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A Case Study on the Design and Feasibility of One Man Copter

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ABSTRACT: *Air transportation has been a topic of intense research and development from the past five decades owing to wide applicability. Appreciable work has been accounted from fulfilling basic needs to incorporation of special features to increase accessibility. With time, advanced technology has revolutionized air transportation for variety of functional and practical utility. Motivated by the need for better control, safety, fast and easy transportation, a novel one-man copter design is proposed to broaden future transportation domain. The work investigates all major issues related to incorporation and its feasibility. The design is extensively reviewed for varying conditions with wider applicability groups and operations. At present, thorough case study is carried out and key controlling variables viz., security, manufacturing, cost, and related implications are discussed and implemented in the proposed design. The results are expected to offer good physical insight about the validation and related implications. The results will be utilized as a part of scientific contribution for better and advanced air transport applications.*

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I. INTRODUCTION

With the ever-increasing population and thus the heavy traffic, world has come to a stand still in terms of transportation. One-man copter is a proposed vehicle for personalized VTOL (Vertical Take-off and Landing) flight to mitigate road traffic problems and reduce commute time in this fast-moving world. Projected Global Growth Rate of Cars on the Road (Source: Business Insider Report,2016) says that in 2015 there were 1.1 billion cars on roads, which will increase to 1.5 billion cars (36% growth) in 2025 and in 2040 there will be 2 billion cars (33% growth) on roads. This indicates the enormous level of traffic and congestion we will be dealing with in future (figure 1). There will be lot of time delay and increase the rate of accidents. Thus, there is an increased demand for use of advanced technology for better transportation.

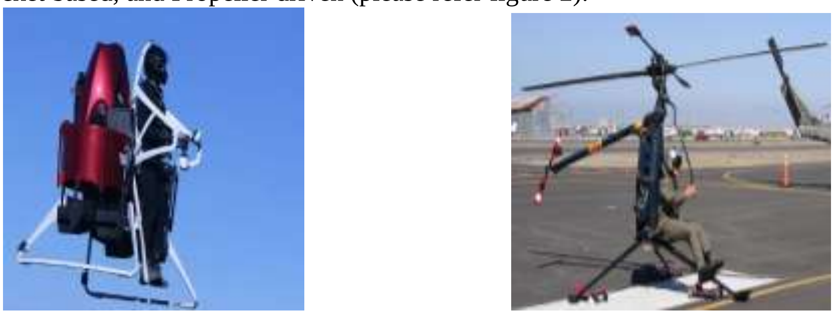
(a) (b) (c)

Figure 1: Projected Global Growth Rate of Cars on the Road (Source: Business Insider Report,2016)

One of solution to address the existing solution could be utilization of one-man copters coupled with modified transportation system to mitigate road traffic problems and reduce commute time in this fast-moving world. The idea of having personalized flying vehicle has been fascinating mankind for a long time. Small autonomous flying machines vividly appeared in scientific fictions or in movies and delighted millions of people however, they can be effectively modified and utilized with wide range of real applications in different areas such as surveillance and security, search and rescue, as well as inspection and exploration. Depending on the task and environment different capabilities, sizes, autonomy levels and platforms are necessary. Presently, in the outdoor environment and large workspaces mostly fixed-wing systems are used, due to the higher energy efficiency and higher velocities. Smaller airplanes belonging to the category of Micro Aerial Vehicle (MAV) were introduced and are being utilized effectively like Black Widow [2]. Besides these rather large vehicles there also exist which are highly developed platforms with various propulsion systems and sizes are found in civilian areas such as the Sky-Sailor [3] and in military application such as the Predator [4], the EADS Barracuda [5] or the Ranger [6] from RUAG. In the indoor environment the use of fixed wing airplanes is strongly limited due to restricted space and often even more importantly: the disability to hover. Real hovering is only possible by using rotary-wing or flapping-wing vehicles. The latter are inspired by nature and imitate the flight of birds or insects.

