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Conceptual Design of a Novel Roadable Flying Car

Haktan YAĞMUR[1], Can BAYAR[1], Tunahan FİLİZ[1],
Bedirhan ERTATLIGÜL[1], Kasım SERBEST[1*]

[1] Department of Mechatronics Engineering, Faculty of Technology, Sakarya University of Applied Sciences

ABSTRACT

Nowadays, the importance of zero-emission flying cars has increased as a solution to the traffic problem caused by population growth. In this study, previous flying car concepts in the literature were examined and a conceptual design study of a novel flying car was made. The configuration in which the designed vehicle can achieve maximum efficiency was selected and a design principle was followed accordingly. A survey was conducted with end-users by comparing the vehicle with other concepts in the world. At the same time, the final system architecture of the vehicle and all subsystem components such as electronic communication, chassis, battery management system, power, and propulsion systems were created and designed. In this way, it is aimed to obtain consistent data in mathematical models and analyzes. CFD and static analyzes of the vehicle were made and the data obtained were compared with the numerical analyzes and the vehicle was developed. It has been given importance to reduce the noise of all systems used in the vehicle in terms of passenger comfort and to develop new noise reduction solutions. The reliability of the system is very important due to the innovativeness of the Flying Car (eVTOL) concept. For this reason, the security of all components of the vehicle, cyber-attacks, flight security, and other possible problems have been examined and solutions have been produced. Autopilot systems, GPS, radar, power supply, and other subsystems that can be used on the vehicle are provided with redundancy. Algorithms and different solutions have been produced for issues such as air movement rules of the designed vehicle in today's cities, communication protocols of vehicles, how to get take off the vehicle, how to plan a route, how to react to problems, battery and charging stations.

Keywords: eVTOL, aircraft, urban air mobility, engineering design

1 Introduction

Urban Air Mobility (UAM) is a service that will revolutionize existing transport opportunities by bringing transport into the air. Due to the continuous increase in population, road traffic is increasing at alarming rates and traffic congestion problem occurs in metropolitan areas. The flying car concept will provide improved shortcuts for individuals to navigate rural and urban areas while reducing traffic congestion. Flying cars (Figure 1) are vehicles that will become popular when it comes to eco-friendly cities due to the important factor of clean propulsion with vertical take-off capability, no acceleration space required, and zero exhaust emissions [1]. Future UAM expectation reveals many different vehicle types according to different city scenarios and technological infrastructures. Since this concept is a new field of transportation and design, fundamentally different vertical take-off and landing aircraft concepts are being developed, which are possible with electric propulsion. To embody the vision of an urban air transport

* Corresponding Author's email: kserbest@subu.edu.tr

system, it is important for the eVTOL concept to know the characteristics of various vehicle technologies and understand their impact on an overall system [2].

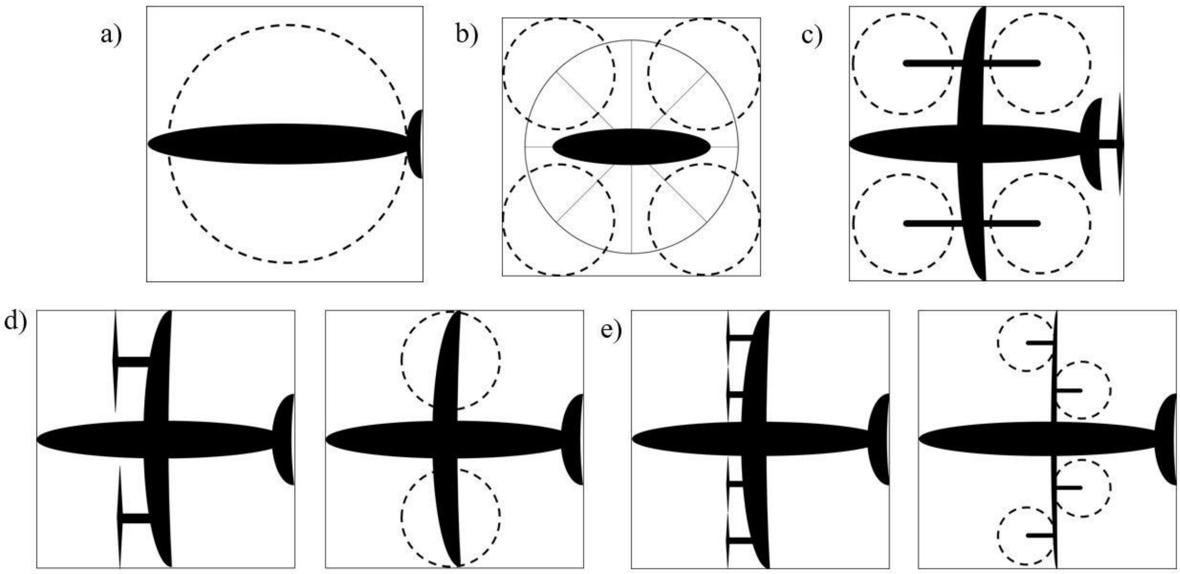


Figure 1: Different concepts of the flying cars. a) helicopter type, b) multirotor type, c) lift and cruise type d) tiltrotor type, tiltwing type.

According to a study conducted by Stanford University in 2019, aviation companies are designing and testing vehicles in different configurations in order to achieve the most configuration and obtain the high-accuracy analysis. In general, proposed designs also use distributed electric propulsion (DEP). Distributed electric drive; It is the presence of electric motors and propellers on more than one rotor to fly the vehicle instead of a relatively single large propeller [3]. For this reason, eVTOL types and rotor set configurations produced by different companies were examined. Different types of flying cars that have developed and become popular especially in our country have also been taken into account (Figure 2).

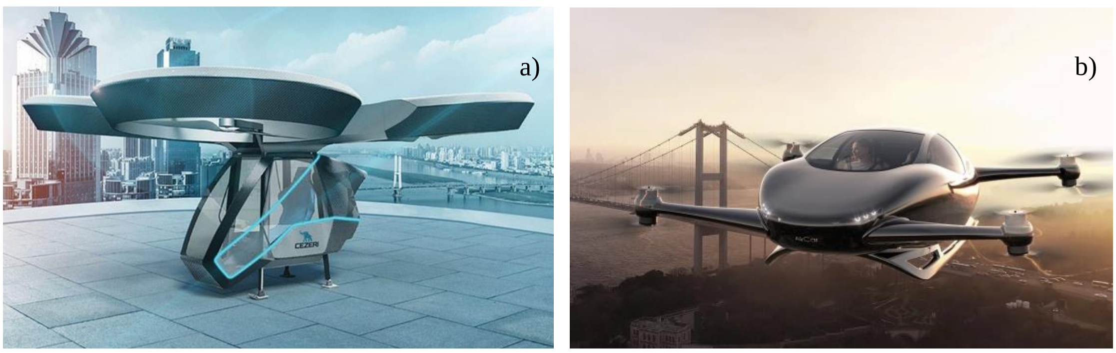


Figure 2: Some commercial air crafts. a) Baykar-Cezeri, b) Softech & AirCar Corp.-AirCar, c) THY Technic-Esinti, d) Audi & Airbus-Pop-up.

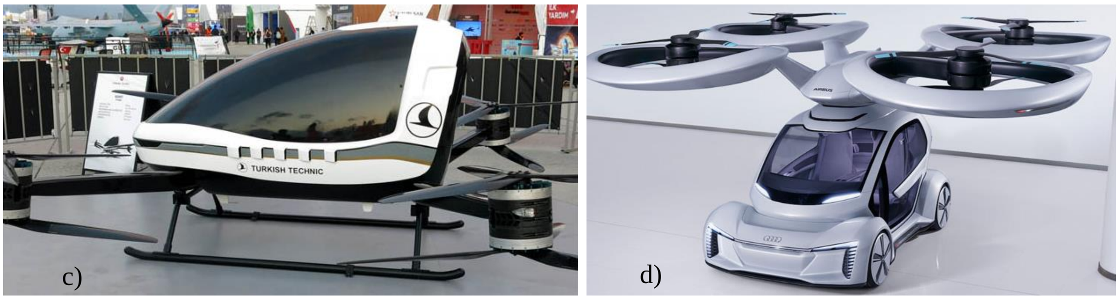


Figure 2: Continue.

When the developed flying car concepts are examined, it has been observed that there are different structures and configurations, as well as structural concept systems with the same logic. For this reason, it is aimed to carry out the concept development process of the Zevahir vehicle we designed in line with the wishes of the users. For this reason, a survey was created to get feedback from users. Users between the ages of 10 and 65 who participated in the survey participated in the survey from different cities and countries. Responses to the "Flying Car Expectations" survey, in which about 100 people participated, were analyzed.

Due to our aim of making a design acceptable to everyone, we have chosen the name of our vehicle as "Zevahir", which means an exterior appearance in Ottoman Turkish. By analyzing today's transportation standards, we approached today's problems with the principle of solution-oriented design. Our Zevahir vehicle has a passenger capacity of 2 people. Our vehicle offers the opportunity to cruise both in the air and on the land. Our vehicle has a stable and balanced flight capacity with 4 rotors and 8 electric motors. It is in a structure that can easily pass all security certification processes and absorb disinformation with its aerodynamic structure. When our vehicle changes from air mode to land mode, thanks to its dynamic design, the propellers fold and take up less space. This provides ease of navigation.

