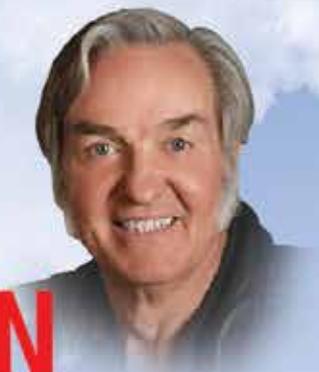


# THE AIR ERA

MAY 2014

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**RUTAN**  
THE CANARD GURU



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Editor in-Chief:

**Joffin Jose**

Managing Editor:

**John Ninan**

Consulting Editor

**AV Balakrishnan**

Associate Editors

**Anandhu Mohandas**

**Adhavan Nagarathinam**

Advisory Board:

**Dr. M.S. Rajamurthy**, Ph.D. (Aero.)

IITB, F.Ae.S.I

**Air Cmde Sajjad Rahim VSM** (Retd.)

Hindustan Aviation Academy

Director (Academics)

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+91 9972212950

theaireramagazine@gmail.com

Classified

+91 9538107417

theaireramagazine@gmail.com

Recruitment Display

+91 9538107417

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Subscription

+91 9538107417

theaireramagazine@gmail.com

Contact:

C 25/2, DRDO Township

C.V. Raman Nagar,

Bangalore 93

Ph: 9844483483, 9538107417

E-mail: theaireramagazine@gmail.com

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## EDITORIAL

The Air Era is a first of its kind aviation magazine aimed at acting as a media for all aviation related activities as well as to enlighten students as well as aviation enthusiasts with the latest trends in the industry. An earlier version of the magazine was published under the title “AviZine” which was published as an in house magazine under the Bangalore Aeronautical Students Association and was well received by the aviation crowd. This motivated us to carry on the efforts to publish a fully-fledged magazine in to the Indian market focussing on the student development with inputs from the experienced sector of aviation to enable job worthy candidates who would push Indian aviation market to its heights.

We urge you to support us in our endeavour by following every edition of our magazine and providing us with constant feedback as we would help to fill the void present in aviation in India.

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## Rolls-Royce unveils future plane engine designs

DERBY, UK (AFP): Rolls-Royce on Thursday unveiled its next generation of fuel-efficient plane engines to power civilian aircraft of the future. Two weeks after announcing a shock profit warning with government cutbacks on defence spending impacting its military engines business, Rolls Royce revealed plans to build on its successful Trent XWB engine used to power Airbus A350 passenger planes. "These new designs are the result of implementing our on-going technology programmes," said Colin Smith, Rolls-Royce Director, Engineering and Technology. "They are designed to deliver even better fuel efficiency, reliability and environmental performance," he said in a statement delivered alongside a media presentation event in Derby, central England, where the Trent XWB is assembled. Rolls said that Advance, the development name for one of its future engines, will burn at least 20 percent less fuel and CO2 emissions compared with the first generation of Trent engines that entered service in 1995. The Advance could be ready by the end of the decade, it added. An even more fuel-efficient model, UltraFan, could be ready for service from 2025. "Both engine designs are the result of the ongoing research and development investment, of approximately USD 1.7 billion a year, which Rolls-Royce makes across its aerospace and non-aerospace businesses," the company added. Rolls Royce is the sole engine provider for the Airbus A350 XWB, a long-range, wide-body plane which is slated to come into service at the end of the year.

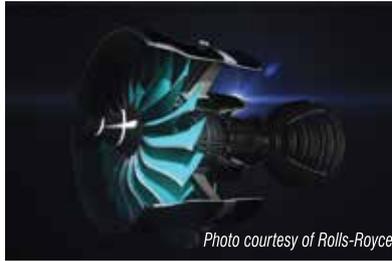


Photo courtesy of Rolls-Royce

## Solar-powered plane to make round-the-world trip next year

NEW DELHI (PTI): Come 2015, India and rest of the world can see the first aircraft that is powered by solar energy and can fly non-stop. The aircraft, to be unveiled in a few months from now, will make a round-the-globe trip next year, showcasing the latest technology in various countries where it will have stopovers, according to Switzerland-based Company Solar Impulse, which is manufacturing it. The plane, weighing around 2,740 kg, will be powered by 12,000 solar cells and can fly at the speed of 70 kms per hour. It can fly day and night continuously, collecting energy from the Sun, the company's CEO Andre Borschberg told PTI here. Maintaining that the plane will have only one pilot as of now, he said that while the aircraft can fly continuously day and night, "the limiting factor is the pilot. He cannot sustain endlessly and has to take rest. "The around-the-world sojourn will be for three months, with the total flight time being 20-25 days and nights. The journey will begin somewhere in the Middle East and the flight's first destination will be India. "We hope to showcase the technology in India to attract young generation which could help young generation to realise their own dreams. We want students to see the pioneering technology," he said.



Photo courtesy Solar Impulse

## Indian DGCA permits use of cell phones on-board flights

Following the aviation regulators - the US Federal Aviation Administration (FAA) and European Aviation Safety Agency (EASA), India's civil aviation regulator, the Directorate General Civil Aviation (DGCA) has amended its CAR (Civil Aviation Requirement) Section 5 Series X Part I permitting the usage of Portable Electronic Devices (PEDs) including cellular telephones.

It is nice to see the DGCA taking this progressive action. Lets hope some passengers do not stretch this relaxation and try to make calls on board.

## US Companies Eager to invest in India's Aviation Sector

WASHINGTON (PTI): Top US companies are eager to invest in India's booming aviation sector's various fields, from security to building new airports, with recent changes in regulatory environment "encouraging" them, American officials have said. "Indian aviation is experiencing dramatic growth across the board, from the emergence of new carriers to a growing middle class ready to take travel by air. Director of US Trade and Development Agency (USTDA) Leocadia I Zak told "The Government of India recognises that growth in the aviation sector means broader growth across the economy, and has already taken steps to enable investment and revise regulations. Last year, the Government approved higher levels of foreign investment in Indian airlines," Noting that India is now the ninth largest aviation market in the world, she said the market now handles almost 121 million domestic and 41 million international passengers. This presents many opportunities for partnership between firms from both the countries.

## Middle-East Airlines sucking talent out of India

Airlines in the Middle East are sucking up the talent out of India leading to a dearth of qualified and competent people back home, a leading industry executive has said.

According to Ravi Menon, the executive director of Air Works, a Mumbai-based aircraft maintenance company, the biggest risk to the maintenance, repair, and overhaul (MRO) space or aviation space is a lack of qualified and competent people. Indian airlines currently opt to go abroad for much of the maintenance work on their planes.

"In the last two months, we as an organisation saw 12 key personnel resign to move to Qatar," Menon told The National.

Airlines in the Middle East are sucking up the talent out of India, he said.

According to him, there are schools but those schools are perhaps more theoretical in their approach rather than an element of practical training.



Shyam Chetty  
Director, CSIR-NAL

# CSIR - National Aerospace Laboratories:

## A leading Indian Aerospace R&D Institution

National Aerospace Laboratories (NAL), a constituent of the Council of Scientific and Industrial Research (CSIR), India is the only civilian aerospace R&D laboratory in the country. Started on June 1, 1959 in Delhi, it moved to Bangalore in 1960 and later on to its own campuses (Kodihalli and Belur) in Bangalore. CSIR-NAL is a high-technology institution focusing on various disciplines in aerospace and has a mandate to develop aerospace technologies with strong science content, design and build small and medium size civil aircraft prototypes, and support all national aerospace programmes. It has many advanced test facilities recognized as National Facilities. These are not only best in the country but also comparable to other similar facilities in the world. NAL's committed efforts over the last five decades have resulted in achieving

expertise and core competencies in most of the disciplines of aeronautics, the areas of core competence include; computational fluid dynamics, experimental aerodynamics, flight mechanics and control, turbo machinery and combustion, composites for airframes, avionics, aerospace materials,

structural design, analysis and testing. It has always readily accepted challenges and delivered programme-critical products and technologies and has become the preferred destination for almost all the mission-mode aerospace programmes in the country. It would not be improper to say that LCA Tejas



Advanced Civil Aircraft Cockpit



India's Largest Autoclave for Airworthy Composites Processing

development would have been difficult without NAL's contributions, and that every major aerospace programme of DRDO and ISRO has significant contributions from CSIR-NAL.

As is in its mandate, in 1983-84, CSIR-NAL started a project to fabricate an all-composite aircraft using Long-Ez plans bought from the Rutan Aircraft Company in USA. The project led by the indefatigable Prof R B Damania, gave CSIR-NAL teams very valuable insights into building airworthy composite structures. The aircraft, called the Light Canard Research Aircraft (LCRA), was ready by the end of 1986 and made its maiden flight on 26 February 1987.

