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Advancements made in the Evolution of present Autonomous Unmanned Aerial Vehicles

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Abstract— **This paper presents recent research into the advancement of unmanned aerial vehicle (UAV) capabilities. It offers information right from the development of first unmanned aerial vehicle to the current status of the UAVs. The paper discusses briefly about the history of UAVs , classification of UAVs into micro/mini UAVs (MAV/ Mini), tactical UAVs (TUAVs),and strategic UAVs and its applications. It highlights the improvements made in power storage and lays down comparison between various energy sources like the Lithium Polymer (Li-Po) Batteries, Super Capacitors (SC), Photo Voltaic (PV) Cells, and Hydrogen Fuel (FC) Cells along with their advantages and disadvantages. Developments in electric motor, avionics , designs and materials used for UAVs are also described in the paper.**

Index Terms— **Advancement, Autonomy, Classification, MAV,UAV**

I. Introduction

Development of autonomous uninhabited aircraft, or so-called "robotic aircraft", in the form of UAVs (Unmanned Aerial Vehicles) and MAVs (Micro Air Vehicles) outfitted with autonomous control devices has progressed quickly in recent years, and interest in this field continues to spread.
First, an uninhabited aircraft is defined [1]. An uninhabited aircraft is defined as the general term for UAV(Uninhabited Aerial Vehicle, Unmanned Aerial Vehicle), ROA (Remotely Operated Aircraft), and RPV (Remotely Piloted Vehicle). Neither an operation pilot nor a passenger is carried by an uninhabited aerial vehicle, but the navigation is the controlled body with the power source which uses the dynamic lift and thrust based on aerodynamics, and flies with autonomous navigation or remote-control navigation. Therefore, neither the rocket which flies a ballistic orbit, nor a cruise missile, a shell, etc. belong to this category. The unmanned air ship which swims in the air by lift simultaneously is not this category.

On the other hand, the AIAA defines a UAV to be "An aircraft which is designed or modified, not to carry a human pilot and is operated through electronic input initiated by the flight controller or by an onboard autonomous flight management control system that does not require flight controller intervention."

II. HISTORY

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The first UAV was created by Americans Lawrence and Elmer Sperry in 1916 [2]. It is shown in Fig.1.They developed the gyroscope which stabilized the body, thereby creating the first auto pilot. It is considered the first time so-called "attitude control" was mounted on an aircraft, creating the first aircraft with automatic steering. In 1916 they developed the "Aerial Torpedo", a pilotless airplane designed to deliver an explosive payload to a target. The Aerial Torpedo successfully flew a distance over 30 miles. It seems the technical immaturity of UAVs in the early twentieth century made them impractical and precluded, their use in World War I and World War II. UAVs started to be taken advantage of from the end of the 1950s during the Vietnam War and the Cold War, and full-scale research and development was underway by the 1970s. Figure 2 is a UAV called Firebee. After the Vietnam War, the U.S. and Israel started to develop smaller and cheaper UAVs.

These were small aircrafts which were powered by small engines similar to those of motorcycles or snowmobiles. They carried a video camera and transmitted images to an operator's base. It seems that the modern UAV was born around this time. The U.S. put UAV to practical use in the Persian Gulf War in 1991, and development of military UAVs progressed quickly after this. The most famous UAV for military use is the Predator. In contrast to research for military purpose, NASA around this time, began to focus on UAV research for civil use. The most momentous project was the 9-year ERAST (Environmental Research Aircrafts and Sensor Technology) project.

Fig.1 First UAV in the world, 1916

Fig.2 UAV in 1960's and 1970's（Firebee）

III. CLASSIFICATION AND APPLICATIONS

UAV classification is something which is done differently by different groups. The European Association of Unmanned Vehicles Systems (EUROUVS) has drawn up a classification of UAV systems based on parameters like size, altitude, endurance, speed and so forth.

Table 1[3] identifies four UAVs main categories: micro/mini UAVs (MAV/ Mini), tactical UAVs (TUAVs),and strategic UAVs. Let's take a closer look at each of these.

