A solution to stabilizing eVTOL and UAM passenger bodies for medical air transportation (air ambulances)

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Abstract

This research paper proposes an innovative solution to address challenges faced by air ambulances, particularly in ensuring patient stability and comfort during flight. The solution comprises a gyroscopic body design and an AI-controlled stabilization system. The gyroscopic design involves a multi-layered structure with interconnected components: a primary hollow base housing flight equipment, a secondary stabilizer maintaining lateral stability, and a central medical body for patients and medical teams. The stabilization system employs modified carpentry levels, cameras, and spherical weights to detect and correct changes in the medical body's center of gravity. The proposed solution enhances patient stability, mitigates motion sickness, and provides a stable platform for medical procedures. It offers potential benefits such as smoother patient transfers, improved flight efficiency, and safer working conditions for the flight crew. The integration of advanced technology showcases the synergy between aerospace engineering and AI, highlighting the adaptability of modern tools in enhancing air ambulance operations. Overall, this comprehensive solution aims to revolutionize air ambulance services, enhancing patient care and operational efficiency in emergency medical scenarios.

Introduction

Air ambulances play a critical and indispensable role in the healthcare system, serving as a lifeline in various emergency medical situations. Their importance lies in their ability to provide rapid medical response and access to remote or inaccessible areas that may be challenging to reach through traditional ground transportation (Griffin & McGwin, 2013). In emergencies such as natural disasters, accidents in remote locations, or situations requiring urgent medical interventions, air ambulances offer a swift means of transportation, significantly reducing the time it takes for patients to receive vital medical care (Diaz et al., 2005). This timely response is especially crucial in life-threatening scenarios where every second counts. By bridging the gap between patients and medical facilities, air ambulances ensure that individuals in critical condition have a higher chance of survival and a better opportunity for a positive medical outcome. Moreover, air ambulances are instrumental in facilitating the transfer of patients between medical facilities, particularly when specialized care or advanced medical procedures are required (Svenson et al., 2006). They enable the seamless transportation of patients over long distances, providing a higher level of care and ensuring that individuals receive appropriate medical attention at the right facility. The capability of air ambulances to swiftly transport patients, bypassing traffic congestion and geographical barriers, is particularly vital in rural or underserved areas with limited access to healthcare facilities. The presence of air ambulances not only saves lives but also provides peace of mind to communities, knowing that emergency medical help is readily available. The combined impact of their rapid response, ability to reach remote areas, and facilitate inter-facility transfers makes air ambulances an indispensable component of modern healthcare, ensuring that individuals in critical condition receive the immediate and specialized care they need.

Background

Understanding the problem

According to Steenhoff (2023), air ambulances face significant challenges that impact both patient care and the well-being of onboard flight crews. One of the prominent issues is the bumpy nature of air ambulance flights, which can pose considerable obstacles to delivering effective medical care. These flights often encounter turbulence and vibrations that result from various factors, including adverse weather conditions, low-altitude flying, and the design characteristics of the aircraft (paras. 7-8).

Turbulence, characterized by sudden and unpredictable changes in air movement, can be particularly problematic during air ambulance operations. The irregular and abrupt movements of the aircraft can cause discomfort, pain, and distress for patients who are already in critical condition. Furthermore, turbulence can hinder medical procedures and treatments being performed onboard, making it challenging for the flight crew to provide consistent and stable care. For example, administering medication, conducting delicate surgical procedures, or monitoring vital signs can become more difficult and potentially less effective due to the constant motion and vibrations.

The vibrations experienced during air ambulance flights can exacerbate the already challenging conditions. These vibrations can be caused by the engines, rotors, or the overall aircraft structure. Vibrations, especially if intense or prolonged, can lead to patient discomfort and even compromise the stability of medical equipment, such as intravenous drips or life support systems. Maintaining a stable and controlled environment is crucial for delivering optimal medical care, and the inherent bumpiness of air ambulance flights presents a significant hurdle to achieving this.