Weight plays a very important role in the aviation industry and it is very important to minimize weight. For this reason, we preferred to use composite materials intensively in our vehicle. Because composite materials lighten the weight of the vehicle and provide high strength and rigidity. Our vehicle will be in communication with the center via UART, SPI, and I2C protocols. It is planned to prevent leaks such as spoofing (forgery attacks) by using signal jammers and deception by making end-to-end encrypted communication between the center and vehicle.

While creating the system of our Zevahir vehicle, criteria such as environmentalism, security, and technological compatibility were taken into consideration. In particular, recyclable and energy-efficient materials were preferred for environmentalism. The fact that our vehicle works entirely with electrical energy will minimize environmental pollution, which is one of the biggest problems of today's transportation. Our autonomous vehicle may be exposed to unexpected situations due to its structure. We have foreseen all these situations and preferred to give priority to security in all systems used.

2 Design Methodology

2.1 System Architecture

The Zevahir System Architecture (Figure 3) includes system components, developed and generalized systems working together to implement the flying car system. Considering the behavior of the multiple systems used, changes were made in the conceptual architecture. In particular, vehicle security and redundancy system components were revised and the final architecture was created. In all revision processes, care has been taken to ensure that the system is simple but effective.

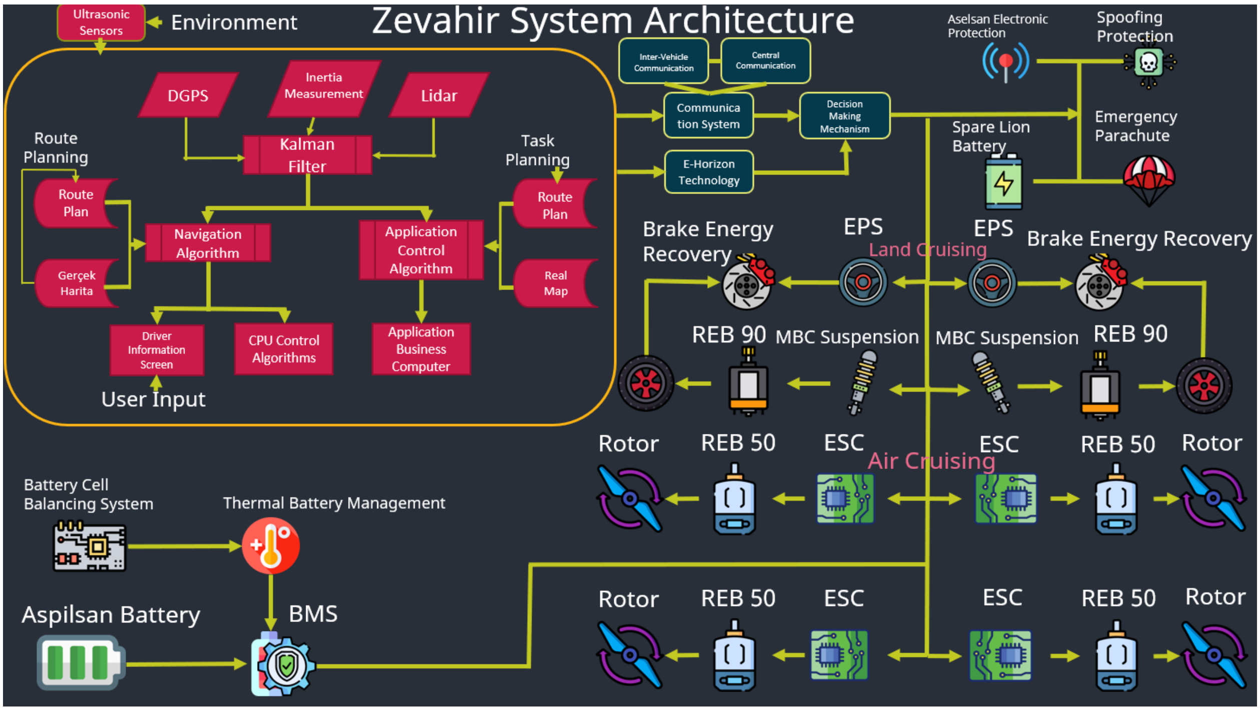


Figure 3: Zevahir system architecture

2.2 Powertrain and Steering System

In the air conditioning power transmission system of the Zevahir vehicle, 2 counter-rotating propellers in 4 engine arms and 8 REB 90 BLDC motors produced by MGM Compro will be used. In case of land, 2 REB 50 BLDC motors connected to the rear wheels will be used. The Vehicle Guidance System is located diagonally to the front and rear of the vehicle in the form of 4 X-shaped rotors for air mode. In the case of land mode, vehicle steering will be made with the EPS system mounted on the vehicle terrain guidance system [4].

Rotor Arm System

Our folding rotor arm system (Figure 4) is a single degree of freedom structure with a total length of 2.6 meters. There are 4 DC motor-driven steering systems in the rotor arm system. While designing the rotor arm, criteria such as being able to withstand the loads acting on the blade, low density to reduce the gravitational forces and long fatigue life was taken into consideration. The rotor arm is designed in a semi-monocoque structure. In order to increase the strength of the arm, PVC or PET foam and balsa wood can be used as an intermediate material in the sandwich structure inside. "OKSB Cylindrical Vibration Damper" product will be used inside the rotor arm and in the wing bottom area, taking into account the vibration that will be created by the engines and the wind.

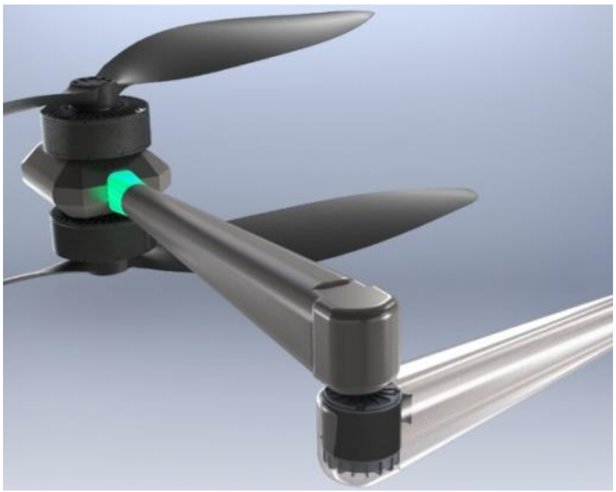


Figure 4: Designed rotor arm system

2.3 Autonomous Control System

Sensors are of great importance for the control of autonomous vehicles. With the Radar system we use in the vehicle, electromagnetic waves at certain frequencies are sent and the waves reflected back from the objects are analyzed with special methods and the speed and size data of the target object can be reached, the vehicle's recognition of traffic lights, road signs, other vehicles and pedestrians with digital cameras, Lidar (Light Detection and Ranging) sensors We have made it possible to detect the direction of the objects around the vehicle and in which direction they are moving, to detect the objects near our vehicle with ultrasonic sensors, and to enable our vehicle to go from the desired route to the desired location in the fastest time with the GPS system. In addition, we supported the GPS system with inertial navigation devices (INS) in order not to disrupt the operation of the GPS system (Tunnel and dense forest areas interfere with the operation of the GPS system.). Rather than collecting all these technological sensors in a certain part of the vehicle, we placed them in different locations of the vehicle so that all sensors are not affected in case of any damage [5].

2.4 Energy Storage System

Lithium-ion batteries with high specific energies, long lifespans and low self-discharge rate are widely used in electric vehicles. Cylindrical cells have been selected for battery pack design considering their advantages. We compared various cylindrical cells on the market based on their chemical composition, nominal voltages, weight, specific energies, and life cycles. Our flying car Zevahir will use the domestic battery system developed by national lithium-ion battery manufacturer Aspilsan. Aspilsan production plan will be introduced and different alternative sources will be obtained in the interim period. Considering these resources, it is concluded that the LG 18650 HG battery cell should be used, as it has a good nominal voltage, better capacity and minimal weight among other batteries [6].

- Battery Management System

The battery management system is an electronic system that allows the battery group to operate within safe operating limits. The battery management system to be used for this purpose can show the voltage, current, temperature, charging status and estimated amount of remaining energy of the battery group. The battery management system we use in our vehicle is designated as the Bq77216 Battery management system of Texas Instruments.

- Battery Cell Balancing System

A large number of cells are used in electric vehicle batteries to obtain the necessary energy. Cell balancing system is used to eliminate the imbalance between cells and increase cell life and therefore battery life. Using the passive balancing system, it is applied as the discharge of excess energy generated during charging in the cells in the battery through serially connected balancing resistors.

- Battery Thermal Management System

The purpose of the cooling system is to keep the battery within the optimum temperature range and to offer the best balance between performance and wear. Zevahir vehicle uses a highly efficient active liquid cooled system in the battery thermal management system. The indirect liquid refrigerated system provides better insulation and performance values between the battery module and its surroundings [7].

2.5 Vehicle Structural System

Durability of the vehicle chassis; it is designed taking into account all factors such as being light, rigid and low part, being easily attached and dismantled mechanical parts, dampening vibrations during flight, reducing load accumulation during landing and costing less. That's why the light vehicle chassis design for Zevahir offers great potential to increase the efficiency of the vehicle.

The chassis (Figure 5) to be produced is designed using the integration of monocoque and platform-type chassis structures. The lower chassis is a platform type structure, while the upper chassis is a monocoque chassis type. The platform chassis is designed of aluminum material and the monocoque chassis is designed from carbon fiber-epoxy composite material. Multiaxial type carbon fiber fabric and epoxy polymer matrix composite material are used in the vehicle. With the help of vacuum infusion technique, layered composite material was used for chassis production. On the lower chassis, 5754 series Alloy Aluminum is used, which is both light and high strength, which can dampen all torsion and vibrations that will occur in the vehicle. Material properties of the chassis part are given in Table 1.