A. Micro/Mini UAVs

Micro/Mini UAVs are the ones which weigh under 30 kilograms and fly at altitudes between 150 and 300 meters, with an endurance of about two hours of operation. They are designed in such a way that they that can operate in urban canyons or even inside buildings, flying along hallways, carrying listening and recording devices, transmitters, or miniature TV cameras. The U.S. Defense Advanced Research Projects Agency (DARPA) has developed a set of criteria with which to distinguish micro UAV. These criteria are presented in Table 2. [4]

B. Tactical UAVs

This category includes heavier platforms flying at higher altitudes (from 3,000 to 8,000 meters).Unlike micro and mini UAVs, which are mostly used for civil/commercial applications, tactical UAVs primarily support military applications. Referring again to Table 1 criteria, tactical UAVs can be divided in six subcategories: Close range (CR), Short Range (SR), Medium Range (MR), Long Range (LR), Endurance (EN), and Medium Altitude Long Range (MALE) UAVs. The lack of satellite communications (Satcom) systems limits the distances over which close, short, and medium range UAVs can operate. The absence of Satcom equipment is mainly due to the size, weight, and cost of antennas for this type of UAV. Long-range UAVs use more advanced technology in order to achieve their missions. Usually by incorporating a satellite link or another platform acting as a relay, in order to overcome the communication problem between the ground station and a UAV caused by the earth's curvature. Medium-range UAV platforms feature more advanced aerodynamical designs and control systems due to their high operational requirements, as exemplified by the AAI Corporation's Shadow 200 and 400 aircraft. MALE UAVs, many readers have probably already heard about the MQ-1 Predator designed and built by U.S. General Atomics Aeronautical Systems. The Predator can operate for up to 40 hours at a maximum range of 3,704 kilometers and has seen extensive service in Kosovo, Afghanistan, and in other areas of conflict that puts human pilots at risk.

C. Strategic UAVs.

At higher altitudes UAVs tend to be heavier platforms with

	Category (acronym)	Maximum TakeOff Weight (kg)	Maximum FlightAltitude (m)	Endurance (hours)	Data Link Range (Km)	Example: Missions	Example: Systems
Micro/Mini UAVs	Micro (MAV)	0.10	250	1	< 10	Scouting, NBC sampling, surveillance inside buildings	Black Widow, MicroStar, Microbat,FanCopter, QuattroCopter, Mosquito,Hornet, Mite
	Mini	< 30	150-300	< 2	< 10	Film and broadcast industries,agriculture, pollution measurements,surveillance insidebuildings,communications relay and EW	Mikado, Aladin, Tracker, DragonEye,Raven, Pointer II, Carolo C40/P50,Skorpio, and R-50, RoboCopter, YH-300SL
Tactical UAVs	Close Range (CR)	150	3.000	2-4	10-30	RSTA, mine detection, search & rescue, EW	Observer I, Phantom, Copter4 Mikado, RoboCopter 300, Pointer,Camcopter, Aerial and AgriculturalRMax
	Short Range (SR)	200	3.000	3-6	30-70	BDA, RSTA, EW, mine detection	Scorpi 6/30, Luna, SilverFox, EyeView, Firebird, R-MaxAgri/Photo, Hornet, Raven,phantom GoldenEye 100, Flyrt,Neptune
	Medium Range	150-500	3.000-5.000	6-10	70-200	BDA, RSTA, EW, mine detection, NBC sampling	Hunter B, Mücke, Aerostar, Falco, Armor X7, Smart UAV, Eagle Eye+, Alice, Extender, Shadow200/400
	Long Range (LR)	-	5.000	6-13	200-500	RSTA, BDA, communications relay	Hunter, Vigilante 502
	Endurance (EN)	500-1.500	5.000-8.000	12-24	> 500	BDA, RSTA, EW, communications relay, NBC sampling	Aerosonde, Vulture II Exp, Shadow 600, Searcher II, Hermes
	Medium Altitude LongEndurance (MALE)	1.000-1.500	5.000-8.000	24-48	> 500	BDA, RSTA, EW weapon delivery, communications relay, NBC sampling	Skyforce, Hermes 1500,Heron MQ-1 Predator, Predator-IT, Eagle-1/2, Darkstar, E-Hunter
Strategic UAVs	High Altitude, Long Endurance (HALE)	2.500-12.500	15.000-20.000	24-48	> 2.000	BDA, RSTA, EW, communications relay, boost phase,intercept launch vehicle,airport security	Global Hawk, Raptor, Condor, Theseus, Helios, Predator B/C, Libellule, EuroHawk, Mercator, SensorCraft, Global Observer

