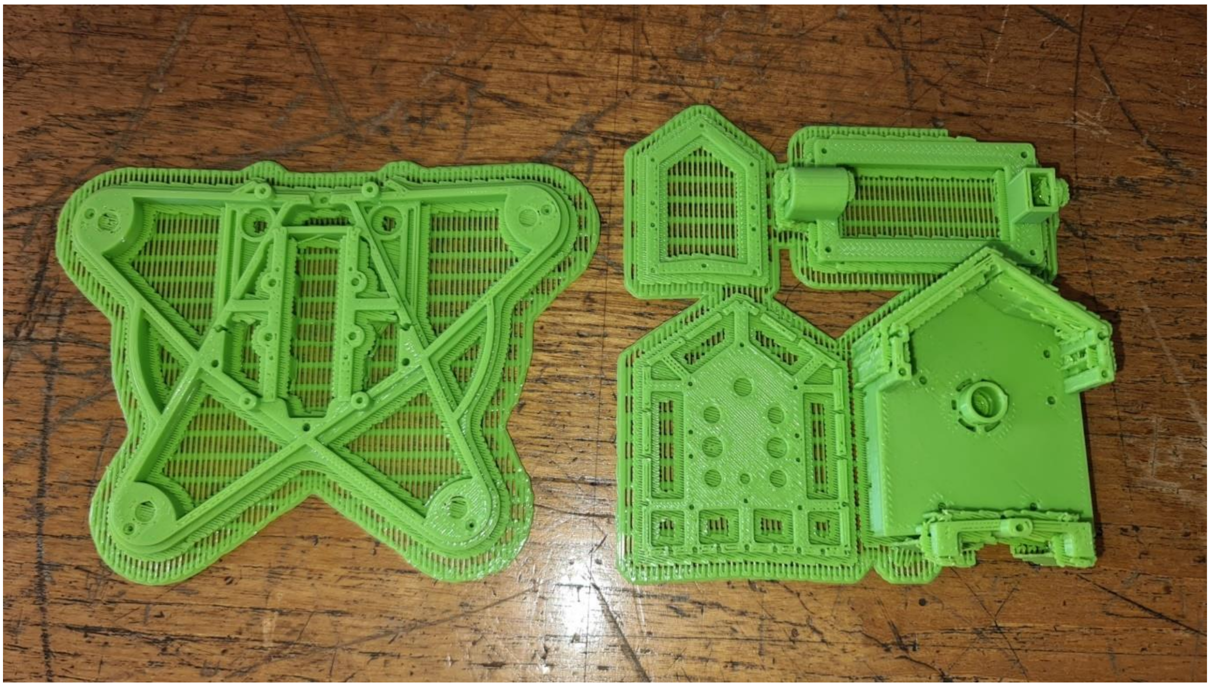
Base with gaps to aid airflow as well as connector holes to attach to the skirt clips. Dipped motor holder.



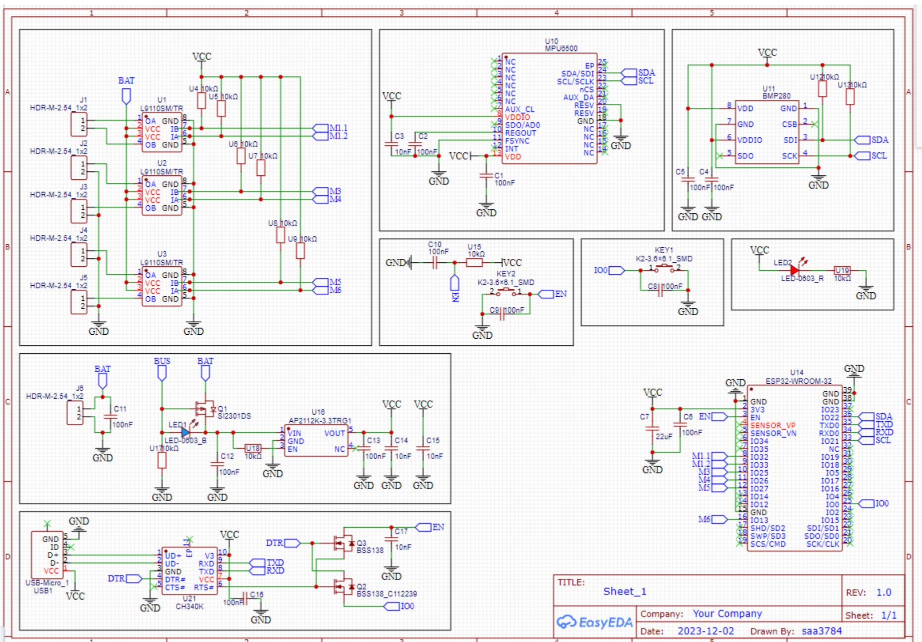
B3 – Skirt Clips Connection Diagram



B4 – Images of 2nd Print



B5 – Schematic & BOM (discontinued PCB)



