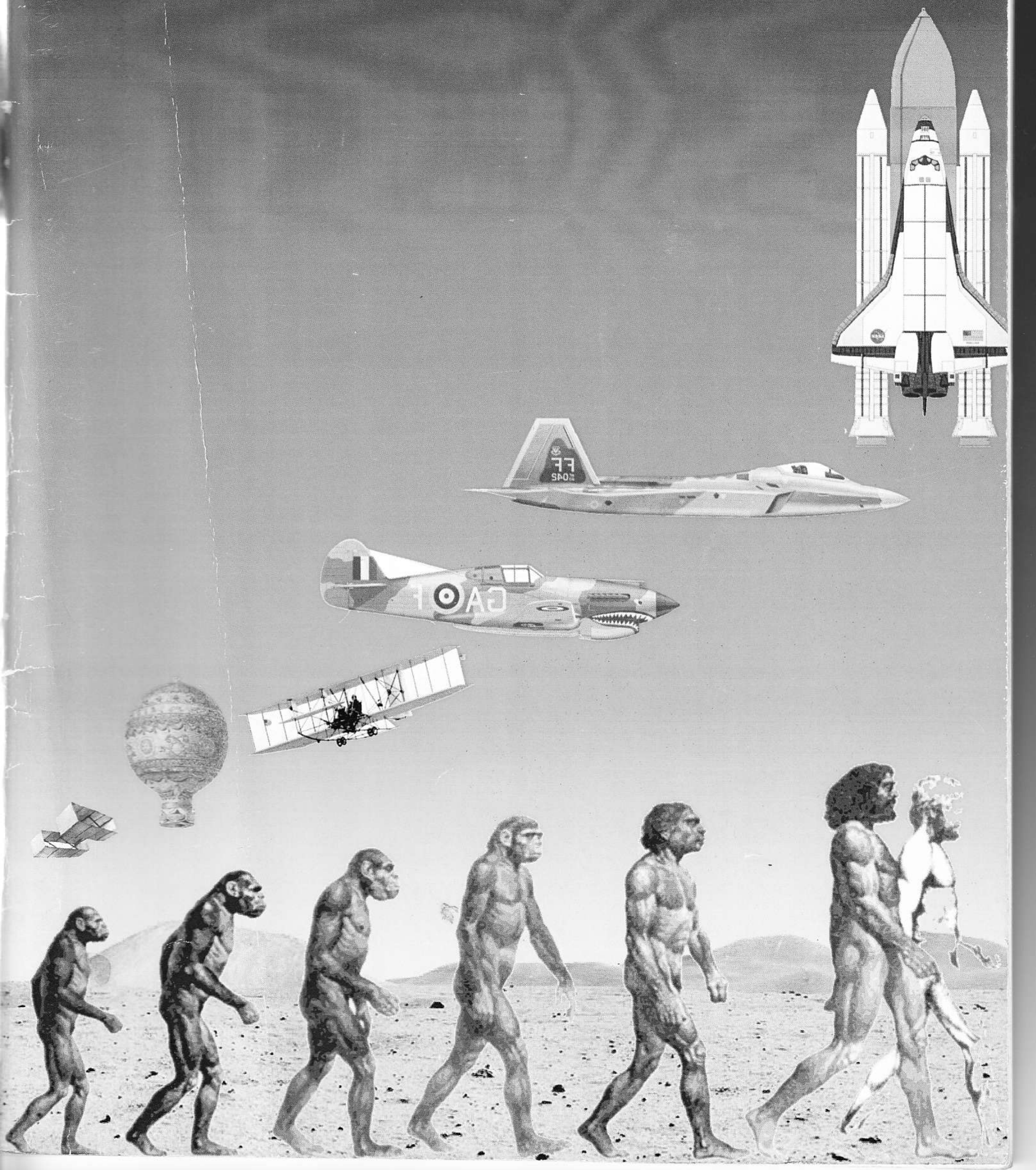
A. Galstyan
L. Zhuravlyova

AVIATION FUNDAMENTALS

STUDENT GUIDE ON PRACTICAL AND LABORATORY ACTIVITY



A. Galstyan, L. Zhuravlyova

AVIATION FUNDAMENTALS

STUDENT GUIDE ON PRACTICAL AND LABORATORY ACTIVITY

Kyiv 2011

УДК 629.7(042.4)

The reviewer Phd, Ass. Prof. Igor S. Gorbunov, NAU.
Approved by the NAU Aerospace Institute editorial board on May, 30, 2011, minute №12
Galstyan A., Zhuravlova L.
Aviation Fundamentals. Student guide on practical and laboratory activity. Kyiv, NAU, 2011. - 81 p.

This methodical guide is intended for the high school graduates and first course students who study the aviation for the future activity in area of aviation and aviation diagnostics and maintenance, partially. This methodical guide is based on the theoretical material of lectures, which are delivered in the first semester. Each session includes theoretical part and practice part. The theoretical part represents the basic information on the themes, covered with lectures Practical part gives the detailed instructions for carrying out the corresponding testing excercises, get the sklls in making:

- necessary search, classification and analysis of the information from external sources
- calculations, concerned with each theme (if necessary)
- practical activity, covered by theme.

Theoretical part is enhanced with schemes, illustrations, text information, which will be used during practical works for carrying out the task. Practical part requires to the theoretical material for conducting necessary measurements, calculations and inspection on the real physical airplane with further material analysis.

This methodical guide will enhance the practical skills for the further training and future professional activity. It will be very useful for the training process of future aviation specialists.

Рецензію надав канд. технічних наук, доцент Горбунов І.С., НАУ
Затверджено редакційною радою Аерокосмічного інституту НАУ, прот. №12 від 30.05.2011
Галстян А., Журавльова Л.
Основи авіації. Практичні та лабораторні роботи, Київ, НАУ, 2011. - 81 с.

Цей методичний посібник призначений для позаурочної роботи у старших класах загальноосвітніх навчальних закладів та студентів початкових курсів, які навчаються за авіаційними спеціальностями, та для тих, які планують подальшу діяльність в технічній сфері. Кожне заняття містить теоретичну та практичу частину, яка дає детальні інструкції щодо виконання відповідних вправ та здобуття навичок у:

- необхідному пошуку, класифікації та аналізу інформації з необхідних ресурсів
- розрахунках, пов'язаних з кожною темою (якщо вимагаються)
- практичій діяльності, пов'язаній з відповідною темою.

Теоретичний матеріал наданий зі схемами, ілюстраціями та текстовою інформацією, яка буде використана під час виконання завдань. Практична частина вимагає використання теоретичного матеріалу для проведення вимірювань, розрахунків та інспекцію реальних літаків для подальшого аналізу матеріалу.

Цей методичний посібник сприяє формуванню практичних навичок для подальшого вдосконалення професійної діяльності, буде дуже корисним для майбутніх авіаційних спеціалістів, фахівців технічної сфери діяльності.

Видання методичного посібника здійснено за кошти ТОВ "Центр Інформаційних технологій ІТС"

УДК 629.7(042.4)

ISBN 978-966-2398-02-1

Content

Preface	5
1. General definitions and notions, aviation terminology	
1.1 Brief aviation history, designers	6
1.2 Famous world manufacturers	8
1.3 Aircraft classification: range and purpose	10
1.4 Aircraft	12
2. Fuselage	
2.1 Fuselage	14
2.2 Fuselage types	16
2.3 Fuselage materials	18
2.4 Possible damages and failures of fuselage	20
2.5 Diagnostics and monitoring	22
3. Wing	
3.1 Wing	24
3.2 Wing types	26
3.3 Materials, possible damages, diagnostics and monitoring	28
4. Tail unit	
4.1 Tail unit	30
4.2 Tail unit types	32
4.3 Materials, possible damages, and diagnostics	34
5. Landing gear	
5.1 Landing gear	36
5.2 Landing gear types	38
5.3 Landing gear materials, possible damages, diagnostics	40
6. Power plant	
6.1 Power plant	42
6.2 Power plant (engine) types	44
6.3 Power plant (engine) materials, possible damages, diagnostics	46
7. Functional systems	
7.1 Functional systems overview	48
8. Aircraft principles of flight	
8.1 Airfoil aerodynamica	50
8.2 Types of airfoils	52
9. Helicopters	
9.1 Types of helicopter	54
9.2 Helicopter construction	56
9.3 Helicopter principle of flight	58
10. Human factor	
10.1 Flight operation: pilots	60
10.2 Flight service: crew	62
10.3 Maintenance: technicians	64
10.4 Air traffic control	66
10.5 Airport service	68
11. Information technologies in aviation	
11.1 Knowledge bases and Databases	70
11.2 Computer based training systems	72
11.3 E-documents	74
11.4 CAD/CAE systems	76
12. Vocabulary	78
13. Links and sources	81

Preface

Aerospace Institute Aviation program prides itself on a core strong liberal arts education surrounded by a focused, comprehensive professional education in aviation. The Aerospace Institute has internships with many different companies in the aviation industry, including airlines, airports, corporate flight departments, fixed base operators, and aviation insurance companies and aircraft manufacturers. We are also one of the few institutes of National Aviation University that delivers full years of an English language as a requirement in all of our degree programs.

We use the real aircraft in the training process and appropriate equipment for maintenance and diagnostics, and other tools like the information technologies of an aircraft life cycle support. We are the only aviation institute with its own hangar and aviation technical base in the domestic airport.

We are a large institute with a sizeable faculty who have a wide variety of professional background experiences including general aviation (aviation maintenance, FBO management, flight instruction, charter operations, and bush flying operations), pilots training, airlines management, aviation law, aviation human factors, airport management.

By definition the education of professional aviation technicians, specialist in the area of technical diagnostics, airport specialists must include extensive hands on learning component. Maintenance, repair and diagnostics of state of actual aircraft and use of appropriate technical and computer tools are utilized in the "Aerospace fundamentals" program. The curriculum relies on extensive use of different learning technologies: lectures, laboratory works and familiarization practice.

The whole course consists of three modules. The first module is devoted to the aviation. It includes historical facts, general information about airplanes and helicopters, reviews the types of the design of an aircraft in whole, and the specifics of its elements.

The second module is devoted to the design and principles of flight the airships, gliders and free flight hot air balloons.

The third module is devoted to the space exploration programs, space vehicles and principles of their flight.

This methodical guide supports the practical and laboratory sessions on the first module.

Each theme examination consists of three stages. On the first stage students become familiar with the new notions and terminology, on the second stage they study the technical characteristics of the element, general design and principles of its functioning. The third stage is devoted to the investigating of elements of different types of aircraft, and their components (fuselage, wing, tail unit, landing gear) in hangar.

Students have the opportunity to consolidate their learning outcomes during the summer familiarization practice, which takes place in Training Aviation Technical Base of National Aviation University in the domestic airport Zhulyany. The sessions of familiarization practice focusing on aircraft elements investigations, collecting and analyzing data about their characteristics, similarities and differences for different types of aircraft.

The proper exercises of this guide are used by students during the familiarization practice.

1.1 Brief aviation history, designers.

The history of human attempting to fly takes thousands of years. First man made objects, which could fly were kites and the earliest known record of flying kite is from around 200 BC in China. A famous genius of renaissance period Leonardo da Vinci dreamt through all his entire life to fly, and found expression in several designs which were not constructed and realized. In the late 18th century ballooning became a major rage in Europe and on October 19th of 1783 the Montgoflier brothers launched the first human manned balloon with humans onboard in Paris. Of course there were attempts to fly on a heavier than air machines like Frenchman Jean-Marie Le Bris did in 1856 on his glider "L'Albatros artificiel". He achieved a height of 100 meters over a distance of 200 meters, while his glider was pulled by a horse. In 1899 Percy Pilcher from the United Kingdom constructed a prototype powered aircraft, which recent research has shown, would have been capable of flight, however Pilcher died in a glider accident before he was able to test his prototype.

In 1900-1914 began the "Pioneer Era" of modern aviation. Ferdinand von Zeppelin began his Zeppelin airship construction in 1899 with a length of 128 meters, driven by two 10.6kW Daimler engines. His first flight occurred on July 2, 1900 for 18 minutes.

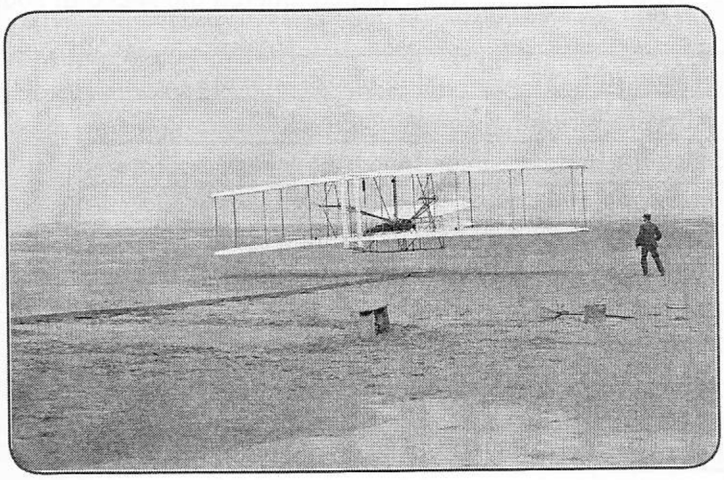


Fig. 1. The first flight by Orville Wright on December 17, 1903

The Wright brothers appear to be the first design team to make serious studied attempts to simultaneously solve the power and control problems. They made the first sustained controlled and heavier-than-air manned flight on December 17, 1903. The first flight by Orville Wright of 37 m in 12 seconds was recorded in a famous photograph (fig. 2). In the fourth flight of the same day Wilbour Wright flew on their biplane 260 m in 59 seconds.

The first time manned helicopter powered by a steam engine was developed by Enrico Forlanini in 1877. It rose to a height of 13 meters, where it remained for some 20 seconds, after a vertical take-off from a park in Milan. Golden Age of aviation began in 1918-1939 - the years between World War I and World War II which saw great advancements in aircraft technology. High-powered monoplanes made of aluminium, based on the founding work of Hugo Junkers during the World War I period replaced those made from wood and fabric low-powered biplanes. World War II saw a drastic increase in pace of aircraft development and production, like the first functional jetplane - Heinkel He 178, flown by Erich Warsitz. But not only the airplanes had a rapid development during a World War II. Helicopters Focke Achgelis Fa 223, Flettner Fl 282 and Sikorsky R-4 were introduced during this period. Igor Ivanovich Sikorsky was a Ukrainian-American pioneer of aviation and helicopters, who designed and flew the world's first multi-engine fixed-wing aircraft - Russky Vityaz in 1913. In 1939 he designed the first viable helicopter Vought-Sikorsky VS-300 which rotor configuration is used by most helicopters today.

After World War II commercial aviation grew rapidly, used mostly ex-military aircraft to transport people and cargo. USSR's Aeroflot became the first airline in the world to operate sustained regular jet services on September 15, 1956 with the Tupolev Tu-104 designed in Tupolev bureau which was founded in 1922 by Andrei Nikolaevich Tupolev - designer of more than 100 types of aircraft, some of which set 78 world records. Boeing 707, which established new levels of comfort, safety and passenger expectations dubbed the Jet Age.

In October 1947 Chuck Yeager took the rocket powered Bell X-1 broke sound barrier. In 1960 The Lockheed A-12 was designed at Lockheed Skunk Works for the Central Intelligence Agency by Clearence Johnson. It was the precursor of the SR-71 "Blackbird" which is the world's fastest and highest-flying operational manned aircraft throughout its career. SR-71 broke the world record in its class - 25929 m of "absolute altitude record" and "absolute speed record" of 3529.6 km/h. A year of 1969 was very eventful for aviation history. This year British VTOL military aircraft Harrier saw the world, Neil Armstrong and Buzz Aldrin set foot on the Moon, Boeing unveiled the Boeing 747 and the Aerospace-BAC Concorde supersonic passenger airliner had its maiden flight.