In addition to the challenges related to the bumpy nature of the flights, flight crew fatigue is another critical problem (Rose et al., 2023). Air ambulance operations involve demanding schedules, long working hours, and irregular shifts due to the unpredictable nature of medical emergencies. Flight crews must be ready to respond to calls at any time, often with limited notice. These factors contribute to cumulative fatigue, which can have detrimental effects on the flight crews' well-being and performance.

Fatigue can impair cognitive function, including decision-making abilities, reaction times, and situational awareness. In a critical and fast-paced environment like an air ambulance, where split-second decisions can be life-saving, flight crew members must be at their optimal level of performance. Fatigue-related impairments can compromise their ability to deliver safe and efficient care to patients. The combination of physical and mental demands, along with irregular sleep patterns and high levels of stress, make flight crew fatigue a pressing concern in air ambulance operations.

Understanding and addressing these challenges is essential for improving the quality of care provided by air ambulances and ensuring the well-being of flight crews. By recognizing the specific issues related to bumpy flights and flight crew fatigue, researchers and industry professionals can work together to develop effective solutions that enhance patient outcomes and support the well-being of the dedicated individuals who serve in air ambulance operations.

Current eVTOLs and UAMs

Electric vertical takeoff and landing (eVTOL) aircraft are electric-powered aircraft capable of vertical takeoff and landing, while urban air mobility (UAM) systems encompass a comprehensive network and infrastructure for efficient aerial transportation within urban areas.

The impact of eVTOL aircraft and UAM systems on faster transportation is substantial and holds the potential to revolutionize urban mobility. One key advantage is their potential to reduce noise pollution and emissions, as they utilize electric motors and batteries instead of traditional combustion engines. This not only improves the environmental sustainability of air travel but also reduces noise disturbances in densely populated urban areas.

Furthermore, eVTOL aircraft and UAM systems have the capability to bypass ground-level congestion by utilizing vertical takeoff and landing. This feature allows for efficient point-to-point transportation, reducing travel times and enhancing overall transportation efficiency (Bernitt, 2022). This ability to travel directly between locations in three-dimensional airspace offers a significant advantage in terms of speed and efficiency as they can navigate directly to their destinations, avoiding traffic congestion on roads and highways.

The introduction of eVTOL aircraft and UAM systems has the potential to transform urban mobility by providing an alternative mode of transportation for short to medium distances. This not only saves time but also improves accessibility, particularly in areas with limited transportation infrastructure or where ground transportation options are limited.

Faster transportation provided by eVTOL aircraft and UAM systems offers numerous benefits to individuals and communities. Commuters can save valuable time, particularly for shorter distances where ground transportation can be slower due to traffic congestion (Bernitt, 2022). This increased efficiency can lead to improved productivity and work-life balance, as less time is spent in transit.

Moreover, faster transportation can have broader economic implications. It can enhance business connectivity, facilitating faster and more frequent interactions between companies and clients. It can also stimulate economic growth by enabling efficient delivery of goods and services within urban areas (Perez et al., 2024). Additionally, faster transportation can contribute to tourism and leisure activities, as visitors can explore multiple destinations more conveniently and efficiently.

The impact of faster transportation extends beyond individuals and businesses. eVTOL aircraft and UAM systems can aid in emergency situations, providing swift transportation for medical personnel, organ transplants, or critical supplies during emergencies or disaster response efforts. This speed can be crucial in saving lives and minimizing the impact of emergencies.

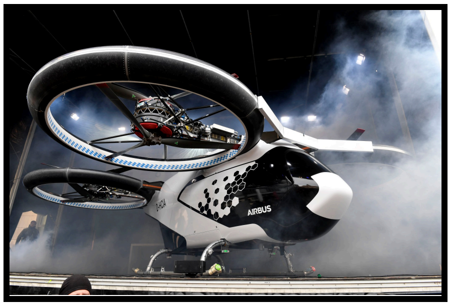


FIGURE *1*. Airbus's CityAirbus© 2019 (Airbus Helicopters, 2019)

FIGURE *2*. Joby Aviation's prototype eVTOL (Bellan, 2023)

Drone flight movements

A typical quadcopter eVTOL or UAM tends to maintain a similar method of directional control as the average household quadcopter drones do. This ensures an easier ability to understand the movements of large UAMs and eVTOLs at a much smaller scale and test changes to different areas at a much cheaper scale.