Micro UAVs Requirements:	
Specification	**Requirement**
Size	< 15 cm
Weight	100 g
Payload	20 g
Range	1-10 Km
Endurance	60 min
Altitude	< 150 m
Speed	15 m/s
Source: "Challenges facing future micro air vehicle development", D.J. Pines & F. Bohorquez AIAA Journal of Aircraft, April 2006	

Table.2 Micro UAVs Requirements

longer range and endurance. Indeed, that makes sense, because big platforms can carry a larger payload and, in order to reach greater distances while f lying for longer time, they require more energy. Thus, big platforms are usually used for high altitude, long endurance and long range purposes as is the case of the High Altitude Long Endurance (HALE) UAVs, which comprise the heaviest UAVs. HALE platforms are strategic UAVs with a MTOW varying from 2.500 kilograms up to 12.000 kilograms and a maximum flight altitude of about 20,000 meters. They are highly automated, with takeoffs and landings being performed automatically. At any time during its mission the ground control station(GCS) can control the HALE UAV. Northrop Grumman's military UAV, the Global Hawk, with 35 hours of endurance is probably the most well-known HALE UAV and offers truly remarkable performance. An example of a non-military HALE is the electric/solar-powered Helios from Aerovironment operated by NASA. The Helios uses solar panels to power electrically driven propellers and has set an altitude record of about 30.000 kilometers. This UAV's design offers many attractive features for civil tasks, such as Earth observation augmenting and complementing remote sensing satellites. Other HALE UAV applications include communications, mapping, and atmospheric monitoring.

IV. POWER STORAGE ADVANCEMENT

Many small UAVs are electrically powered. Furthermore, for these electrically powered vehicles, the power storage system, in most cases a battery, represents the largest component by weight in the vehicle. Improvements in power storage represent the largest "target of opportunity" to decrease the weight of the vehicle and/or improve the performance. So here the main focus will be on present design considerations for high energy density, cost effective, non-carbon emitting and renewable energy sources. The following energy sources and combinations thereof are considered:

- Lithium Polymer (Li-Po) Batteries;
- Super Capacitors (SC);
- Photo Voltaic (PV) Cells; and
- Hydrogen Fuel (FC) Cells.

(Lithium Polymer batteries and super capacitors are in essence only energy storage mediums. However in the context of UAV power sources these energy stores can be considered as energy sources for supplying power to the UAV and associated onboard equipment.)

A. Lithium Polymer(Li-Po) Batteries

In lithium-ion cells a rigid case presses the electrodes and the separator onto each other whereas in polymer cells external pressure is not required because the electrode sheets and the separator sheets are laminated onto each other Lithium polymer batteries, the next generation power source [5] since no metal battery cell casing is needed, the weight of the battery is reduced and it can be formed to shape. The denser packaging without inter cell spacing and the lack of metal casing increases the energy density of Li-Po batteries to over 20% higher than that of a classical Li-ion batteries. Lithium polymer cells are considered fully charged when the cell terminal voltage reaches 4.2 V and are fully discharged when the cell terminal voltages decreases to a voltage of 3.0V [5]. In rechargeable Lithium based batteries, the radio-controlled model aircraft demands for higher current draw batteries has caused a decrease in the total storage capacity for a given weight. Such tradeoffs are useful for applications such as 3-D aerobatic aircraft where run time is limited and thrust-to-weight is a primary motivating factor. However, for longer endurance UAVs, the surge current requirement is likely to be far less than 5C so there would be a net penalty involved in using the higher current draw rated battery

Lithium Polymer Cell Advantages - High energy density; Low self-discharge properties; The flexible casing of the polymer batteries allow for design freedom in terms of profile thicknesses; Low maintenance.

Lithium Polymer Cell Disadvantages Special charging circuits required to maintain cell voltage within safe limits; Subject to aging; Subject to cell balancing for series stack configurations; High procurement cost; Requires special disposal processes.

Moreover along with improvement in energy density there is also reduction in the cost as shown in Fig.3.