Figure 5: Designed platform-monocoque chassis

Table 1: Structural material properties

Name of Material	Poisson Ratio (MPa)	Density (g/cm^3)	Slip strength (MPa)	Tensile strength (MPa)
CFRP Material	0,3	1,54	59,45	1192
5754 Aluminum	0,33	2,67	25.9	185
Carbon Epoxy Composite	0,4	1,6	67,5	1860
Steel	0,3	7.7	190	500

3 Flight Envelopes

In aerodynamics, the flight envelope defines operational limits for an air platform based on the maximum speed and load factor given a certain atmospheric density. The flight envelope is, indeed, the area where an aircraft can operate safely.

If a flying car flies "outside the envelope", it can be damaged. Therefore, our wind limitations were set at 50 knots (92.6 km/h) [8]. The airtime is thought to be 29.3 minutes thanks to the battery technology we use and the selection of light materials we choose. The fast-charging time of the vehicle is 80% in approximately 25 minutes. The range of our vehicle is determined as 65km (40 Miles) where the user can easily go to any location, he/she wants based on Istanbul, the largest city in our country. The approximate cruising speed of our vehicle will be 90 km / h. Our vehicle, which has a passenger capacity of 2 people, has a total capacity of 220 kg of useful cargo. When creating the flight envelope, it is primarily based on the requirements and requirements of vehicle concept tasks.

According to the land power needs of our flying car, rolling resistance and wind resistance applied to the car, the required torque and moment were found. Acceleration power calculation has been made on land.

3.1 Vehicle Weight Breakdown

When creating the weight breakdown of the Zevahir vehicle, care was taken to make the system both durable and light. As a result, composite materials that lighten the weight of the vehicle, which are necessary for easy take-off of the vehicle, were used extensively in the vehicle. All factors were examined and the vehicle weight breakdown table was created (Figure 6).

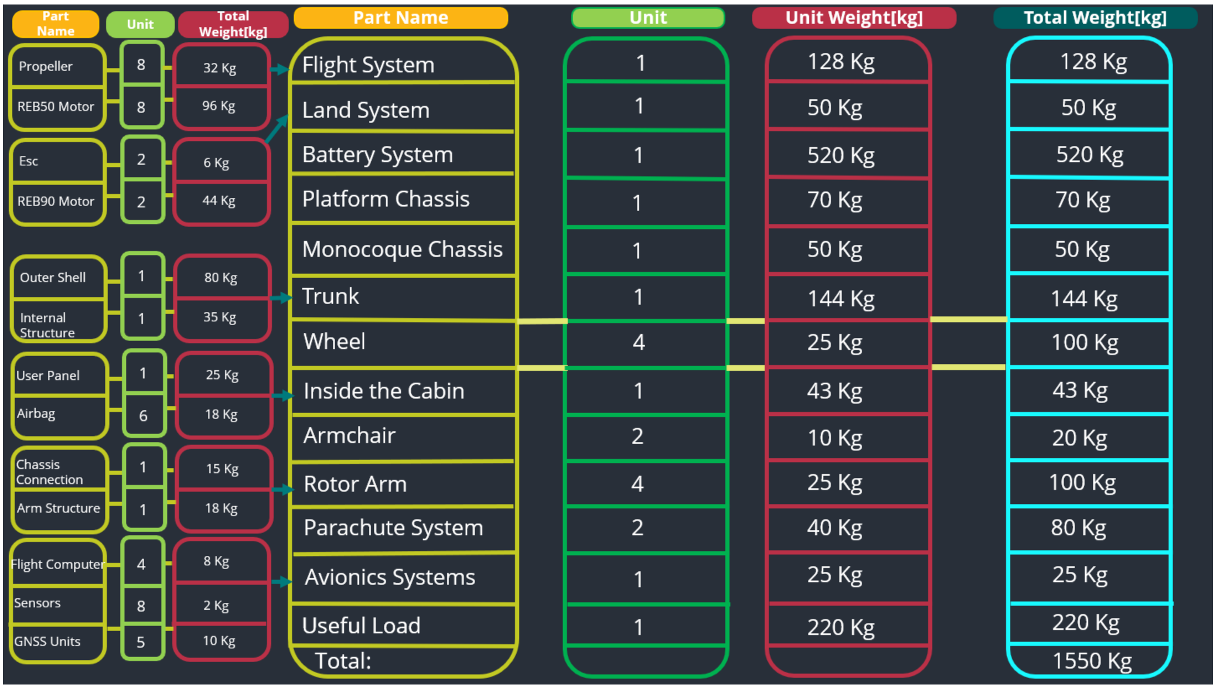


Figure 6: Vehicle Weight Breakdown

4 User and Vehicle Safety

4.1 Reliability of Power-Propulsion-Drive Systems

The targeted purposes can be achieved by using the data obtained by the sensors placed on smart systems (ultrasonic, camera, infrared), GPS systems, remote communication devices, voice and video transfer systems. These sensors, GPS receivers and communication devices are auxiliary tools for navigation. Since the Zevahir is an autonomous vehicle, the control unit is sensor-oriented. These sensors will be able to communicate with other autonomous vehicles in the surrounding area and handle traffic in a healthy way thanks to lidars, radars, navigation systems and internet access. In order to operate in sync with other vehicles, radars, signaling systems, traffic lanes, all kinds of road lines in the same way have standards in themselves, and by having the ability and qualities to communicate with the systems in the autonomous vehicle without leaving a blind spot, situations such as disrupting the mission of the systems are minimized and the situations that cause accidents are eliminated as much as possible [9]. Figure 7 contains information about the safety systems used in the vehicle.