Hovering is the ability of a drone to maintain a fixed position in the air without any significant movement. It involves maintaining a delicate balance between the upward lift generated by the propellers and the gravitational force pulling the drone downward. The flight control system constantly adjusts the propeller speeds to counteract any drift caused by wind or other external factors, allowing the drone to remain stationary in the air.

Ascending and descending maneuvers involve changing the altitude of the drone. To ascend, the drone increases the overall thrust generated by the propellers, causing it to climb vertically. The flight control system regulates the propeller speeds to ensure a smooth ascent. Descending, on the other hand, involves reducing the thrust and gradually lowering the drone's altitude. The flight control system carefully adjusts the descent rate to prevent sudden drops or loss of control.

California Aeronautical Institute's Johnston (2023) defines three movements around the different axes of a drone as: Roll, Pitch and Yaw.

Roll is a maneuver that involves the rotation of the drone around its longitudinal axis. It causes the drone to tilt to the left or right. To achieve roll, the drone adjusts the speeds of the propellers on opposite sides. By increasing the speed of the propellers on one side and decreasing the speed on the other side, a torque is generated, causing the drone to roll in the desired direction.

Pitch refers to the tilting of the drone forward or backward. It involves adjusting the speeds of the propellers on the front and rear of the drone. By increasing the speed of the propellers at the rear and decreasing the speed at the front, the drone generates a pitching motion.

Yaw is the rotation of the drone around its vertical axis, causing it to turn left or right. Unlike roll and pitch, which involve varying the speeds of the propellers on opposite sides, yaw is achieved by changing the speeds of the propellers in the same direction. To initiate a yaw maneuver, the drone adjusts the speeds of the propellers either clockwise or counterclockwise. By increasing the speed of the propellers rotating in one direction and decreasing the speed of the propellers rotating in the opposite direction, a torque is generated, causing the drone to yaw in the desired direction.

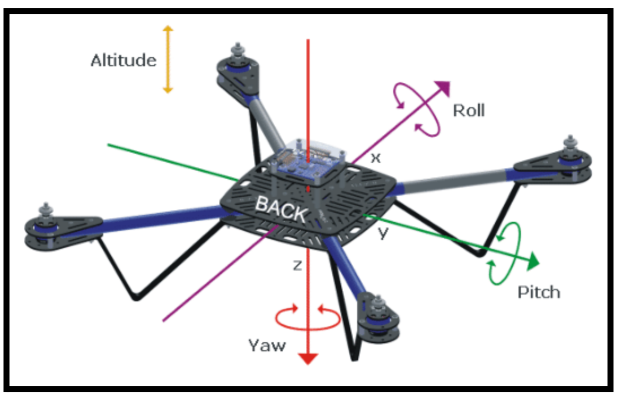


FIGURE 3. Drone movements (Etigowni et al., 2018)

Building a solution

Requirements

- The solution must be able to combat most if not all the turbulence faced by the air ambulance.
- The solution must retain a stable orientation even when performing a pitch or a roll to ensure that the patient is not rocked around during simple flight maneuvers.
- The solution must be able to fly for a similar time as compared to the UAMs and eVTOLs present in the current market, and should not be energetically demanding.
- The solution should not take up too much of the the mass percentage of the vehicle

- The solution must not affect the vehicle's ability to fly (vertically ascend & descend and hover)

Literature review: Léon Foucault's Gyroscope

Léon Foucault's gyroscope is a remarkable invention that has had a profound impact on various fields of science and technology. The gyroscope consists of a spinning wheel or rotor mounted in a set of gimbal rings, allowing it to rotate freely in any direction. One of the key features of the gyroscope is its ability to maintain stability in its central wheel, which is crucial for its functionality and practical applications.