Theme 1. General definitions and notions, aviation terminology

Practical and laboratory activity

1. What was the first in history man made object that could fly? (mark the checkbox with number of correct answer)

1. A balloon	2. A dirigible	
3. A kite	4. A helicopter	Correct is
5. A glider	6. A rocket	
7. An airplane	8. A Space Shuttle	

2. Who was the first man, that conquered the speed of sound in an aircraft?

1. Hugo Junkers	2. Buzz Aldrin	
3. Orville Wright	4. Chuck Yeager	Correct is
5. Erich Warsitz	6. Neil Armstrong	
7. Wilbour Wright	8. Igor Sikorsky	

3. What did Montgoflier brothers launch, that is human manned, for the first time in history?

1. A kite	2. A balloon	
3. A dirigible	4. A rocket	Correct is
5. A paper airplane	6. A supersonic airplane	
7. A helicopter	8. A Concorde	

4. How do you think, what type of an airplane did Wright brothers build?

1. Biplane	2. Parasol	
3. Monoplane	4. Rocket plane	Correct is
5. Triplane	6. Multiplane	
7. One and half plane	8. Jet airplane	

5. Connect two related terms

Wright •	• Helicopter
Sikorsky •	• supersonic
Bell X-1 •	• Harrier
Kite •	• Moon
Montgoflier •	• Tu-104
VTOL •	• SR-71
Buzz Aldrin •	• brothers
Tupolev •	• Zeppelin
Dirigible •	• China
CIA •	• Balloon

1.2 Famous world manufacturers.

The first aircraft world manufacturer was Short Brothers plc, Founded in 1908, a British aerospace company, based in Belfast, Northern Ireland. Founded in 1908 and was a manufacturer of flying boats during the 1920s, 1930s, and 1940s and Royal Air Force bombers throughout the Second World War. From the 1960s Shorts turned primarily to the production of passenger aircraft for regional airlines, major components for aerospace prime manufacturers, and missiles for British armed forces. In 1989 the company was bought by Bombardier, a Canadian conglomerate, founded by Joseph-Armand Bombardier as L'Auto-Neige Bombardier Limitée in 1942, at Valcourt in the Eastern Townships, Quebec. Over the years it has been a large manufacturer of regional aircraft, business jets, mass transportation equipment, recreational equipment and a financial services provider. Bombardier is a Fortune Global 500 conglomerate company. In 1986, Bombardier acquired Canadair after the Canadian government-owned aircraft manufacturing company had recorded the largest corporate loss in Canadian business history. Shortly thereafter, de Havilland Canada from Boeing, Short Brothers and Learjet operations were added. The aerospace arm now accounts for over half of the company's revenue. The Boeing Company is an American multinational aerospace and defense corporation, founded in 1916 by William E. Boeing in Seattle, Washington. Boeing has expanded over the years, merging with McDonnell Douglas in 1997. Boeing is among the largest global aircraft manufacturers by revenue, orders and deliveries, and the third largest aerospace and defense contractor in the world based on defense-related revenue. Boeing is the largest exporter by value in the United States. To compete with American companies such as Boeing, McDonnell Douglas, and Lockheed, Airbus Industrie began as a consortium of European aviation firms. Today Airbus A380 airplane is the largest passenger airliner in the world (fig.3), but the largest and heaviest aircraft that flew multiple times is Antonov 225, designed by the Antonov Design Bureau in the 1980s. Antonov Design Bureau, is a Ukrainian aircraft manufacturing and services company, established On May 31, 1946 by Oleg Antonov after being given the task of developing a new utility plane to be powered by a 730-horsepower engine. The resulting design, the An-2, first flew in August 1947 and was a monumental success, in spite of its antiquated styling (a biplane with fixed landing gear). For the An-2, Antonov and his assistants were awarded a Stalin Prize and 100,000 rubles in 1952.

Fig. 3. Airbus A-380

Such American companies as General Dynamics, Lockheed martin, Northrop Grumman, Boeing, European Dassault, Alenia Aeronautica, Saab and Russian Mikoyan-Gurevich, Sukhoi, Yakovlev, Tupolev produce most of the military aircraft. Each manufacturer has it's best known airplanes like General Dynamics and Lockheed F-16 which were ordered more than 4,000, making it the largest and most successful program for General Dynamics since World War II, Lockheed SR-71, which was the only plane to be the fastest operational aircraft in the world from the day it entered service until the day it was retired, Northrop F-14 remained the Navy's best all-around fighter for well over 20 years for its extremely flexible and superior weapons system, Boeing and Lockheed Martin F-22 – the best computerized and intelligent fighter, Dassault Rafale fighter, Saab Gripen for its advanced radar system, Mikoyan – Gurevich MIG-25 – the best soviet interceptor with speed of M 3.2, Sukhoi SU-35 having the best manoeuvrability and air superiority till nowadays, Tupolev Tu-160 (fig. 4) – the largest supersonic strategic bomber in the world with a range of 18000 km – almost the half of the Earth's equator length.


Fig. 4. Tupolev Tu-160

Practical and laboratory activity

1. What company produces the largest passenger airliner?

1. General Dynamics	2. Antonov	Correct is
3. Boeing	4. Sukhoi	
5. Bombardier	6. Tupolev	
7. Airbus	8. Lockheed	

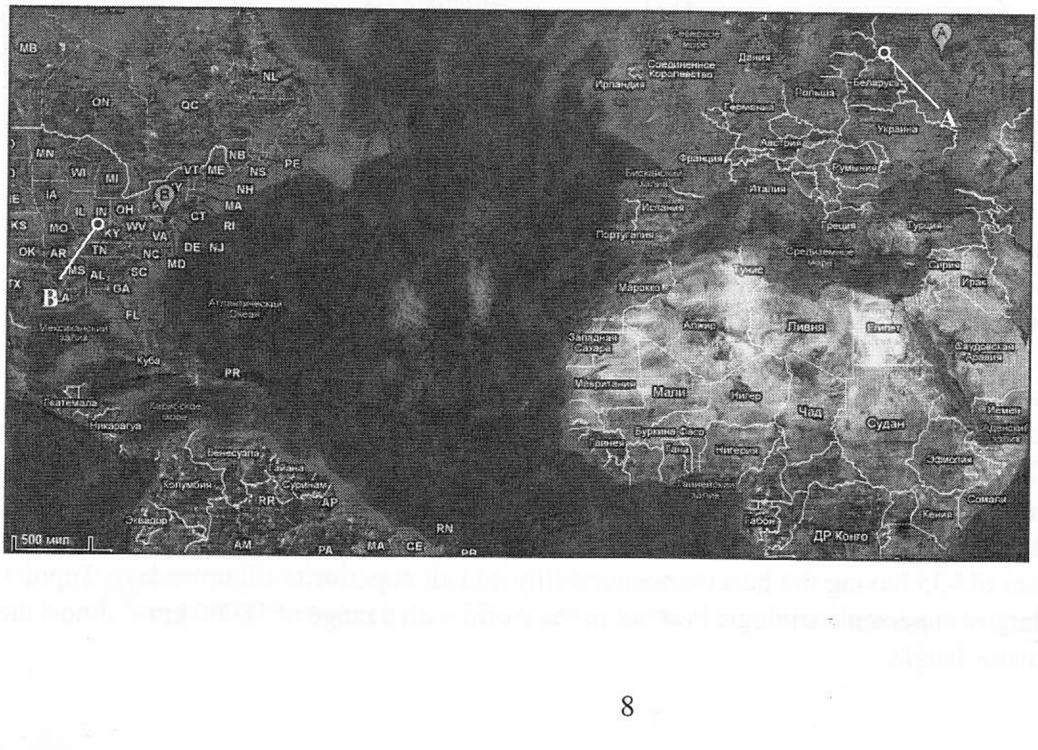
2. What companies produce military and civil aircrafts?

1. Boeing	2. Northrop Grumman	
3. General Dynamics	4. Saab	Correct is
5. Mikoyan-Gurevich	6. Tupolev	
7. Lockheed	8. Dassault	

3. Connect two related terms.

Mikoyan-Gurevich •	• F-16
Su-35 •	• 1916
General Dynamics •	• F-14
Strategic bomber •	• A-380
William E. Boeing •	• Tu-160
Short Brothers •	• Fighter
Antonov •	• Mig-25
F-22 •	• An-2
Civil •	• 1908
Northrop •	• Sukhoi

4. Calculate the time, necessary for the largest supersonic strategic bomber Tu-160 to reach point B if its cruise speed is 917 km/h.



1.3 Aircraft classification: range and purpose.

To distinguish aircrafts the classification was implemented. The main classification of aircrafts is considered by intended purpose and divided by military and civil aircrafts. A table below (table 1) shows the relation of aircraft types to their classification.

Table 1. Aircraft classification by intended purpose.

Military		**Civil**	
Type	Translation	Type	Translation
Mother aircraft	Воздушный авианосец	Passenger	Пассажирский
Landing aircraft	Десантный	Mail	Почтовый
Fighter	Истребитель	Agricultural	Сельскохозяйственный
Fighter-bomber	Истребитель-бомбардировщик	Experimental	Экспериментальный
Plane / spotter	Корректировщик	Sanitary	Санитарный
Multipurpose, special purpose	Многоцелевой, специальный	Geological	Геологоразведочный
Interception plane	Перехватчик	Firefighting	Пожарный
Rocket carrier	Ракетоносец	Sport	Спортивный
Reconnaisance	Разведчик	Transport	Транспортный
Transport	Транспортный	Trainer	Учебно-тренировочный
Front bomber	Фронтовой бомбардировщик		
Low-flying attack plane	Штурмовик		

Another classification of aircraft is considered by physical characteristics, take-off weight capabilities, engine type, flight speed, landing gear type, wings type and location and fuselage type. All of these aircraft types are listed in table 2.

Table 2*. Aircraft classification by different capabilities.

Take-off mass	**Engines quantity**	**Engines type**	**Wings quantity and type**	**Wings location**	**Fuselage type**	**Landing gear type (LG)**	**Flight speed**	**Take-off and landing type (TOL)**	**Sources of thrust**	**Control method**
class 1 >75 t	single	Piston	Mono-plane	High-wing	Single-fuselage	Wheel LG	Subsonic <0.8 M	Vertical-TOL	Propeller	Un-manned
class 2 30 to 75 t	double	Turbo-prop	One and half plane	Mid-wing	Narrow - fuselage	Tail LG	Transonic 0.8 to 1.2 M	Short TOL	Jet	Piloted
class 3 10 to 30 t	triple	Turbojet	Biplane	Low-wing	Wide-fuselage	Nose LG	Super-sonic 1.2 to 5 M	Normal TOL		
class 4 <10 t	quad	Rocket	Triplane		Double - bubble	Bicycle type LG	Hyper-sonic >5 M			
light-weight <495 kg	five	Com-bined	Multi-plane		Flying wing	Ski type LG				
	six		Gull type		Double-decked	Tracked type LG				
	seven		Parasol			Hydro-planes				
	eight to twelve					Amphi-bian				

*Note: rows and columns in this table are not related

Practical and laboratory activity

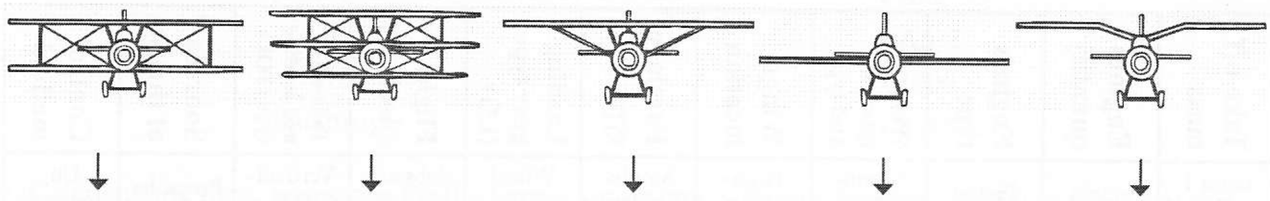
1. What main classification types aircrafts divided on? (put correct answer numbers into the check-box).

1. Military	2. Transport	Correct are
3. Fighter	4. Trainer	
5. Reconnaissance	6. Civil	
7. Agricultural	8. Passenger	

2. Connect two related terms.

Wings quantity •	• Double - decked
Engine type •	• Wings location
Propeller •	• Fighter
Fuselage type •	• Take-off and landing
VTOL •	• Source of thrust
Piloted •	• Biplane
Mid-wing •	• Double
Trainer •	• Control
Military •	• Piston
Engines quantity •	• Civil

3. Try to guess, which picture of an airplane is related to the wings location and type.



Gull type	Biplane	Monoplane	Parasol	Triplane

4. Count the number of military and civil airplanes in the university hangar.

Military: Civil:

5. What types of airplanes are in the university hangar? Fill in the table below.

Airplane name	Wings type	Wing location	Source of thrust	Engine type

1.4 Aircraft.

Any vehicle which is able to fly by being supported by the air or the atmosphere of a planet, can be called an aircraft. This type of machines counters the force of gravity by using either static lift or by using the dynamic lift of an airfoil, or in a few cases the downward thrust from jet engines. An airfoil (fig. 6) is the shape of the wing seeing as a cross section of it. An airfoil-shaped body moved through a fluid (the gas in aerodynamics is considered as a fluid) produces an aerodynamic force - the resultant force of lift force and drag force arising in a center of pressure and exerted on a body by the fluid in which the body is immersed, and is due to the relative motion between the body and the fluid. The science which studies the interaction of moving body with air is called aerodyna-mics. The most common type of an aircraft are airplanes. Typical airplane is shown on the picture below (fig.5)

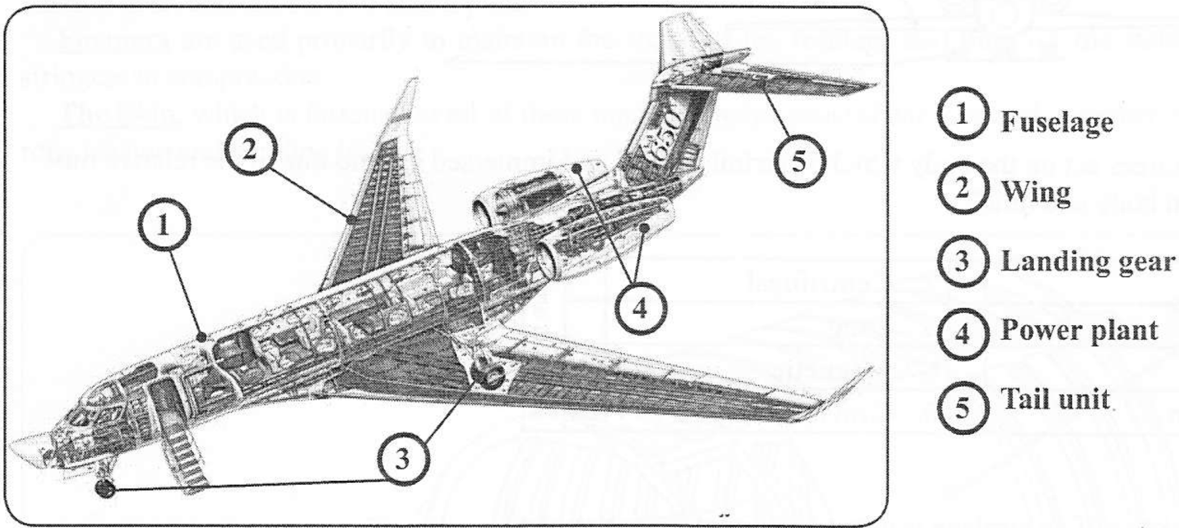


Fig. 5. Gulfstream G650

An airplane consist of next distinguishable parts:

- Fuselage
- Wings
- Landing gear
- Power plant
- Tail Unit

These parts will be studied in next lessons. Although airplane is considered as one of the most safe transport there will be always a possibility of an accident during flight. An aviation accident is defined as an occurrence associated with the operation of an aircraft which takes place between the time any person boards the aircraft with the intention of flight and all such persons have disembarked, in which a person is fatally or seriously injured, the aircraft sustains damage or structural failure or the aircraft is missing or is completely inaccessible. To lower the risk of an accident the special organisation ICAO (International Civil Aviation Organization) has been established in 1944. This organization codifies the principles and techniques of international air navigation and fosters the planning and development of international air transport to ensure safe and orderly growth. One of the main aims of ICAO is flight safety. It is a term encompassing the theory, investigation and categorization of flight failures, and the prevention of such failures through regulation, education and training. Also, to prevent any flight accident different kinds of diagnostics of an airplane and its parts or systems is schedually performed during the whole aircraft life cycle. A life cycle is the process of managing the entire life cycle of a product from its conception, through design and manufacture, to service and disposal.

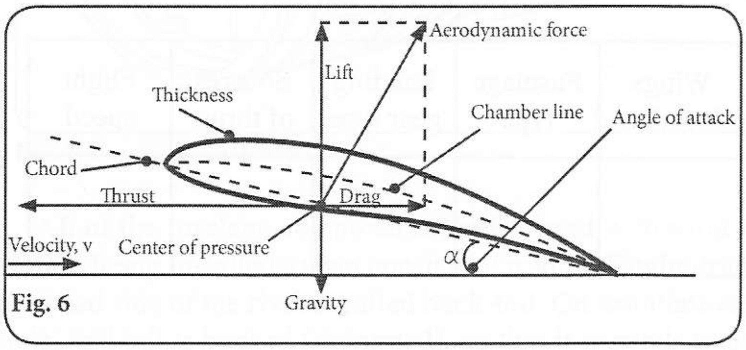
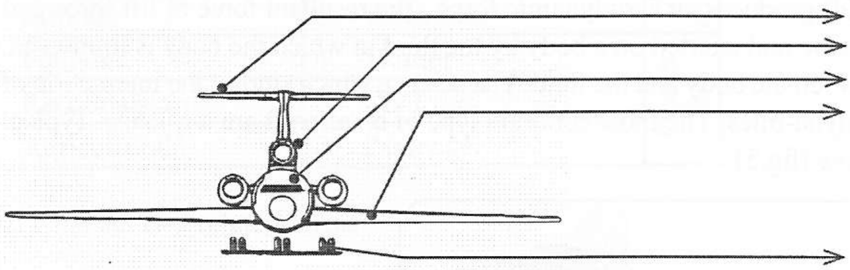


Fig. 6

Practical and laboratory activity

1. On the picture below you see a schematic airplane drawing. Write down near the arrows the name of an airplane part.



2. What forces act on the body which is airfoil shaped and immersed in fluid due to the relative motion between body and fluid?