Believing in a higher efficiency in small scale of the insect-like locomotion, several groups around the globe work on flapping-wing vehicles, such as the DelFly [7] or the MicroBat [1]. Even if there are examples showing good flying abilities, there does not exist a flapping mechanism that produces enough lift to carry enough sensor payload for autonomous missions yet. As long as there is not an improvement in the field of actuators (faster, more stroke), sensors (lighter, more accurate) or sensor processing (image based flight), this will not be the case. This reduces the reasonable choice for autonomous indoor operation to the range of rotary-wing vehicles and more precisely to helicopters. Possible foreseen missions could be surveillance of exhibitions, search for survivors in buildings threatened by collapse after an earthquake or similar scenarios. In rescue cases in small buildings such as normal houses, the size of the MAV and the autonomy can be of high importance to pass narrow spaces. In order to address this scenario, the European project muFly [8] was launched in July 2006 with the goal of designing a fully autonomous micro helicopter in the size and mass of a small bird.

A One-man copter is a vehicle for personalized VTOL (Vertical Take-off and Landing) flight. The first one-man copter was developed in 1919. Two kinds of personal air vehicles (VTOL) have been designed till date viz., Jet Pack/ Rocket based, and Propeller driven (please refer figure 2).



(a) (b)

Figure 2: VTOL Air Vehicles (a) Jet pack / rocket based and (b) Propeller driven.

The jet packs are generally used by astronauts in extravehicular activities. The first jet pack was developed by Aleksandar Fyodorovich in 1919 which was powered by Oxygen and methane. Perox thrusting (90% conc.) in (1/10)th of a millisecond, volume expands upto 5000 times. The catalyst used here is silver. The problems with the perox propellant are Short duration, Exhaust velocity is less, hence poor specific impulse. The high expense of the peroxide propellant. The sheer difficulty of manually flying such a device. These jet packs are dangerous for a healthy person, aged person, children. These can even cause health issues.

Following the classical flying backpack [9], by Justin Capra also called as the "flying rucksack" in 1956. The technical design was similar to the models created earlier at the bell laboratories and is presently at a museum Ploiesti (figure 3). This was followed by the invention of **Jump Belt** [10] where, thrust was generated by high-pressure compressed nitrogen. Two small nozzles were affixed to the belt and directed vertically downward. It was possible with the aid of the jump belt's thrust to run at 45 to 50 km/h (figure 4). At the start of 1960, Richard Peoples made his first tethered flight with his **Aeropack** [11]. The jet of gas was provided by a hydrogen peroxide-powered rocket, but the jet could also be provided by a turbojet engine (figure 5).

Figure 3: Flying Backpack.

Figure 4: Jump Belt.

Figure 5: Aeropack

In 2007, Christian Stadler came up with a special kind of jet pack "**Christian Stadler Wingsuit"** [12-13], which used a wingsuit along with peroxide thrusters (figure 6) trailed by **Troy Hartman jetpack and parafoil** [14], which was a wingless jetpack with two turbojet motors strapped to his back (figure 7).
In 2008, the **Martin Jetpack** [15], an experimental aircraft that used ducted fans for lift. On 29 May 2011, the Martin Jetpack successfully completed a remotely controlled unmanned test flight to 1,500 m (5,000 ft) above sea level (figure 8).

Figure 6: Stadler Wingsuit.

Figure 7: Troy Hartman jetpack and parafoil.

Figure 8: Martin's Jetpack.

The concept of Propeller driven copters emerged out of science fiction in the 1920s and became popular in the 1960s. The steady evolution of one-man copter reinstated with classical **Hiller VZ-1 Pawnee** [16] in 1955**.** It comprised of a unique direct-lift rotor aircraft, using contra rotating ducted fans for lift and utilizing extended ducts. The pilot sifted body weight for movements (figure 9). The work was closely followed by **The Bensen B-10 Propcopter** [17] which was an unconventional VTOL aircraft developed by Igor Bensen (figure 10). The pilot sat astride a beam that had an engine mounted at either end of it, each driving a rotor to provide lift. Each of these rotors was surrounded by a system of four pivotable vanes to direct its downwash. And linked to a control stick for the pilot, this provided control of the craft.