In the context of a gyroscope, stability refers to the characteristic of the central wheel to remain unaffected by external forces or disturbances while the rotor is spinning. This stability is achieved through the principles of angular momentum and precession.

The spinning rotor possesses angular momentum, which is a property of rotating objects. According to the conservation of angular momentum, when no external torque acts on the system, the total angular momentum remains constant. This property allows the central wheel of the gyroscope to resist changes in its orientation (The Editors of Encyclopaedia Britannica, 2023).

Furthermore, the gyroscope exhibits a phenomenon known as precession. Precession is the tilting or turning motion of the gyroscope's axis of rotation in response to an external torque. This motion is perpendicular to the applied force and the axis of rotation, resulting in a characteristic circular or elliptical path.

In the case of Foucault's gyroscope, the stability of the central wheel is maintained due to the gyroscopic effect produced by the spinning rotor. When an external force or torque is applied to the gyroscope, such as a change in orientation or an external disturbance, the gyroscopic effect causes the central wheel to resist the change and maintain its stability.

The gyroscopic effect is a consequence of the conservation of angular momentum. As the external force attempts to alter the orientation of the gyroscope, the angular momentum of the spinning rotor resists the change and induces a precession motion. This precession counters the applied torque and keeps the central wheel stable.

Foucault's gyroscope has found numerous applications in navigation systems, aerospace engineering, robotics, and even in everyday devices like smartphones and gaming consoles (The Editors of Encyclopaedia Britannica, 2023). Its ability to maintain stability in the central wheel has been crucial for accurate measurement, navigation, and stabilization in various fields.

In conclusion, Léon Foucault's gyroscope is a remarkable invention that achieves stability in its central wheel through the principles of angular momentum and precession. This stability allows the gyroscope to resist external forces or disturbances, making it an invaluable tool in a wide range of scientific, technological, and practical applications.

FIGURE 4. Léon Foucault's gyroscope (Rama, 2018)

Developing the solution

Taking inspiration from the gyroscope, a similar principle can be added to help stabilize the longitudinal and lateral axes of the vehicle.

Piece 1 - Longitudinal stabilizer

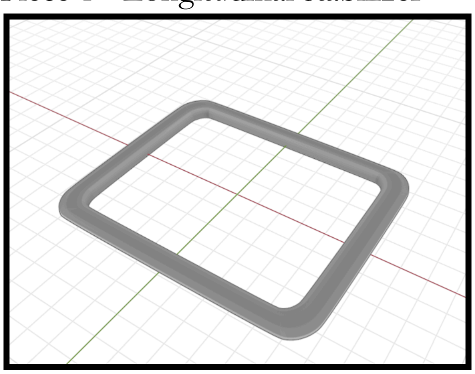


FIGURE 5. Piece 1

Starting with a hollow base, this acts as the main drone-like element. A thick perimeter of a rounded rectangle would be filled with all the necessary equipment to ensure flight and remote control. Upon the 4 rounded ‘corners’ would also be where the propellers would be attached. This body would consist of the mainframe of operation, including but not limited to: the battery, the electric speed controllers, the different avionic systems and a remote control receiver.

Piece 2 - Lateral stabilizer

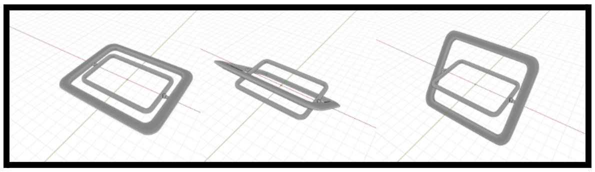


FIGURE 6. Piece 2 and its Function

A secondary hollow rounded rectangular structure would be placed in the middle of the primary one discussed earlier. The only point of attachment between both these rounded rectangular structures would be rods connected with strong bearing at the leading and trailing edges. This would ensure that whenever Piece 1 rotates around the longitudinal axis, Piece 2 would remain stable throughout. This would help ensure that whenever the vehicle needs to perform a rolling maneuver, piece 2 would remain stable.