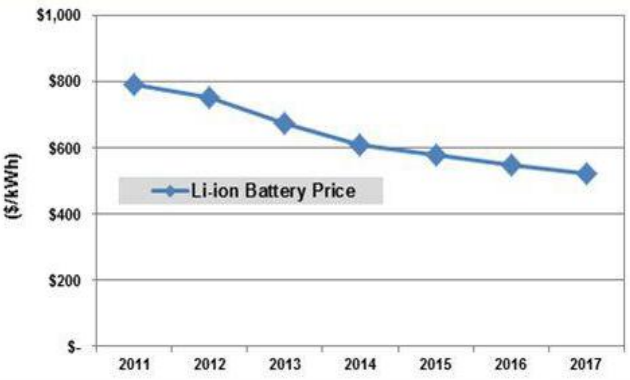

Fig.3 Fall in Li-ion Price over years

B. Super-Capacitors

Super capacitors, (SC) or Ultra-capacitors are also known as Electric Double Layer Capacitors (EDLC). Super capacitors have a double layer construction consisting of two carbon electrodes immersed in an organic electrolyte. During charging, ions in the electrolyte move towards electrodes of opposite polarity; this is caused by an electric field between the electrodes resulting from the applied voltage.

Consequently, two separate charged layers are produced. Even though the capacitors have a similar construction to batteries, their functioning depends on electrostatic action. No chemical action is required; the effect of this is an easily reversible cycle with a lifetime of several hundreds of thousands of cycles [6].

Super-Capacitors Advantages - High cell voltages are possible, but there is a trade-off with storage capacity; High power density; No special charging or voltage detection circuits required; Very fast charge and discharge capability; Life cycle of more than 500,000 cycles or 10-12 year life time.

Super-Capacitors Disadvantages - Low energy density; Low power to weight ratio when compared to current battery technology; Moderate initial procurement cost; High self discharge rate.

C. Photo Voltaic Cells

The power output of photovoltaic cells depends primarily on the absolute value and spectral distribution of irradiance in the plane of the photovoltaic cell and the resulting operational temperature [7]. The total amount of energy produced by the photovoltaic cells is a function of the geographical position (latitude, longitude, and altitude), time of the year, atmospheric absorption and efficiency of the photovoltaic cells. The Linke turbidity factor [8] is used to characterize the clearness of the sky. The lower this factor, the clearer the sky, the larger the beam irradiation and the lower the relative fraction of the diffuse irradiation. For higher altitudes, the absorption is lower because of less radiation scattering by the atmosphere which lowers the Linke turbidity factor. Typical values for the Linke turbidity factor are listed in Table 3. When designing solar powered UAVs, consideration has to be given to the expected operating time of the year. Designing for minimum available solar energy conditions may result in an over design by a factor of 2 under maximum available solar energy conditions. An over design factor of 2 has significant negative impact on the UAV airframe design in terms of size and cost. A positive impact may be that the excess solar energy available may be used to overcome the increased aerodynamic drag when the UAV is flying at faster speeds. This may result in UAVs which can be operated at higher flying speeds during the summer months, when the available solar energy is at a maximum.

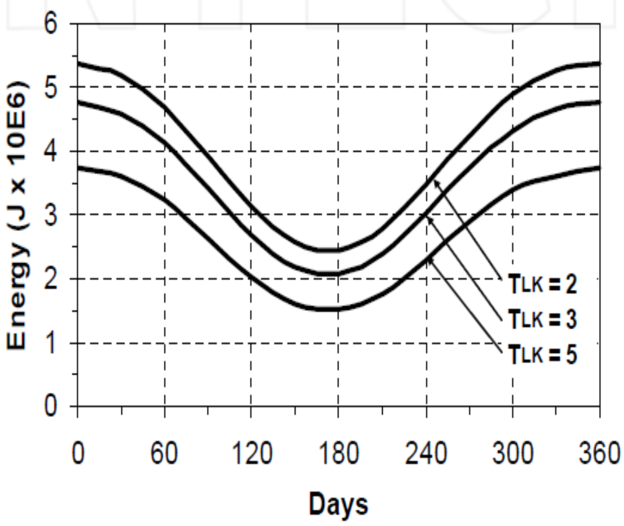

Fig. 4. Available solar energy per day which can be collected by a 1 m^2 photovoltaic array with a 16% efficiency for various values of Linke turbidity factor where day 1 corresponds to the summer solstice in the southern hemisphere

TLK	*Sky Condition*
1	Pure sky
2	Very clear sky
3	Clear sky
5	Summer with water vapours
7	Polluted urban industrial

Table 3. Values for Linke turbidity

Figure 4 shows the theoretically available energy which can be collected in the southern hemisphere at a latitude of 25 degrees by a photovoltaic array of 1 m^2 with an efficiency of 16% as a function of the time of the year. Another issue to consider is matching the output of the photovoltaic cells to the input of the energy storage medium, which can make a great difference in the efficiency of power utilization, thus some form of maximum power point tracker will be required. [7]

When designing solar powered UAVs, consideration has to be given to the expected operating time of the year. Designing for minimum available solar energy conditions may result in an over design by a factor of 2 under maximum available solar energy conditions.