Figure 9 : Hiller VZ-1 Pawnee.

Figure 10 : The Bensen B-10 Propcopter.

Characteristics of Mosquito Aviation XE	
Empty Weight	135 kg
Gross Weight	277 kg
Fuel Capacity	45 L
Powerplant	1 × Compact Radial Engines MZ 202 2 cylinder, 2 stroke, 48 kW (64 hp)
Maximum Speed	129 km/h

Table 1: Characteristics of Mosquito Aviation XE

Piasecki Aircraft developed **The Piasecki VZ-8 Airgeep** [18] (company designation PA-59) which was a prototype vertical take-off and landing (VTOL) aircraft (figure 11). The Airgeep was developed to fulfill a US Army Transportation Research Command contract for a flying jeep in 1957. In the last decade, **The Mosquito Aviation XE** [19] was developed on the principle of the Mosquito Air, but the open frame was replaced with an enclosed body. It was a single seat homebuilt helicopter (figure 12). The XE airframe was a uni-body construction resulting in a single structural element, offering aerodynamic cleanliness and good looks. (Table 1) entails the specifications of the Mosquito Aviation XE.

Figure 11 : Piasecki VZ-8 Airgeep.

Figure 12 : Mosquito Aviation XE.

GEN Corporation of Nagano developed **The GEN H-4** [20] which was a Japanese helicopter. The aircraft was intended to be supplied as a kit for amateur construction (figure 13). It featured two contra-rotating main rotors, a single-seat open cockpit without a windshield, four-wheeled landing gear and four twin-cylinder, air-cooled, two-stroke, 10 hp (7 kW) GEN 125-F engines to provide operational redundancy since the aircraft cannot auto-rotate in the event of a power failure (table 2). A greater breakthrough occurred with the development of **The Ehang 184** [21]**.** Ehang 184 was the first passenger drone introduced by Chinese entrepreneurs in Computer Electric Show 2016 (figure 14). Since 2011, several commercial developers and amateur builders have conducted short manned flights on experimental electric multi-rotor craft. In January 2016, the first commercially produced drone capable of carrying a human was introduced by Chinese entrepreneurs (table 3).

Figure 13: GEN H-4 Landing and Cruising.

Figure 14: Ehang 184 on Display.

Characteristics of GEN H-4	
Empty Weight	70 kg
Gross Weight	220 kg
Fuel Capacity	19 L
Powerplant	4 × GEN 125-F two cylinder, air-cooled, two stroke engines, 7.5 kW (10 hp) each
Maximum Speed	200 km/h
Rate of Climb	4 m/s

Table 2: Characteristics of GEN H-4.

Characteristics of Ehang 184	
Net Weight	**240 kg**
Maximum Output	**152 kW**
Cruising Duration	**25 min**
Rated Payload	**100 kg**
Average Cruising Speed	**60 km/h**
Maximum Altitude	**3500 m (above sea level)**

Table 3: Characteristics of Ehang 184.

In recently, **The Dubai Air Taxi** [22] prompted the development. It is a prototype electric hover-vehicle was designed by Germany's Volocopter (Figure 15). Specs wise, it can soar across the Dubai skyline for 30 minutes, with a maximum speed of 100 kilometers per hour (62 mph). Dubai's transport authorities expect air-taxis to become a fundamental cornerstone of the city's public transport; much like busses, subways, and ordinary taxis. Passengers will be able to book air-taxis through an app, and track its journey and arrival, much like Uber. Dubai's transport chiefs expect it'll take five years for it to become a thing, as they figure out the safety and legal aspects of the service.

Figure 15: Dubai Air Taxi.