Piece 3 - The medical body

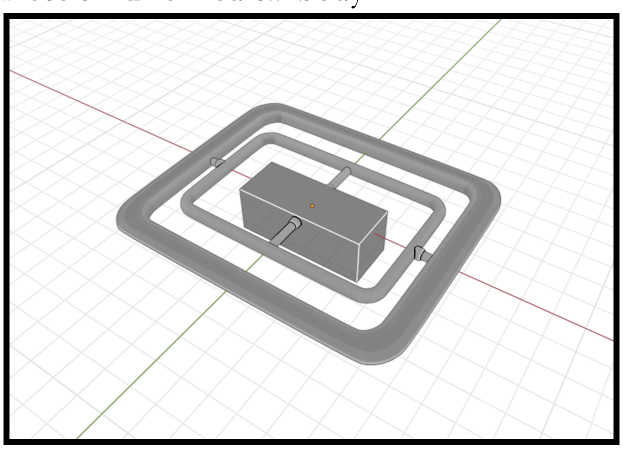


FIGURE 7. Piece 3

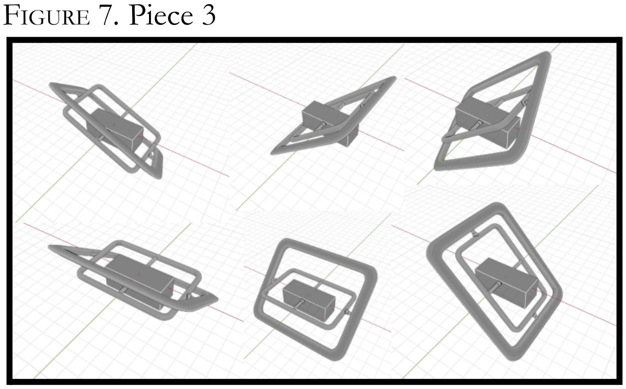
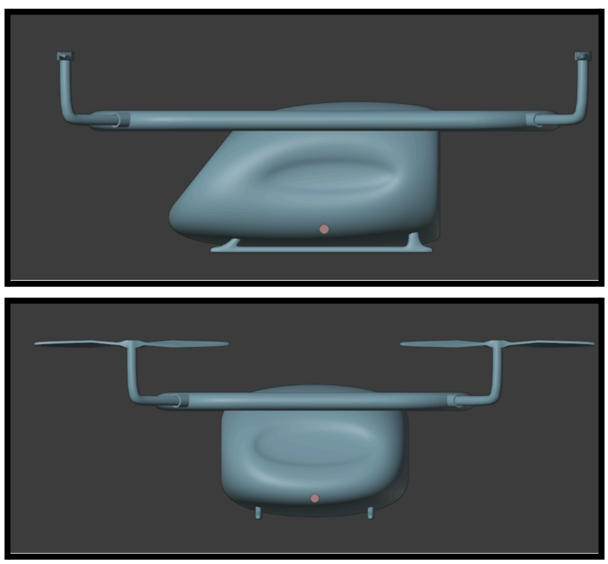


FIGURE 8. Piece 3 functioning

The central cuboid structure in fig. 7 represents the medical body in which the patient, the emergency medical team and the medical equipment would be present. The point of contact of this medical body to the 2 outer stabilizing structures would be rods connected with strong bearing on the top left and right sides. This would ensure that whenever Piece 1 and 2 rotates around the lateral axis, the medical body would remain stable throughout. This would help ensure that whenever the vehicle needs to perform a pitching maneuver, the patient would remain stable.