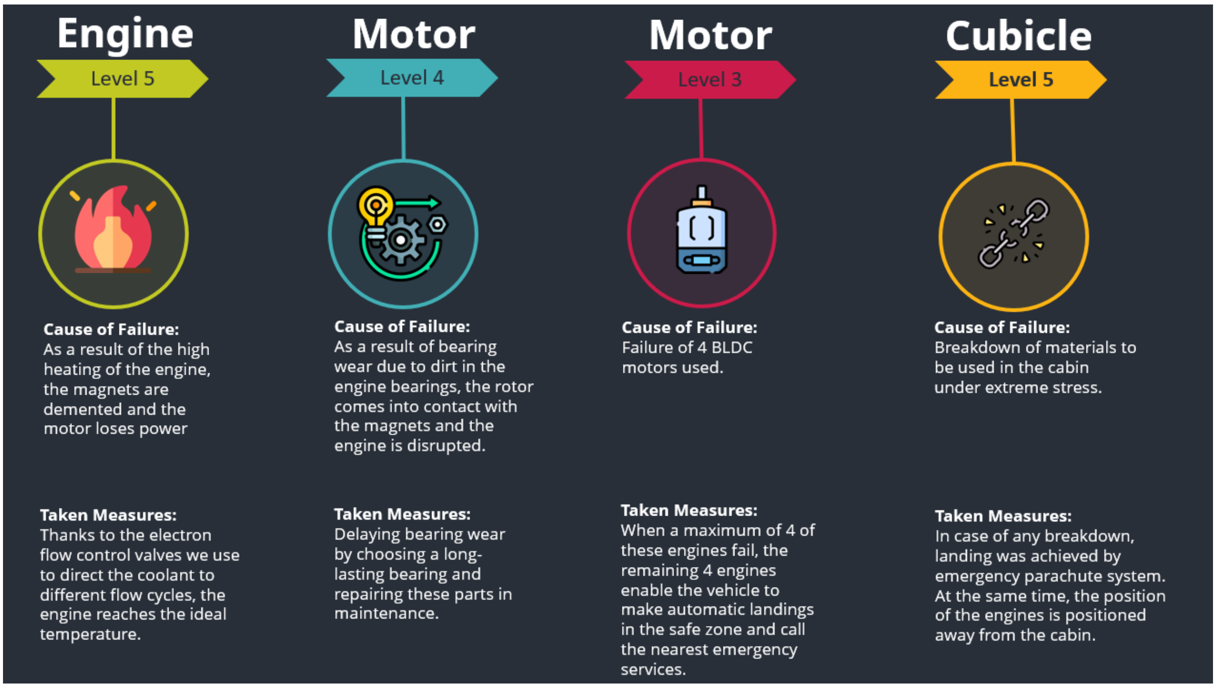


Figure 7: Safety systems in the vehicle

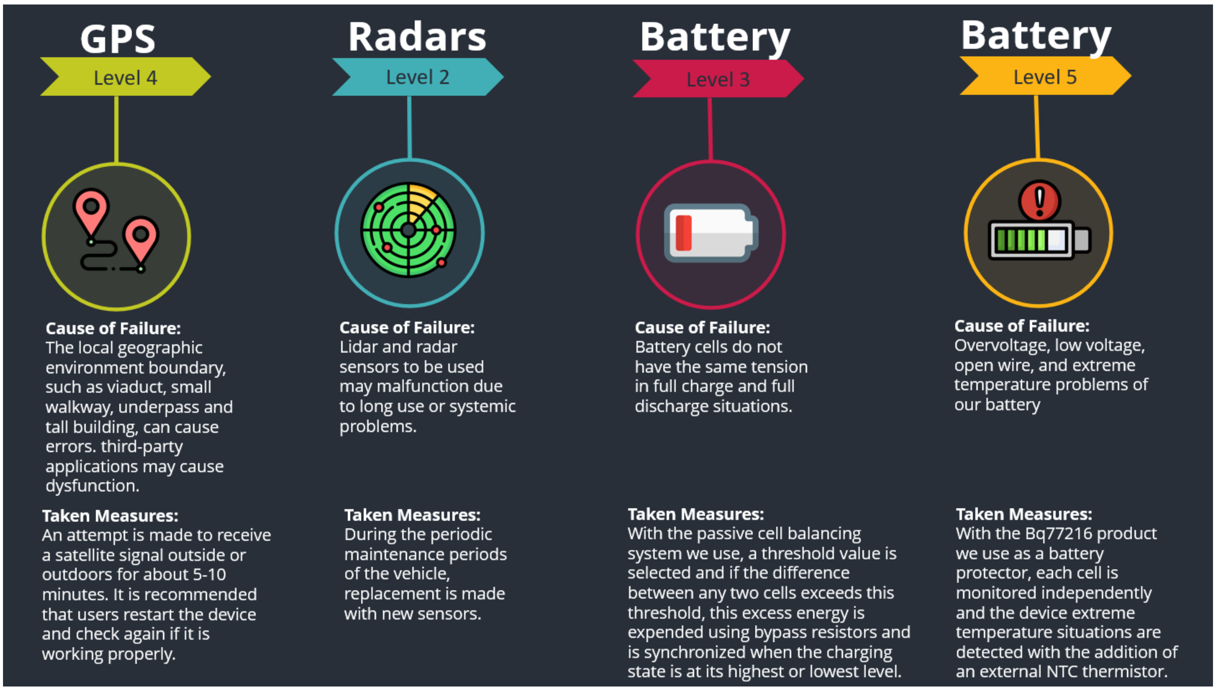


Figure 7: Continue

Since our vehicle has electric motor feature, it disturbs the user with lower sound than internal combustion engine vehicles. It has been observed that the noise that flying cars give to the environment is usually caused by wheels, propellers and aerodynamic noise. Propeller noises are caused by the interaction of the propeller blades with the surrounding air. By reducing the emission level, we aimed to reduce the propeller rotation speed by installing a speed reduction transmission and simultaneously increased the propeller diameter and reduced the number of revolutions. That's how we slowed down the propeller speed. Thanks to the falling propeller speed, the wind noise from the propeller decreased. Since electric vehicles are obliged to make at least 56 dB of noise when driving at 20km/h or less, we have minimized the dB level to be formed in the landings and takeoffs in accordance with this measure thanks to the 8 BLDC engines we use in our vehicle and the appropriate weight of the vehicle. All structural parts of our car flying in aerodynamic noise create turbulence and noise-emitting resistance to airflow during flight. Essentially, structural parts are optimally placed and shaped during the design and design of the flying car body, but some parts (antennas, sensors, etc.) require minimum distance and mounting places. Thus, a placement is realized to reduce the noise. For the wheel, we avoided the choice of thin-cheeked tires within the scope of comfort and noise measures. The areas used for the purpose of comprehension of the materials and equipment used are shown in Figure 8 on the vehicle [9].

Figure 8: Sound insulation materials used in the vehicle

4.2 Flight Safety

The position of the engines we use in our vehicle is positioned as far away from the body as possible. This is because it is intended to minimize the damage that will bring the user in case of a possible mishap. It is aimed to prevent a possible accident by alerting other drivers with the vehicle lighting we use in the design while driving in the air.

When electrical problems arise in our vehicle, the flight will continue with the transfer of power from the backup battery. In the event of a possible lightning strike, current and voltage fluctuations may occur in electrical cables and equipment as the current moves on the surface of the body of the flying car. Cable bundles are covered with protective material so that lightning does not damage electrical systems. In addition, a protruding static discharger was used at the ends of the propeller and behind them to dispose of the static load accumulated on the flying car.

The redundancy of autonomous systems is very important for vehicle safety. Backup systems operate in parallel with the main, active system throughout the flight, running their own algorithms using their own independent sensors and air data computers. A basic voting scheme is used to compare outputs and determine which of the two backup systems will be activated in the event of a failure of the active system. Voting logic creates a majority when there is a dispute, and the majority disables the output from the device that disagrees, and in this way, the redundancy system that we have created in our vehicle will be activated and security will be ensured in case of any failure.

Thanks to redundant inertia measurement systems, it is possible to accurately track the movement of the vehicle along the road. Due to the provision of independent backup power supplies for each of the critical driving systems, critical driving components remain online during a power outage or circuit break and continue to travel.

Our vehicle, veronte Autopilot 4x, uses three redundant autopilot systems that can be connected to an external 4th autopilot core for advanced configurations. All this is managed by a different peer-reviewed microprocessor who at any time runs voting algorithms to select the autopilot kernel responsible for eVTOL control. One of the key factors in the Veronte Autopilot 4x is that it is designed to not be a single point of failure. Even in the event of an arbitrator error, the autopilot remains operational for eVTOL control. Veronte Autopilot 4x has a DAL B compliance level security certificate data pack. Figure 9 contains measures related to flight safety.

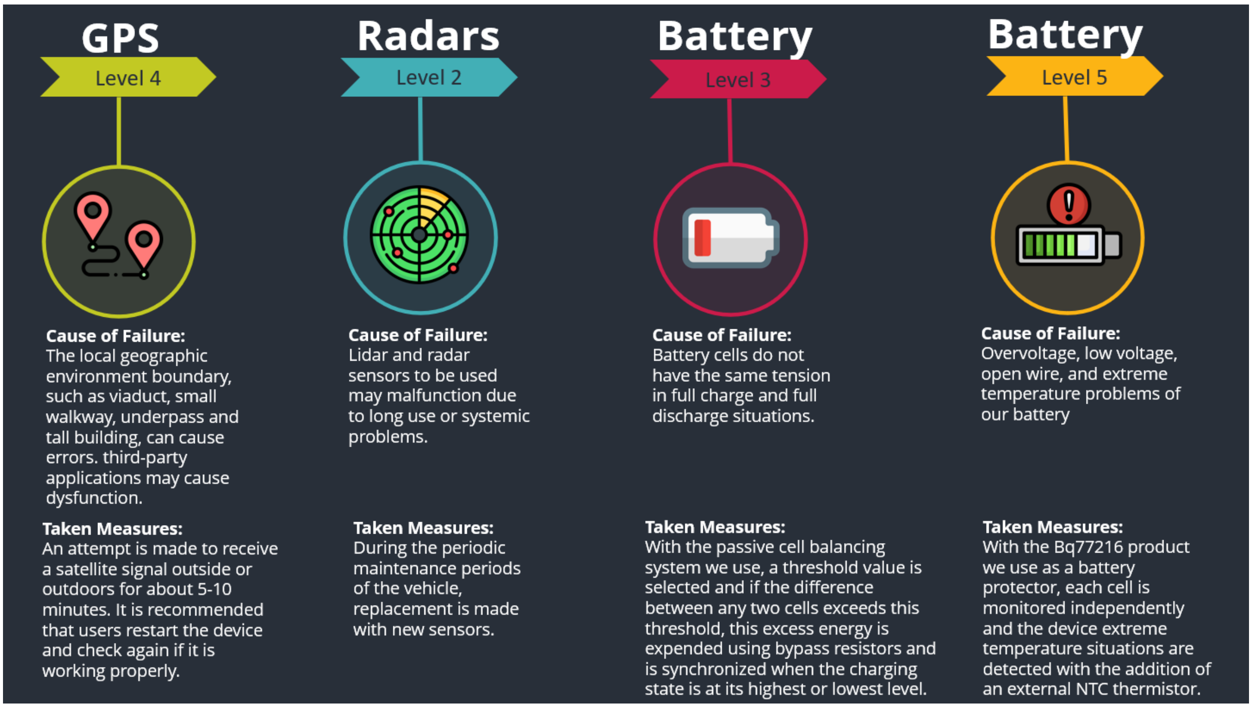


Figure 9: Flight safety measures

4.3 Cyber Security

Aviation relies on cyber-enabled technologies to improve safety, efficiency, capability, flight routes and flying car range. Collecting and analyzing more data provides benefits such as more efficient flight routes, lower flight times, lower fuel consumption and carbon emissions. Data, planning, communications, and management can also be subject to cyberattacks because they are the most basic flight business assets. While autonomous vehicles are expected to be much less prone to accidents than driver-controlled vehicles, they can pose a more serious threat. Due to the wireless hardware and software updates that autonomous vehicles routinely need, they have the potential to be easily attacked by hackers. Examples of other cyberattacks include spoofing attacks, jamming (radio jamming), intercepting user information, sabotaging traffic lights, RJF (Radio Jammer Frequency) [10].

In order to prevent Zevahir from being cyber-attacked in any way, data from 2 different satellites are used to test whether this data is compatible or not. Cross-vehicle communication and data exchange is done end-to-end in an encrypted manner. Casper/FDR and AVISPA protocols, a channel protocols that we use in our vehicle for the purpose of creating a safe space, preventing communication and data leaks. In addition, multiple authentication methods are used in accounts and access to the tool's data against the theft of account passwords. In our tool, hardware and software updates are meticulously made from reliable sources to prevent much malware. Sensors used to guide driving, millimeter-wave radars, ultrasonic sensors, software, and hardware to increase sensor resistance to attacks were used to prevent attacks on cameras. When ultrasound against ultrasonic sensors, radios, and cameras are used against (Millimeter Waves MMW) radars, ultrasound, radio, and laser do not come into physical contact with targeted sensors. Thus, these attacks are neutralized. Thanks to artificial intelligence sensors, spoofing and interference are detected and disconnected, preventing attacks by using signal jammers and misleading [11]. Figure 10 describes the measures taken regarding cybersecurity.