ID	Name	Designator	Footprint	Quantity	Manufacturer Part	Manufacturer	Supplier	upplier Pa	Price
1	100nF	C1,C2,C4,C5,C6,C8,C9,C10,C11,C12,C13,C16	C0402	12	CL05A104KA5NNNC	SAMSUNG(三星)	LCSC	C100072	0.002
2	10nF	C3,C14,C15,C17	C0402	4	CC0402KRX7R9BB103	YAGEO(国巨)	LCSC	C60133	0.001
3	22uF	C7	C0603	1	CL10A226MQ8NRNC	SAMSUNG(三星)	LCSC	C59461	0.008
4	HDR-M-2.54_1x2	C,M1,M2,M3,M4,PWR	HDR-M-2.54_1X2	6			LCSC	C124375	0.022
5	K2-3.6×6.1_SMD	IO0,EN	KEY-SMD_2P-L6.2-W3.6-LS8.0	2	K2-1107ST-A4SW-06		LCSC	C118141	0.054
6	LED-0603_B	LED1	LED0603_BLUE	1	19-217/BHC-ZL1M2RY/3T	EVERLIGHT(台湾亿光)	LCSC	C72041	0.02
7	LED-0603_R	LED2	LED0603_RED	1	19-217/R6C-AL1M2VY/3T	EVERLIGHT(台湾亿光)	LCSC	C72044	0.017
8	SI2301DS	Q1	SOT-23-3_L2.9-W1.3-P1.90-LS2.4-BR	1	SI2301DS	TECH PUBLIC(台舟)	LCSC	C2841444	0.056
9	BSS138_C112239	Q2	SOT-23-3_L2.9-W1.6-P1.90-LS2.8-BR	1	BSS138	SHIKUES(时科)	LCSC	C112239	0.018
10	BSS138	Q3	SOT-23-3_L2.9-W1.6-P1.90-LS2.8-BR	1	BSS138	SHIKUES(时科)	LCSC	C112239	0.018
11	L9110SM/TR	U1,U2,U3	SOP-8_L4.9-W3.9-P1.27-LS6.0-BL	3	L9110SM/TR	HGSEMI(华冠)	LCSC	C725348	0.177
12	10kΩ	U4,U5,U6,U7,U8,U9,U12,U13,U15,U17,U18,U19	R0402	12	RAT021002FTH	RALEC(旺诠)	LCSC	C5119777	0.003
13	MPU6500	U10	QFN-24_L3.0-W3.0-P0.40-BL-EP	1	MPU-6500	TDK InvenSense(应美盛)	LCSC	C50278	2.484
14	BMP280	U11	LGA-8_L2.5-W2.0-P0.65_AMP6127	1	BMP280	Bosch(博世)	LCSC	C83291	1.641
15	ESP32-WROOM-32	U14	WIFIM-SMD_ESP32-WROOM-32-N4	1	ESP32-WROOM-32-N4	ESPRESSIF(乐鑫)	LCSC	C82899	3.012
16	AP2112K-3.3TRG1	U16	SOT-25-5_L2.9-W1.6-P0.95-LS2.8-BL	1	AP2112K-3.3TRG1	DIODES(美台)	LCSC	C51118	0.076
17	CH340K	U21	ESOP-10_L4.9-W3.9-P1.00-LS6.2-BL-EP	1	CH340K	WCH(南京沁恒)	LCSC	C968586	0.622
18	USB-Micro_1	USB1	MICRO-USB-SMD_5P-P0.65-H-F_C10418	1		ValuePro	LCSC	C10418	0.056
			TOTAL						8.287