1. Lift	2. Centrifugal			Correct are
3. Elastic	4. Drag			
5. Thrust	6. Magnetic			
7. Tension	8. Gravity			

3. Diagnostics of an airplane is carried out in order to prevent ______________________

4. What common distinguishable parts does airplane consist of?

1. Fuselage	2. Centrifugal			Correct are
3. Tail unit	4. Elevator			
5. Cockpit	6. Landing gear			
7. Power plant	8. Rudder			

5. Select any airplane you wish in the hangar and fill in the table below.

Airplane name	Take-off mass	Quantity of engines	Wings quantity and type	Wings location	Fuselage type	Landing gear type	Sources of thrust	Flight speed

2.1 Fuselage.

The fuselage is an aircraft main body which holds crew, cargo or passengers. Fuselage also serves to position the control and stabilization surfaces, required for aircraft stability and manoeuvrability. Earlier fuselages were made of wood and fabrics, but modern aviation use special hardened aluminium alloys for frame and skin of fuselage and even composite materials such as carbon fibre.

The main fuselage components are longerons (or stringers), bulkhead, formers (frames) and skin (fig.7).

Longerons are longitudinal construction part of fuselage to which the skin is also fastened. Longerons are attached to formers and resist the majority of fuselage bending loads.

Bulkheads are used where concentrated loads are introduced into the fuselage, such as those at wing, landing gear, and tail surface attach points.

Formers are used primarily to maintain the shape of the fuselage and improve the stability of the stringers in compression.

The Skin, which is fastened to all of these members helps resist shear load and, together with longerons tension and bending loads.

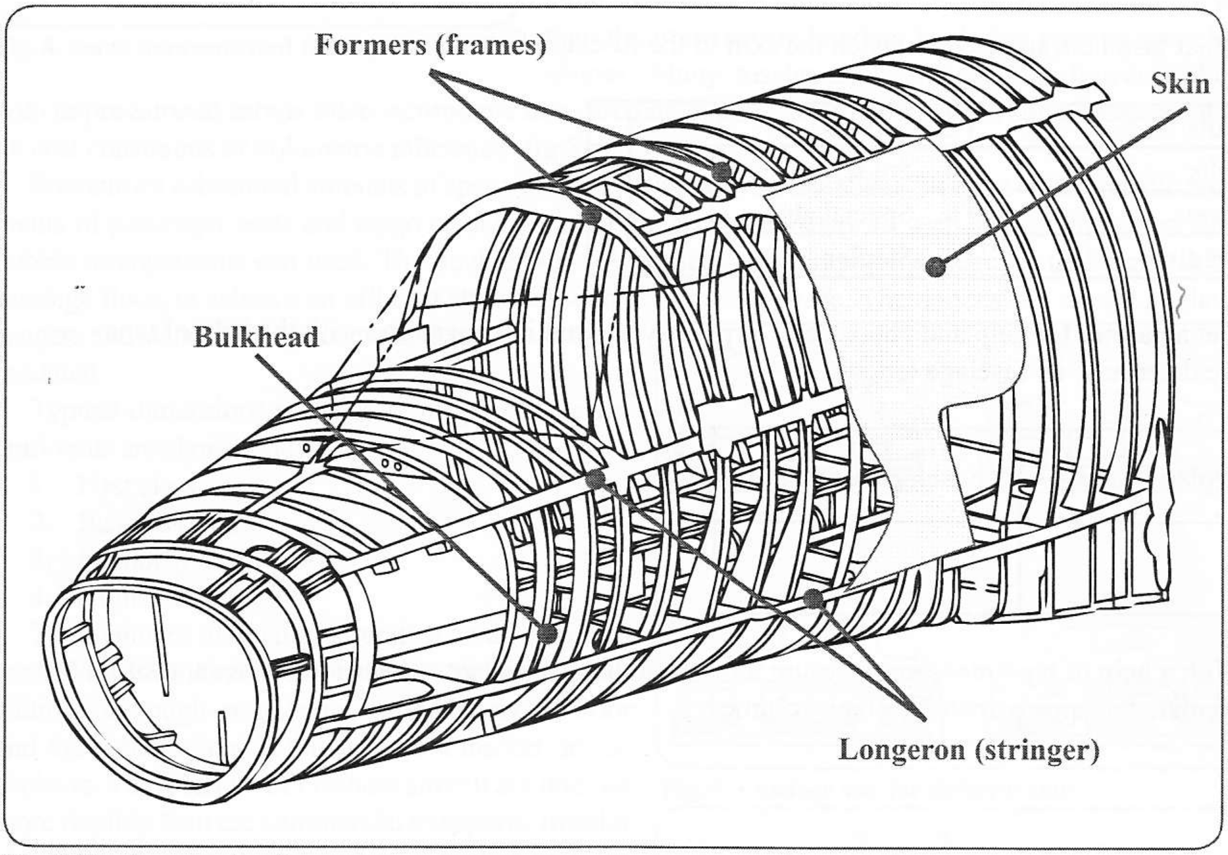


Fig. 7. Fuselage construction

All of the fuselage components are fastened with solid rivets - a permanent mechanical fasteners. Before being installed a rivet consists of a smooth cylindrical shaft with a head on one end. The end of the head side of the rivet is called buck-tail. On installation the rivet is placed in a punched pre-drilled hole, and tail is bucked (deformed), so that it expands to about 1.5 times the original shaft diameter, holding the rivet in place. Solid rivets which are used in aviation construction for the applications where reliability and safety count. Typical materials for aircraft rivets are aluminium alloys, titanium and nickel-based alloys.

Practical and laboratory activity

1. What longitudinal components does fuselage consist of?

1. Rivets	2. Skin	Correct is
3. Bulkheads	4. Ribs	
5. Longerons	6. Struts	
7. Formers	8. Spars	

2. What components are used to withstand concentrated loads in fuselage?

1. Formers	2. Spars	Correct is
3. Skin	4. Ribs	
5. Rivets	6. Longerons	
7. Bulkheads	8. Bolts	

3. What fasteners are used to fasten the skin to the fuselage frame?

1. Nails	2. Screws	Correct is
3. Bolts	4. Soldering	
5. Rivets	6. Special glue	
7. Welding	8. Stapler	

4. Get a partner for help and choose any airplane you want in hangar and with the help of tape-measure determine its fuselage length.

Airplane name	Fuselage length, m

5. With a help of tape-measure, measure the length of 1/4 fuselage surface curvature (approx). After that calculate the approximate fuselage volume.

AREA FOR CALCULATION

Fuselage length, m	1/4 fuselage surface curvature length, m	Full fuselage curvature length, m	Fuselage cross-section area, m^2	Fuselage volume, m^3

2.2 Fuselage types.

Most fuselages are shaped like cylinders. Others are shaped like rectangular prisms, with rounded corners. A rounded shape makes the plane have less drag. Commercial planes like the Boeing 727 are shaped like cylinders. Their cylindrical shape helps them produce less drag when they are flying at high speeds. But this isn't the only reason that commercial planes are shaped this way. Another reason to use a cylindrical shape has to do with air pressure at high altitudes. If you ever gone to the top of a mountain, you certainly could found it harder to breathe. That happens because the higher we go, the less air there is. Since commercial planes fly at 9 km or more, air is forced into the cabin to make up for the lack of air at high altitudes. This allows passengers to breathe normally during a flight. Because a cylinder is round on the inside, it can maintain its shape as air is forced into the cabin and the air pressure increases. So the most ideal shape for the fuselage at high altitudes is oval or rounded in cross-section. That is why big planes don't have a rectangular-shaped cross section of the fuselage - they fly at high altitudes, so their fuselage requires to pay attention for high pressure inside. When the fuselage is pressurized, a circular fuselage can resist the loads with tension stresses, rather than the more severe bending loads that arise on non-circular shapes. Many fuselages are not circular, however. Aircraft with unpressurized cabins often incorporate non-circular, even rectangular cabins in some cases, as dictated by cost constraints or volumetric efficiency (fig.8).

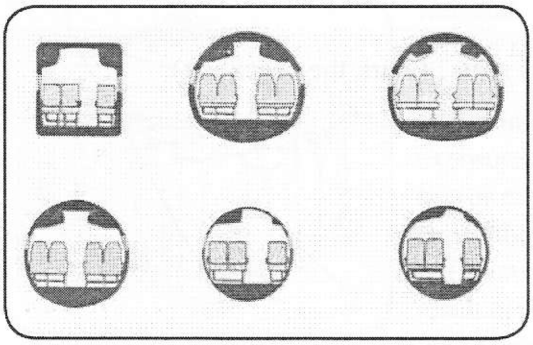


Fig. 8. Small unpressurized fuselage shapes

Sometimes substantial amounts of space would be wasted with a circular fuselage when specific arrangements of passenger seats and cargo containers must be accommodated. In such cases, elliptical or double-bubble arrangements can used. The double-bubble geometry uses intersecting circles, tied together by the fuselage floor, to achieve an efficient structure with less wasted space. The dimensions are set so that passengers and standard cargo containers may be accommodated.

Typical dimensions and classes for passenger aircraft seats are shown on (fig.9).

1. First class
2. Business Class
3. Economy class
4. High density

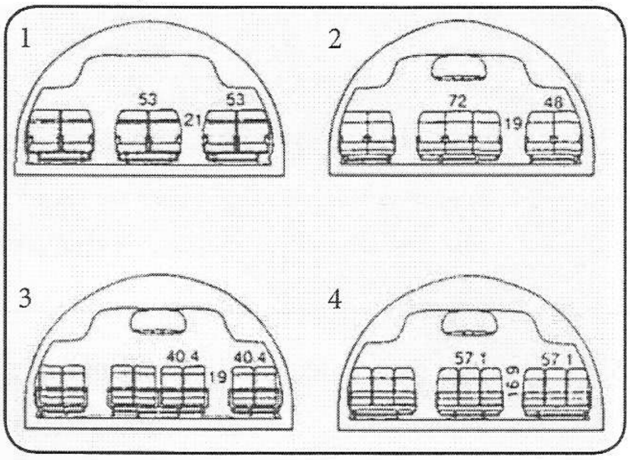


Fig. 9. Fuselage size for different class

The diameter of smaller aircraft such as commuters and business aircraft is dictated by similar considerations, although cargo is not carried below the floor and the cabin height is much more a market-driven decision. The interiors of business aircraft are laid out more flexibly than are commercial transports. Interior appointments often cost millions of dollars and can be very luxurious, especially for the larger long range aircraft such as the Gulfstream V or Global Express. Business aircraft based on commercial transports such as the Boeing Business Jet provide even greater possibilities.

Recent interest in very large aircraft suggests that additional creative possibilities exist for the aircraft interior. The figure (fig. 10) illustrates some concepts for large aircraft fuselage cross sections as described by Douglas Aircraft in 1966. More recently, aircraft such as the Airbus A380 have been designed with interesting interior possibilities. On the figure 9 you can see such types of fuselage shape: Double-bubble (1), Double-decked (2), single-decked (3), conventional cross-section (4).

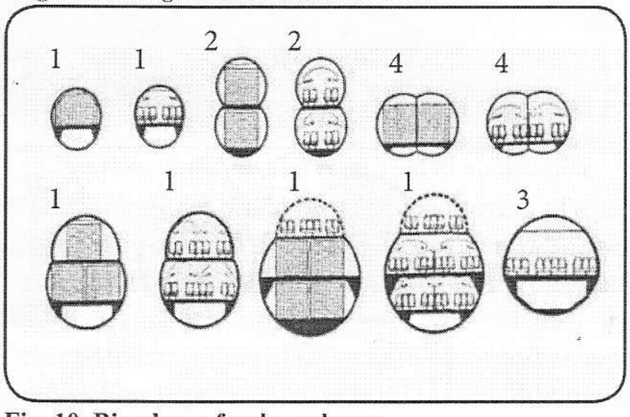


Fig. 10. Big planes fuselage shapes

Fuselage

Practical and laboratory activity

1. What fuselage shapes cannot have a pressurized modern aircraft?

1. Double-bubble	2. Flying wing	Correct is
3. Rectangular	4. Narrow	
5. Single-decked	6. Wide	
7. Double-decked	8. Other	

2. What is the difference between 1st class and economy class seats? (mark the checkbox)

1. Space between seats		Correct is
2. Luggage availability		
3. Seat cost		
4. Quantity of passengers		

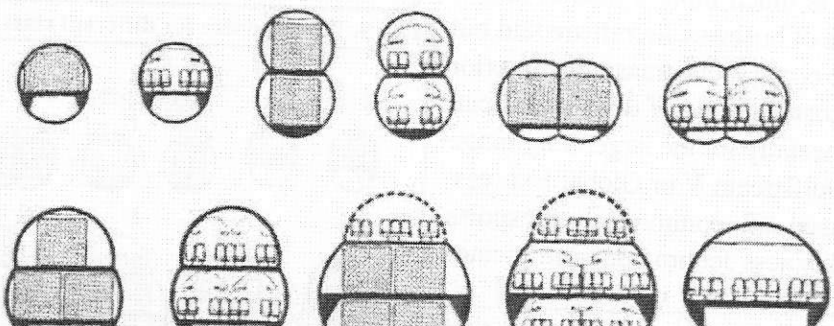
3. What fuselage types are used to accommodate more passengers?

1. Single-decked		Correct is
2. Double-bubble		
3. Double-decked		
4. Conventional		

4. Select any airplane you wish in the hangar and fill in the table below.

Airplane name	Fuselage shape	Pressurization (yes/no)	Classes

5. Connect two related items and find the odd one.



2.3 Fuselage materials.

The most common metals in aircraft construction are aluminium, magnesium, titanium, steel, and their alloys. Aluminium alloy is widely used in modern aircraft construction. It is vital to the aviation industry because the alloy has a high strength-to-weight ratio. Aluminium alloys are corrosion-resistant and comparatively easy to fabricate. The outstanding characteristic of aluminium is its lightweight. Magnesium, the world's lightest structural metal, is a silvery-white material weighing only two-thirds as much as aluminium. Magnesium is used in the manufacture of helicopters. Magnesium's low resistance to corrosion has limited its use in conventional aircraft. Titanium is a lightweight, strong, corrosion-resistant metal. It was discovered years ago, but only recently has it been made suitable for use in aircraft. Recent developments make titanium ideal for applications where aluminium alloys are too weak and stainless steel is too heavy. In addition, titanium is unaffected by long exposure to seawater and marine atmosphere. An alloy is composed of two or more metals. The metal present in the alloy in the largest portion is called the base metal. All other metals added to the alloy are called alloying elements. Alloying elements, in either small or large amounts, may result in a marked change in the properties of the base metal. For example, pure aluminium is relatively soft and weak. When small amounts of other elements such as copper, manganese,and magnesium are added, aluminium's strength is increased many times. An increase or a decrease in an alloy's strength and hardness may be achieved through heat treatment of the alloy. Alloys are of great importance to the aircraft industry. Alloys provide materials with properties not possessed by a pure metal alone. Alloy steels that are of much greater strength than those found in other fields of engineering have been developed. These steels contain small percentages of carbon, nickel, chromium, vanadium, and molybdenum. Such steels are made into tubes, rods, and wires. Another type of steel that is used extensively is stainless steel. This alloy resists corrosion and is particularly valuable for use in or near salt water. Materials used in fuselage structure are all of aluminium alloy. Skin, longerons, formers are all made of special aluminium alloys.

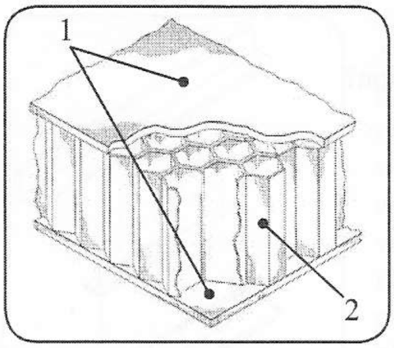


Fig. 11. Sandwich composite

In addition to metals, various types of plastic materials are found in aircraft construction. Transparent plastic is found in canopies, windshields, and other transparent enclosures. Transparent plastic surfaces are handled with care, because this material is relatively soft and scratches easily. At approximately 107°C, transparent plastic becomes soft and very pliable. Reinforced plastic is made for use in the construction of radomes, wing tips, stabilizer tips, antenna covers, and flight controls. Reinforced plastic has a high strength-to-weight ratio and is resistant to mild and rot. Its ease of fabrication make it equally suitable for other parts of the aircraft. Reinforced plastic is a sandwich-type material (fig. 11). It is made up of two outer facings (1) and a centre layer (2). The facings are made up of several layers of glass cloth, bonded together with a liquid resin. The core material (centre layer) consists of a honeycomb structure made of glass cloth. Reinforced plastic is fabricated into a variety of cell sizes. High-performance aircraft require an extra high strength-to-weight ratio material. Fabrication of composite materials satisfies the special requirement. These materials are mechanically fastened to conventional substructures. Another type of composite construction consists of thin graphite (carbon fibre) epoxy skins bonded to an aluminium honeycomb core. Each carbon filament thread is a bundle of many thousand carbon filaments. A single such filament is a thin tube with a diameter of 5–8 micrometers and consists almost exclusively of carbon. On the figure (fig.12) you can see a texture of carbon fibre fabric and a magnified comparison of single fibre tube with human hair.