Correcting center of gravity change in the medical body (Piece 3)

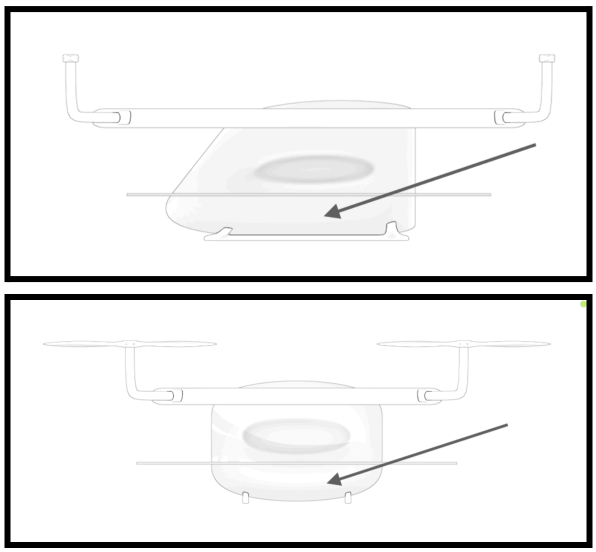
This solution relies majorly on the natural stabilization of the central medical body due to bearings and gravity. Thus in order to achieve maximum efficiency of this solution, the medical body must always have its center of gravity to be near to if not at the bottom center.



Figures 9 & 10. The proposed position of center of gravity on an imagined medical body.

This center of gravity would remain stable when the distribution of mass inside the medical body would also be unchanged. But since the air ambulance would require constant movement by the different teams in the EMS, the center of gravity would always be shifting. A change of this too much towards either side increases the chance of creating head on drag, enough of which would potentially tip over the entire medical body since there are no motors at the rotating points of connections among either stabilizers or the body. Thus, there must also be a mechanism that is able to combat every shifting center of gravity in a quick and efficient way to always ensure the stability of the vehicle.

A solution can be designed that can be placed in the bottom quarter of the medical body which would make use of an artificially intelligent computer, spherical weights and modified carpentry levels.



FIGURES 11 & 12. The proposed position of the stabilizing solution for the medical body

The first part of this solution would be two modified carpentry levels with a camera placed parallel to either level. One level would be placed in the center of the lateral axis while the other would be placed in the center of the longitudinal axis. The cameras and the level would be at an equidistant position from the expected position of the center of gravity.

A typical household level makes use of a small cylindrical compartment filled completely with liquid with a small air bubble in it to understand whether an object is level to the surface or not. Instead of utilizing the air bubble to understand this, the modified level would utilize clear water with a thin layer of black oil. This thin contrasting layer would make it easier for the cameras to identify the layer of oil apart from its surrounding. The cameras would be fitted to a small computer which would distinguish this oil layer and measure its angle from a calibrated position at all times during a flight. Any change in the angle of the oil layer in the camera would automatically alert the computer of a change in the center of gravity of the medical body.

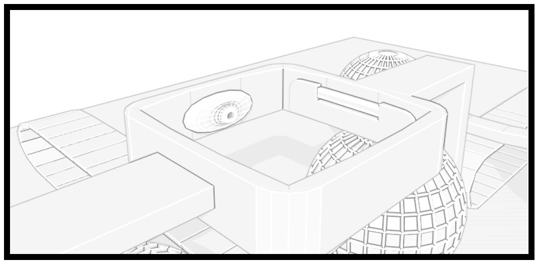


FIGURE 13. Placement of the cameras and the modified level

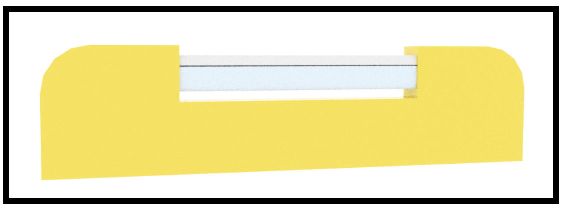


FIGURE 14. The modified level

Once alerted, the computer would move the motors to move the spherical weights in order to combat the change in mass distribution and bring back the center of gravity to its expected position. There would be a total of three tracks, one long one down the center of the lateral axis and two shorter ones down the center of the longitudinal axis with a break in the middle. This would allow the rectification of any unnecessary roll or pitch that is done by the medical body.