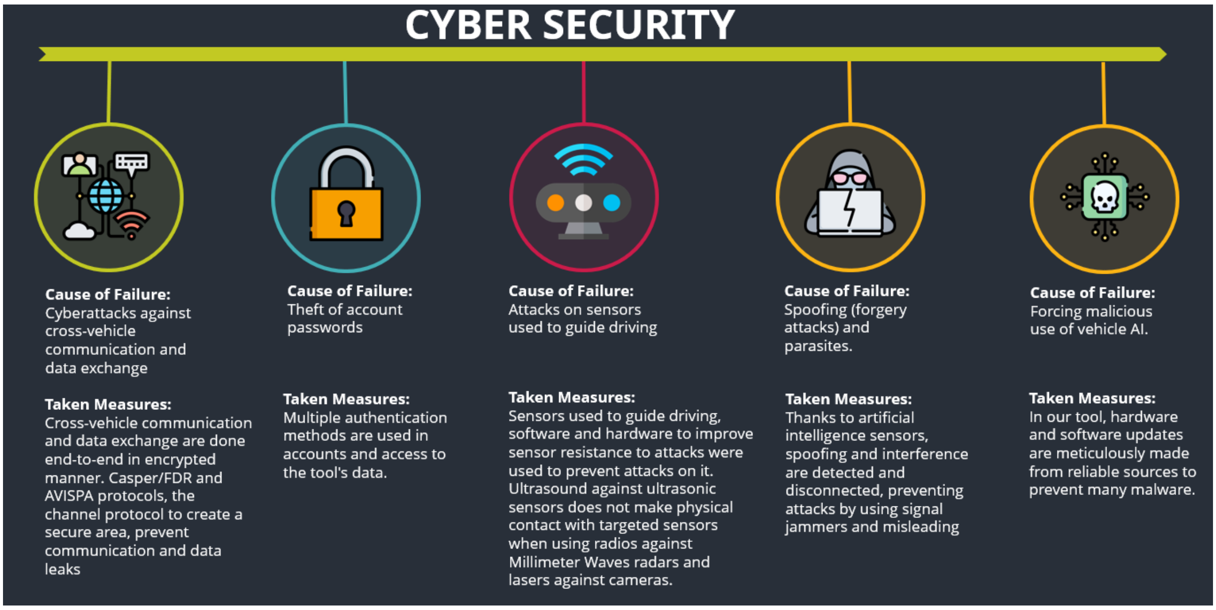


Figure 10: Cyber Security Measures

5 Air Traffic Management System

It is aimed to ensure the balance of capacity, safety and comfort when creating the air traffic management system of Zevahir vehicle. Maximum gain is achieved by taking into account time and costs when providing traffic flow management. The control systems created were autonomous and coordinated with both flight and land travel. The performance competencies of the Zevahir vehicle were examined and components of the air traffic management system were created within the framework of the rules of international civil aviation organizations. In the promotional video created for a better understanding of the air traffic management system, all stages of Zevahir vehicle in urban transportation are shown. The simulation shows that the user in the eastern settlement of the city calls the vehicle from the central garage with an application and goes to the desired point. At the same time, simulation of how the central station will be, how to recharge, vehicle communication and how to make vehicle landing boarding are included in the simulation.

5.1 Rules of Action in the Air

Today, the increase in the number of people using autonomous vehicles raises questions about the reliability of autonomous vehicles. However, advanced technology used in autonomous vehicles removes the question marks in mind. Advanced sensors, superior algorithms and artificial intelligence technologies are used to enable these vehicles to meet the rules of movement in the air.

Zevahir hosts all kinds of techniques and technologies and communicates with other vehicles that are the main subject of traffic (Figure 11), interacts with the environment, sends information to its surroundings and analyzes it by taking the information around it, adapts to the environment, as well as designing the entire environment outside the vehicle to communicate with the Zevahir. Flying car users will be entitled to travel in accordance with the rules of the vehicles after training and information [8].

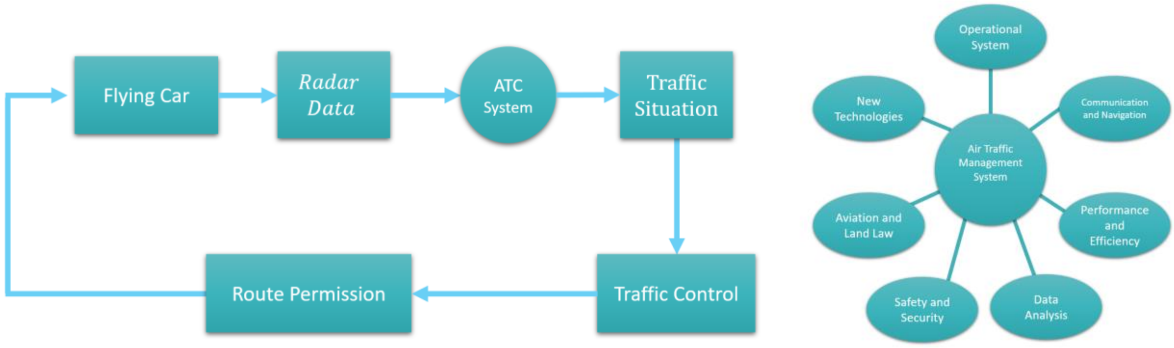


Figure 11: ATC: Air Traffic Control System Components

With these systems, it becomes possible to use the entire airspace efficiently by monitoring the movements of flying vehicles. In the event that more than one flying car coincides with the same airspace sector in the same time zone, strategic control, that is, the pre-calculation of the collision hazards of the 2 vehicles, takes place and the priority one must be allowed to pass and the speed of the other vehicle must be slowed down (figure 12).

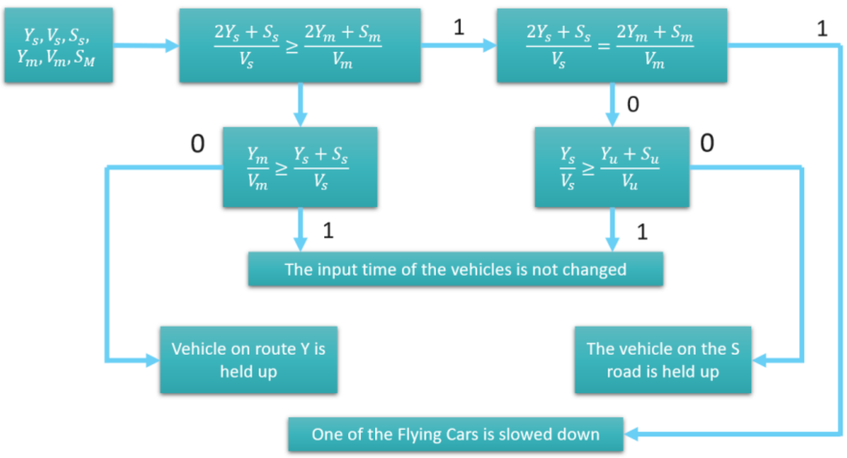


Figure 12: Determination of vehicle priorities on intersecting routes

Users who do not comply with the rules inside or outside the vehicle will face sanctions according to the size of their crime. Examples of these sanctions include deprivation of a vehicle for a certain period of time, imprisonment and fines. At the same time, when a violation of the rules is committed within the vehicle, the vehicle will land at the nearest station and the security forces will be notified (Figure 13).

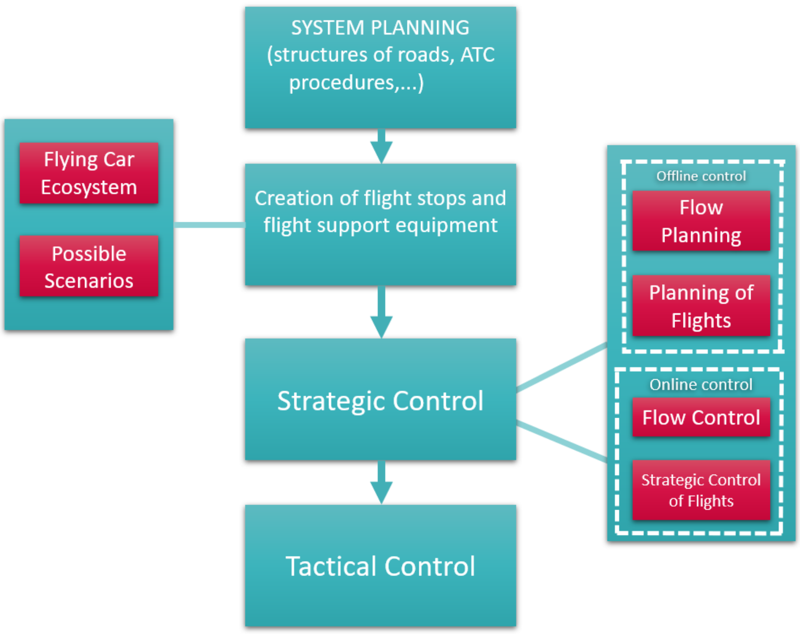


Figure 13: Planning and control functions of the air traffic system

5.2 Communication of Vehicles

Vehicles will be able to communicate with each other through communication technologies such as LoRaWAN, LTE-M1, Wi-SUN(6lowPEN), NBIOT, WAVIOT, WIFI, Bluetooth, ZWave. UART

Communication, SPI and I2C protocols and vehicles will be in contact with the center. In communication between peripherals, data will be collected through computer systems, GPS devices, sensors and complementary technologies used by them (3G, LTE, WLAN, Wi-Fi and DSRC). This collected data will be analyzed in cloud computing and applications located within the tool [11].