Solar Energy Advantages - Very little maintenance required; Photovoltaic cells are non-polluting; Essentially no operating cost.

Solar Energy Disadvantages - it can only generate electrical power during daylight hours; photovoltaic cell efficiency is rather low in the rage of 14% to 18% for commercially available terrestrial grade cells. Space grade cells have efficiencies as high as 24% [7].

D. Hydrogen Fuel Cells

Polymer electrolyte membrane fuel cells (PEMFC) are constructed using a solid polymer as electrolyte, absorbent electrodes combined with a platinum catalyst. Hydrogen gas is recombined with oxygen gas producing electricity with water vapour as emission. Onboard storage of the hydrogen would be required for UAV applications. Alternatively, hydrogen may be manufactured onboard the UAV from electrolysis of water using solar energy. A closed loop system could be operated whereby the water from of the PEMFC can be electrolyzed into oxygen and hydrogen for later re-use. Oxygen is generally obtained from the surrounding air. Operating temperatures are relatively low around 80 °C, enabling quick starting and reduced wear. Platinum catalysts are required for operation and to reduce corrosion. Polymer electrolyte membrane fuel cells are able to deliver high energy densities at low weight and volume, in comparison to other fuel cells [9].

Fuel Cell Advantages - Relative high efficiency; High energy density; Low noise; Non carbon producing only water emission; Low maintenance.

Fuel Cell Disadvantages

The biggest disadvantages of using PEMFCs are the initial procurement cost and the safety issues regarding the storage of the onboard hydrogen gas. PEMFCs also suffer from a limited lifetime.

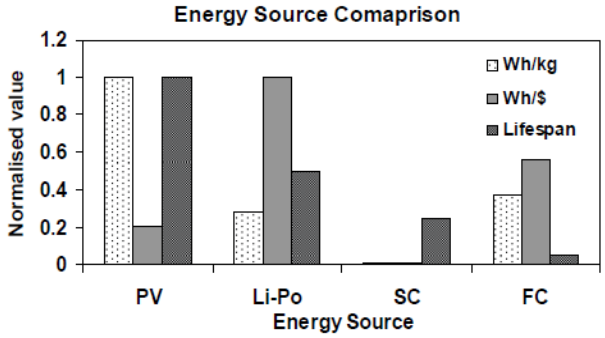

Fig. 5. Normalised comparison of the key performance parameters for the energy sources considered

Electrical Power Source Comparison

When considering an electrical energy source for powering of an UAV the before mentioned advantages and disadvantages must be compared. The key performance parameters for energy sources in UAV applications were identified as:

- Energy density (Wh/kg);
- Energy unit cost (Wh/$); and
- Lifespan (years).

Figure 5 shows a comparison of the key performance parameters for the energy sources considered.

V. ELECTRIC MOTOR ADVANCEMENT

In addition to power storage evolutions, the primary propulsion means have also undergone an evolution. Fig 6. shows a picture of three electric motors designed for a similar application but using different technologies. The motor on the left is a “traditional” brushed motor and gearbox circa 2001 that has a mass of 269g. The middle motor is a brushless motor replacement which has a mass of 209g, a savings of 22.3%. The motor on the right is an “outrunner” motor or external can motor which drives the propeller directly. This high torque motor eliminates the necessity for a gearbox thus providing a further weight savings of 13.3% over the inrunner brushless motor. Also seen is as a reduction in the number of moving parts, enhancing its reliability. Costs for these improved motors also seem to be decreasing as their utility becomes more widespread amongst mass-market users. One potential drawback to the outrunner motor appears in the form of integration. Since the majority of the external surface is rotating, there is no direct way to attach a heat sink to aid in cooling, as would be the case for the other motor types[10]. This requires more consideration for cooling airflow and the associated impacts of that flow on the overall system design.

Testing of these motors indicate that all three have similar initial performance characteristics at certain specific design points. However, the brushed motor typically degrades more rapidly with use than the other two. During a recent series of wind tunnel tests, the geared inrunner motor was tested with the same propeller as an outrunner motor of the type shown. At 60fps, the motors were consuming similar power levels (168 watts vs. 173 watts), produced similar net thrust values (1.15lb vs. 1.2lb.) and had similar propulsive system (i.e. combined motor and propeller) efficiencies (55.7% vs. 56%).