After the LCRA success, CSIR-

NAL seriously started the preparatory work to design and build small and medium sized aircraft. Today, NAL's two seat aircraft (15 built so far) named 'HANSA' a pioneering ab-initio all composite design, certified by DGCA in the year 2000 under JAR-VLA certification is catering to the needs of flying clubs in the country. SARAS, the 14 seat (7 ton class) multirole transport aircraft to be certified under FAR 23 category is being designed and built by CSIR-NAL had its maiden flight on May 29, 2004. It has been designed for multiple roles like executive transport, light

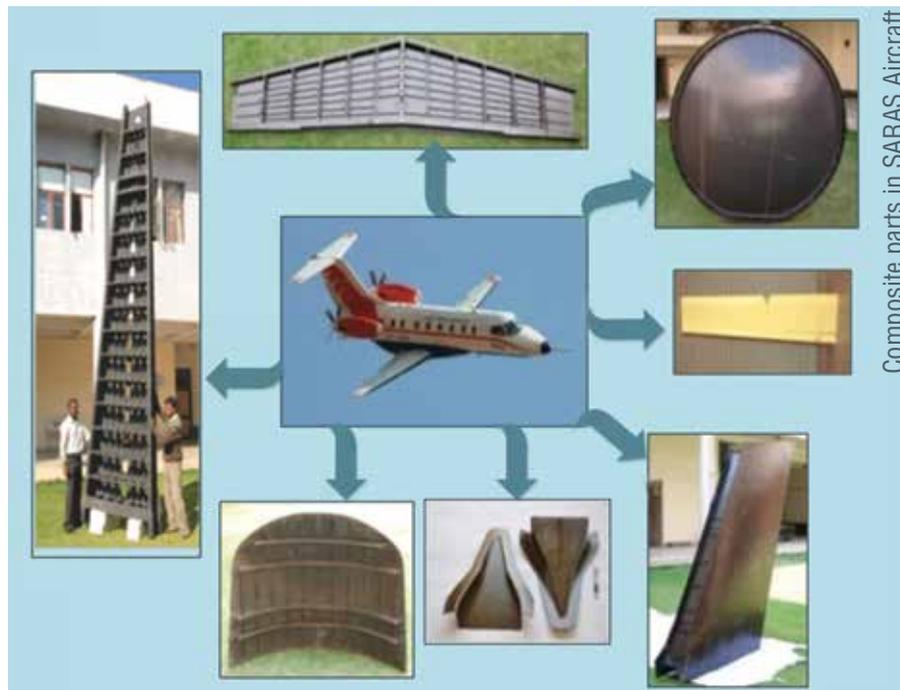
package carrier, remote sensing, air ambulance etc. Indian Air Force is expected to be the launch customer for SARAS with HAL as the production partner. The five seat General Civil Aviation aircraft named CNM-5 has the distinction of being the country's first public-private partnership (PPP) for development of civil transport aircraft. It is being developed by CSIR-NAL in collaboration with M/s Mahindra Aerospace Pvt. Ltd. (MAPL), Bangalore and had its maiden flight on the 1st September 2011 in Australia. It is proposed to be certified first under CASA, the Australian Certification Authority. CNM-5 is an ideal aircraft for air taxi, air ambulance, training, tourism and cargo applications.

NAL's contributions to major national programmes have enabled it to carve a niche for itself. Key technology successes of NAL include; Carbon fibre composite airframe components using innovative and cost-effective fabrication technologies and Fly-by-wire Flight Control Laws design and development for the Tejas programme. An achievement with far reaching implications is the development of aerospace grade carbon fibres, a technology which is high on the list of sanctions. CSIR-NAL is playing a lead role jointly with many academic institutions in the National Programme on Micro Air Vehicles (NP-MICAV) of DRDO/DST. Black Kite, Golden Hawk and Pushpak MAVs with a 300mm span, 300gms weight and endurance of 30 minutes have been developed. These MAVs are currently undergoing user



trials. NAL also developed 1.6 m span, 1.3 m length, 2 kg weight high altitude mini UAV ‘Slybird’ successfully tested at Leh & Ladakah ( 12000 ft above the sea level ). The other key technology successes are; nano-coatings, sunshield mirrors for satellites, and design and development of 55HP Wankel engine with VRDE for DRDO-ADE’s Nishant UAV. NAL’s association with India’s space programmes including the contributions for GSLV and RLV has been very fruitful. NAL has carried out acoustic tests on all of ISRO’s launch vehicle stages as well as satellites. NAL is very proud to say that every Indian aerospace vehicle has graduated out of NAL’s 1.2m Trisonic Wind Tunnel which is performing reliably for over 50 years.

CSIR-NAL has made significant contributions in the area of new technologies and systems. The high speed combustor design and related test facilities has been developed for hypersonic vehicles. Radomes are an area of strength in NAL and its multi disciplinary team has established a niche technology covering mechanical, electromagnetic, aerodynamic and



Composite parts in SARAS Aircraft

structural design, testing and certification aspects. Radomes have been developed for ground based as well as airborne applications, this include the 12.9 meter dia Doppler Weather Radar Radome for ISRO, and nose radomes for Jaguar and Saras aircrafts. The institution contributed to development of advanced aircraft

structures including co-cured co-bonded composite parts, variable resin infusion technology, and design of indigenous autoclaves for composite airframe manufacture. Active Noise Control (ANC) system for fighter aircraft has been developed and as also a host of surface modification technologies.

Over the years, NAL has successfully addressed the avionics challenge. DRISHTI, an airport runway visibility assessor system developed is a fast and accurate transmissometer. Currently the systems are installed at New Delhi, Kolkata and Lucknow airports. Soon other airports across the country would be equipped with NAL’s indigenously developed DRISHTI. Engine Instruments and Crew Alert System (EICAS) and a 3-axes digital autopilot system developed for Saras aircraft is first of its kind in India and has the potential for use in other aircraft programmes both in India and Abroad. CSIR-NAL’s Flight Operation Quality Assurance (FOQA) software has been the key tool for aviation and is being used by many Indian aircraft for over a decade. The



Clockwise: Black Kite MAV (300mm), Golden Hawk MAV (300mm), mini UAV Slybird (2kg, 1.6 m wing span), and Pushpak MAV (300mm)



DRISHTI is suitable for CAT I, II and III airports meets ICAO and WMO specifications.

Centre for Electromagnetics at NAL is contributing to the electromagnetic design & development of ground based and airborne radomes for various national programmes.

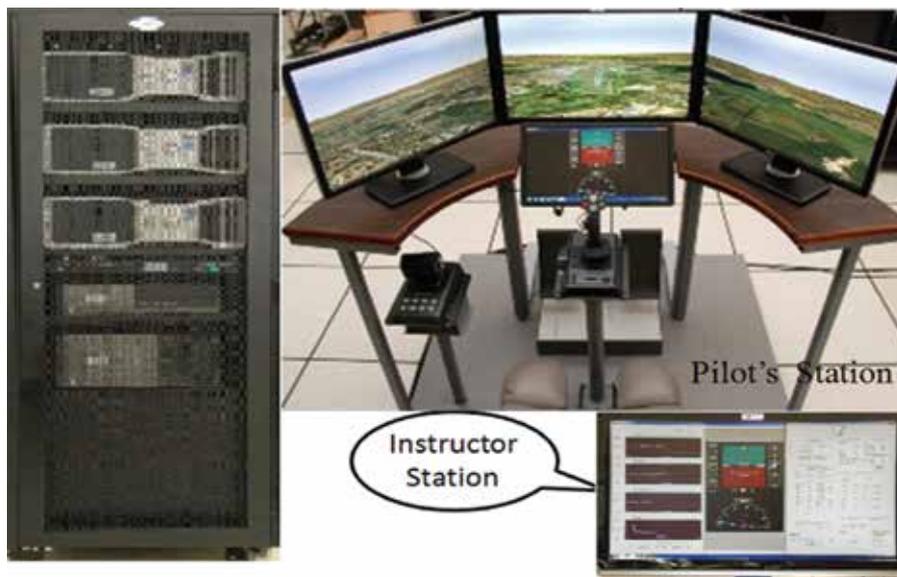
CSIR-NAL is known for its expertise and capabilities in many disciplines of aeronautics. It has a very strong base in advanced computational and experimental fluid dynamics which has substantially contributed to speeding up the design of complex flight vehicles. At CSIR-NAL, several advanced flow diagnostic techniques such as BoS, PIV, PSP etc., have been successfully developed and deployed. Our laboratory is recognized as India's premier organization for carrying out failure analysis and

accident investigations of aircraft. CSIR-NAL's structural technological capabilities cover dynamic analysis of structures including aeroelastic testing and analysis. The full-scale fatigue test facility provides inputs that can lead to a substantial increase in the operational life of airframes. NAL has achieved considerable success in using smart materials for structural health monitoring and also as sensors and actuators. It has a proven ability in the area of design, testing and analysis of advanced engine components.

Many technologies have been developed for societal applications. NAL's pioneering efforts in parallel processing hardware and software development have given the country advanced metrological computational capabilities. NALSUN solar selective coating for industrial and domestic solar water heaters, wind turbines of 300kW and 500 kW capacity for wind energy harvesting, coatings for cutting

tools to enhance wear resistance and improved tool life are some of the significant achievements with societal impact.

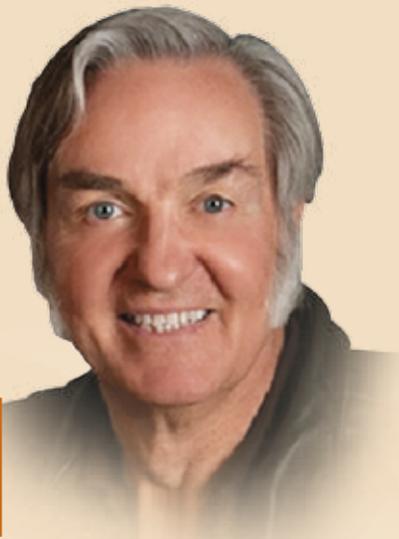
CSIR-NAL is continuously striving towards new strategic initiatives to meet the challenges of future. To name a few initiatives in pipeline; a major programme initiative on national civil aircraft development for regional connectivity, and design & development of sub 200 mm class Micro Air Vehicles to meet the needs of strategic and civilian sector. Further, NAL is expected to play a significant role in the proposed development of Advanced Medium Combat Aircraft by ADA and the Fifth Generation Fighter Aircraft and Medium Transport Aircraft programmes of HAL. In conclusion it may be said that CSIR-NAL aims to reach greater heights in futuristic aerospace technologies by active participation in many major national programmes.



NALSim flight simulator for ASTE-TPS

# RUTAN

## THE CANARD GURU



Dr. M.S. Rajamurthy, Ph.D. (Aero.)  
IITB, F.Ae.S.I  
Scientist 'G' (Retd.), CSIR-NAL

If there was a Noble prize for Aircraft Design, Burt Rutan would have been an unanimous choice. This brilliant designer has dramatically revolutionized aircraft design – particularly general aviation. While most of the designers live through a few designs in their life time, Rutan has gone at a phenomenal pace from a simple homebuilt VariViggen to White Knight - a dream machine for manned space flight – a private venture which no one ever dreamt or realized. The technological breakthroughs Rutan has brought in airplane design and composites are exceptionally unique. With Williams mini jet engines, he ushered in the dawn of jet powered small aircraft. Rutan's flying machines speaks for him. He is aptly called the "Canard Guru" as most of his designs have a fore plane or canard.