1.1 Major Problems in the Past One-Man Copter

Initially the major problem faced then was the fuel load and safety. Till today the evolution of One Man Copter though theoretically possible has not been practically feasible due to various constraints like:

1. **Safety:** In the above design of one-man copter, human safety and vehicle safety were not quantified.
2. **Fuel Load**: Total weight of the one-man copter can be reduced by eliminating fuel weight and using electric motors and batteries.
3. **Lack of technology to meet objectives (Low time of flight):** The copters we discussed above lack the modern technologies and are not up to date.
4. **Cost:** The materials and the products they used to make the one-man copter were not cost effective.

1.2 Motivation and Specific Objectives:

The investigations on one-man copter have grown over the years and continue to emerge with special attention on key concerns of (a) a unique flight experience for the people (b) A futuristic approach to decrease the stress of traffic and accidents on road (c) To conserve Non- Renewable energy resources. The present work is motivated by the need to accomplish aerial operations for future transportation with:

1. Safe handling and operation.
2. Performance reliability and reproducibility.
3. Time and Cost minimization.

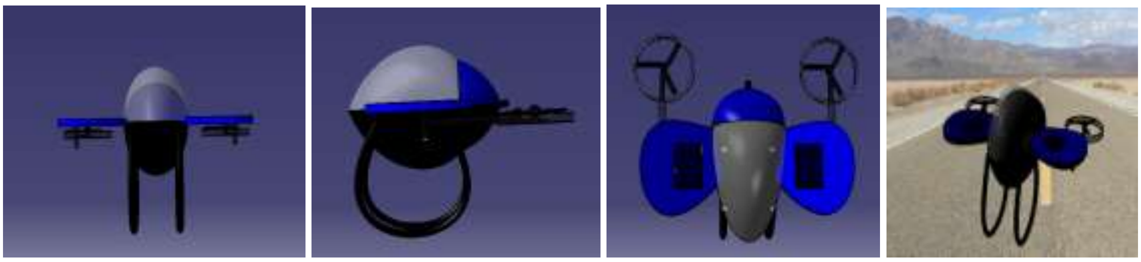
The main objectives of present work are:

1. To have an aerodynamically stable air-vehicle, capable of controlled automatic flight.
2. To make use of renewable energies to provide adequate, continuous and uniform power supply to the One-Man Copter.
3. To use advanced, lightweight and cost-effective materials which are rigid and strong enough to withstand various external conditions in the design of the One-Man Copter.

The current work lies within the scope of designing a fully autonomous aerial one-man copter in this small size bears various challenges and needs cutting-edge technologies. The design process consists of many different parts and to reach the ambitious goals, all the individual processes should be thoroughly investigated.

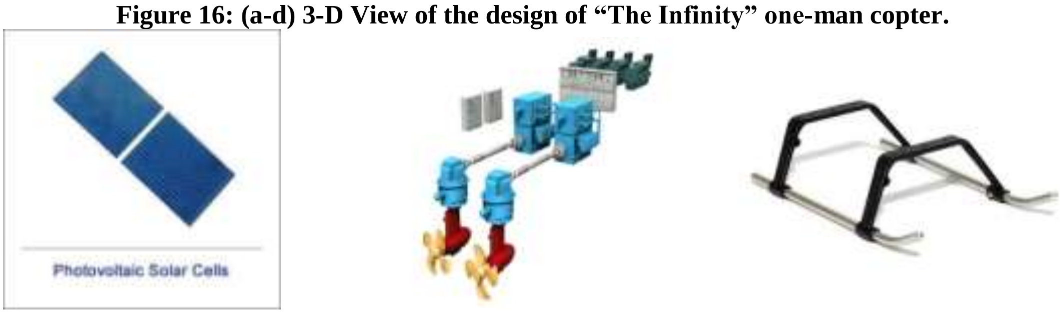
II. PROJECTED DESIGN

To address the existing issues in manned aerial vehicles for tentative transportation and to enhance the human and vehicle safety and security, a novel one-man copter design is proposed which adheres to the combination of the advantages of existing copters coupled with the solution to their drawbacks. The attracting vision of the design are being user friendly, harnessing state of the art technological advancement to expand transportation. The projected one-man copter is "**The infinity**" design (figure 16). The copter essentially comprises of: (a)Electric Power System backed by solar cells. (b) Two Counter-Rotating Rotors (c) Cyclic Control System (d) Altitude Control System (e) GPS System (f) Rain and Ice Removal System (f) Landing Gear System and (g) Emergency Landing System (please refer figure 17)