Appendix C

C1 - Arduino Code (.ino)

```
#include <WiFi.h>
#include <Wire.h>
#include <Arduino.h>
#include <Arduino_JSON.h>
#include <AsyncTCP.h>
#include <ESPAsyncWebServer.h>
#include <Adafruit_Sensor.h>
#include <Adafruit_ADXL345_U.h>
#include <Adafruit_BMP280.h>
#include "SPIFFS.h"

#define ssid "******"
#define password "***********"

AsyncWebServer server(80);
AsyncEventSource events("/events");
JSONVar readings;

Adafruit_BMP280 bmp; // I2C
#define sensor 33 //IR-Sensor
#define motorA1 26 // Motors
#define motorA2 27
#define motorB1 12
#define motorB2 13

bool go;
String header;
String skirtState = "off";
const long timeoutTime = 2000;
unsigned long previousTime = 0;
unsigned long lastTimeTemperature = 0;
unsigned long lastTimeAcc = 0;
unsigned long temperatureDelay = 1000;
unsigned long pressureAltitudeDelay = 1000;
unsigned long accelerometerDelay = 200;
unsigned long currentTime = millis();

Adafruit_ADXL345_Unified adxl;

sensors_event_t a;
float accX, accY, accZ;
float temperature, pressure, altitude;

void initADXL(){
 if (!adxl.begin()) {
   Serial.println("Failed to initialize ADXL345 sensor!");
   while (1);
 }
 Serial.println("ADXL345 sensor initialized successfully!");
}

void initBMP(){
 if (!bmp.begin(0x76)) {
   Serial.println("Could not find a valid BMP280 sensor, check wiring!");
   while (1);
 }
 Serial.println("BMP sensor initialized successfully!");
}

void initSPIFFS() {
 if (!SPIFFS.begin()) {
   Serial.println("An error has occurred while mounting SPIFFS");
 }
 Serial.println("SPIFFS mounted successfully");
}
```

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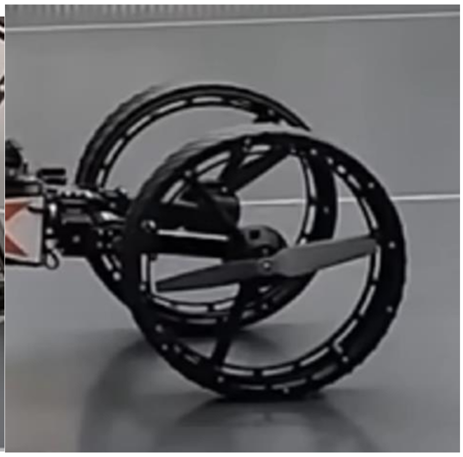
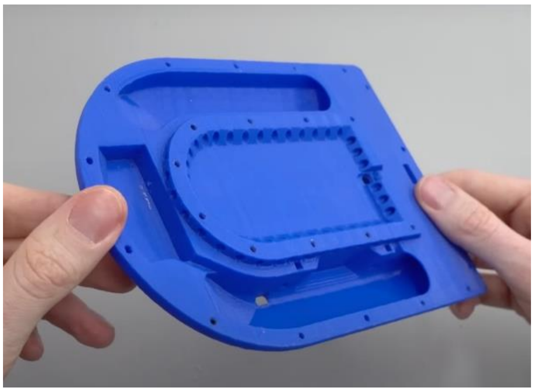
[2] – Alternative version for ARTEx(timestamp 1:08) - https://www.youtube.com/watch?v=m1FNcNvboSg&ab_channel=TechPlanet – Images



[3] – Sharrow/Toroidal propellers - https://www.youtube.com/watch?v=MGy8jvf-DZ0&ab_channel=Ziroth

[3] – RC hovercraft by Tom Stanton - https://www.youtube.com/watch?v=ii2b9yyLduE&ab_channel=TomStanton




[4] - Propeller Holders - https://www.thingiverse.com/thing:195633

[5] - Hovercraft Base - https://www.thingiverse.com/thing:2700850

[6] - Mini Drone - https://www.thingiverse.com/thing:3249126

[7] - hovercraft base - https://www.thingiverse.com/thing:4150197/comments

[8] - 3D Printed RC Hovercraft - https://www.youtube.com/watch?v=rCYRUXrFhZc

[9] - DC110 ABS FPV for SP F3 RACING EVO Brush Flight control - https://www.thingiverse.com/thing:1751876

[10] - Wipkviey T16 Mini Drone - https://www.amazon.co.uk/dp/B0CCNSQWXK?psc=1&smid=A2BVG7KER3UN4X&ref_=chk_typ_imgToDp

[11] – PS4 controller as ESP controller - https://www.youtube.com/watch?v=BmlKBs27pgE