It is not surprising that in February 2000, he was honored by the Engineers Council with Clarence L. "Kelly" Johnson "Skunk Works" award. Interestingly, Kelly tops the list of great designers admired by Rutan. Since then, Rutan has innumerable awards and honors

including few honorary doctorates. Time magazine puts him as "One of the century's most innovative designers". Newsweek refers him as "the man responsible for more innovations in modern aviation than any living engineer." Let us know more about this magnificent man and his flying machines.

After working for two years designing and developing the Bede BD-J5, he

formed the Rutan Aircraft Factory (RAF). For the next 10 years, he shaped the landscape of homebuilt aircraft with the Vari Viggen, VariEze, Quickie, Defiant, Long-EZ, Grizzly, Solitaire and Catbird.

Having participated in innumerable stall and spin test flights, he understood the need for a stall resistant design for the general aviation enthusiast. Individual fliers with a Private Pilot License



Elbert Rutan was born in Dinuba, California, in June 1943. After obtaining a B.S. in Aeronautical engineering in 1965, he took up the career of a Civilian Flight Test Project Engineer at Edwards AFB, California. This career, which he pursued until 1972, shaped him and his design approach. He was a specialist in flying qualities for 13 programs and wrote MIL 83-691, the spec. for testing stall and spin on all types of airplanes.

(PPL) will have experience in spin. An inadvertent input from the pilot during stall could lead to spin which could be fatal. Large number of fatal accidents in general aviation was of this kind and Rutan realized that the best solution to prevent spin is to prevent stall. It is here; he used the canard to its best advantage. If the canard were to stall first, the aircraft will automatically pitch down and wing stall is prevented.

Rutan's revolution in light airplane design started with VariViggen, which he built in 1972. Its name and shape were inspired by SAAB AJ-37 Viggen, the Swedish Air Force attack plane. With a wing of 19ft. span and a canard, powered by 150hp Lycoming O-320 engine driving a pusher propeller, VariViggen had a max. Speed of 163mph, range of 400miles and a ceiling of 14,000ft. It had remarkable flying characteristics - it displayed no conventional stall and could climb, cruise, glide, turn, and land with continuous full back-stick at a stable speed of 52mph throughout. It was like a fighter to fly and gave lot of thrill. Nearly 250 VariViggens were built based on the plans sold by Rutan.

In 1975, with VariEze, Rutan ushered in the era of composite home-built aircraft. VariEze – getting its name from the ease of construction – was an all-composite aircraft using fiberglass and rigid urethane foam core. VariEze

had winglets instead of the conventional fin and rudders were located in them. While the proto-type used a 63hp VW engine, 100Hp Continental O-200 was typically used.

This was followed by an enlarged, longer-range and easier-to-fly version of VariEze named Long-EZ. With looks



similar to VariEze and using a more powerful 115hp Avco Lycoming O-235 engine, Long-Ez had a top speed of 183mph and a range of 1430miles. A few thousand plans of this pair were sold and a few hundred were built and flown. Using these two aircraft Dick Rutan (brother of Burt) and Jeana Yeager broke a series of world records for speed and distance.



In 1978, Rutan brought out a four-place canard design named Defiant. This had two 160hp Avco Lycoming O-320 tractor-pusher engines. With a wing span of 29 ft. this machine had a range of 1130 miles.

In 1982, Rutan built a single place self-launching sailplane - Solitaire. As usual it had a canard – a hall mark of Rutan's



designs. A 23hp KFM 107E Retractable engine located in the nose driving a prop gave it the self launching capability. With a span of nearly 42ft it had a glide ratio of 32:1. Solitaire sailplane was the winner of a contest by the Soaring Society of America, to make soaring more accessible by removing the need for the tow plane. The aircraft worked very well, but few were ever built.



The real glory to Rutan and the Rutan Aircraft Factory (RAF) came from the Voyager. Designed for maximum fuel efficiency, the twin-engine Voyager was an all-composite aircraft with an airframe weighing only 939Lbs. Its main wing was so flexible that the tip deflection in flight was around 0.9-1.5m. Carrying 3180Kg fuel (accounting 72% of its gross weight); it was a virtual "flying fuel tank". This fuel was distributed in 17 fuel tanks and to maintain c.g. at a suitable value, pilots had to shift fuel from tank to tank. Construction of Voyager took almost





two years from 1982-84 involving more than 22,000 man-hours.

Voyager made its first test flight on Jun.22, 1984. On Dec.14, 1986, with Dick Rutan and Jeana Yeager at the controls, the Voyager took to the skies. Nine days, three minutes and 44 seconds, later Voyager touched down at Edwards AFB, California, on Dec.23, 1986, having successfully circled the globe on the first non-stop, un-refueled flight. Only 106lbs of fuel remained in the Voyager's tanks at landing. This flight nearly doubled the previous distance record set in 1962 by a USAF/ Boeing B-52H.

The Voyager earned Burt Rutan the FAI Gold Medal, the Collier Trophy, and the Society of Experimental Test Pilots (SETP)'s Doolittle Trophy. President Ronald Reagan presented the Presidential Citizens Medal to Burt Rutan, Dick Rutan and Jeana Yeager. The Voyager is now on permanent display in the main gallery of the Smithsonian National Air & Space Museum in Washington, D.C.

In 1982, Beech aircraft approached Rutan and his company, Scaled Composites in Mojave, California, to participate in the final configuration study of their new business turboprop to replace their King air. Thus emerged the Starship, the world's first FAA certified pressurized all-composite business turboprop.

Starship had a compound sweep wing, rear-mounted Pratt & Whitney turboprops in pusher configuration and a canard. Designed with a glass

cockpit, Starship was quite advanced in technology and took five and half years and a funding in excess of 300 Million dollars to get FAA certification.

In 1993, Rutan brought out an all asymmetric beauty called Boomerang. Deriving its name from the forward swept wing in the shape of a boomerang, it had a main fuselage and second boom with engines and fins on both. While there was a horizontal stabilizer between the two fins, an asymmetric extension was provided on the right side. Powered by two Lycoming TIO-360 engines it has a great performance too. With a gross weight of 4242lbs, five seats and 170 gals of fuel it could cruise at 300mph and cover a distance of 2100nm.



In 1997, Rutan designed a high-altitude, long endurance aircraft for telecommunication, atmospheric sampling & Earth monitoring science missions. Named Proteus after the mythological Greek sea-god who could change his appearance at will, it features an unconventional tandem-wing, twin-boom configuration with two rear-mounted turboprops on the fuselage. Its modular construction allows payloads to be carried in a variety of locations. Removable tip sections can be added to or removed from the rear wing or the forward canards to tailor the Proteus' aerodynamics for various external payloads or for maximum altitude.



The main landing gear is set wide apart to allow large payloads to be carried externally under the fuselage. Mainly built with epoxite graphite composite materials except for the left wing tip is made of glass fiber to make it radio transparent, it is designed for extreme reliability. With the Rutan trademark of Canard, Proteus takes off and lands in a characteristic three-point attitude. With short take-off and landing rolls, it can be operated from regional airports. Normally flown by two pilots in a pressurized cabin, the Proteus has potential to perform its missions semi-autonomously.

In October 2000, the Proteus set three world altitude records during envelope-expansion flights over California's high desert. The records were certified by the Swiss-based international aviation record certification agency Federation



Aeronautique Inter-nationale. The first records were for a peak altitude of 63,245ft and sustained

horizontal flight at 62,385ft. On a second flight, the Proteus reached a peak altitude of 55,994ft while carrying

a (2,200lbs.) payload. All three records were certified for aircraft in the Class C-1E, Group III with gross weights of 12,500 lbs. or less.

Proteus continues to participate in the scientific missions of NASA and has supported the International Atmospheric Science community. In April 2003, Proteus flew as a surrogate UAV in a follow-on “Detect, See and Avoid” flight demonstration for NASA involving both cooperative and non-cooperative (non-transponder-equipped) target aircraft.

On April 18, 2003, in Mojave, Calif., Rutan unveiled his mega plan - Private travel into space—at an affordable cost. His space system was designed to achieve sub-orbital space travel, and

win the \$10-million “X-Prize” offered to the creators of the first private vehicle to accomplish such a feat. It comprised of a three-person craft “Spaceship One” which will be taken up to 52,000ft by another carrier aircraft called the White Knight under its fuselage.



Spaceship One



The White Knight and Spaceship One have almost identical cockpits and share system components. The cockpit is quite unique as can be seen in the picture.

Once clear of the aircraft, Spaceship One fires its single rocket engine and

climb steeply. The engine burns for over a minute, putting the spacecraft on a trajectory to reach an altitude of 100Km, a widely accepted boundary between the earth’s atmosphere and space. After passing through its peak altitude, Spaceship One will quickly descend, again on a steep trajectory.

The spacecraft also has a unique feature to deal with

the heat of reentry: the trailing edge of its wings, and the twin tail sections attached to them, rise from the horizontal to nearly the vertical position.

On Jun.28, 2003, the 60th birthday of Burt Rutan was celebrated at Mojave, California in a unique way. About 100



Spaceship One under White Knight One in flight



Boomerang at Rutan's 60th birthday bash



Flock of Long-Ez at Rutan's 60th Birthday



pilots flew to Mojave in Rutan designed canard aircraft, mainly Long-Ez.. The pictures below tell it all - A flock of Long-Ez with their nose down is virtually saluting the master who created them and the men & women who touched the skies with these machines saying THANKS BURT.

A year later, on Oct.4, 2004, Spaceship One demonstrated its capability for sub-orbital space flight and was awarded Ansari X-prize, yet again demonstrating the genius of Burt Rutan and his Scaled Composite team. Rutan said "Manned space flight is not only for governments to do. We proved it can be done by a small company operating with limited resources and a few dozen dedicated employees. The next 25 years will be a wild ride; one that history will note was done for everyone's benefit." Spaceflight was no longer the exclusive realm of government and with that single flight, and winning \$10 million Ansari X PRIZE, a new industry was born.