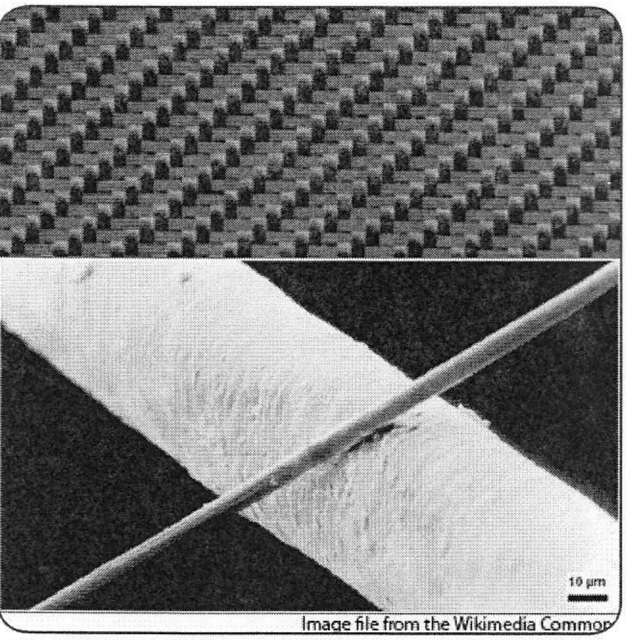


Fig. 12. Carbon fibre material compared to human hair

Practical and laboratory activity

1. In common, what materials are used in fuselage production?

1. Aluminium alloys	2. Carbon/glass fibre	Correct is
3. Magnesium Alloys	4. Plastics	
5. Titanium	6. Beryllium	
7. Steel	8. Iron	

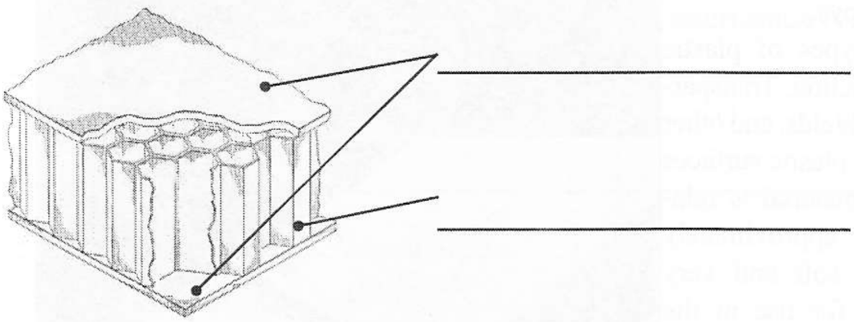
2. What is the toughest metallic material below used in aviation production?

1. Titanium		Correct is
2. Magnesium alloys		
3. Aluminium alloys		
4. Beryllium		

3. What materials are called sandwich-type materials?

1. Magnesium alloys	2. Titanium	Correct is
3. Aluminium alloys	4. Composite materials	
5. Plastics	6. Iron	
7. Steel	8. Transparent thermoplastic	

4. What parts does typical sandwich composite materials consist of?

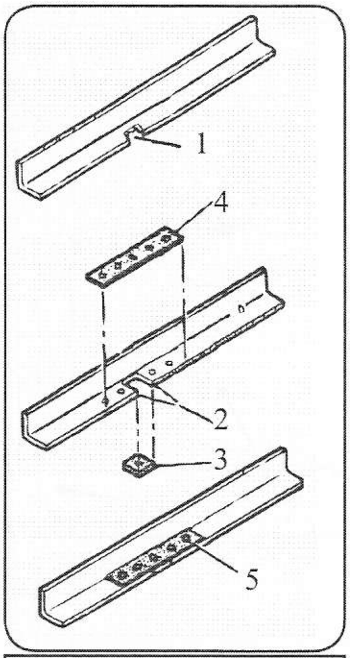


5. Connect two related terms

Aluminium alloys •	• Engine blades
Transparent thermoplastic •	• Skin
Titanium •	• Landing gear
Steel •	• Window
Carbon fibre •	• Lightweight

2.4 Possible damages and failures of fuselage.

Usually the most common fuselage damages are related with skin damage beginning from paint scratch to severe skin breakage. Due to the presence of abrasive particles in the air the aircraft paint cover can be damaged because of interaction between fuselage and abrasive particles during high speeds flight. Paint is an important component of fuselage because it protects the skin from corrosion, which arises due to moisture and temperature action on material. One of the most important places in fuselage construction, where failures may be found are joints. These are external places where wings, tail unit and control surfaces are fitted to the fuselage. A high stress concentration in these places take place. In these places cracks are often found, so the inspection for cracks should be performed. As in all other forms of repairs, the first step is to inspect the damaged area thoroughly to determine the extent of the damage. Inspect the internal structure for damage or signs of strain. Members that are bent, fractured, or wrinkled must be replaced or repaired. They may be sheared considerably without visible evidence of such a condition. You should drill out rivets at various points in the damaged area and examine them for signs of shear failure. The rivet holes in stringers, longerons, bulkheads, formers, frames, rings, and other internal members must be kept in the best condition possible. If any of these members are loosened by the removal of rivets, their location should be marked so they can be returned to their original position. After the extent of damage has been determined, it should be classified in one of the following categories: negligible damage, damage repairable by patching (fig.13), damage repairable by insertion, or damage requiring replacement of parts.When any part of the airframe has been damaged,the first step is to clean all grease, dirt, and paint in the vicinity of the damage so the extent of the damage may be determined. The adjacent structure must be inspected to determine what secondary damage may have resulted from the transmission of the load or loads that caused the initial damage. You should thoroughly inspect the adjacent structures for dents, scratches, abrasions, punctures, cracks, loose seams, and distortions. Check all bolted fittings that may have been damaged or loosened by the load that caused the damage to the structure.



1. **Damaged stringer**
2. **Damage cut out smooth with corner radii**
3. **Filler splice**
4. **Reinforcement splice**
5. **Assembled repair**

Fig. 13. Stringer repair by patching

Types of repairs.

The type of repair to be made will depend on the materials, tools, amount of time available, accessibility to the damaged area, and maintenance level. The types of repair are permanent, temporary, and one-time flight (ferry). Repairs are also classified as either internal or external. A permanent repair is one that restores the strength of the repaired structure equal to or greater than its original strength and satisfies aerodynamic, thermal, and interchangeability requirements, This ensures the designed capabilities of the aircraft. The temporary repair restores the load-carrying ability of the structure but is not aerodynamically smooth or able to satisfy interchangeability requirements. This repair should be replaced by a permanent type as soon as possible in order for the aircraft to be restored to its normal condition. The one-time flight repair restores a limited load-carrying ability to the damaged structure in order to fly the aircraft to a depot maintenance activity for a permanent repair. When this type of repair is made, the aircraft cockpit should be placarded to limit the performance of the aircraft.

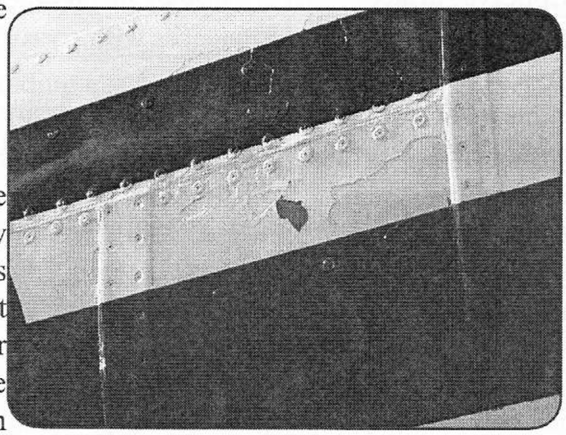


Fig. 14. Fuselage damage caused by flying ice chunks

Fuselage

Practical and laboratory activity

1. What are the most common fuselage damages

1. Skin damages	2. Corrosion	
3. Stringer damages	4. Rivets breakage	Correct is
5. Bulkhead damages	6. Erosion	
7. Fuselage deformation	8. Dirt	

2. What are the primary goals of the aircraft paint?

1. To show the advertisement		Correct are
2. To protect fuselage from corrosion		
3. To increase aerodynamic efficiency		
4. To make airplane look better		

3. Rivets purpose is:

1. To fasten the skin to the fuselage frame		Correct is
2. To fasten the fuselage frame to the skin		
3. To close the holes in skin		
4. To increase drag in special places		

4. What places the high stress concentration arise in?

1. Places with rivets	2. Flat surfaces	Correct is
3. Joint places	4. Convex surfaces	
5. Concave surfaces	6. Rough surfaces	
7. Places with thin skin	8. Places with corrosion	

5. Choose one of the airplanes in the university hangar and find some damage on the fuselage skin. After you detected the damage, fill in the table below.

Damage level is chosen from: insignificant, moderate, severe

Airplane name	Damage place	Damage type	Damage level	Type of repair

2.5 Diagnostics and monitoring.

There are three methods that can be used to ensure a thorough investigation has been made. The three methods are visual inspection, hardness testing, and nondestructive inspection for cracks.

Visual inspection - a thorough inspection of the structure should be made for dents, scratches, abrasions, punctures, cracks, distortion, loose joints, breaks, and buckled or wrinkled skin. All riveted and bolted joints in the vicinity of the damaged area should be checked for elongated holes and loose, sheared, or damaged rivets or bolts. If any doubt exists about the failure of a rivet or bolt, the fastener should be removed for a more thorough inspection. All access panels, hatches, and doors should be opened to inspect the internal structure.

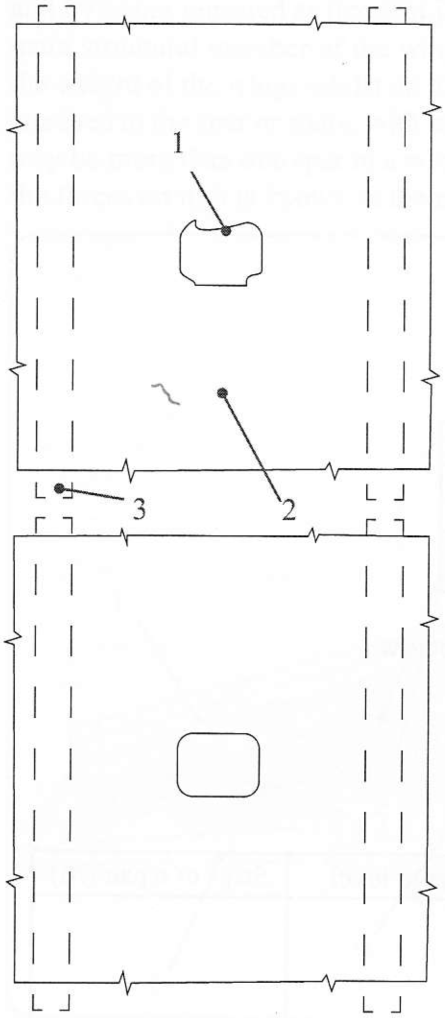


Fig. 15. Rounding the hole corners in fuselage skin.

Hardness testing - when fire has damaged the airframe, the paint will be blistered or scorched and the metal will be discoloured. When these conditions exist, the affected area should first be cleaned and the paint removed. Following this, a hardness test should be conducted to determine if the metal has lost any of its strength characteristics. This test can be performed with the Barcol or Riehle portable hardness tester. If the material to be tested is removed from the airframe, then a more reliable test can be made by using a standard bench tester. If the alloy to be tested is either clad or anodized, the surface coating must be removed to the bare metal at the point of penetrator contact. This is necessary because clad surfaces are softer and anodized surfaces are harder than the base alloy.

Inspection for cracks - the existence of suspected cracks or the full extent of apparent cracks in structural members cannot be accurately determined by visual inspection. In cases where it is necessary for cracks to be accurately defined, a nondestructive inspection is usually performed. Fittings should receive a special investigation if they are cracked, since this could cause an entire component to fail. Fittings are used to attach sections of wings together and wings to fuselage, as well as attachment of stabilizers, control surfaces, landing gear, and engine mounts.

Cleanup of damage - along with the investigation of damage, you should clean all jagged holes, tears, or damaged material. The cleaned sections must include all the area in which minute cracks are present. The affected area must be cut and rounded to form a smooth regular outline like it is shown (fig. 15), where 1 - a hole in the fuselage skin, 2 - skin, 3 - frame. If a rectangular or square-shaped cutout is made, the radii for the corners should be a minimum of one-fourth inch, unless otherwise specified. All burrs should be removed from the edges of the cutout. All dented plates should be restored to their original shape if possible. Shallow abrasions or scratches should be burnished with a burnishing tool that will compress the projecting metal along the edges down into the scratch. Burnishing has no cutting action and removes no metal. When surface irregularities are smoothed by burnishing, the stress concentration will be lessened.

Practical and laboratory activity

1. What methods of inspection do you know?

1. Hardness testing		2. Dirt inspection		Correct are
3. Chemical inspection		4. Visual inspection		
5. Electrical inspection		6. Radioactive inspection		
7. Magnetic inspection		8. Inspection for cracks		

2. Why does the cleanup of damage performed?

1. To prevent the possibility of the future damage growth		Correct is
2. To make flat surface		
3. To ease the work on damage elimination		
4. To make damaged surface look better		

3. How does the square-shaped cutouts are treated?

1. Corners are sharpened	2. Increasing the corners quantity	Correct is
3. Cutout is decreased	4. Cutout is increased	
5. Corners are rounded	6. Corners are glued	
7. Corners are obtused	8. Corners are painted with red	

4. Choose any airplane you want in the hangar and fill in the table below

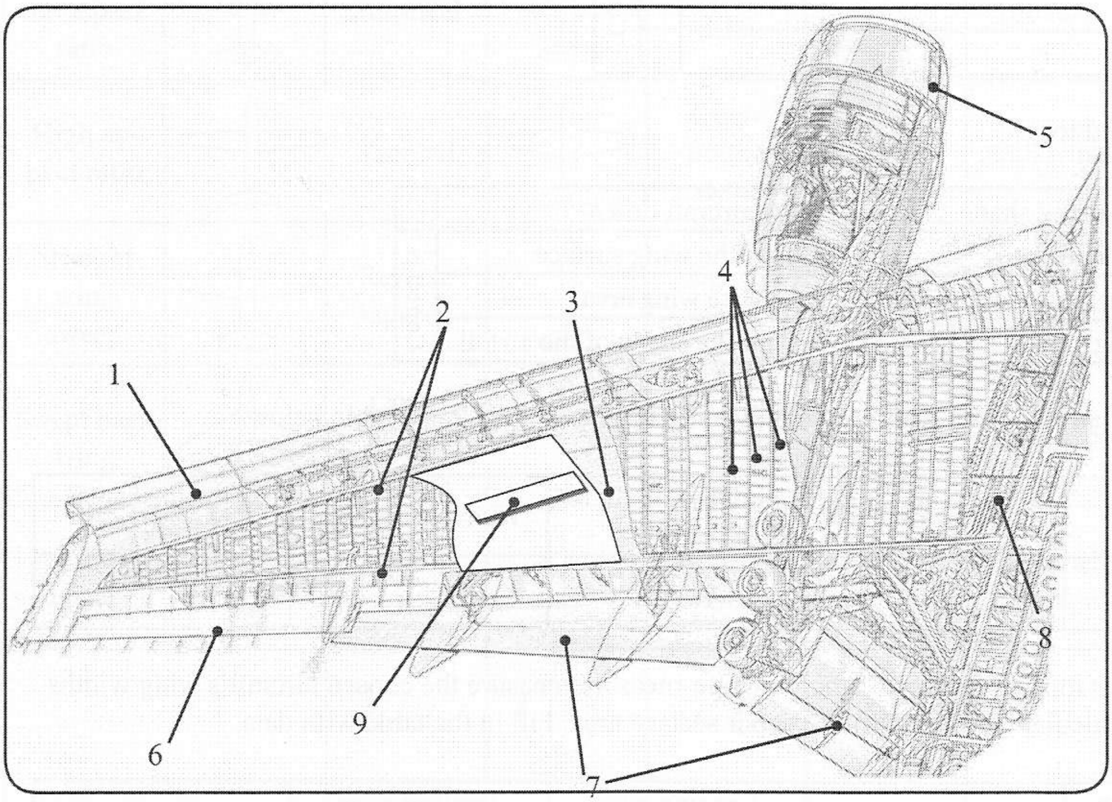
Damage level is chosen from: insignificant, moderate, severe

Repair steps numbers:

Airplane name	Inspection type	Damage type	Damage level	Steps of repair (№)

3.1 Wing.

All planes have wings (fig.16), that is possibly the most important part of an airplane that hangs it in the air. The wings are shaped with smooth surfaces and attached to the fuselage. The smooth surfaces are slightly curved from the front or leading edge, to the back or trailing edge. Air moving around the wing produces the upward lift for the airplane. The shape of the wings determines how fast and high the plane can fly. A cut through the wing from front to back is called an airfoil. Usually ribs (4) incorporate the airfoil shape of the wing, and the skin (3) adopts this shape when stretched over the ribs. Ribs are forming elements of the structure of a wing, especially in traditional construction. The ribs attach to the main spar, and by being repeated at frequent intervals, form a skeletal shape for the wing. The spar (2) is often the main structural member of the wing, running spanwise at right angles. The spar carries flight loads and the weight of the wings whilst on the ground. Other structural and forming members such as ribs may be attached to the spar or spars, with stressed skin construction also sharing the loads where it is used. There may be more than one spar in a wing or none at all. However, where a single spar carries the majority of the forces on it, it is known as the main spar.