(a)Front view **(b) Side view** **(c) Top View** **(d) Isometric** View

Figure 16: (a-d) 3-D View of the design of "The Infinity" one-man copter.



(a) (b) (c)

Figure 17: Components of one-man copter.

The copter encompasses a circular closed cockpit made of glass fiber is placed over an infinity shaped frame which houses two counter-rotating rotors. With single person seating capacity, the cockpit houses the control systems and digital interface for the entire Copter. An LED panel is present which provides information about the external and internal conditions and location of the copter to the passenger. The counter-rotating rotors are responsible for performing VTOL, direction control and movement. A landing stand will be present for safe VTOL.

III. WORKING OF "THE INFINITY" ONE MAN COPTER

The power system of one-man copter is powered by electricity only and backed by solar cells. Electrical motors are used as being more efficient than the mechanical engines. Using electrical motors will reduce the load due to fuel. Electric glass panels which are capable of generating electricity when heated to a certain temperature are employed. Motors are used to run the propellers / ducted fans. This is expected to bring down the cost. Maximum of 4 motors to be used and maximum power generated is **100-150kW**. The Average cruising speed of "The Infinity" one-man copter is **60-100km/h** and the maximum battery capacity is **15-**

20kWh. The battery charging depends on the output (1h for 200A output). The load capacity is **100-150 kg**. Air conditioning system is accessible. The battery powered electric motors is the main source of power supply for the rotors (figure 18). Solar cells are used for the electric power system. As the rotors start to rotate, lift is generated due to pressure difference above and below the rotors (figure 19). After reaching an altitude **(5 km)** the rotors will tilt by 90 degrees and produce cruising thrust. There is an automated cyclic control system which will control the direction of the copter. The altitude is kept within a range of 6-10 km by the altitude control system. LED projectors are incorporated with Head-Up Display to show an animated visualisation of the copter's travel path from its location to destination the person wants to go.

For landing, the copter is brought to a lower altitude and the power is switched off and the rotors auto-rotate and land at the required spot. There will be emergency controls and instrumentation panels which the pilot can operate by giving inputs to the computerized instrumentation panel. Electric heated elements on the glass are present for rain or ice removal. There will be fire-detecting system in place. In case of emergency, a signal will be given to the pilot and the auto-locked door will open and the pilot can jump off the copter using rope cables or parachute or ejector seat. In case of false alarm, the pilot can lock the door again giving a command.

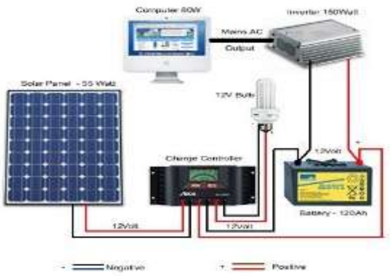


Figure 18: Power system of the one-man copter.

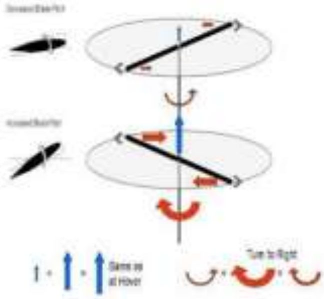


Figure 19: Counter rotating rotor.