Around the same time, Rutan designed a jet power aircraft exclusively for uninterrupted circum-navigation of the globe. Called the GlobalFlyer, it had twin tail booms mounted outboard of a shorter central fuselage pod. The pressurized cockpit located in the front fuselage provided 7 feet of space for the pilot to sit. A single turbofan engine is

mounted on the aft fuselage several feet behind the cockpit. The outboard tail booms contain large fuel tanks and end in tail surfaces. The entire construction was of Carbon Fiber Reinforced Composites. The fuel distributed among thirteen tanks comprised 83% of the take-off weight. The wing span was 114 feet.

Sponsored by Richard Branson's airline-Virgin Atlantic, the aircraft was built by Scaled Composites, and owned by pilot Steve Fossett. Hence, the name Virgin Atlantic GlobalFlyer.

Following solo test flights in Jan.2005 at Mojave, California, GlobalFlyer was moved to Salina Municipal Airport in Salina, Kansas. On Feb.28, 2005, Steve Fossett tookoff on a solo nonstop airplane flight around the world and completed on Mar.3, 2005. He took 67 hours and 1 minute and set the Absolute World Record for the fastest nonstop unrefueled circumnavigation, beating the mark set by the previous Rutan-designed Voyager.

In Feb. 2006, Steve Fossett carried out a second circumnavigation to break the Absolute Distance Without Landing Record for airplanes and to exceed the longest distance by any kind of aircraft. On Feb.8, 2006 GlobalFlyer took off and flew eastbound from Kennedy Space Center, and landed after 76hr. and 45min. with an official distance

of 25,766 miles. A month later, Steve Fossett flew the GlobalFlyer for the Absolute Distance Over a Closed Circuit record which required the aircraft to take off and land at the same place and the distance measured over verifiable waypoints. Fossett started in Salina, Kansas on Mar.14, 2006 and flew eastbound around the world. Upon leaving Japan he flew south and then tracked along the Equator in order to maximize the distance while crossing the Pacific Ocean. He landed in Salina, Kansas on Mar.17, 2006 after traversing a total of 25,294 miles to set a new Absolute Distance Over a Closed Circuit Record.

The GlobalFlyer is now on permanent display at the Smithsonian Institution National Air and Space Museum Steven F. Udvar-Hazy Center adjacent to Washington Dulles airport.

Success of Spaceship One paved way for White Knight Two and Spaceship Two. These are almost double the size of White Knight One and Spaceship One, and the stamp of Rutan design is obvious. Developed for Virgin Galactic, Spaceship Two is under developmental test flights and will shortly usher-in the era of commercial space travel.

Burt Rutan retired from Scaled Composites on Mar.31, 2011, and is enjoying a retired life at his new home in Idaho. He had health issues. In 2009 he suffered from constrictive pericarditis, which nearly killed him. He has a defibrillator implanted in his chest which he calls his "stand by ignition system". Fortunately, there has never been a need for it to fire.

During his career Burt Rutan has come up with 367 concepts. Forty-five of his concepts have flown. Rutan says some of the concepts that have not seen the light of day are being saved for his biography. May the spirit of Canard Guru continue.

Photo Credits: Scaled Composites.



# Aviation Maintenance: HAZARDS IN THE WORKPLACE

Aviation is an unforgiving industry. One slip, one mistake, and people's lives are never the same again. Have you encountered the apathetic employee? Negative? Or has the 'I don't care' attitude? What is your goal in aviation? Is it just to get through your day and collect a paycheck? If so, you chose the wrong profession.

The goal of every mechanic, inspector, and support personnel should be the safety of the aircraft. If not today, then one day, someone you know will fly on the airplane on which you are working. Does that put a lead ball in the bottom of your stomach? Or, are you satisfied the aircraft maintenance is at a proficient level to keep those you love safe?

What do you do that contributes to increase or decrease risks in the workplace? In this article, we will look at aviation maintenance human factors, attitudes, and habits of a safe mechanic.

## Human Factors:

The definition of aviation maintenance human factors is the application of science and engineering to ensure that people can work safe and efficient. Some of the aviation maintenance human factors are qualifications, training, motivation, safety, professionalism, capabilities, and limitations. The Federal Aviation Administration (FAA) has a training video that talks about this and uses the word PEAR as an acronym to

assist aviation personnel in remembering human factors.

- **P – people**
  - o psychological – attitude, aptitude, training, mental fitness to duty, etc
  - o physical – gender, physical fitness, size, strength, vision, etc
- **E – environmental**
  - o social technical – management/employee relationship, job security, safety culture, etc
  - o physical – proper clothing, lighting, cooling/heating, correct tools for the job, etc
- **A – actions**
  - o objectives of the job, tasks – singular



or multiple, skills, number of people, acceptable standards

- **R – resources**

- o technical manuals, tools, time to complete the job, training for the job, etc.

PEAR is an excellent way to remember the maintenance human factors that are involved in a technician’s daily life.

Listed below are some examples of real life instances that led to either injury or death to aviation maintenance personnel.

- 1) Mechanics placed on mandatory ten to twelve hour work shift for thirteen days straight and one day off. This schedule was ongoing for over six months. A supervisor left work, fell asleep while driving, crashed, and was pronounced dead at the scene of the accident. He left behind a wife and six children at 44 years old.
- 2) An avionics technician needed to perform a check. He noticed a circuit breaker that he needed closed was open and collared. He

removed the circuit breaker tag, pushed in the breaker, and almost injured another mechanic as a flight control moved with him near it. The mechanic received disciplinary action, and the almost injured mechanic had to go home due to his anger towards the other mechanic.

- 3) A mechanic needed to turn on hydraulics. He followed the safety procedures in place for the company. An avionic tech was working inside a bay that housed some hydraulic lines. The mechanic turned on hydraulics. A line capped with a plastic plug, under high pressure, shot the plug out, and hydraulic fluid covered the avionic technician. Another mechanic led the avionic technician to the emergency shower to rinse the hydraulic fluid off, and he suffered from blurred vision for several days.
- 4) Avionic Tech A was working near a HF antenna. An inexperienced Avionic Tech B resets a circuit breaker that Avionic Tech A tagged for safety. Avionic Tech A

received a shock. When recovered, in anger, he ran to the flight deck, and Avionic Tech A proceeded to beat Avionic Tech B until other mechanics were able to pull Avionic Tech A off. Avionic Tech A and B were both fired.

- 5) Overnight, ice covered the ramp. Two mechanics took golf carts to race. One flipped over, injuring one mechanic and damaging the golf cart.

Human factor, simply defined, is about doing the right thing all the time, not only when it is easy. If you do not know, ask. If you are in doubt, ask. If you are not trained, then do not do the job until you receive proper training. If pressured to cut corners, be confident enough to say no.

### Attitude

Next, let us talk about attitude.

“Attitude is a little thing that makes a big difference.” – Winston Churchill.

How many times have you, as a mechanic, walked up to another mechanic and pointed out an unsafe condition? What propelled you to do so? What stopped you from doing so? What was their reaction? With fifteen years of aviation maintenance experience, I have personally seen more people allow their fellow mechanic to practice unsafe behavior, than to confront them.

Common reactions for the mechanic who does point out the hazard are: a) it is not important, (b) I will not get hurt, (c) worry about yourself, not about me.

When it comes to Personal Protective Equipment, PPE, it is everyone’s business. Wearing safety glasses, hearing protection, gloves, face shields, and harnesses are steps in the right direction to eliminate common injuries that occur in the workplace.

To get back to the basis, consider the ABC’s penned by Wanda Hope Carter –

- A - Avoid negative sources, people, places, things, and habits.
- B - Believe in yourself.
- C - Consider things from every angle.
- D - Don't give up and don't give in.
- E - Enjoy life today – yesterday is gone, tomorrow may never come.
- F - Family and friends are hidden treasures – seek them and enjoy their riches.
- G - Give more than you planned to.
- H - Hang on to your dreams.
- I - Ignore those who try to discourage you.
- J - Just do it!
- K - Keep trying, no matter how hard it seems, it will get easier.
- L - Love yourself first and most.
- M - Make it happen.
- N - Never lie, cheat, or steal – always strike a fair deal.
- O - Open your eyes and see things as they really are.
- P - Practice makes perfect.
- Q - Quitters never win, and winners never quit.
- R - Read, study, and learn about everything important in your life.
- S - Stop procrastinating.
- T - Take control of your own destiny.
- U - Understand yourself in order to better understand others.
- V - Visualize it.
- W - Want it more than anything.
- X - 'Excel-lerate' your efforts.
- Y - You are unique of all God's creations, nothing can replace YOU.
- Z - Zero in on your target and go for it!

### Habits of a Safe Mechanic

From personal experience and observations, here are twenty habits to practice every day.

- 1) Go to work with the goal of returning home with no injuries.
- 2) Keep in mind the safety of those who will be flying on the aircraft you are working.
- 3) Do not compromise safety.
- 4) Be able to tell your boss "No" when it comes to procedures that put either the passengers, flight crew, or maintenance personnel in a safety risk.
- 5) Use personal protection equipment habitually.
- 6) Teach younger maintenance personnel the importance of using personal protection equipment.
- 7) Do not be afraid to confront those who are practicing unsafe habits.
- 8) Clean as you go. Air hoses, electrical cords, spills, metal shavings, foreign object debris.
- 9) If you find an easier or better way of doing a job, communicate that with your boss or six-sigma coordinator.
- 10) Be proactive instead of reactive to situations.
- 11) Never stop learning.
- 12) Learn to work well with others.
- 13) Enjoy your job.
- 14) Know the regulations.
- 15) Don't rush a job.
- 16) Know the difference between being arrogant and confident. Leave your pride outside the facility.
- 17) Every small problem needs to be addressed.
- 18) Focus on the task even if that means turning off electronic distractions.
- 19) Attention to details – in the task and in the paperwork.
- 20) Work as if someone's life depends on it – because it does.