1. Slats
2. Spars
3. Skin
4. Ribs
5. Power plant
6. Aileron
7. Flaps
8. Reinforced rib
9. Spoiler

Fig. 16. Boeing 747 wing.

The hinged control surfaces are used to steer and control the airplane. Ailerons (6) can be used to generate a rolling motion for an aircraft. Ailerons are small hinged sections on the outboard portion of a wing. Ailerons usually work in opposition: as the right aileron is deflected upward, the left is deflected downward, and vice versa. The ailerons work by changing the effective shape of the airfoil of the outer portion of the wing. Spoilers (9) are small, hinged plates on the top portion of wings. Spoilers can be used to slow an aircraft, or to make an aircraft descend, if they are deployed on both wings. Spoilers can also be used to generate a rolling motion for an aircraft, if they are deployed on only one wing. During take-off and landing the airplane's velocity is relatively low. To keep the lift high (to avoid objects on the ground), airplane designers try to increase the wing area and change the airfoil shape by putting some moving parts on the wings' leading and trailing edges. The part on the leading edge is called a slat (1), while the part on the trailing edge is called a flap (7). The flaps and slats move along metal tracks built into the wings. Moving the flaps aft (toward the tail) and the slats forward increases the wing area. Pivoting the leading edge of the slat and the trailing edge of the flap downward increases the effective camber of the airfoil, which increases the lift. In addition, the large aft-projected area of the flap increases the drag of the aircraft. This helps the airplane slow down for landing.

Practical and laboratory activity

1. What constructional element incorporates airfoil shape?

1. Spars	2. Skin	Correct is
3. Spoilers	4. Slats	
5. Ribs	6. Flaps	
7. Wing	8. Aileron	

2. What term from below does not represent the control surface?

1. Ailerons		Correct is
2. Flaps		
3. Slats		
4. Spars		

3. Slats are used to:

1. Incorporate airfoil shape	2. Slow aircraft down	Correct is
3. Carry flight loads	4. Cover the wing surface	
5. Generate a rolling motion	6. Decrease wing area	
7. Increase wing area	8. Adopt the shape of the airfoil	

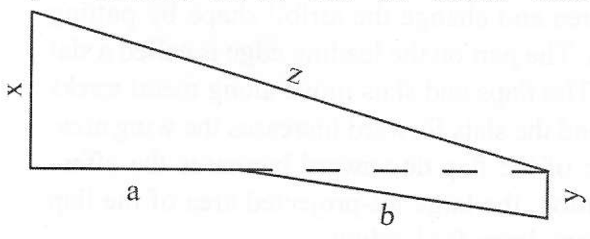
4. Choose any airplane you want in the university hangar and fill in the table below.

Airplane name	Number of slats	Number of ailerons	Number of flaps	Number of spoilers

5. Get a partner for help and with a help of tape-measure measure the chosen aircraft's wing widths and lengths and calculate its approximate upper surface area. Fill in the table with data.

Wing root width, m	Wing tip width, m	Leading edge length (s)*, m	Trailing edge length (s)*, m	Area, m²

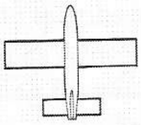
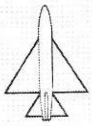
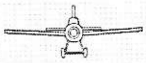
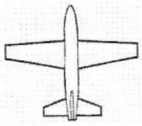
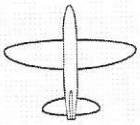
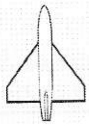
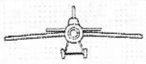
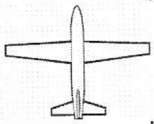
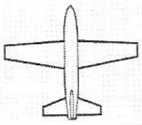
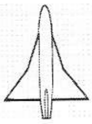
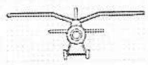
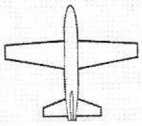
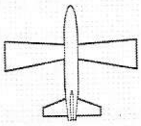
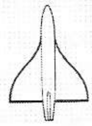
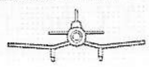
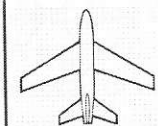
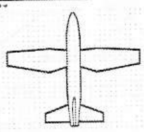
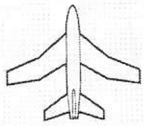
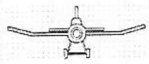
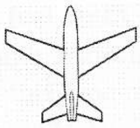
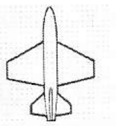
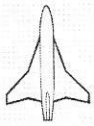
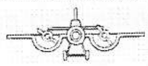
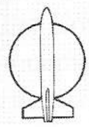
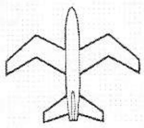
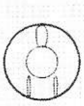
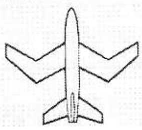
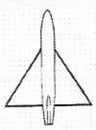
*Tip: depending on the wing different types, they have complex shapes like this one below. So, as you see, a and b are different size trailing edge lengths and they are measured separately. To make the area calculation easier, you may divide the wing on the simpler surfaces, shown with the dashed lines.



3.2 Wing types.

Wing types are subdivided on several classifications like wing platform, planform variation along span, dihedral and anhedral. All of the wing types are listed in the table 3.

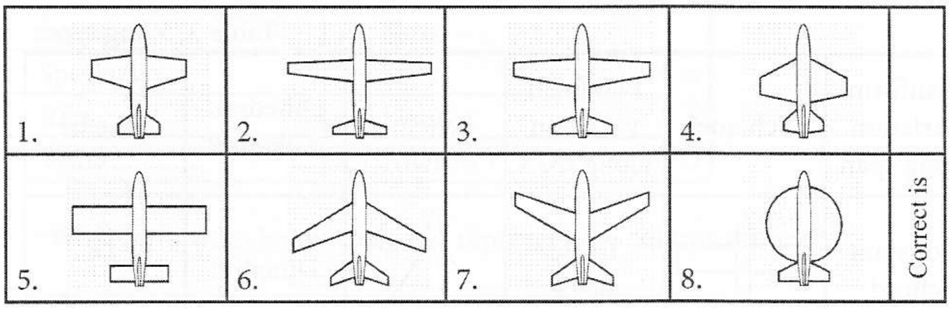
Table 3. Wing types.

Wing platform	Scheme	Planform variation along span	Scheme	Planform variation along span	Scheme	Dihedral/ Anhedral	Scheme
Low aspect ratio		Constant chord		Tailed delta		Dihedral	
Moderate aspect ratio		Elliptical		Cropped delta		Anhedral	
High aspect ratio		Tapered		Compound delta		Gull wing	
Straight wing sweep		Reverse tapered		Ogival delta		Inverted gull	
Swept back wing		Compound tapered		Crescent		Cranked	
Forward swept wing		Trapezoidal		Cranked arrow		Channel wing	
		Circular		M-wing			
		Flying saucer		W-wing			
		Tailless delta					

The wing planform is the silhouette of the wing when viewed from above or below and the aspect ratio is the span divided by the mean or average chord. It is a measure of how long and slender the wing appears when seen from above or below. The wing chord may be varied along the span of the wing, for both structural and aerodynamic reasons, so we use a term - planform variation along span. Angling the wings up or down spanwise from root to tip can help to resolve various design issues, such as stability and control in flight, this is where the term dihedral/anhedral takes place.

Practical and laboratory activity

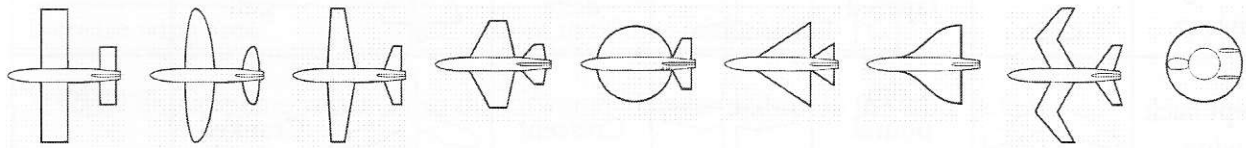
1. What shape of the wing represents swept back wing platform?



2. What is a dihedral angle?

1. Upward spanwise from root to tip		Correct is
2. Angle between two wings		
3. Angle of the wing swept back		
4. Downward spanwise from root to tip		

3. Connect two related items

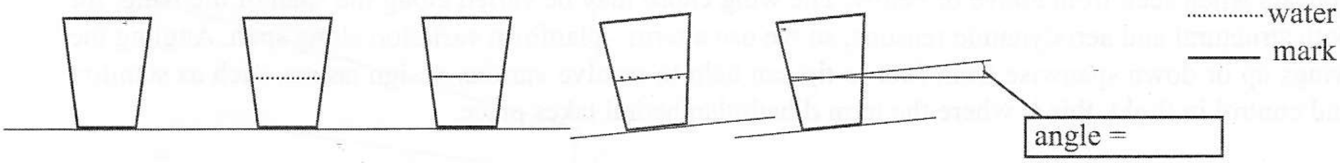


Tapered — Tailed delta — Elliptical — Constant chord — M-wing — Ogival delta — Flying saucer — Circular — Trapezoidal

4. Select any airplane you want in the university hangar and fill in the table below.

Aircraft name	Wing platform	Planform variation along span	Dihedral/anhedral wing type

5. Determine the dihedral or anhedral angle value (in degrees) of the chosen airplane. For this purpose take the glass, half-filled with water and draw a mark line water level on the glass with permanent marker. Now put the glass on the most flat surface of the wing and mark the change of the water level. Take the protractor and determine the angle between these marks. The process is schematically shown below.



3.3 Materials, possible damages, diagnostics and monitoring.

The wings of an aircraft are designed to develop lift when they are moved through the air. The particular wing design depends upon many factors for example, size, weight, use of the aircraft, desired landing speed, and desired rate of climb. In some aircraft, the larger compartments of the wings are used as fuel tanks. The fuel tanks inside the wing are sealed with rubber. The wings are designated as right and left, corresponding to the right- and left-hand sides of a pilot seated in the aircraft. Wing is a part of the airplane, so it consist of the same materials as a fuselage. Like the skin of the fuselage, the skin of the wing is made of an aluminium alloys. The skin is attached to all the structural member sand carries part of the wing loads and stresses. During flight, the loads imposed on the wing structure act primarily on the skin. From the skin, the loads are transmitted to the ribs and then to the spars. The spars support all distributed loads as well concentrated weights, such as a fuselage, landing gear, and nacelle. Corrugated sheet aluminum alloy is often used as a subcovering for wing structures. Inspection and access panels are usually provided on the lower surface of a wing. Drain holes are also placed in the lower surfaces. Walkways are provided on the areas of the wing where personnel should walk or step. The substructure is stiffened or reinforced in the vicinity of the walkways to take such loads. Walkways are usually covered with a nonskid surface. Some aircraft have no built-in walkways. In these cases removable mats or covers are used to protect the wing surface.

Possible wing damages and monitoring.

Damages to the airframe are many and may vary from those that are classified as negligible to those that are so extensive that an entire member of the airframe must be replaced. The slightest damage could affect the flight characteristics of the aircraft. The most common causes of damage to the airframe are collision, stress, heat, corrosion, foreign objects, fatigue, and combat damage. Let's look at the most common damages that wing suffer from.

Stress - this type of damage is usually identified by loosened, sheared, or popped rivets; wrinkled skin or webs and cracked or deformed structural members. This damage is usually caused by violent manoeuvres or rough landings like it is shown on the (fig. 17) picture, especially severe damages to the wing can cause the full fuel tanks during such landing. When the pilot reports these discrepancies on the yellow sheet, a thorough inspection of the entire aircraft must be performed.

Collision - this type of damage is often the result of carelessness by maintenance personnel. It varies from minor damage, such as dented or broken areas of skin, to extensive damage, such as torn or crushed structural members and misalignment of the aircraft.

Corrosion - damage to airframe components and the structure caused by corrosion will develop into permanent damage or failure if not properly treated. The corrosion control section of the maintenance instructions manual describes the maximum damage limits. These limits should be checked carefully, and if they are exceeded, the component or structure must be repaired or replaced.

Fatigue - this type of damage is more noticeable as the operating time of the aircraft accumulates. The damage will begin as small cracks, caused by vibration and other loads imposed on skin fittings, especially in joint places like where the wing attaches to the fuselage, and load-bearing members, where the fittings are attached.

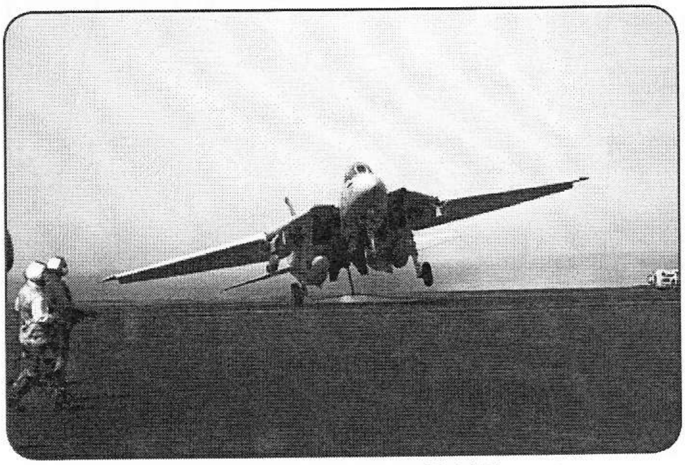


Fig. 17. Rough landing of the military F-14 Tomcat

Heat - certain areas of high-performance aircraft are exposed to high temperatures. These areas usually include the engine bleed lines, fuselage sections around the engine, the aft fuselage and horizontal stabilizer, and the wing sections around the boundary layer control system. Some aircraft structural repair manuals include diagrams that illustrate the heat danger areas.