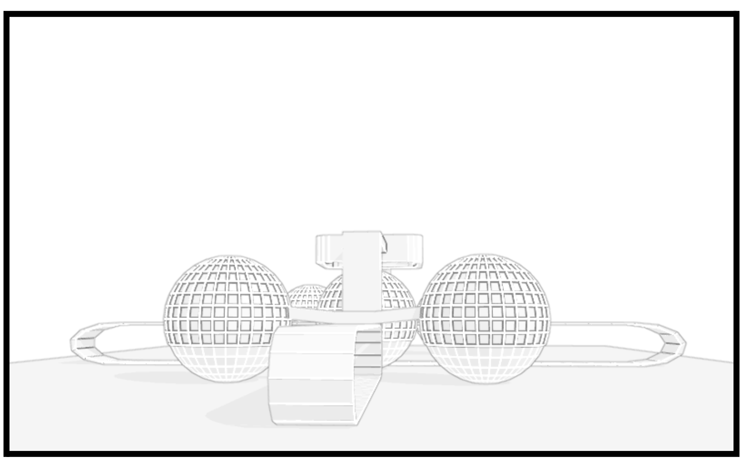


FIGURE 15. The spherical weights attached to the tracks

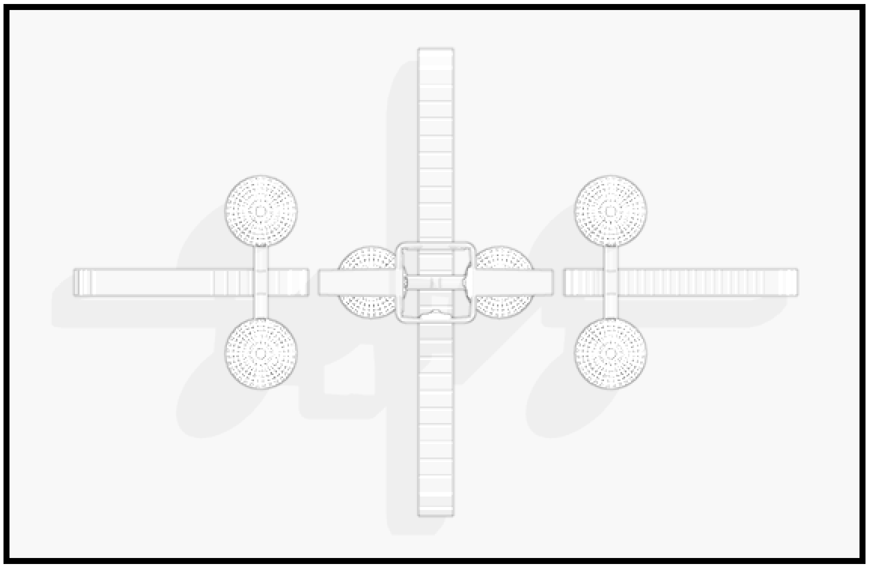


FIGURE 16. Placement of the tracks and look of entire stabilizing contraption

The camera would always be watching and analyzing for any change in the angle of the oil layer in the level in order to immediately change the position of the weights. Based on the magnitude of the change in angle of the layer from its calibrated center, the distance of change in movement of the weights would also differ. The data of the mass of each weight and the distance it would travel for different changes in angles would vary from aircraft to aircraft due to its shape, dimensions and/or overall mass.

Implementation

The use of this solution can have major impacts on the current air ambulance systems. Firstly, it would provide superior kinematic stability to patients during flight, mitigating the risk of perturbations, abrupt accelerations, or turbulence that may negatively impact patients, particularly those in critical condition. This would ensure a smoother and more comfortable transport experience, reducing the likelihood of additional traumas or complications.

The level body configuration of the air ambulance furnishes a stable platform for medical procedures and interventions. Medical professionals benefit from a controlled biomechanical environment to execute delicate procedures, administer medications, or employ medical equipment, leading to enhanced precision and accuracy in delivering medical care to patients during transit.

Motion sickness, a frequently encountered physiological challenge during airborne travel, especially in the presence of frequent tilting or sudden movements, can be significantly minimized by the gyroscopic body design of the air ambulance (Kremer et al., para., 4). By maintaining a stable attitude, the air ambulance diminishes the probability of motion sickness among patients and medical personnel, thereby fostering a more comfortable and less nauseating milieu. This empowers medical professionals to concentrate on their duties without being impeded by personal discomfort.