In conclusion, hazards in the workplace are unavoidable. However, being proactive by taking steps in learning how to reduce the risks falls to the individual mechanic. Be aware of your surroundings. Be conscientious of using personal protection equipment. Watch the back of your fellow mechanic. Blow the whistle on unsafe maintenance practices. The life you save from injury or death may be your own, your family, or your friends. Safety is no joking matter. A crash in the aviation field affects us all. We have to work together by utilizing human factors, attitude, and safe habits to prevent disasters from occurring.

Together we work safe; together we fly safe.



**K-Trina Meador** is a Quality Inspector located in Oklahoma. She holds her airframe and powerplant license and her Federal Communication Commission certificate. She has served as an aircraft mechanic, avionics technician, and quality inspector since 1999. Airframes worked include Saab 340, Embraer 135/140, KC135, P-3, King Air 200, Gulfstream 550/650, Boeing 737 and 787, MD80, Beech 1900, Caravan 208 and CRJ 200/900. In addition, she is an author of six fiction titles penned under the name K. Meador.



Air Cmde Sajjad Rahim VSM (Retd.)  
Hindustan Aviation Academy  
Director (Academics)

## CAREERS IN AVIATION

You can aim for the unexplored, the unveiled, and the spaces above and beyond. You can create an entire new horizon for yourself. Still amongst the better paid and more attractive jobs going, in popular expectation the profession has special mystique attached to it, whether on ground or in the air. Those who succeed in realising the almost universal childhood dream are generally a pleased lot. Although the employment scenario has not been so encouraging in the last decade, there is a wave of change sweeping the civil aviation sector and the entry of new private and international airlines is throwing up new opportunities.

If a person has a scientific bent of mind, he can opt for a career as a pilot, aircraft maintenance engineer, a design engineer etc. And if a person is good at communication, he can consider a career as air hostess or flight steward or in customer care. The other lesser

known but exquisite job profiles also exist.

The Aviation careers can be classified into; careers in the air and careers on the ground further these could be in civil aviation or in military aviation. Careers in the air in the civil aviation could be either in the cockpit or in the passenger cabin. The cockpit crew constitutes, pilot, who could be captain or second officer i.e. co-pilot, and a flight engineer. A commercial pilot flies an aircraft carrying passengers or cargo or both. Most commercial pilots are employed by national or private airlines. There are corporate houses those have their own aircraft. Pilots are also employed for agricultural work such as seeding and spraying.

The cabin crew constitutes, air hostess, steward and purser, they are responsible for not only taking care of the passengers but to ensure that all cabin systems are operated as per the direction of the

captain. Train the passengers in the use of emergency system, ensure cabin discipline. An air hostess and a steward with 5 yrs experience can become a purser.

To become a pilot or cabin crew one has to have aptitude. To become a pilot a person must be passionate to fly, have good coordination of mind and limbs. He should remain calm in emergency, be patient, should have commitment, confidence and shoulder responsibility. Have emotional stability, adaptability, stamina, team spirit and capacity to work hard. Aptitude for cabin crew include common sense, sense of responsibility, initiative, outgoing friendly personality, courtesy & politeness, physical stamina and capacity to work for long hours on feet.

Various careers in civil aviation on the ground exist. They may or may not be so well known. They all compliment the airline jobs. These are; Aircraft



maintenance Engineer, Airport Staff, Reservation & Marketing, Customer Support, Air Traffic Controller. The tasks revolve around a safe and structured air-borne journey for the passengers.

The whole aviation activity begins with the design & manufacturing of an aircraft. The personnel involved have to be suitably qualified with engineering degree. In India these are under PSUs or DRDO. Organisations viz; ADA, ADE, GTRE, NAL and HAL are actively involved in this area. The Aeronautical Engineers are also needed by Space organisation ISRO and the Defence Laboratories DRDL. There are many private corporate houses those have entered the aviation sector in design and manufacture as well as operations.

The demand for quality is very high in aviation. To ensure quality, there are organisations which monitor every stage of manufacture, maintenance and operation to ensure compliance of laid down procedure and guide lines. The Director General of Civil Aviation, in India is the regulatory body entrusted with this task. Another regulatory body is the Airport Authority of India, which

manages the airports. The Centre for Military Airworthiness and Certification CEMILAC and DGAQA are likewise responsible for quality monitoring in defence.

Apart from the openings in civil aviation sector there are openings in the military aviation. Not only the Indian Air Force but Indian Army, Indian Navy, Cost Guards, BSF have openings.

In the Indian Air Force one can join in the flying branch or ground duty branch. In the Flying branch as a cockpit crew the options are; flying pilot and flying navigator. As a ground duty officer, the openings are in technical, administrative, logistics, accounts, metrology and medical branches. The technical officer can also opt to fly as flying pilot, flight engineer, flight signaller or flight gunner. An administrative officer can become an air traffic controller or a fighter controller. In the lower cadre also there are openings in various trades

In the Indian army, the Army Air Corp takes officers as helicopter pilots for their communication duty as well as technical officers with engineering degree for helicopter maintenance and technicians in the lower cadre.

The Indian Navy commissions officers in their Executive branch as pilot and observer and in the technical branch as maintenance engineers. As in the IAF and Army lower cadre employment is available.

The Coast Guard and BSF require air crew for merry time petrol and movement of their personnel in case of urgent moves respectively.

Aviation brings immense benefit to the community and economy. The air traffic in India is increasing at a tremendous pace. The Tata SIA joint venture of more the \$100 m and Jet Etihad deal \$900m as well as FDI participation of 49% in aviation will do well to this sector. India is the 9th largest aviation market handling 121m domestic and 41m international passengers. Govt initiative of new green field airports and modernisation of the existing airports will attract more to aviation.

The eligibility and remuneration for various jobs can be known from the respective sites of the organisations and are dynamic hence not given here. The purpose of this article is only to let the interested know the various options available.

# Aviation

## PHOTOGRAPHY

Dr. M.S. Rajamurthy

Aviation photography is all about the passion for those magnificent flying machines and the appreciation of their beauty. It blends the love for these machines with the artistic skill of the photographer in bringing out pictures that tell their own stories. Innumerable aviation photograph sites on the internet are a testimony to this.

It is amazing that these sites add a few hundred photos every day to their collection. This is understandable when one realizes the possibilities that aircrafts present. The beauty of the aircraft is that the same machine has different looks through different color schemes and logos. This is more so with civilian transport aircraft of different airlines. It is not just those looks, the engineering that makes these machines, be it the shape of wings, those giant landing gear wheel bogies, the control surfaces on the wings each adds up. The atmospheric condition

— the bright blue sky, clouds, evening sky with a flash of colors all add to

the drama of an aircraft flying, which inspires the photographer.

Most of the aviation photographers are plane spotters who enjoy identifying the aircrafts, their history and technical nuances associated with them. There are innumerable plane spotter groups across the globe. In India, too, we have the first officially recognized group — Aviation Photographers India Foundation.

In our country, till recently, photographing aircraft meant inviting some kind of trouble. Famous nature photographer of yester years, late Mr.C.Rajagopal.

FRCP., was fascinated by aircrafts and took up photography to take their pictures. But soon the restrictions took him away to nature photography. His fascination towards aircrafts continued through his life.

In the recent years, there has been a positive development and DGCA has issued specific notifications enabling general public to photograph aircraft at/near airport or from inside the aircraft. Mr. Devesh Agarwal of Bangalore Aviation, who is an accomplished aviation photographer, explains this very well in his article at their link <http://www.bangaloreaviation.com/2010/12/dgca-rules-on-taking-photographs-of.html>. This article also provides links to relevant DGCA notices.

Air Museums are great sources for aviation photography, particularly for those who are interested in history of aviation. HAL Heritage museum in Bengaluru houses many aircraft from its stables (their condition is not comparable to those elsewhere) and photography is permitted there. Many Air Force Stations have vintage aircraft





Following link is one such. <http://www.dpreview.com/articles/4293153502/> aviation-photography

Those who are serious about aviation photography can join Facebook group of Aviation Photographers India Foundation, India's first officially recognized plane spotting group. This group has accomplished photographers who can guide and help in attaining excellence in aviation photography.

standing guard at the entrances or inside.

Airshows present great opportunity for aviation photography. In India, we have two biennial shows, Aero-India held in Bengaluru and India Aviation held in Hyderabad. The former's focus is more on the military aviation, even though the civil aviation players participate. The India Aviation at Hyderabad is a total civil aviation event. As these two events are staggered, there will be an air show every year.

For aviation photography a good camera, preferably a Digital SLR with a set of lenses is required. While wide angle lens is required for photographing from close quarters or indoors, a longer focal length tele-zoom is required for capturing the aircraft in flight. DSLRs are sold with a normal zoom lens covering 27-80mm focal length and some brands offer kits with an additional lens covering 80-200mm. For good photos of aircraft in flight one needs a focal length around 300mm. Tripod or Monopod is an accessory that will be very useful.

While compact cameras come with good zoom capability, most of them lack a viewfinder. Viewfinder is a must for aviation photography as most of the time, aircraft are captured during takeoff/landing or in flight in bright daylight conditions.