Practical and laboratory activity

1. What material is used for wing skin?

1. Plastics	2. Carbon and glass fibre	Correct is
3. Magnesium Alloys	4. Aluminium alloys	
5. Iron	6. Beryllium	
7. Steel	8. Titanium	

2. What wing structural element loads primarily act on?

1. Spars		Correct is
2. Skin		
3. Ribs		
4. Longerons		

3. What damage type is usually caused by violent manoeuvres or rough landings?

1. Collision	2. Corrosion	Correct is
3. Fatigue	4. Stress	
5. Heat	6. Abrasive wear	
7. Vibration	8. Explosion	

4. Choose any airplane you want in the university hangar and fill in the table below.

Aircraft name	Damage place on wing	Damage type	Cause of damage

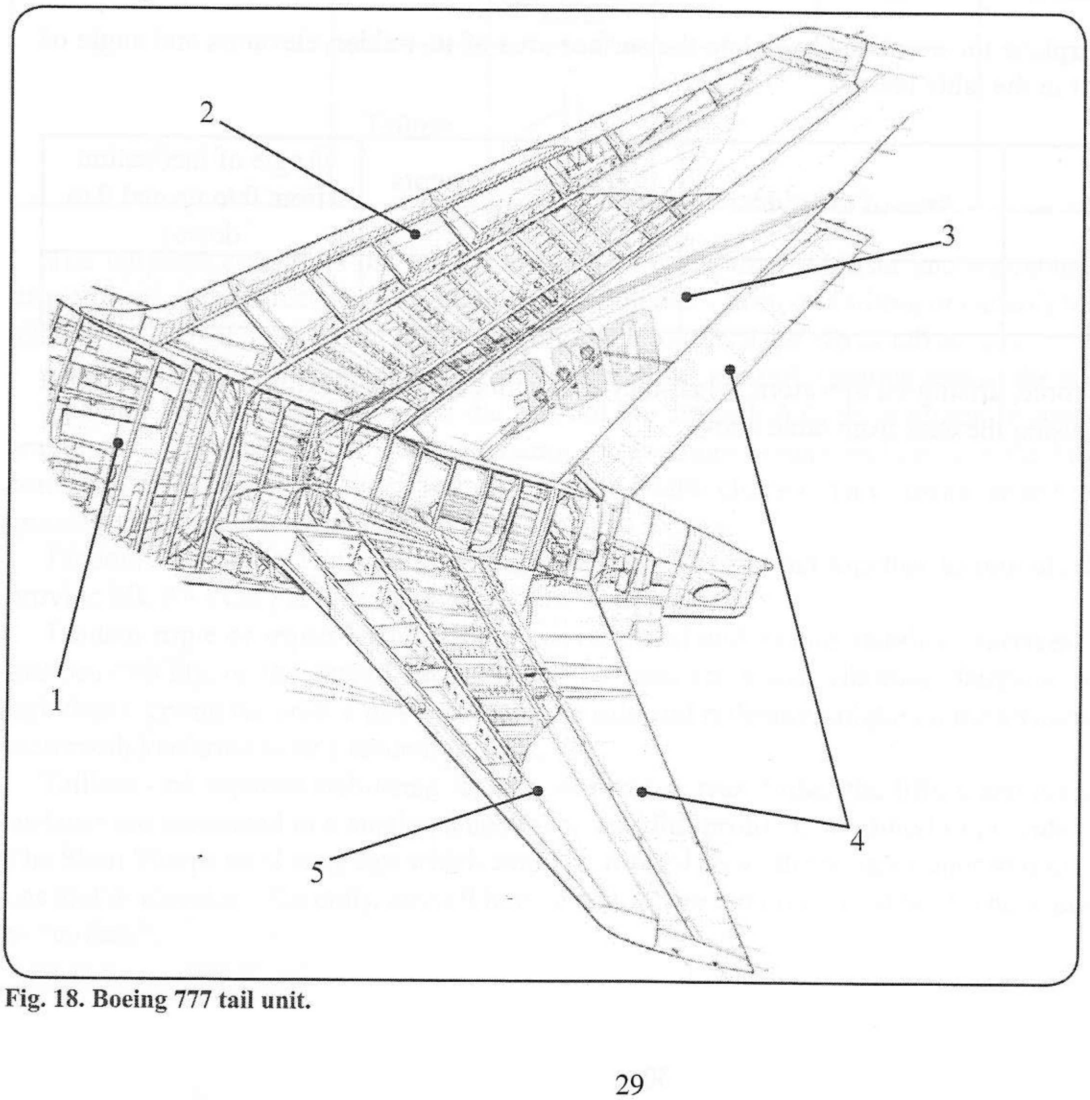
5. An airplane technician didn't properly calibrate the flaps angle of inclination so that the flap on the left wing has a maximum angle of inclination into lower position several degrees more than the flap from the right wing. A pilot is approaching on landing and lowers the flaps by the maximum angle. What situation can occur?

Tail unit

4.1 Tail unit.

A tail unit of the aircraft (fig. 18) consist of a horizontal stabilizer (5) and vertical stabilizer (2). Horizontal stabilizer includes an elevator (4) and vertical stabilizer include rudder (3). The horizontal stabilizer is a fixed wing section whose job is to provide stability for the aircraft, to keep it flying straight. The horizontal stabilizer prevents up-and-down, or pitching, motion of the aircraft nose. The elevator is the small moving section at the rear of the stabilizer that is attached to the fixed sections by hinges. Because the elevator moves, it varies the amount of force generated by the tail surface and is used to generate and control the pitching motion of the aircraft. There is an elevator attached to each side of the fuselage. The elevators work in pairs; when the right elevator goes up, the left elevator also goes up. The elevator is used to control the position of the nose of the aircraft and the angle of attack of the wing. Changing the inclination of the wing to the local flight path changes the amount of lift which the wing generates. This, in turn, causes the aircraft to climb or dive. During take off the elevators are used to bring the nose of the aircraft up to begin the climb out. During a banked turn, elevator inputs can increase the lift and cause a tighter turn. That is why elevator performance is so important for fighter aircraft.

The Vertical stabilizer is a fixed wing section whose job is to provide stability for the aircraft, to keep it flying straight. The vertical stabilizer prevents side-to-side, or yawing, motion of the aircraft nose. The rudder is the small moving section at the rear of the stabilizer that is attached to the fixed sections by hinges. Because the rudder moves, it varies the amount of force generated by the tail surface and is used to generate and control the yawing motion of the aircraft. Interestingly, it is not used to turn the aircraft in flight. Aircraft turns are caused by banking the aircraft to one side using either ailerons or spoilers. The banking creates an unbalanced side force component of the large wing lift force which causes the aircraft's flight path to curve. The rudder input insures that the aircraft is properly aligned to the curved flight path during the manoeuvre. Otherwise, the aircraft would encounter additional drag or even a possible adverse yaw condition in which, due to increased drag from the control surfaces, the nose would move farther off the flight path.



1. Fuselage
2. Vertical stabilizer
3. Rudder
4. Elevators
5. Horizontal stabilizer

Fig. 18. Boeing 777 tail unit.

Theme 4. Tail unit

Practical and laboratory activity

1. A tail unit consist of:

1. Horizontal stabilizer	2. Rudder	
3. Angular stabilizer	4. Elevator	Correct is
5. Vertical stabilizer	6. Ailerons	
7. Flaps	8. Stabilizer	

2. The elevator purpose is to:

1. Control the yawing motion of the aircraft		Correct is
2. Control the rolling motion of the aircraft		
3. Control the straight motion of the aircraft		
4. Control the pitching motion of the aircraft		

3. What control surface controls the yawing motion of an aircraft?

1. Elevator	2. Rudder		
3. Flaps	4. Ailerons		Correct is
5. Spoilers	6. Vertical stabilizer		
7. Horizontal stabilizer	8. None of the mentioned		

4. Choose any airplane tou want and calculate the surface area of its rudder, elevators and angle of their inclination. Fill in the table below

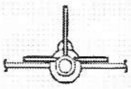
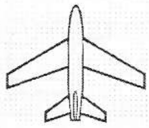
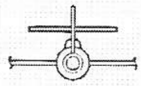
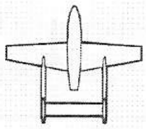
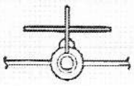
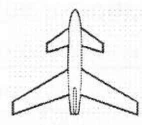
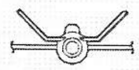
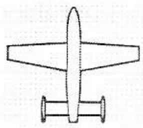
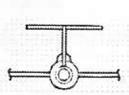
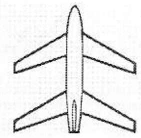
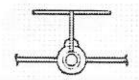
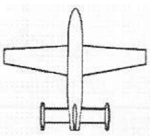
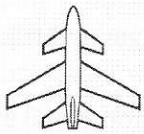
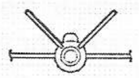
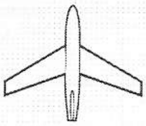
Aircraft name	Area of the rudder	Area of the elevators (sum)	Angle of inclination (from 0 to up and 0 to down)

5. Calculate the force, arising on elevators, when they are inclined by the maximum angle up at the speed of 200 km/h, using the data from table above.

4.2 Tail unit types.

Tailplanes like wings subdivided on several types which are listed in table below (table 4).

Table 4. Types of tailplanes.

Location of tailplane	Scheme	Horizontal stabilizer	Scheme	Horizontal stabilizer position	Scheme	Vertical stabilizers	Scheme
Low		Conven-tional		Cruciform tail		Twin boom A	
Mid		Canard		Pelican tail		Twin tail A	
High		Tandem		T-tail		Multiple tails	
		Triple tandem		V-tail			
		Tailless					

The tailplane comprises the tail-mounted fixed horizontal stabiliser and movable elevator. Besides its planform, it is characterised by number of tailplanes - from 0 (Tailless or canard) to 3 (Roe triplane), location of tailplane - mounted high, mid or low on the fuselage, fin or tail booms.

Conventional - "tailplane" stabiliser at the rear of the aircraft, forming part of the tail or empennage.

Canard - "foreplane" stabilizer at the front of the aircraft. A fairly common feature of the 4.5th generation jet fighters as supersonic aerodynamics grew more mature and because the forward surface can contribute lift during level flight. But due to poor stealth characteristics these are not found on true fifth generation jet fighters. A good example is the Saab Viggen.

Tandem - two main wings, one behind the other. The two act together to provide stability and both provide lift. An example is the Rutan Quickie.

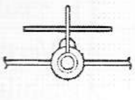
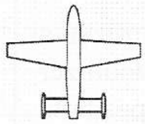
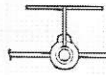
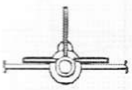
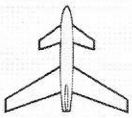
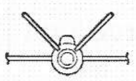
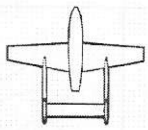
Tandem triple or triplet - having both conventional and canard stabiliser surfaces. This may be for manoeuvrability, or the canard surfaces may be used for active vibration damping, to smooth out air turbulence giving the crew a more comfortable ride and reducing fatigue on the airframe. Popularly (but incorrectly) referred to as a tandem triplane.

Tailless - no separate stabilising surface, at front or rear. Either the lifting and horizontal stabilising surfaces are combined in a single plane, or the aerofoil profile is modified to provide inherent stability. The Short Sherpa used wing tips which could be rotated about the wing's major axis to act as either ailerons and/or elevators. Recently, aircraft having a tailplane but no vertical tail fin have also been described as "tailless".

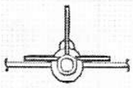
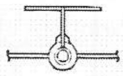
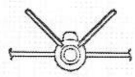
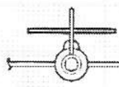
Tail unit

Practical and laboratory activity

1. What shape of the tail unit represents horizontal stabilizer position of cruciform tail?

1. 	2. 	3. 	4. 	Correct is
5. 	6. 	7. 	8. 	

2. Find the odd term which does not represent the location of tailplane

Low-type	High-type	V-type	Mid-type
			

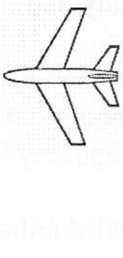
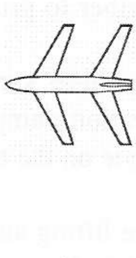
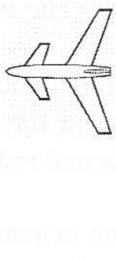
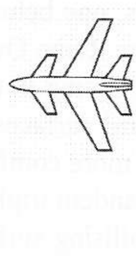
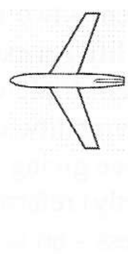
3. Select any airplane you want in the university hangar and fill in the table below.

Aircraft name	Location of tailplane	Horizontal stabilizer position	Vertical stabilizer type

4. What does tailplane comprise?

1. Control the yawing motion of the aircraft		Correct is
2. Control the rolling motion of the aircraft		
3. Control the straight motion of the aircraft		
4. Control the pitching motion of the aircraft		

5. Connect two related terms.

				
Tandem	Triple tan-dem	Tailless	Conventional	Canard

4.2 Materials, possible damages, and diagnostics.

Being the fuselage part, the tail unit is made of the same materials, (refer to the part 2.3 fuselage materials for more information). Nowadays quite often in modern airplanes the more and more of the composite materials are used in production of the tailplanes and its control surfaces. Composite materials can withstand the loads which the tailplane takes and reduces the weight of the airplane, which leads to less fuel consumption and larger flight distance. Also composites such as carbon fibres, glass fibres and kevlar are corrosion preventative.

Considering the tailplane as a set of wings, the possible damages are very similar to the airplane wings. In joint places, where huge loads applied on the control surfaces and stabilizers cracks and deformation can arise eventually. But the possible advantage on one hand of the tailplane that is made of nonmetallic composites is that it is corrosion resistant. On the other hand, these materials have poor impact resistance, if the tail unit parts are damaged with foreign objects, birds strike or instruments.

The most common types of damage to the surface are abrasions, scratches, scars, and minor dents. These minor surface damages require no repair other than the replacement of the original protective coating to prevent corrosion if no breaks, holes, or cracks exist.

Sandwich construction repair

Repairing delaminations. Facing-to-core voids of less than 2.5 inches in diameter can usually be repaired by drilling a series of holes 0.06 to 0.10 inch in diameter in the upper facing over the void area. An expandable forming resin, is then injected through the holes with a pressure-type caulking gun. When the void is on the lower surface of the panel, only sufficient resin must be injected so as to completely fill the void. With voids on the upper surface, the core area should be filled until the resin comes out of the injection holes. These holes should be sealed with a thermosetting epoxy resin adhesive, and the entire assembly cured with lamps, as required for the adhesive system. When the void areas are large, it is necessary to remove the facing over the damaged area and follow the repair procedures for a puncture.

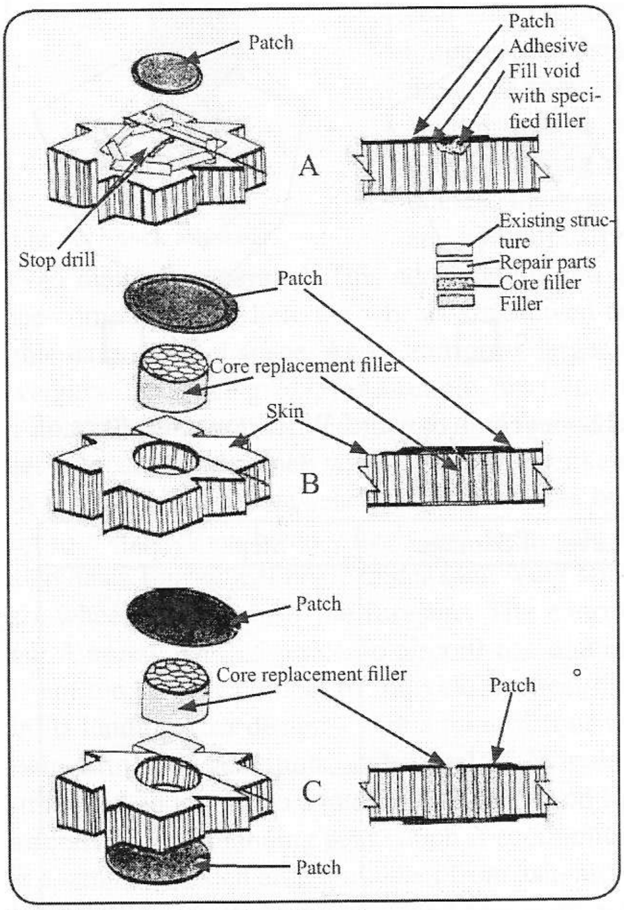


Fig. 19. Sandwich material repair.

Repairing Punctures. A puncture is defined as a crack, break, or hole through one or both skin facings with resulting damage to the honeycomb and/or balsa wood core. The size of the puncture, amount of damage to the core, assembly to be repaired (rudder, elevator, etc.), and previous repairs to the damaged assembly are factors to be considered in determining the type of repair to be made. Damage to a honeycomb and/or balsa wood core assembly that exceeds a specified length or diameter in inches or the total number of repairs exceeds a specified percentage of the total bonded area necessitates replacement of the assembly.

A standard procedure of sandwich materials puncture repair is shown on a figure (fig. 19)

A: Mask area around damage approximately 5 cm beyond stop holes. A patch is a same material as damage facing patch must extend at least 2-3 cm beyond stop holes.

B: Patch 2 cm beyond the hole on all sides bevel edges 45.

C: The final step of repair.

Practical and laboratory activity

1. What materials have poor impact resistance?

1. Aluminium alloys	2. Carbon and glass fibre composites		Correct is
3. Magnesium Alloys	4. Plastics		
5. Titanium	6. Beryllium		
7. Steel	8. Iron		

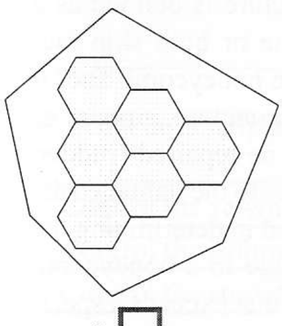
2. A puncture is:

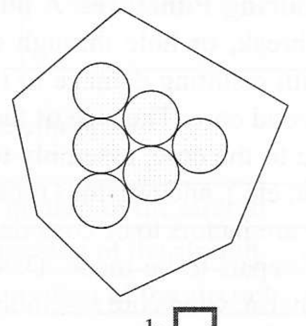
1. A dented place on a flat surface where honeycomb is inside		Correct is
2. A hole through one or both skin facings resulting damage to the honeycomb		
3. An abrasive wear of the skin due to the dust particles in air		
4. A process of the sandwich composites repair		

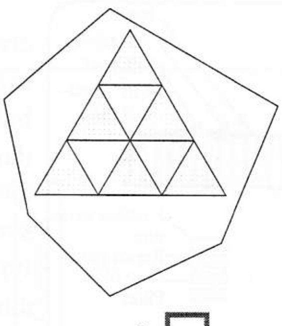
3. The most common damages to the surface are:

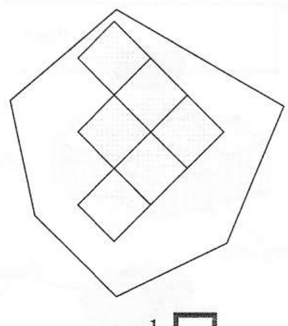
1. Abrasions		2. Corrosion		Correct are
3. Deformation		4. Scratches		
5. Scars		6. Bulge		
7. Holes		8. Dents		

4. What structure does honeycomb look like?


a ☐


b ☐


c ☐


d ☐

5. In a university hangar find an airplane with exposed honeycomb damage. Write down the steps of its repair in table below.