5.3 Get in-out the Vehicle

There are 3 types of station as specified in the city ecosystem. Parking lots and charging stations will be located around the stations. The type of first station we have created is the major station. This station will usually be used for public transport activities and will be able to accommodate more large crowds of people. Minor stations will be used both for individual purposes and as intermediate stations. These stations will be used as waiting points when the charging capacity is insufficient to go to the desired area. Both stations will be capable of generating renewable energy with solar panels, with both manual and smart charging. In any unexpected situation at emergency landing points, the vehicle will land at these points and find a short-term solution to the problems. Garages reserved for individual use can be customized, but car owners will choose and use features such as increased charging capacity and smart charging according to their own wishes and needs. Garages will be used more often, especially in areas where there is no air transportation. A comfortable environment will be provided in accordance with public transport rules for users to travel.

5.4 Route Planning

The user will travel autonomously by selecting their destination from the map on the vehicle's console or through the app on their phone. The route to the selected route will be determined as soon as possible. The destination will be reached by making an automatic route change in the air traffic that may occur. If the user changes course while traveling, the system will take the route chosen by the user to the destination as soon as possible [12]. Figure 14 includes a route plan diagram and Figure 15 contains maneuvering components.

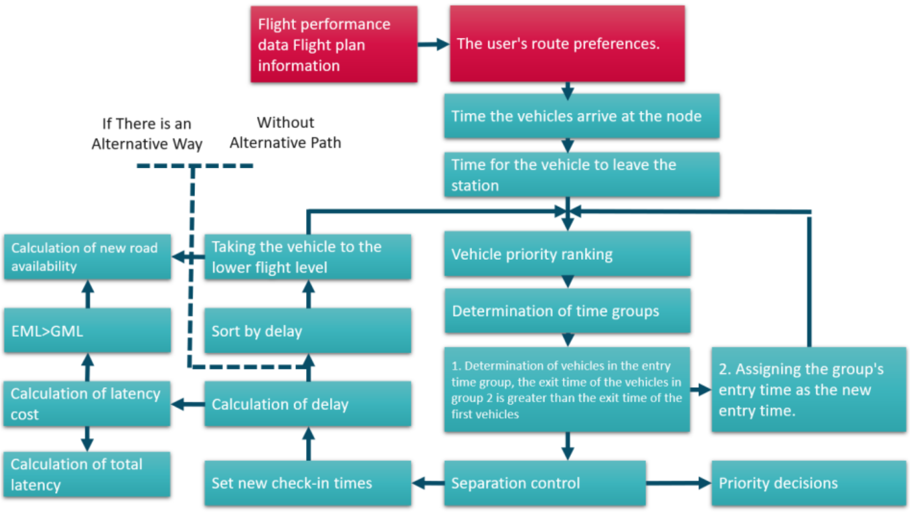


Figure 14: Route plan block diagram

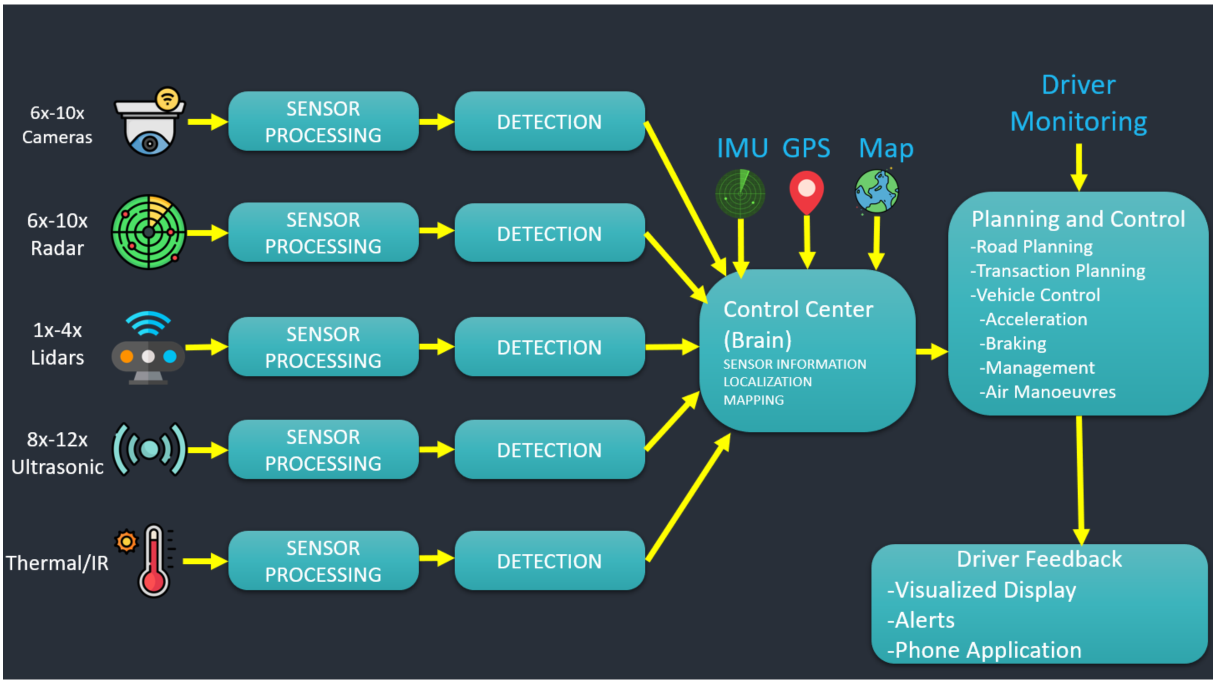


Figure 15: Route maneuvering components

5.5 Unexpectable Situations

In adverse weather conditions, the vehicle will not be available for safety. In case of unexpected traffic congestion, automatic route changes will be made to the destination at the shortest route and time, which will not cost other vehicle users. The user will be able to shape his/her travel according to the flow of traffic according to his/her request. In case of any disturbance, the user will press the emergency button to land at the nearest emergency landing site indicated on the map and the emergency service will be notified. In cases such as heart attack and fainting, the user will not be able to press the button, so the Zevahir smartwatch on the arm will activate the emergency system of the vehicle.

5.6 Battery Status and Charging Station

Battery management is a matter to consider as it affects airtime and charging time in autonomous vehicles. The concepts of energy density and power density related to the capacity of batteries are important; Energy density indicates the amount of energy stored in unit volume. The power density of the batteries refers to the amount of power (energy transfer rate) produced by the unit volume.

Charging will be done autonomously when the charging capacity drops to 30%. Thanks to the algorithms created, information will be provided to the user according to how many hours the vehicle will charge and whether the charging capacity will be sufficient according to the region to be visited. Charging will be carried out at stations in the city for public transportation and in people's garages for individual use. Data such as where to charge, how long to wait to fill the capacity will be created and users will be notified. Figure 16 displays the charging filling system.

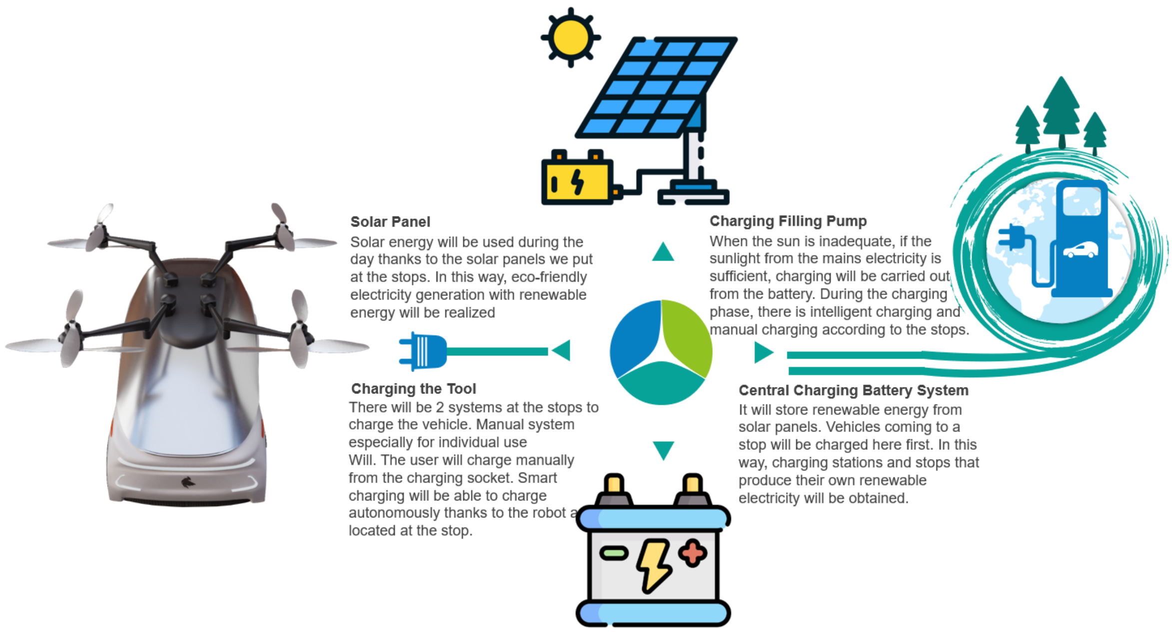


Figure 16: Charging System

6 Flight Analysis

In this study, the necessary design, analysis, and calculations were made to perform air taxi or other operational tasks of a flying car with vertical landing and take-off capability. At the same time, the algorithms and products are necessary for the avionic working principles of the system. In different city scenarios, detailed researches and compilations have been made about many flying car concepts and ecosystems, such as the rules of movement of the vehicle in the air. In line with these studies, it is aimed to obtain consistent calculations. Using Autodesk Flow Design software, our vehicle; it has been observed that the values such as drift coefficient for flight (cd), drag coefficient for vertical take-off, drift coefficient on land and which area of our vehicle is most pressured in these cases. Figure 17 contains computational flow analysis results.