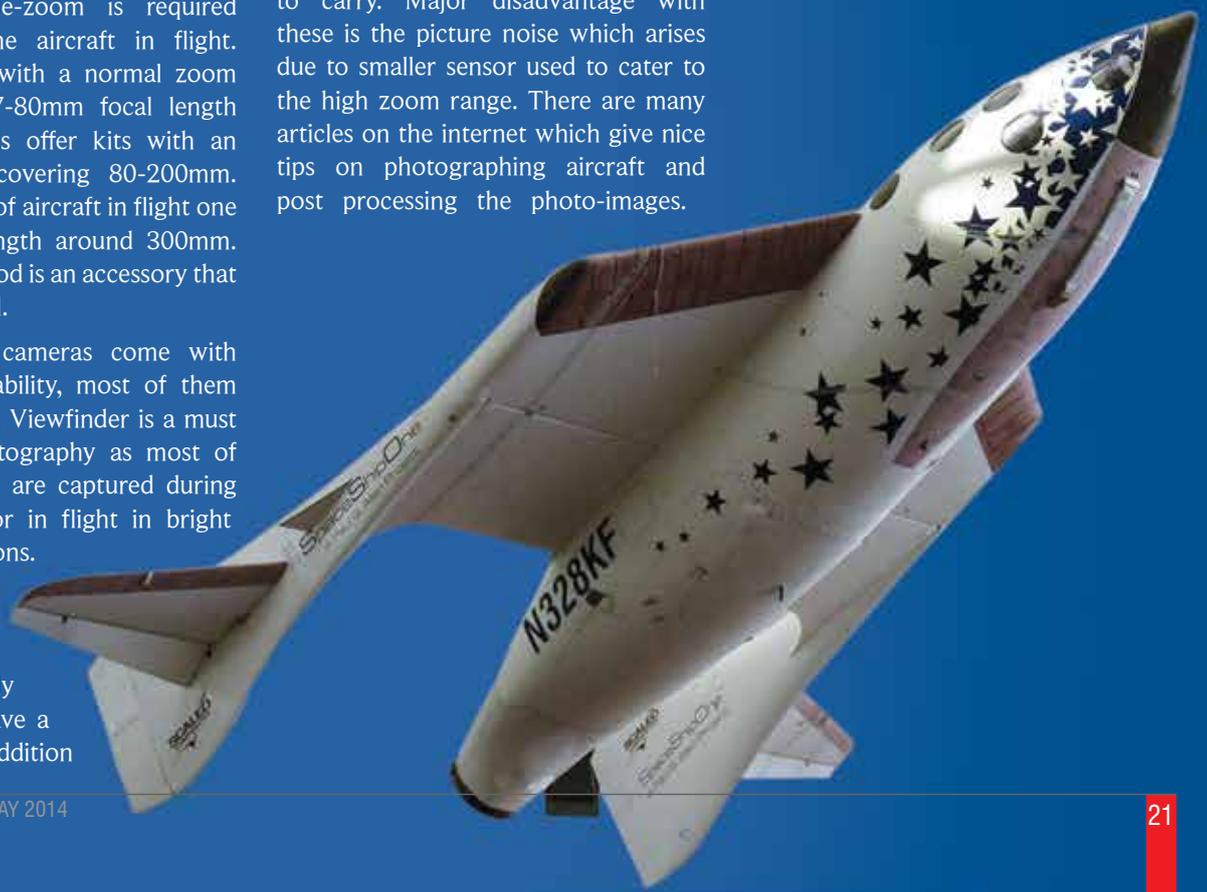
Compared to DSLRs, Bridge-cameras are relatively cheaper. They have a viewfinder(in addition



to the LCD display) and a fixed lens system with good zoom capability covering a range of 27-400mm and beyond. They are compact and easy to carry. Major disadvantage with these is the picture noise which arises due to smaller sensor used to cater to the high zoom range. There are many articles on the internet which give nice tips on photographing aircraft and post processing the photo-images.

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Photos by the author





# AERODYNAMICS of non-flying structures

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Hasnain Saleem

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For a very long time the science of aerodynamics has been conceived as one which limits its application to the understanding of the flow and the associated physics along and across bodies which are unique to the aerospace industry. While aerodynamics associated with the aircraft plays an astronomical role in estimating the degree of the aircrafts flying capability, the development of state of the art engines to drive high speed sports cars has made the incorporation of aerodynamics to maintain the cars performance while keeping the fuel consumption in check not only desirable but in most cases indispensable. With the population growth rate curve steepening every decade it is paramount that the knowledge from various fields of applied science and engineering is brought together in a manner which is so coordinated that the society we live realizes sustainability and robust

lifestyle. With this intention in mind many qualified researchers have taken keen interest in investigating the flow behavior in the vicinity of structures such as bridges, buildings etc.

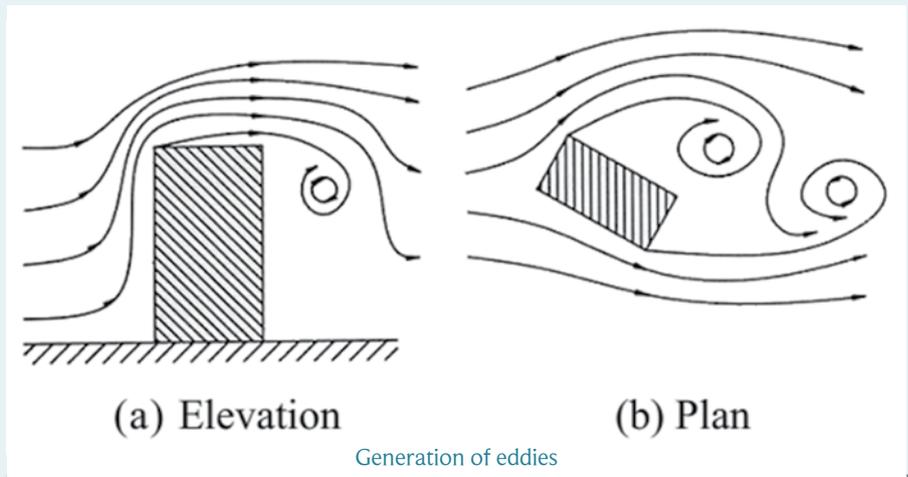
With urbanization on the rise, most developing countries have seen a shattering increase in the human population density particularly in major metropolitan cities. Accommodation of these people requires a change in the approach in the method adopted to build and maintain structures which house these people. Emerging issues are not merely concerned with wind hazard mitigation but also extend prohibitively in domains of pollutant flow behavior both in close vicinity and far field of buildings, pedestrian comfort, internal flows which are central in establishing and maintaining an efficient ventilation system etc. the need to realize a sustainable society as far as practically possible with the

ever-growing demand of the inflating population requires the design of building structures to be approached from an aerodynamic standpoint. The science that investigates the effects and hazards of wind flow along and across structures such as bridges, tall buildings is termed as industrial aerodynamics. With increasing number of major metropolitan cities using tall, slender buildings as crowning jewels of their architectural civilization the limits imposed on structural integrity and complex fluid structure interaction have been pushed ever so far. A major driver in these sciences is the optimum spacing of the building structures, while the usual norm is to maintain one building spacing across all sides of a building, relative change in the orientation of the building with respect to its surrounding and the incoming velocity profile has been an effective solution against the formation of low pressure or suction

regions between closely spaced building of near identical geometry.

Most buildings in aerodynamic literature are referred to as bluff bodies. The flow past these bodies is characterized by turbulent flow separation in their wake associated with increased values of drag forces brought on by the incoming wind. The problem is escalated by close arrangement of neighboring buildings which tend to the formation of low pressure or suction regions which under adverse wind conditions could have an unpleasant effect. Simple quasi-static treatment of wind loading, which is universally applied to design of structures unique to aerospace industry, can be unacceptably conservative for design of buildings. On the other hand such simple treatment can easily lead to erroneous results and under-estimations.

Wind is a phenomenon of great complexity because of the many flow situations arising from the interaction of wind with structures. Wind is composed of a multitude of eddies of varying sizes and rotational characteristics carried along in a general stream of air moving relative to the earth's surface. These eddies give wind its gusty or turbulent character. The gustiness of strong winds in the lower levels of the atmosphere largely arises from interaction with surface features. The average wind speed over a time period of the order of ten minutes or more, tends to increase with height, while the gustiness tends to decrease with height. Unlike the flow across streamlined bodies where every degree of care is taken to minimize flow separation to elevate the aerodynamic efficiency, flow across building structures is highly complex in the sense that the

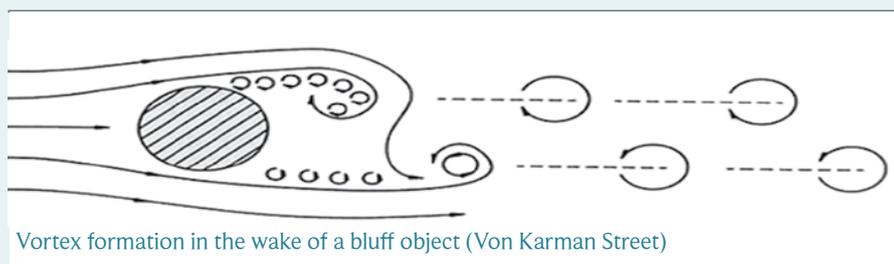


variation of primitive flow field variables is not limited to the streamline or flow direction but is uncomfortably significant in directions perpendicular to the flow. Major characteristics of the flow across buildings are increased Reynolds number, periodically shed row of alternating vortices (Von Karman street).

A consequence of turbulence is that dynamic loading on a structure depends on the size of the eddies (vortices). Large eddies, whose dimensions are comparable with the structure, give rise to well correlated pressures as they envelop the structure. On the other hand, small eddies result in pressures on various parts of a structure that become practically uncorrelated with distance of separation. Eddies generated around a typical structure are shown below

A little understanding of basic flow mechanics would show that the flow across building structures is essentially turbulent and at least up to a certain altitude highly gusty. As shown above the flow remains fairly steady until it reaches a certain critical separation distance upstream of the building. Flow separation is seen as the flow negotiates

across the sharp building corners leading to the formation of periodically shed row of alternating vortices. These vortices generates whirling winds of significant vorticity caused due to local flow acceleration immediately in the building wake. The elevated values of flow velocity results in a corresponding depression in the local pressure thereby creating suction (Bernoulli's principle). Another important consequence of the shedding of these vortices or eddies as they are commonly called is the generation of a resultant force perpendicular to the plane in which these eddies are shed. The theoretical foundation of this phenomena is commonly used to justify the generation of lift by an airfoil and is referred to as the Kutta -Joukowski's theorem. The theorem is used to predict the magnitude of the lift force a given flow would generate with a given incoming free stream velocity and vortex strength or circulation. Circulation being highly dominant in the building wake causes generation of such forces which may cause personnel inconvenience leading to a feeling of breathlessness due to formation of low pressure or suction regions coupled with transition of wind masses of different flow rates. The degree of the criticality of the said situation can be conveniently expressed in terms of the values of the coefficient of pressure at predetermined locations which may be desirable and crucial from



an aerodynamic standpoint. These have lead many major town planning studies to incorporate wind flow investigation.