Aircraft name	Location of damage	Level of damage	Steps to repair

5.1 Landing gear.

In aviation, the undercarriage or landing gear is the structure (usually wheels) that supports an aircraft and allows it to move across the surface of the Earth when it is not flying. Wheeled undercarriages normally come in two types: conventional or "taildragger" undercarriage, where there are two main wheels towards the front of the aircraft and a single, much smaller, wheel or skid at the rear; or tricycle undercarriage where there are two main wheels (or wheel assemblies) under the wings and a third smaller wheel in the nose. The taildragger arrangement was common during the early propeller era, as it allows more room for propeller clearance. Most modern aircraft have tricycle undercarriages. Taildraggers are considered harder to land and take-off (because the arrangement is unstable, that is, a small deviation from straight-line travel is naturally amplified by the greater drag of the main wheel which has moved farther away from the plane's centre of gravity due to the deviation), and usually require special pilot training. Landing gear usually includes wheels equipped with shock absorbers for solid ground, but some aircraft are equipped with skis for snow or floats for water, and/or skids or pontoons (helicopters). Shock absorbers (fig. 20) must absorb or dissipate energy. They consist of a rod (1) on which the piston with seals (2) is mounted. A rod with a piston is dealed inside the cylinder (3) which serves as a reservoir for oil (4). To absorb shock with maximum effectiveness the absorbers have a floating piston (5) inside a reservoir with oil. This floating piston divides the reservoir on two chambers - one with oil and another with gas (6). This fluid filled piston/cylinder combination is a dashpot.

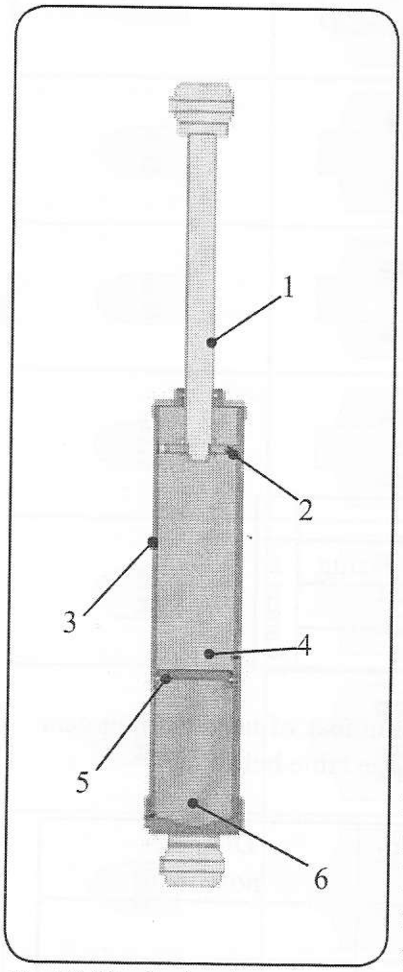


Fig. 20. Shock absorber

To decrease drag in flight some undercarriages retract into the wings and/or fuselage with wheels flush against the surface or concealed behind doors; this is called retractable gear (fig. 21). A retractable landing gear structure includes hydraulic ram (1) or actuator which pushes the hinge mechanism (2) that is connected to the strut (3). A wheel (5) is mounted on a wheel boss (4), connected to the strut. In a such way the landing gear is retracting into the wing or fuselage (6). If the wheels rest protruding and partially exposed to the air stream after being retracted, the system is called semi-retractable. Most retraction systems are hydraulically-operated, though some are electrically-operated or even manually-operated. This adds weight and complexity to the design. In retractable gear systems, the compartment where the wheels are stowed are called wheel wells, which may also diminish valuable cargo or fuel space. As aircraft grow larger, they employ more wheels to cope with the increasing weights. The Boeing 747, for example, has five sets of wheels: a nose-wheel assembly and four sets of four-wheel bogies. A set is located under each wing, and two inner sets are located in the fuselage, a little rearward of the outer bogies, adding up to a total of eighteen wheels and tires. The Airbus A380 also has a four-wheel bogie under each wing with two sets of six-wheel bogies under the fuselage. The enormous Ukrainian Antonov An-225 jet cargo aircraft has one of the largest, if not the largest, number of individual wheel/tire assemblies in its landing gear design - with a total of four wheels on the twin-strut nose gear units, and a total of 28 main gear wheel/tire units, adding up to a total of 32 wheels and tires. For light aircraft a type of landing gear which is economical to produce is a simple wooden arch laminated from ash, as used on some home built aircraft. A similar arched gear is often formed from spring steel. The main advantage of such gear is that no other shock absorbing device is needed; the deflecting leaf provides the shock absorption.

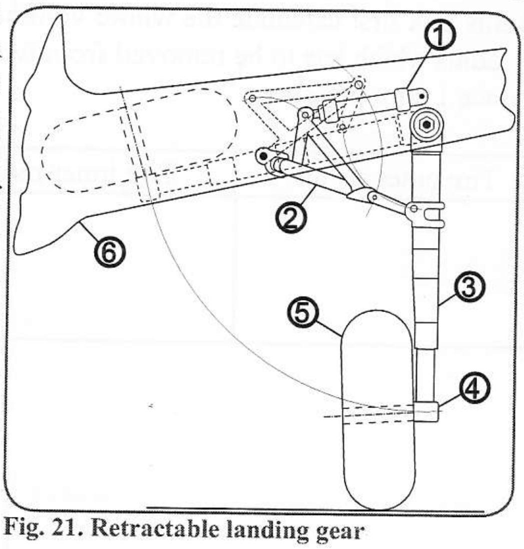


Fig. 21. Retractable landing gear

Practical and laboratory activity

1. Modern landing gear usually includes wheels equipped with:

1. Tires	2. Springs	Correct is
3. Shock absorbers	4. Bolts	
5. Brakes	6. Automatic tire pump	
7. Manometers	8. Anti-slick system	

2. Shock absorbers:

1. Absorb and dissipate energy		Correct is
2. Release energy		
3. Produce energy		
4. Store energy		

3. Landing gear is retracted into the fuselage or landing gear to:

1. Increase drag	2. Ballance the airplane	Correct is
3. Protect from damage	4. Protect hydraulics from freezing	
5. Fill the space inside wing or fuselage	6. Decrease drag	
7. Pump up the tire before next landing	8. Protect birds against strike	

4. Select any aircraft you want in the university hangar and count the number of nose landing gear wheels and main landing gear wheels. Determine their diameter and fill in the table below.

Aircraft name	Nose LG wheels quantity	Main LG wheels quantity	Diameter nose/main

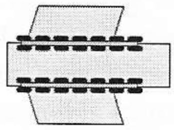
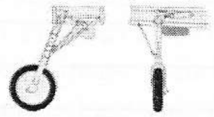
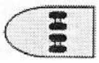
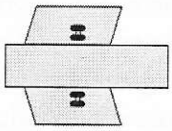
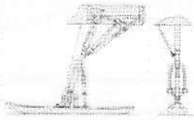
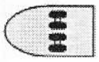
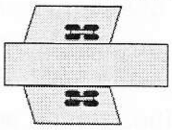
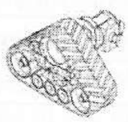
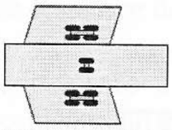
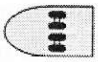
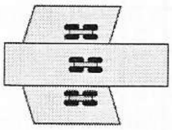
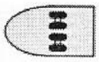
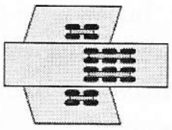
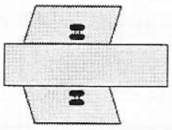
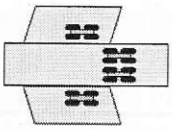
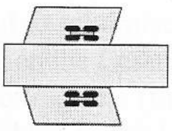
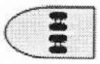
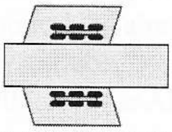
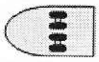
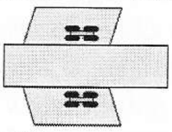
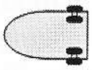
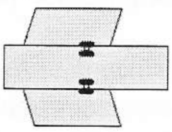
5. Now calculate the volume of necessary gas to fill the nose wheel tire for the chosen plane. To carry out this task first calculate the whole volume of tire with outer radius, then calculate the volume of inner radius which has to be removed from whole volume and you will get the necessary amount of air to produce 1 atm. pressure.

Tire outer radius	Tire inner radius	Tire thickness	Volume, m^3

AREA FOR CALCULATION

5.2 Landing gear types.

Table 5. Landing gear configuration and types.

Nose	Configuration	Example	Other types	Name
		Antonov 225		Standard
		A318, A319, A320, A321		Ski
		A300, A310, A330		Crawler
		A340-200/300		Pontoon
		A340-500/600		
		A380		
		Boeing 737		
		Boeing 747		
		Boeing 757, 767		
		Boeing 777		
		Boeing 787		
		Boeing B-52		

Practical and laboratory activity

1. What nonstandard landing gear do you know?

1.	
2.	
3.	

2. A pontoon type of landing gear retracts into:

1. Wings	2. Fuselage	
3. Cockpit	4. Tail unit	Correct is
5. It does not retract	6. It does not exist	
7. It is a part of wing	8. None of the variants is correct	

3. What factor influence on the quantity of landing gear and wheels?

1. Fuselage length	2. Wings size	
3. Airplane mass	4. Type of engines	Correct is
5. Flight range	6. Airplane mass and geometrical size	
7. Airplane run speed	8. Quantity of passengers	

4. In the university hangar choose any airplane you want and determine the landing gear type according to the table in your workbook (table 5) and draw it in the table below.

Aircraft name	Landing gear type (picture)	Name of the airplane with similar type from table 5	Name of the landing gear if it is nonstandard

5. What parameters influence on landing gear location?

5.3 Landing gear materials, possible damages, diagnostics.

Landing gear materials are made in most cases of steel and titanium. Struts and cylinders of the landing gear are made of steel alloys to withstand high stresses during aircraft landing. Aluminium, bronze alloys also used, but as a parts of piston, and those parts which doesn't take part in high loads support. When the airplane goes on landing, the shock absorber carries a huge load on itself and compresses the gas inside the gas chamber. Due to the compression gas heats up and this can be dangerous and leads to the damage of the landing gear. To prevent the explosion of tire or damage of the landing gear and loose of its characteristics, when oil is foaming under the heavy use, a neutral gas should be pumped inside the shock absorber like nitrogen. It is a non-explosive and noncorrosive gas which doesn't react with metal. Landing gear wheels are also pumped with a nitrogen.

The possible landing gear damages are: leakage of the shock absorber, cracks in places where huge loads act, abrasive scratches on the strut, brakes failure, tire slippage, actuators failure. Cracks appear due to the weather condition changes and excess of permissible loads on the landing gear (fig. 22). Abrasive scratches appear in most cases during landing and take-off, when the landing gear strut has contact with small particle of dust which are raising from the ground. A tire slippage suggests that during maintenance a soap, water, installation liquids could have contact with tire. Brakes of the landing gear can fail due to the problems in hydraulic system or due to overheating even it is possible that they can melt and tires can explode.

Malfunctions or human errors (or a combination of these) related to retractable landing gear have been the cause of numerous accidents and incidents throughout aviation history. Distraction and preoccupation during the landing sequence played a prominent role in the approximately 100 gear-up landing incidents that occurred each year in the United States between 1998 and 2003. A gear-up landing incident, also known as a belly landing, is an accident that may result from the pilot simply forgetting, or failing, to lower the landing gear before landing or a mechanical malfunction that does not allow the landing gear to be lowered. Although rarely fatal, a gear-up landing is very expensive, as it causes massive airframe damage. For propeller driven aircraft it almost always requires a complete rebuild of engines because the propellers strike the ground and suffer a sudden stoppage if they are running during the impact. Many aircraft between the wars - at the time when retractable gear was becoming commonplace - were deliberately designed to allow the bottom of the wheels to protrude below the fuselage even when retracted to reduce the damage caused if the pilot forgot to extend the landing gear or in case the plane was shot down and forced to crash-land. Examples include the Avro Anson and the Douglas DC-3. The modern-day Fairchild-Republic A-10 Thunderbolt II carries on this legacy: it is similarly designed in an effort to avoid (further) damage during a gear-up landing, a possible consequence of battle damage.

Some aircraft have a stiffened fuselage bottom or added firm structures, designed to minimise structural damage in a wheels-up landing. When the Cessna Skymaster was converted for a military spotting role (the O-2 Skymaster), fibreglass railings were added to the length of the fuselage; they were adequate to support the aircraft without damage if it was landed on a grassy surface.

On September 21, 2005, JetBlue Airways Flight 292 successfully landed with its nose gear turned 90 degrees sideways, resulting in a shower of sparks and flame after touchdown. This type of incident is very uncommon as the nose oleo struts are designed with centring cams to hold the nose wheels straight until they are compressed by the weight of the aircraft.

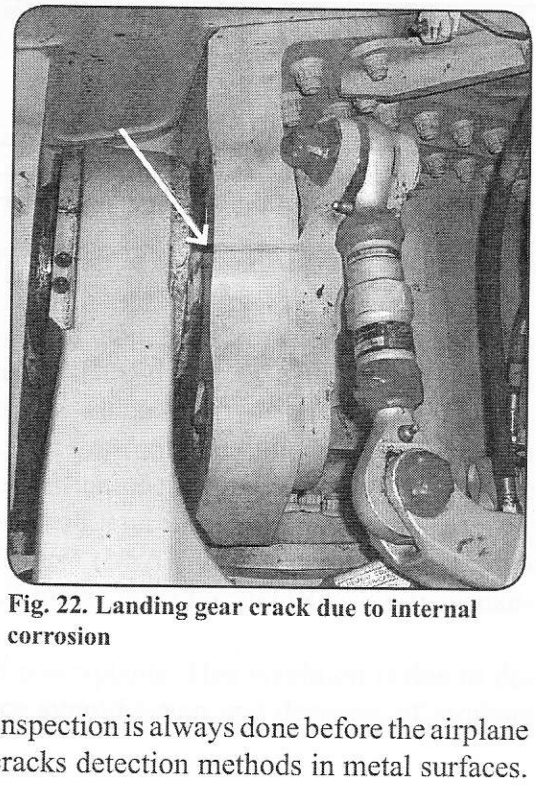


Fig. 22. Landing gear crack due to internal corrosion

To prevent the accidents related to the landing gear a visual inspection is always done before the airplane take-off, which can include supersonic, magnetic and paint cracks detection methods in metal surfaces.

Practical and laboratory activity

1. What gas is often used in landing gear shock absorbers?

1. Argon	2. Oxygen		Correct is
3. Nitrogen	4. Neon		
5. Helium	6. Hydrogen		
7. Krypton	8. Chlorine		

2. Abrasive scratches on a landing gear strut appear due to:

1. Rapid temperature changes		Correct is
2. Hydraulic liquid leakage		
3. Lack of the lubricant		
4. Contact with small particles of dust		

3. What is the most frequent incident or accident which is related to landing gear operation?

1. Tire explosion	2. Brakes melting	Correct is
3. Strut breakage	4. Hydraulic liquid leakage	
5. Belly landing	6. Actuators failure	
7. Landing gear deformation	8. Freezing of the landing gear on high altitudes	

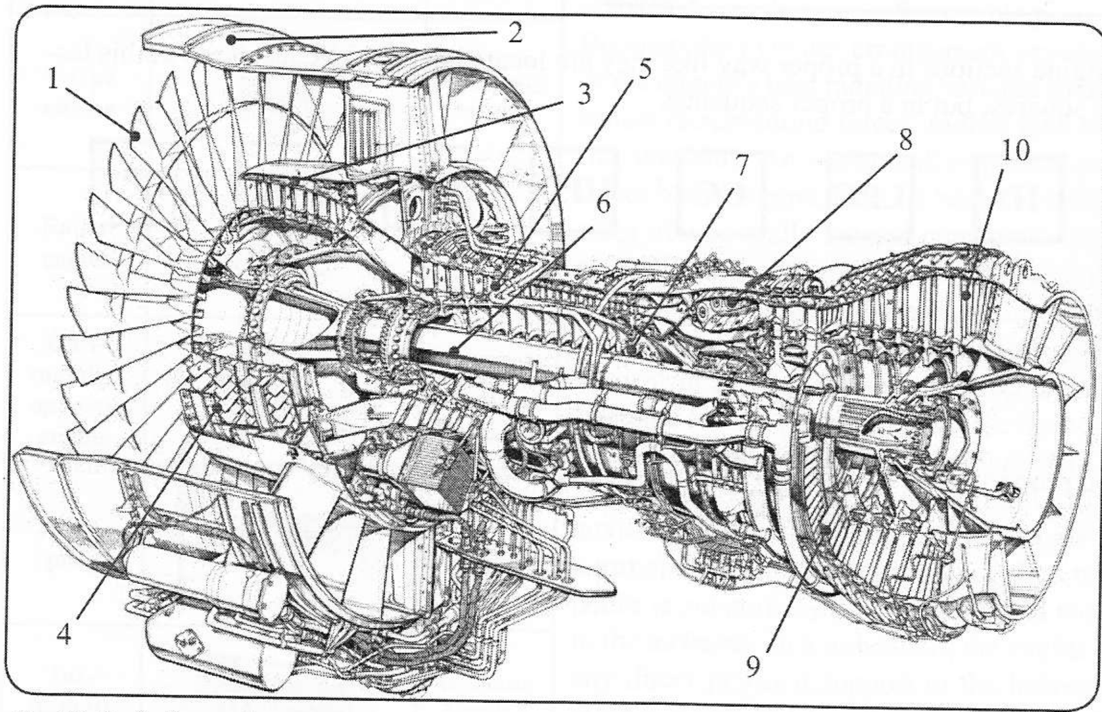
4. Choose any airplane you want in the university hangar and find damages on the landing gear. Fill in the table below.