The notable aerodynamic characteristics of "The Infinity" one-man copter are:

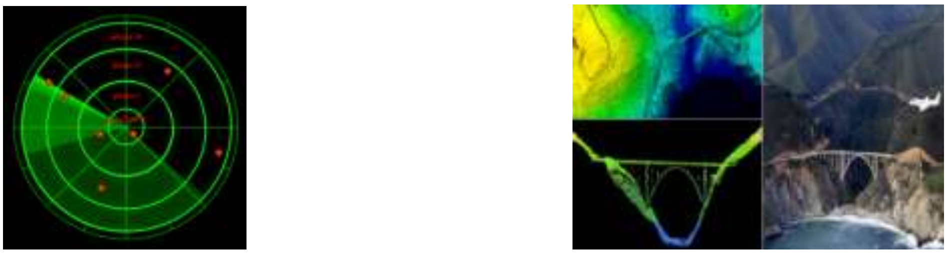
1. Two vertically-oriented rotor blades which provide lift capable of tilt-rotation.
2. The rotors provide lift the same way as helicopters- both forward and directional thrust.
3. Infinity shape cross-plated below the primary hub.
4. No need for tail rotors.
5. Light-weighted rotor blades and infinity-shaped plates for drag reduction.
6. Thrust can be achieved by varying the speeds of each rotor accordingly.

The distinguished technical features of "The Infinity" one-man copter are:

1. An amphibious copter which can land on ground as well as on water.
2. Fully auto-pilot system.
3. LED projectors with Head-Up Display to show an animated visualisation of the copter's travel path from its location to the destination.
4. Solar cells utilization for the electric power system along with electric glass panel capable of producing power.
5. Emergency controls and instrumentation panels which the pilot can operate by giving inputs to the computerized instrumentation panel.
6. Propellers convention for VTOL.
7. Electric heated elements on the glass are present for rain or ice removal.
8. Fire-detecting system in place.
9. In case of emergency, a signal will be send to the pilot and the auto-locked door will open and the pilot can jump off the copter using rope cables or parachute or ejector seat.
10. In case of false alarm, the pilot can lock the door again giving a command.

Effectiveness of the "The Infinity" One Man Copter is in being:

1. **Fully automated**- Capable of transporting children, adults and elderly people alike.
2. **Capable of VTOL**- No need for a runway or helipad for landing and take-off and pilot's license.
3. **Low altitude flight** (~6-10km above) with moderate power capabilities to fly above traffic.
4. **LED panels**-which show the map view of the copters travel on the glass.
5. **LIDAR, RADAR and SONAR**, coupled with onscreen controls, for guidance and easy servicing.



(a) (b)

Figure 20: View of the copters travel on the glass.

Novelty of the "The Infinity" One Man Copter:

a) Being compact, it will come under the category of microlight, hence won't require a pilot license.
b) Since it doesn't need to be parked at the airport, hence no expenditure on airport taxes and fee.
c) Being VTOL capable, therefore no requirement of runway.
d) Faster than road commute, as road distance is longer than aerial distance thus, reduction in road traffic.
e) Managing road traffic is difficult as we only have 2 dimensions to move along, but with these personal vehicles, we have 3 dimensions to travel in. Therefore, the same no. of vehicles in 2-D will be congesting whereas this is not the case in space.

f) The One Man Copter represents utilization of advanced and state-of-art technological aspects with a design that meets the its primary objectives of **safety, simplicity and light-weight**.

IV. CONCLUSION

A thorough case study was carried out on the utilization of one-man copter as potential solution to the ever so demanding transportation complications. The history of the one-man copters is well researched upon and notable aspects were collected. A motivation of lightening the ground transportation with effective utilization of space and a modified zonal system paves the way for one-man copter as the futuristic transportation systems. A novel design is proposed with combination of the advantages of existing copters and the solution to their drawbacks. The novelty of the design lies in significant control of propulsive and aerodynamic features. Further analysis with a small- scale model testing under varied conditions will lead to design fabrication into a full-scale model of One Man Copter and refining its adaptability. Being a fully automated, ultralight and safe air vehicle, which would mitigate road traffic in the future, it would revolutionize futuristic air transportation.

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