A rather common problem associated with extremely tall or slender structures is their tendency to sway with low but sustained amplitudes. The determination of the natural frequency of oscillation of these building which characterizes its static and dynamic response forms the major part of the design process which aims at maintaining the static and dynamic stability of these buildings. These structures respond dynamically to the effects of wind in a manner that causes the structure to twist and flex with one assisting the other the coupling can be highly dangerous eventually causing a structural collapse. The best known structural collapse due to wind was the Tacoma Narrows Bridge which occurred in 1940 at a wind speed of only about 19 m/s. It failed after it had developed a coupled torsional and flexural mode of oscillation. The dynamic response of a building in an event of inertial coupling is beyond the scope of this article and hence will not be attempted.



Development of computational techniques has helped widen the horizon of understanding of the flow behavior and the prevailing physics.

While the effect of varying wind incidence, inclined building geometry and cluster spacing on the severity of the vortex shedding phenomenon remains to be seen, the accomplishment of such an endeavor would require seemingly close and physically feasible validation by experiments typically conducted in a wind tunnel. A wind tunnel is a tool used in aerodynamic research to study the effects of air moving past solid objects. A wind tunnel consists of a closed tubular passage with the object under

test mounted in the middle. A powerful fan system moves air past the object; the fan must have straightening vanes to smooth the airflow. The test object is instrumented with a sensitive balance to measure the forces generated by airflow which may have smoke or other substances injected to make the flow lines around the object visible.

In totality the current trends in industrial aerodynamics are highly exciting and challenging where the need to continuously evolve the science to comprehend the flow characteristics to realize a sustainable society goes without saying.

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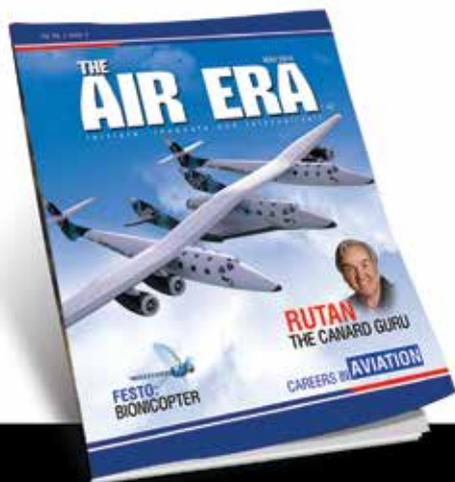
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# FESTO: BIONICOPTER

The BioniCopter is the latest robotic marvel from German technology firm Festo, a company known for the creation of numerous devices that mimic wildlife including birds, jellyfish and penguins. Meant to mimic the motions of a dragonfly the BioniCopter is capable of flying in all directions including backward, and can also hover indefinitely in the same spot. Festo is an independent company in its third generation of family ownership and is a worldwide leader in automation as well as a world market leader in industrial training and development. At Festo,

16,700 employees from 176 countries pursue a common goal: the maximum productivity and competitiveness of the customers in factory and process automation.

## New innovations with bionics

The BionicOpter was developed as part of the Bionic Learning Network. Together with colleges, universities and development companies, Festo has spent many years developing and supporting projects and test models whose basic technical principles are derived from nature. After bird

flight had been deciphered with the SmartBird, the developers took on their next-biggest challenge: modelling the dragonfly at a technical level – with even more functions and even less weight.

## A natural model for flight

With the BionicOpter, Festo has applied these highly complex characteristics to an ultra-lightweight flying object at a technical level. For the first time, there is a model that can master more flight conditions than a helicopter, plane and glider combined. In addition to controlling the flapping frequency and the twisting of the individual wings, each of the four wings features an amplitude controller. This means that the direction of thrust and the intensity of thrust for all four wings can be adjusted individually, thus enabling the remote-controlled dragonfly to move in almost any orientation in space. The intelligent kinematics corrects any vibrations during flight and ensures flight stability both indoors and outdoors.





### Thirteen degrees of freedom for unique flight manoeuvres

A motor in the bottom part of the housing provides the drive for the common beat frequency of the four wings, which is adjustable between 15 and 20 Hz (1st degree of freedom).

Like a real dragonfly, the BionicOpter's wings can be turned from horizontal to vertical. Each wing is individually actuated by a servo motor during this process and twisted by up to 90 degrees (2nd, 3rd, 4th, 5th degree of freedom).

Four motors at the wing joints control the amplitudes. A linear movement in the wing root infinitely adjusts the integrated crank mechanism to vary the deflection between approximately 80 and 130 degrees (6th, 7th, 8th, 9th degree of freedom).

The swivelling of the wings determines the thrust direction. The thrust intensity can be regulated using the amplitude controller. The combination of both enables the dragonfly to hover on the spot, manoeuvre backwards and transition smoothly from hovering to forward flight.

The last four degrees of freedom are in the head and tail. The body of the dragonfly is fitted with four flexible muscles made of nitinol. These shape memory alloys (SMAs) contract when exposed to heat and expand when they cool down. Passing an electric current through the SMAs produces ultralight actuators that move the head

### Integration of functions in the smallest of spaces

The unique flight behaviour is made possible by the lightweight design of the model dragonfly and the integration of its functions: sensors, actuators and mechanical components as well as communication, open and closed-loop control systems are installed in a very small space and connected to one another.

### Highly complex system with easy operation

Despite its complexity, the highly integrated system can be operated easily and intuitively via a smartphone. The flapping frequency, amplitude and installation angle are controlled by software and electronics; the pilot just has to steer the dragonfly – there is no need to coordinate the complex motion sequences.

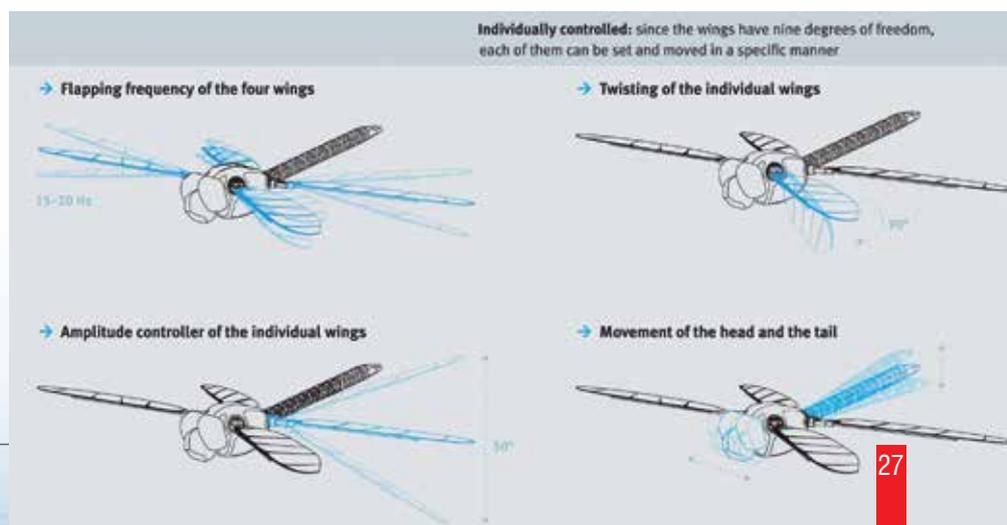
### Dynamic flight behaviour in all directions in space

Up and down, forwards, backwards and to the side: the flapping wing design of the BionicOpter enables it to fly in all directions in space and hover in mid-air just like a helicopter. Unlike a helicopter, however, the dragonfly does not need

to tilt forwards to generate forward thrust. This means that it can fly horizontally as well as float like a glider. Its lightweight design means it is able to start autonomously.

### Open and closed-loop control on board

All these manoeuvres can be executed with ease using a smart- phone. During operation, the remote-control system simply transfers the signals that tell the object which direction to fly in and at what speed. The microcontroller calculates all the parameters that can be adjusted mechanically based on the recorded flight data and the pilot's input. The processor actuates the nine servo motors to translate these parameters into movement using beat frequency, a swivel device and the amplitude controller.



horizontally and the tail vertically. (10th, 11th, 12th, 13th degree of freedom)

### Process reliability through condition monitoring

In order to stabilise the flying object, data on the position and the twisting of the wings is continuously recorded and evaluated in real time during the dragonfly's flight. The acceleration and tilting angle of the BionicOpter in space can be measured using the inertia sensors. The integrated position and acceleration sensors detect the speed and spatial direction of the dragonfly's flight.

For Festo, the principle of continuous diagnostics is a guarantee of operational reliability and process stability – whether in bionic flying objects or everyday industrial use.

As a global manufacturer of pneumatic and electric automation technology, Festo's core business is helping to shape the production and working environments of the future and offers its customers innovative solutions for the production systems of tomorrow and beyond.