Fig.6. Similar motors using different configuration technologies [10]

VI. DESIGN AND MATERIAL ANALYSIS

A. Fuselage Design

The design of the fuselage is based on payload requirements, aerodynamics, and structures. The overall dimensions of the fuselage affect the drag through several factors. Fuselages with smaller fineness ratios have less wetted area to enclose a given volume, but more wetted area when the diameter and length of the cabin are fixed. The higher Reynolds number and increased tail length generally lead to improved aerodynamics for long, thin fuselages, at the expense of structural weight. Selection of the best layout requires a detailed study of these trade-offs, but to start the design process, something must be chosen. This is generally done by selecting a value not too different from existing aircraft with similar requirements. In UAV fuselage design, the payload requires a fuselage being able to hold a camera, batteries, servo, and targeting ball.

Except the payload requirement, other considerations are:

- Low aerodynamic drag
- Minimum aerodynamic instability
- Ease of assembly and disassembly of fuselage
- structural support for wing and tail forces acting in flight, which involves simple stress analysis for the entire fuselage

B. Aircraft Nose and Tail Cone Design

The fuselage shape must be such that separation is avoided when possible. This requires that the nose and tail cone fineness ratios be sufficiently large so that excessive flow accelerations are avoided. As speed of the plane increases, the drag coefficient increase as well. Different type of fuselage shape can give different drag coefficient as well. But as shown in Fig.7, below Mach number 0.5, the shape of the airplane does not give too much difference.[11]

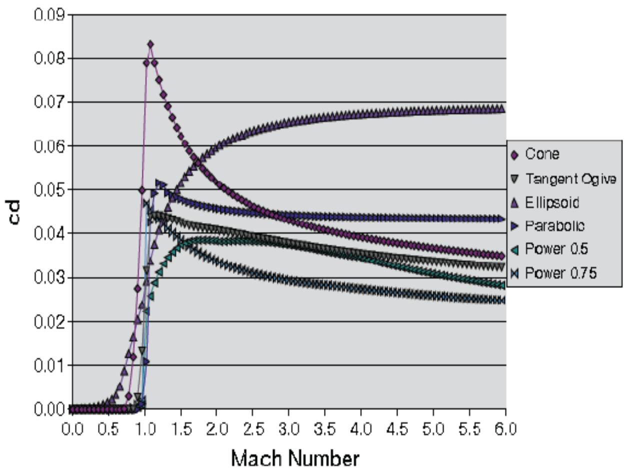

Fig 7. Drag at different speeds for different shapes

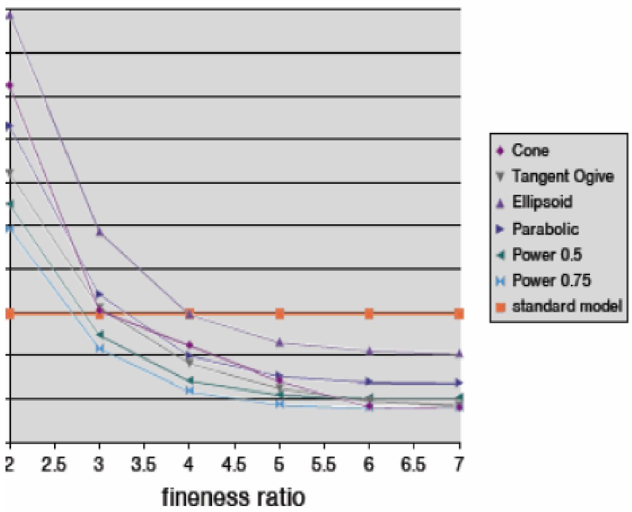

Fig 8. Drag Loss VS Fineness Ratio

Except the shape of the fuselage, the nose and tail cone *fineness ratio* play an important role in fuselage design as well. Fig.8 shows the simulation graph for drag loss for different *fineness ratio*.