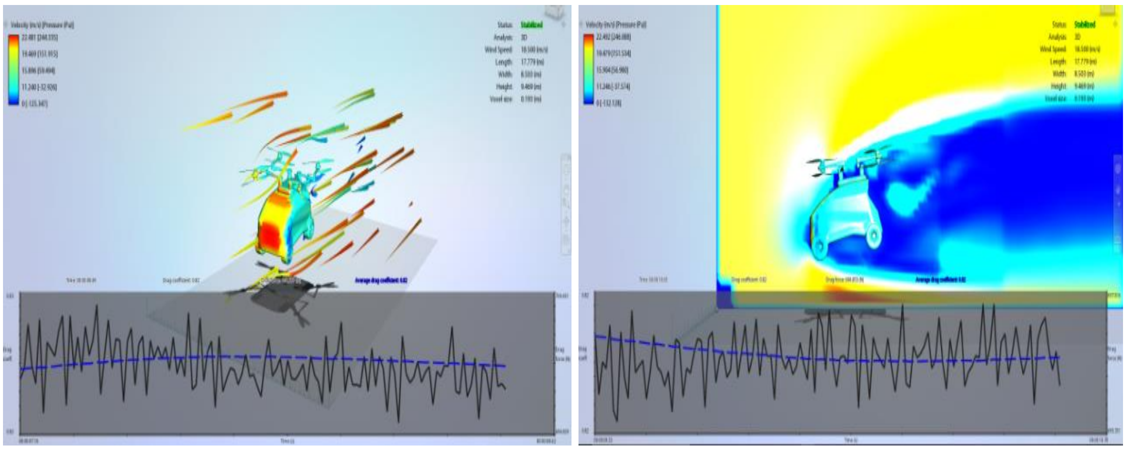


Figure 17: Results of aerodynamic analysis of the vehicle's air course

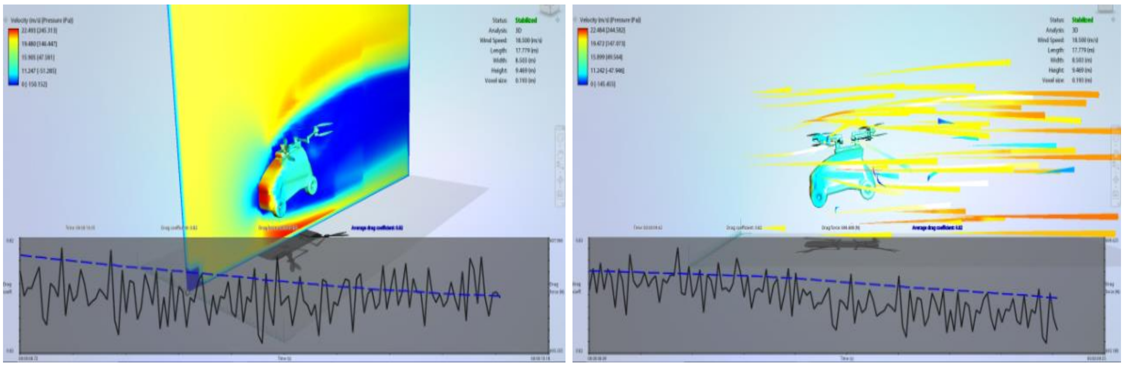


Figure 17: Continue

As shown in Figure 17, the design has been improved because the front body of the Zevahir, the first part where it encountered the wind, is subjected to more pressure. The maximum pressure our vehicle encounters in the air at a cruising speed of 100 km/h is 22.481 kPa, while the average drag coefficient for flight is 0.82 cd. In order to achieve more accurate results, it is assumed that our vehicle flies with a slope of 7 degrees, where it performs its maximum performance in the air.

Figure 18 contains the results of the vehicle's air friction analysis in land use. When the results were examined, it was concluded that the most pressure, such as the result obtained while the air was traveling at a speed of 80km/h, occurred on the front of our vehicle. The average drift coefficient on land is 0.69 cd and the maximum pressure value it encounters is 27.273 kPa.

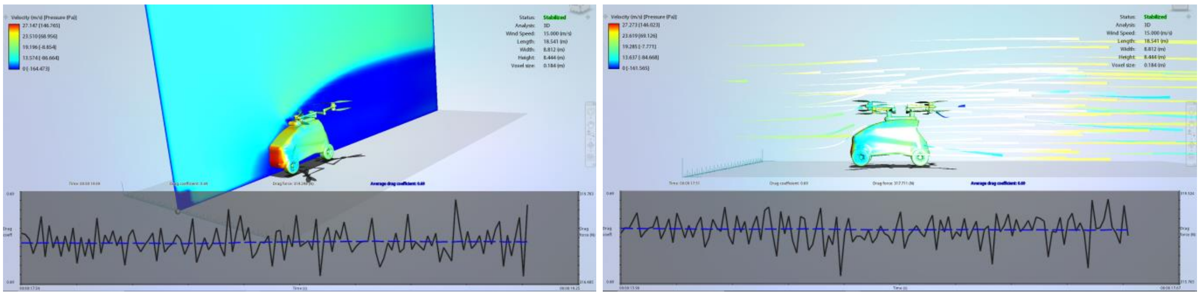


Figure 18: Results of aerodynamic analysis of the vehicle's land course

Since the acceleration direction was upwards during vertical takeoff, pressure was observed more in the ceiling, propeller and windshield areas of our vehicle, and the greatest pressure value encountered was 2.581 kPa. During vertical takeoff, the average drag coefficient of the Zevahir is 0.64 cd.

By calculating the power of climbing on land, the power and strength needed for our vehicle to climb the slope at 7° is obtained. In order for our vehicle to travel safely on land, the maximum speed is determined as 120 km/h and the cruising speed is 90 km/h by applying the speed limit on the roadways.

When calculating the power of our vehicle in the air, the intensity and sound speed of the air were calculated according to our flight height of 35m altitude. Propeller dimensions and rotor robustness were calculated using environmental conditions and momentum theory analysis. Then, the total power for the propeller was calculated with momentum disk theory.

It has a total capacity of 83 kWh with the li-ion battery pack we use in our vehicle. A total of 316.6V voltage and 264Ah current were achieved in the battery configuration of 3.6v, 3Ah 22x4s4p each. In this way, our flying car is provided with a flight time of 29.3 minutes in the air.

7 Results and Discussion

As a result of the design and analysis studies, our flying car named Zevahir is seen as a two-seater hybrid vehicle with a 3.1 m long and single freedom grade folding rotor arm system, suitable for use both on land and air, developed in terms of air traffic management system and safety considerations, weighing a total of 1550 kg and with a flight time of about 30 minutes in the air. Final design images for our vehicle are given in Figure 19.