### Materials used

Wing structure	Carbon-fibre rod
Wing surface	Polyester membrane
Housing and mechanical system:	Aluminium, polyamide (sintered) and terpolymer (deep-drawn ABS)



### Technical data:

Beat frequency	Between 15 and 20 Hz
Wingspan	63 cm
Body length	44 cm
Weight	175 grams
Degrees of freedom	13
Processor	ARM microcontroller
Motor	1 brushless VS external rotor
Wing actuation	8 servo motors
Head and body actuators	4 shape memory alloys (SMAs)
Sensors	Inertia, acceleration and position sensors
Battery	2 LiPo cells, 7,6 volts
Wireless modules	2.4 GHz spectrum
Wireless remote control	Smartphone or digital spectrum transmitter

#### Project initiator:

Dr. Wilfried Stoll, Managing Partner, Festo Holding GmbH

#### Project team

##### Project management:

Dr.-Ing. Heinrich Frontzek

Dipl.-Des. Elias Knubben, Festo AG & Co. KG

##### Scientific support:

Dr. rer. nat. Nina Gaissert, Festo AG & Co. KG

##### Design and manufacture:

Rainer Mugrauer, Günter Mugrauer

Effekt-Technik GmbH, Schlaitdorf

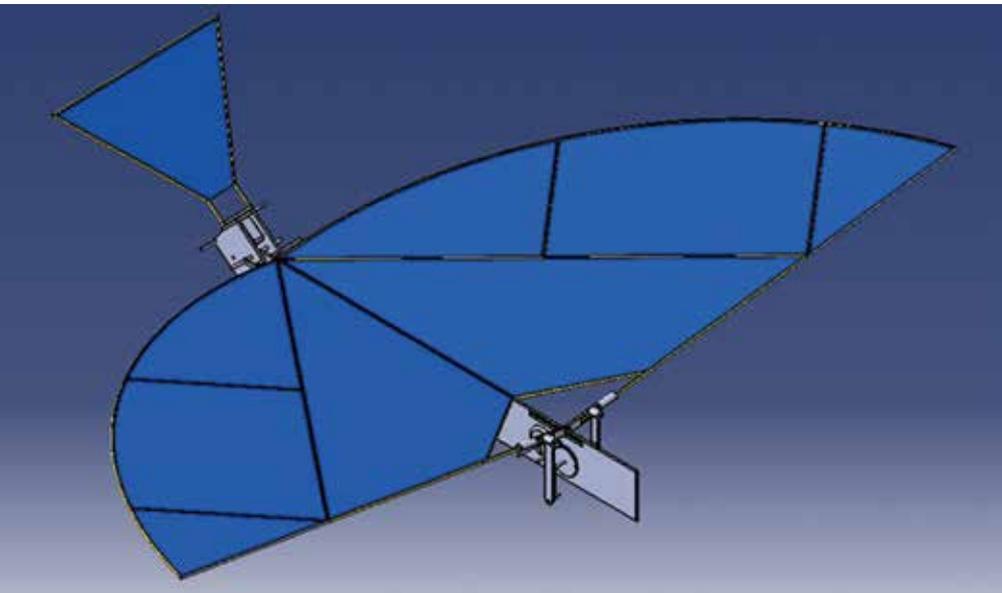
##### Electronics and integration:

Dipl.-Ing. Agalya Jebens,

Dipl.-Inf. Kristof Jebens, JNTec GbR, Gärtringen

# ORNITHOPTERS:

## HUMAN ATTEMPT TO FLY LIKE BIRDS



An Ornithopter is an aircraft heavier than air, which flies like a bird by flapping its wings. The special feature lies in the wings that do not only generate lift but also thrust.

The purpose of this project is to achieve humanity's oldest aeronautical dream: flight with mechanical flapping wings. Many early aircraft concepts assumed that such imitation of birds and bats was the proper design direction. However, the challenge of achieving both efficient lift and thrust with flapping wings was far greater than simply using the wings for lift and providing thrust with a separate propulsor. This notion, first articulated

by Sir George Cayley in 1799, provided the template for successful mechanical flight from the Wright Brothers to this day.

The notion of ornithopter flight became marginalized, although it continued to fascinate inventors and researchers as described in the History section. One of the reasons for this is that successful full-scale piloted ornithopter flight is one of the last great aeronautical records. Despite all of the amazing aerospace achievements since the Wright Brothers, such as hypersonic flight, voyages to the moon, and travelling around the world without

refueling, this ancient quest remains to be accomplished.

In recent years the subject of the flying vehicles propelled by flapping wings, also known as Ornithopters has been an area of interest because of its applications especially in military for surveillance. Ornithopters are the heavier than air aircrafts which fly like a bird by flapping its wings. Wing produces both thrust and lift in this case. This renewed interest has raised a host of new problems in vehicle dynamics and controls to explore.

When a bird is just gliding, it moves forward through the air, with its wings held in a fixed position. The wings are at a slight angle, so they deflect the air gently downward. Pushing the air downward causes a reaction force in the opposite direction. The reaction force is called lift. Lift is a force that acts roughly perpendicular to the wing surface and keeps the bird from falling. There is also air resistance or drag on the body and wings of the bird. This force would eventually cause the bird to slow down, and then it wouldn't have enough speed to fly. To make up for this, the bird can lean forward a little and go into a shallow dive. That way, the lift force produced by the wings is angled forward slightly and helps the bird speed up.

The slight angle of the wings is called the angle of attack. If the angle of attack is too great, the wing will produce a lot of drag. If the angle is too small, the wing won't produce enough lift. The best angle depends on the shape of the wing. The ornithopter wing usually consists of a thin fabric membrane, which takes on a curved or cambered shape, when it pushes against the air. Birds have more of a rounded leading edge to help reduce air resistance. The inner part of the wing, near the bird's body, is more curved than the outer part.

Take-off can be one of the most energetically demanding aspects of flight, as the bird needs to generate enough airflow under the wing to create lift. In small birds a jump up will suffice, while for larger birds this is not possible. In this situation, birds need to take a run up in order to generate the airflow to take off. Large birds often simplify take off by facing into the wind, and if they can, perching on a branch or cliff so that all they need to do is drop off into the air. Landing is also a problem for many large birds with high airspeeds. This problem is dealt with in some species by aiming for a point below the intended landing area (such as a nest on a cliff) then pulling up beforehand. If timed correctly, the airspeed once the target is reached is virtually zero. Landing on water is simpler, and the larger waterfowl species prefer to do so whenever possible and some species, such as swans, are only able to land on water. In order to lose height and velocity rapidly prior to landing, some large birds such as geese indulge in a rapid alternating series of sideslips in manoeuvres termed as whiffing.

In order to better study the control of flapping wing flight we propose to develop a large scale working model. We are aiming to fabricate a 29inch wingspan ornithopter with surveillance capabilities. It is capable of carrying heavy (above 500gms) computer, battery and sensor package and is

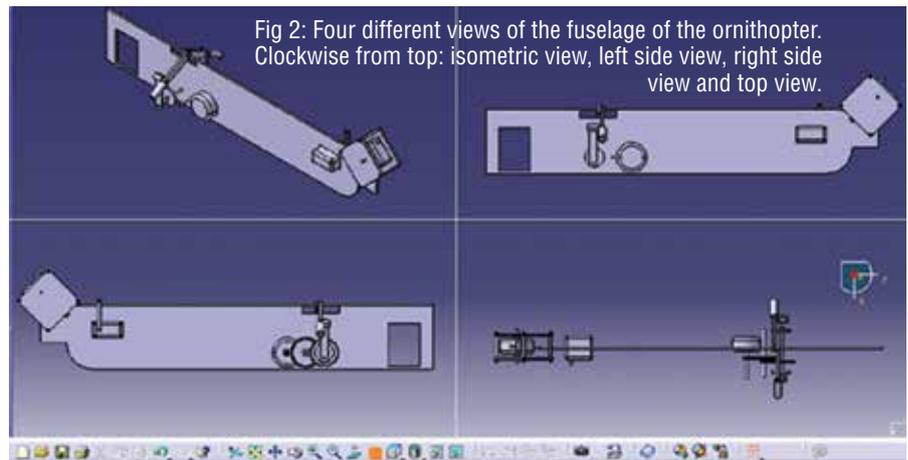


Fig 2: Four different views of the fuselage of the ornithopter. Clockwise from top: isometric view, left side view, right side view and top view.

designed especially for the application of reconnaissance, camouflage, and target practice and also for controls research. The increase in payload carrying capacity will be helpful for carrying out various other tasks. Fig 2 shows different views of the ornithopter fuselage designed by us. Fig 3 shows the top view of the complete assembly which includes fuselage, wing and tail.

Practical applications capitalize on the resemblance to birds or insects. The Colorado Division of Wildlife has used these machines to help save

the endangered Gunnison Sage Grouse. An artificial hawk under the control of an operator causes the grouse to remain on the ground so they can be captured for study.

Because ornithopters can be made to resemble birds or insects, they could be used for military applications, such as aerial reconnaissance without alerting the enemies that they are under surveillance. Several ornithopters have been flown with video cameras on board, some of which can hover and manoeuvre in small spaces.

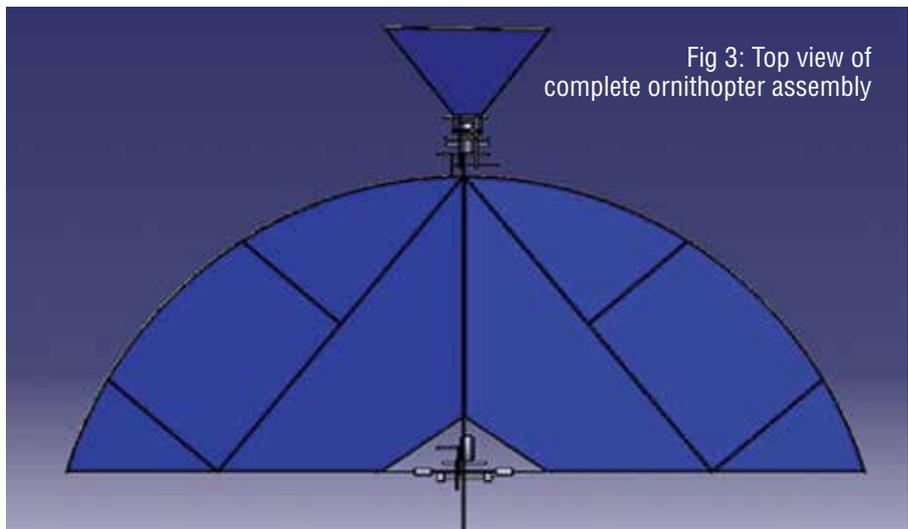


Fig 3: Top view of complete ornithopter assembly

Project by 8th Semester students MVJCE

Project team members:

Darshan R, Karthik C H, Nithin Kumar, Shabarish P R

Under the guidance:

M S Deepa Asst prof, Aeronautical Dept., MVJCE



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## **HINDUSTAN AVIATION ACADEMY**

P. B. No. 3776, Ashwathnagar, Marathahalli, Bangalore- 560037

Tel: 080 65467129, 65607448, 25238650, 25232217, 25225816, 25222554. Fax: 080 25232448

Email: haeas@rediffmail.com, contactus@evehans.com

www.hindustanacademy.edu.in