Not surprisingly, the elliptical shape has poorer performance than the other shapes, but except from that, and perhaps the parabolic shape, the difference in apogee between the other shapes is so small for the higher fineness ratios, that other criteria may be taken into account when selecting the shape.
In this UAV design, one of key factors in UAV fuselage shape design is the payload. According to the payloads weights, centre of gravity as well as the attribution of the different parts, the width, namely the aircraft lateral diameter is no less than 9cm. In order to make sure the Centre of Gravity is behind the aerodynamic centre, which is design to make sure of the aircraft stability and easily manoeuvrability, and based on the fact that the tail of the plane is relatively high, the batteries and camera should be put into the very front to counter the weight. As such, the nose should be designed so as to have enough space to hold the payloads at the very front. That's the main reason of this design. Fineness ratio 2 is restricted by the overall length of the fuselage and diameter of the fuselage. Any longer fuselage will increase the drag even more. Besides all these considerations, the shape also depends on the manufacturability.

Choice of materials emphasizes not only strength/weight ratio but also:

- Nose transparency for camera function
- Comparably large strength allied to lightness
- Strong stiffness and toughness for the rear rod
- Low cost and weight for all parts
- Low cost and weight for all parts
- Fracture toughness
- Crack propagation rate
- Stress corrosion resistance
- Exfoliation corrosion resistance

Today, the main material used is aluminium alloys for all kinds of aircraft, which is pure aluminium mixed with other metals to improve its strength. In the real world of aircraft, conventional stiffened fuselages (skin/frames/stiffeners), sandwich fuselages, double walls (skin with an interior panel), insulation blankets in between the skin and the interior panels, application of damping improving visco-elastic layers, application of piezo electric elements for active noise control, etc, are designed and launched to strength the fuselage. Since the UAV does not need too much strength, only the skin with basic holding structure would be enough.
Below is a comparison of material property comparison for different kinds of possible materials for aircraft fuselage, aluminium sheet, wood, Styrofoam, plastics, and carbon fibres. Considering all the factors listed at the beginning of this section, including stress factors, cost, manufacturability, weight-to-stress ratio, and resistant to corrosion or stress concentration, etc, plastics are the best choice, and vacuum forming method is chosen for plastics' manufacture.

VII. AVIONICS IMPROVEMENT

To improve the performance of UAV, its weight need to be decreased. In UAV a large proportion of weight is contributed by its avionics. So with time the weight and size of avionics components have decreased ,thus helping in further increasing the performance of UAV. Not only have these systems become dramatically smaller, but they have also become more capable.
Table 5 shows a collection of inertial measurement systems from various time periods. Note both the weight improvement as well as functionality have risen concurrently.[10]

Continued improvement from technologies such as micro-mechanical machines (MEMS) appear to be accelerating more functionality into smaller form factors. For example, the MEMS devices being used are all single-element devices, i.e. one axis gyro or accelerometer. MEMS devices are currently available which package 3-axis accelerometer or dual-axis gyros in a single chip[10] .This added functionality can either be used directly to lower the part count and board surface area or it can be used to provide redundancy to improve reliability. Other types of microelectronics, such as counters (for measuring RPM), analog-to-digital converters, sensors (pressure, temperature), and others are also benefiting from advances in packaging and microcontroller improvements.

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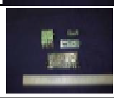
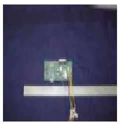
Table.4 Comparison between different materials

Material	Density	Tensile Strength @73 °F	Stiffness (E)	Method of manufacture	Price
Aluminum sheet	2.7 g/cm3	30,000psi	70000MPa	Forging	Expensive
Wood	0.8 g/cm3	550psi	10000MPa	Adhesive Bonding	Cheap
Styrofoam	0.18 g/cm3	100psi	5000MPa	Hotwire Cut by CNC	Cheap
Plastics (PVC)	1.15 g/cm3	7,000psi	3000MPa	Vacuum Forming	Very cheap
Carbon fiber	1.78 g/cm3	100,000psi	50000MPa	Epoxy Resin	Very expensive

Unit	Year produced	Weight (g)	Functions	Picture
Exdrone 2-Axis Wing leveler	1985	770	1 gyro, wings leveling only	
COTS Autonavigation 5-axis	2002	159	3-axis gyro, 2-axis accelerometer	
LaRC Gen1 5-axis IMU	2003	105	3-axis gyro, 2-axis accelerometer, airspeed, altimeter, GPS	
LaRC Gen2 6-axis IMU	2004	54.5	3-axis gyro, 3 axis acclerometer, airspeed, altimeter, GPS, microphone, temperature	

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