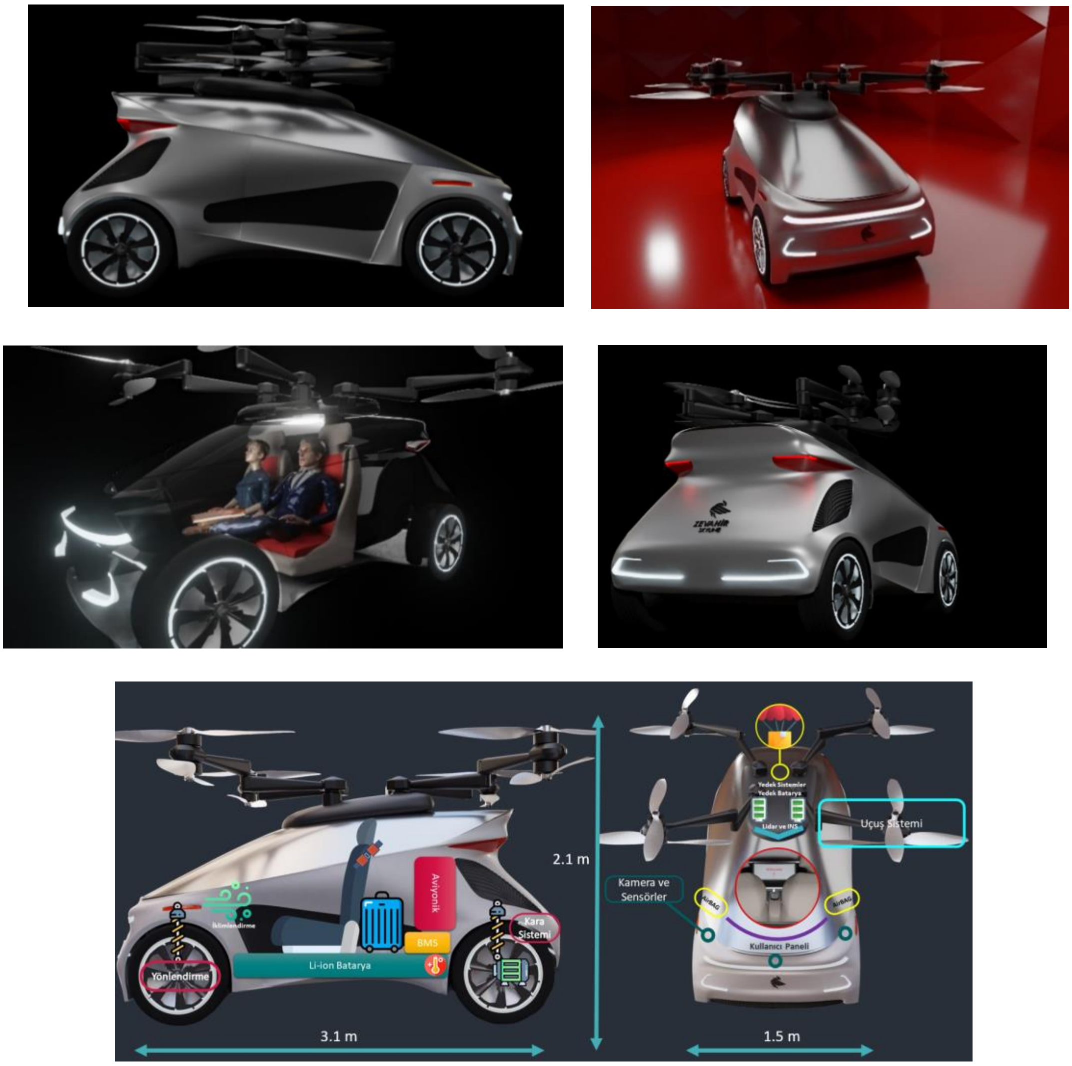
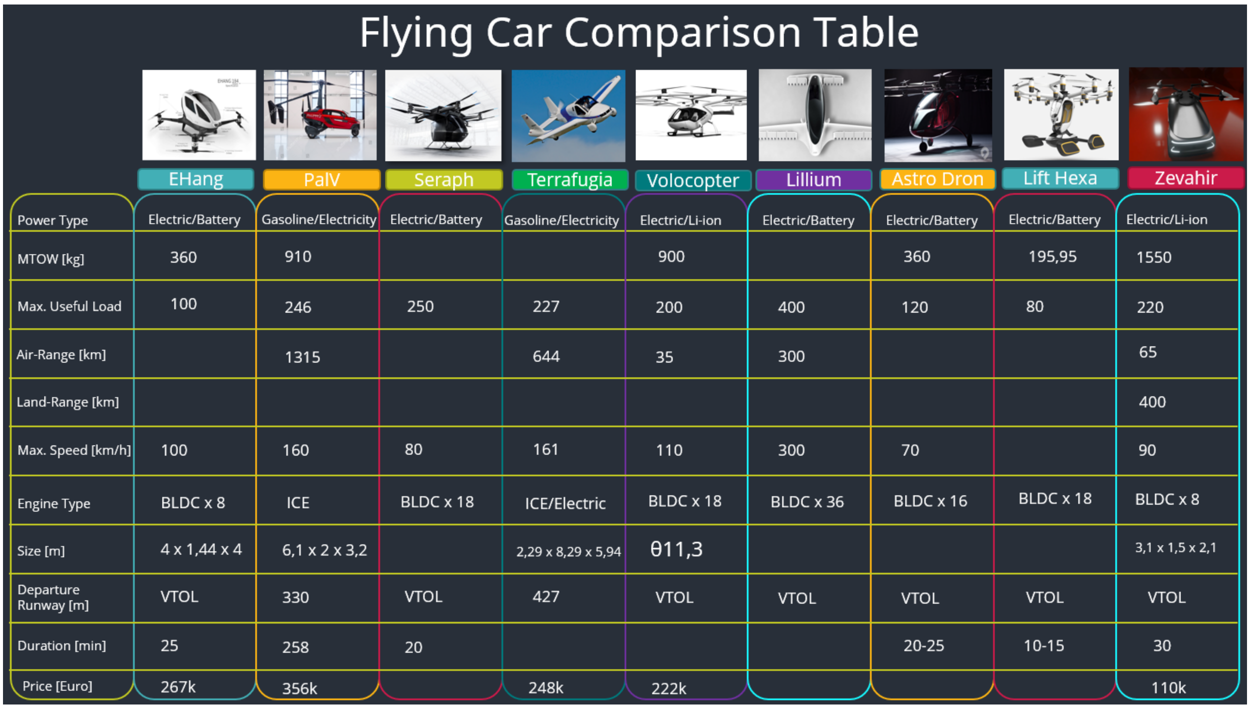


Figure 19: Final design studies of the Zevahir

Detailed promotional animation of the vehicle can be found at the https://youtu.be/SWHjnIm35hY link. It is also included in the air traffic management simulation at the https://youtu.be/SiXgxLvnZZk link.

As a result of our flying car concept work, it has developed a tool that can solve traffic problems in the future, contribute to the environmentally friendly urban ecosystem and offer people faster travel. Zevahir vehicle will be able to travel with more reliable autopilot systems with the development of software and electronic communication systems in the future. In the event of a decrease in the popularity of land traffic in the future, the land mode on the vehicle can be removed and modernized so that it can only be used for air-to-air missions. At the same time, if battery technologies develop, the chronic battery weight problem of flying car concepts will disappear. In this way, the vehicle will be able to offer longer flight. In the calculations mentioned during the flight, calculation problems arising from vehicle weight problems were observed. Therefore, factors such as increasing the propeller diameter and reducing the number of revolutions, increasing the number of propeller blades, and choosing lighter materials and products were taken into consideration by optimizing the design and mathematical model of the vehicle in the future. At the same time, it was decided to design a more aclaptinous folding rotor arm system. Flying cars can be used in many different missions as they offer autonomous driving with vertical landing and take-off capability. The vehicle can be used in emergency operations, cargo transportation, air taxi operations and security situations. For example, the E-Hang vehicle was recently commissioned in Spain for use in internal and external security as a police vehicle [4]. In order for flying car concepts to become widespread in the world, vehicle designs must resemble today's vehicles. It is also important to study other vehicle concepts and to know the technologies developing in the world. Therefore, Zevahir vehicle has been examined by comparing it to other flying car concepts in terms of its characteristics (Figure 20).


Flying Car Comparison Table

	EHang	PalV	Seraph	Terrafugia	Volocopter	Lillium	Astro Dron	Lift Hexa	Zevahir
Power Type	Electric/Battery	Gasoline/Electricity	Electric/Battery	Gasoline/Electricity	Electric/Li-ion	Electric/Battery	Electric/Battery	Electric/Battery	Electric/Li-ion
MTOW [kg]	360	910			900		360	195,95	1550
Max. Useful Load	100	246	250	227	200	400	120	80	220
Air-Range [km]		1315		644	35	300			65
Land-Range [km]									400
Max. Speed [km/h]	100	160	80	161	110	300	70		90
Engine Type	BLDC x 8	ICE	BLDC x 18	ICE/Electric	BLDC x 18	BLDC x 36	BLDC x 16	BLDC x 18	BLDC x 8
Size [m]	4 x 1,44 x 4	6,1 x 2 x 3,2		2,29 x 8,29 x 5,94	θ11,3				3,1 x 1,5 x 2,1
Departure Runway [m]	VTOL	330	VTOL	427	VTOL	VTOL	VTOL	VTOL	VTOL
Duration [min]	25	258	20				20-25	10-15	30
Price [Euro]	267k	356k		248k	222k				110k

Figure 20: Comparison of Zevahir and other flying car concepts

8 Conclusions

An innovative flying car concept was proposed in this study. The next stage of this work, which is on a conceptual level, is the production of a scaled-up model of the proposed concept. Today's flying car concepts often include land driving. However, it is foreseen that the ability to drive on land will disappear completely in these vehicles in the coming years. Therefore, as one of the next studies, it is planned to develop a vehicle that is fully suitable for airborne use.

9 Declarations

9.1 Study Limitations

None.

9.2 Acknowledgements

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9.3 Funding source

None.

9.4 Competing Interests

There is no conflict of interest in this study.

9.5 Authors’ Contributions

Haktan YAĞMUR: Developing ideas for the article, planning the methods to reach the results, taking responsibility for the explanation and presentation of the results, taking responsibility for the literature review, taking responsibility for the creation of the entire manuscript.

Can BAYAR: Developing ideas for the article, planning the methods to reach the results, taking responsibility for the explanation and presentation of the results, taking responsibility for the literature review, taking responsibility for the creation of the entire manuscript.

Tunahan FİLİZ: Developing ideas for the article, planning the methods to reach the results, taking responsibility for the explanation and presentation of the results, taking responsibility for the creation of the entire manuscript.

Bedirhan ERTATLIGÜL: Developing ideas for the article, planning the methods to reach the results, taking responsibility for the explanation and presentation of the results, taking responsibility for the creation of the entire manuscript.

Corresponding Author Kasım SERBEST: Developing ideas for the article, planning the methods to reach the results, taking responsibility for the creation of the entire manuscript.

10 Human and Animal Related Study

10.1 Ethical Approval

Not required,

10.2 Informed Consent

Not required.

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