The level body configuration also facilitates optimal patient monitoring during the flight. Vital signs and medical instrumentation can be secured more effectively, ensuring precise readings and mitigating the risk of instrumentation displacement. This enables medical professionals to closely monitor patient conditions and respond promptly to any emergent changes or critical situations that may arise.

The gyroscopic body design provides a safer operational context for the flight crew. By affording a more stable and secure workspace, it allows crew members to traverse the cabin without the necessity of bracing against sudden tilts or shifts. This minimizes the risk of crew injuries and ensures their focus remains on administering medical care rather than self-preservation during flight.

The level body configuration also streamlines patient transfer procedures. It facilitates smoother transitions between different modes of transport or medical facilities, particularly in challenging terrains or remote locations, where maintaining stability during patient transfer is of paramount importance.

Imagined implementation of this solution (iis)

FIGURE 17. Bottom-left view of the iis

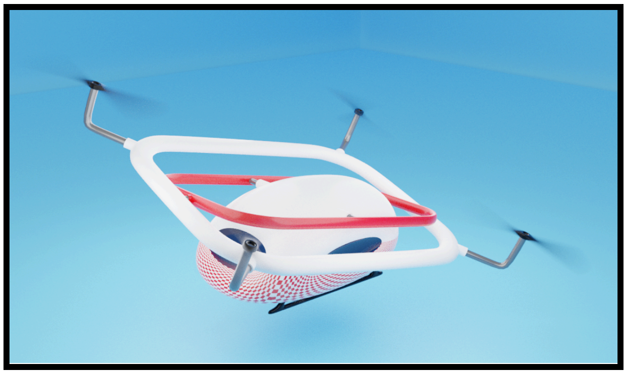


FIGURE 18. Top-right view of the iis

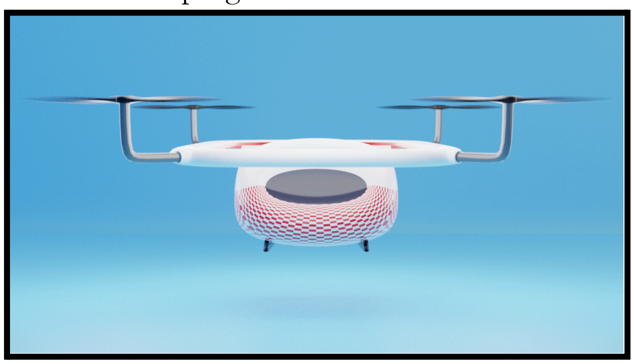


FIGURE 19. Front view of the iis

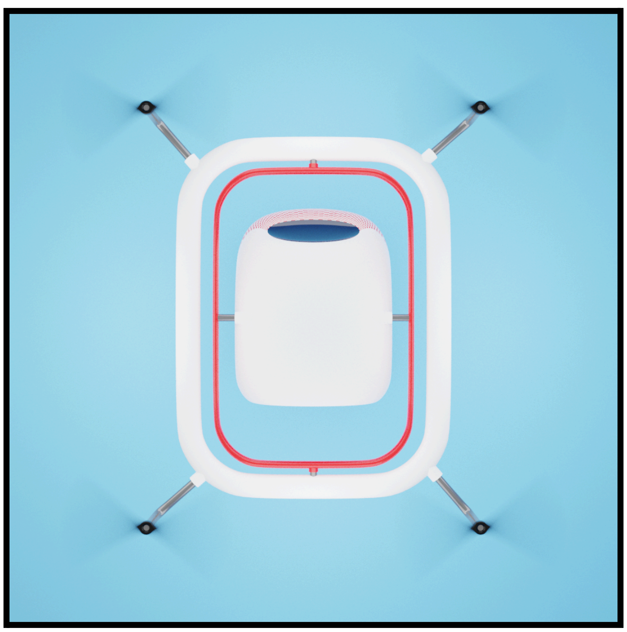


FIGURE 20. Top view of the iis

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