Aircraft name	Landing gear location	Damage location	Damage type

5. Once you located the damage and described it, write down the causes of damage and ways to eliminate it.

6.1 Power plant

A power plant is a system that creates thrust to move the aircraft. A power plant consists of an engine, auxiliary systems and engine nacelles. Modern aircrafts use turbofan engines. An example of a turbofan engine is shown on figure 23. In these engines the main component which create thrust is fan (1). A part of the air comes through the fan and is ejected through the outer contour (2) into the atmosphere. This air serves also for air conditioning system of the aircraft and creates from 70% to 80% of the whole engine thrust. Another part of the air comes through the internal contour of the engine (3) and injects into the low pressure compressor (LPC) (4). A LPC compresses the air up to several times and direct it into the high pressure compressor (HPC) (5) for further compression. These two compressors are mounted on two different shafts (two spools). A LPC is mounted on internal shaft (6) and HPC is mounted on the external shaft (7). After the HPC the air flows into the combustion chamber (8). Fuel atomizes inside the combustion chamber through the fuel injectors. After that fuel mixes with heated and compressed by compressor air and create fuel-air mixture. A spark plug combusts the mixture and the compressed gas pressure rapidly increases. After the combustion chamber a compressed hot gas flows through the high pressure turbine (HPT) (9) which is mounted on the external shaft and rotates the HPC. Then the air comes through the low pressure turbine (LPT) (10) which is mounted on an internal shaft.



1. Fan
2. Outer contour casing
3. Internal contour casing
4. LPC
5. HPC
6. Internal shaft
7. External shaft
8. Combustion chamber
9. HPT
10. LPT
11. Nozzle

Fig. 23. Turbofan engine cutaway

Low pressure turbine connected with fan through the shaft. The air is now cooled and comes through the engine nozzle.

Turbofan engines come in a variety of engines configurations. Although far from common, the single shaft turbofan is the simplest configuration, comprising a fan and HPC driven by a single turbine unit, all of the same shaft. One of the earliest turbofans was CJ805-23, which featured an integrated fan/low pressure turbine unit located in the turbojet exhaust jet pipe. Hot gas from the turbojet turbine exhaust expanded through the LPT, the fan blades being the radial extension of the turbine blades. One of the problems with the aft fan configuration is hot gas leakage from the LP turbine to the fan.

The main turbofan engine manufacturers are: General Electric (USA), CFM International (a joint of GE and French SNECMA), Rolls Royce (British), Pratt&Whitney, Aviadvigatel (Russia), Ivchenko-Progress (Ukraine).

Modern airplanes try to decrease the quantity of mounted powerplants. This condition is due to decrease of fuel consumption, failures occurrence, maintenance simplification and decrease of airplane mass.

Practical and laboratory activity

1. What does power plant consist of?

1. Engine		2. Auxiliary systems		Correct are
3. Engine nacelles		4. Fan		
5. Propeller		6. Inlet duct		
7. Nozzle		8. Fuel tanks		

2. A fuel-air mixture is created in:

1. High pressure compressor		Correct is
2. Combustion chamber		
3. High pressure turbine		
4. Nozzle		

3. Arrange the engine sections in a proper way like they are located in engine, considered in this lesson. Draw the same squares, but in a proper sequence.

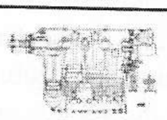
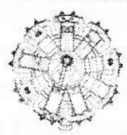
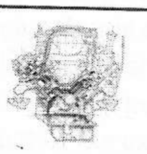
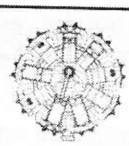
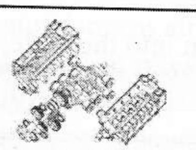
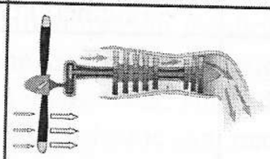
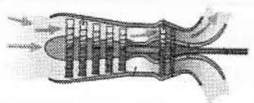
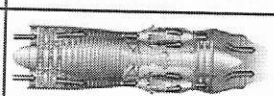
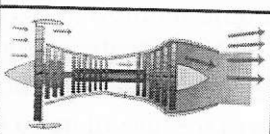
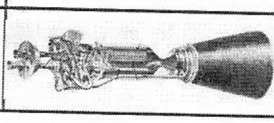
FAN	ID	LPC	CC	HPC	HPT	N	LPT

4. Now, after you properly arranged engine sections connect them in a way they connected in considered engine.

6.2 Power plant (engine) types

A table 6 shows the overview of basic types of aircraft engines and their design concepts. An inline engine has cylinders lined up in one row. It typically has an even number of cylinders, but there are instances of three- and five- cylinder engines. The biggest advantage of an inline engine is that it allows the aircraft to be designed with a narrow frontal area for low drag. Rotary engines have all the cylinders in a circle around the crankcase like a radial engine, but the difference is that the crankshaft is bolted to the airframe, and the propeller is bolted to the engine case. The entire engine rotates with the propeller, providing plenty of airflow for cooling regardless of the aircraft's forward speed. Cylinders in V-engine are arranged in two in-line banks, tilted 30-60 degrees apart from each other. The V design provides a higher power-to-weight ratio than an inline engine, while still providing a small frontal area. Radial engine has one or more rows of cylinders arranged in a circle around a centrally-located crankcase. Each row must have an odd number of cylinders in order to produce smooth operation. A radial engine has only one crank throw per row and a relatively small crankcase, resulting in a favourable power to weight ratio. Because the cylinder arrangement exposes a large amount of the engine's heat radiating surfaces to the air and tends to cancel reciprocating forces, radials tend to cool evenly and run smoothly. An horizontally-opposed engine, also call a flat or boxer engine, has two banks of cylinders on opposite sides of a centrally located crankcase. The engine is either air cooled or liquid cooled, but air cooled versions predominate. Opposed engines are mounted with the crankshaft horizontal in airplanes, but may be mounted with the crankshaft vertical in helicopters. A turboprop is very efficient when operated within the realm of cruise speeds it was designed for, which is typically 200 to 400 mi/h (320 to 640 km/h). Turboshaft engines are used primarily for helicopters and auxiliary power units. A turboshaft engine is very similar to a turboprop, with a key difference: In a turboprop the propeller is supported by the engine, and the engine is bolted to the airframe. In a turboshaft, the engine does not provide any direct physical support to the helicopter's rotors. The rotor is connected to a transmission, which itself is bolted to the airframe, and the turboshaft engine simply feeds the transmission via a rotating shaft. A turbojet is the simplest of all aircraft gas turbines. It features a compressor to draw air in and compress it, a combustion section which adds fuel and ignites it, one or more turbines that extract power from the expanding exhaust gases to drive the compressor, and an exhaust nozzle which accelerates the exhaust out the back of the engine to create thrust. A turbofan engine is much the same as a turbojet, but with an enlarged fan at the front which provides thrust in much the same way as a ducted propeller, resulting in improved fuel-efficiency. Although the fan creates thrust like a propeller, the surrounding duct frees it from many of the restrictions which limit propeller performance. This operation is a more efficient way to provide thrust than simply using the jet nozzle alone and turbofans are more efficient than propellers in the trans-sonic range of aircraft speeds, and can operate in the supersonic realm. Rocket engines are not used for most aircraft as the energy and propellant efficiency is very poor except at high speeds, but have been employed for short bursts of speed and takeoff.

Table 6. Basic types of aircraft engines

Engine type	Scheme	Examples
In-line engine		Wright Flyer
Rotary engine		Fokker Dr. I, Le Rhone 9J
V-type engine		Spitfires, P-51 Mustang
Radial engine		Mitsubishi Zero, P-47 Thunderbolt
Horizontally-opposed engine		Micro Aviation Bantam, Reality Escapade
Turboprop		Airbus A400M, Tupolev Tu-95
Turboshaft		Aerospatiale Alouette II
Turbojet		He 178, Me 262, Concorde
Turbofan		Boeing 737, Airbus A320
Rocket		Bell X-1, North American X-15

Practical and laboratory activity

1. What engine types use propeller to create thrust?

1. Turboprop	2. Turbojet	Correct is
3. Piston engines	4. Turbofan	
5. Turboshaft	6. Pulse jet	
7. Ramjet	8. Rocket	

2. A jet engine is fuelled with:

1. Petrol		Correct is
2. Kerosene		
3. Hydrogen		
4. Nitro methane		

3. What engines are not used for most of the aircraft?

1. Turboprop engines.	2. Turbofan engines	Correct is
3. Rocket engines	4. Turbojet engines	
5. Radial engines	6. Turboshaft engines	
7. V-type engines	8. Rotary engines	

4. Choose any airplane you want in the university hangar and write down into the table, what engine type is installed on that plane.

Aircraft name	Quantity of engines	Engine(s) position	Engine(s) type

5. Fill in the table below.

Aircraft name	Engine type

6.3 Power plant (engine) materials, possible damages, diagnostics.

Strong, lightweight, corrosion-resistant, thermally stable components are essential to the viability of any aircraft design, and certain materials have been developed to provide these and other desirable traits.

Materials of aircraft engines differ from airframe materials. Pistons in piston engines often made of a cast aluminium alloy for excellent and lightweight thermal conductivity, piston rings are commonly made from cast iron. Cast iron retains the integrity of its original shape under heat, load and other dynamic forces.

Jet engines use another types of materials. Titanium, first created in sufficiently pure form of commercial use during the 1950s, is utilized in the most critical engine components. While it is very difficult to shape, its extreme hardness renders it strong when subjected to intense heat. To improve malleability titanium is often alloyed with other metals such as nickel and aluminium. All three metals are prized by the aerospace industry because of their relatively high strength/weight ratio.

The intake fan at the front of the engine must be extremely strong so that it doesn't fracture when large birds and other debris are sucked into its blades; it is thus made of a titanium alloy. In modern engines sometimes composite materials such as kevlar and carbon fibre are used to produce fan blades. The intermediate compressor is made from aluminium, while the high pressure section nearer the intense heat of the combustor is made of nickel and titanium alloys better able to withstand extreme temperatures. The combustion chamber is also made of nickel and titanium alloys, and the turbine blades, which must endure the most intense heat of the engine, consist of nickel-titanium-aluminum alloys. Often, both the combustion chamber and the turbine receive special ceramic coatings that better enable them to resist heat. The inner duct of the exhaust system is crafted from titanium, while the outer exhaust duct is made from composites-synthetic fibres held together with resins. Although fibreglass was used for years, it is now being supplanted by Kevlar, which is even lighter and stronger. The thrust reverser consists of titanium alloy.

Damages of the jet engine is the most common problem of the whole aircraft damages. Foreign object damage is any damage attributed to a foreign object (i.e. any object that is not part of the vehicle) that can be expressed in physical or economic terms and may or may not degrade the pro-duct's required safety or performance characteristics. FOD is an abbreviation often used in aviation to describe both the damage done to aircraft by foreign objects, and the foreign objects themselves. These damages can be caused by birds strike, volcanic ash, maintenance tools left by maintenance staff.

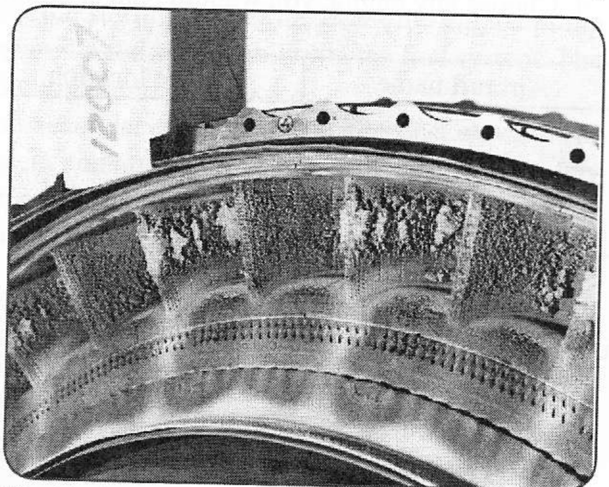


Fig. 24. Consequences of the volcanic ash

Volcanic ash can harm an aircraft engine (fig. 24). The effect on jet aircraft engines is particularly severe as large amounts of air are sucked in during combustion operation, posing a great danger to aircraft flying near ash clouds. Very fine volcanic ash particles (particularly glass-rich if from an eruption under ice) sucked into a jet engine melt at about 1,100 °C, fusing onto the blades and other parts of the turbine (which operates at about 1,400 °C). The effect on the operation of a jet engine is often to cause it to cut out-failure of all a plane's engines is common: volcanic ash particles can erode and destroy parts, drive it out-of-balance, and cause jams in rotating machinery. Also simple lack of oxygen is given as a probable cause of engine failure. Fooling of the engine temperature sensors. And compressor stall and flameout can be other reason. Often a simple abrasions can cause damage of engine's compressor or turbine blades, after which cracks can appear and cause the blade breakage. When the blade is broken, vibration occurs due to the compressor or turbine disk unbalance occurrence. Such vibration can destroy other engine blades or parts which leads to catastrophic accident.

Power plant

Practical and laboratory activity

1. What material is used in the most critical engine components?

1. Aluminium alloys	2. Carbon and glass fibber		Correct is
3. Magnesium Alloys	4. Plastics		
5. Titanium	6. Beryllium		
7. Steel	8. Iron		

2. Modern lightweight fan blades are made of:

1. Aluminium alloys		Correct is
2. Plastics		
3. Composite materials		
4. Steel alloys		

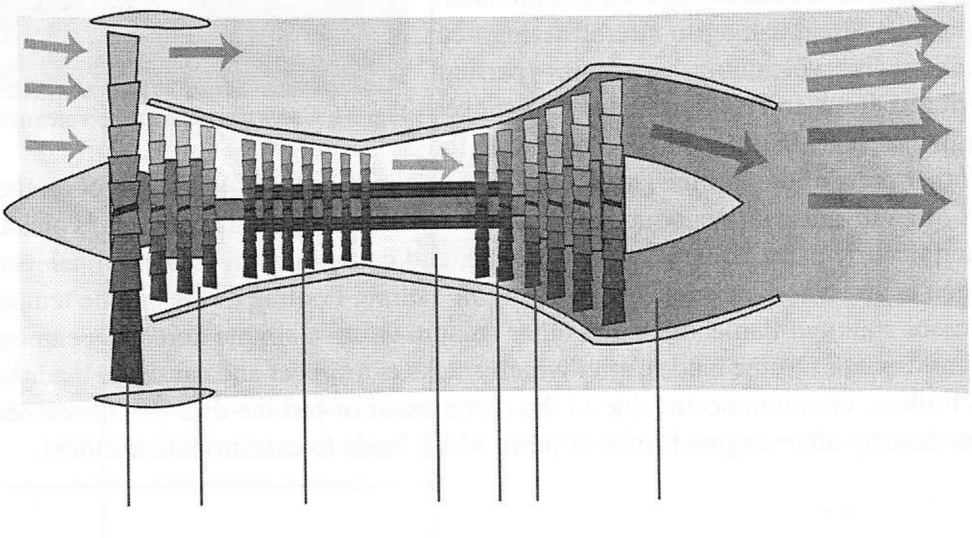
3. The most common engine damage is:

1. Foreign objects hit	2. Fan destruction		Correct is
3. Turbine blades melting	4. Fuel injector clogging		
5. Compressor blades rupture	6. Compressor surge		
7. Nozzle melting	8. Volcanic ash sticking		

4. Choose any engine you want in hangar and try to find engine damages. Fill in the table

Aircraft name	Engine location	Damage location	Damage type

5. An illustration below illustrates the turbofan engine. Under each engine section put numbers that reflect the level of engine stress (heat, forces, pressure) according to engine principle of work.



7.1 Functional systems overview

An aircraft is a very complex machine that contains several systems and each of them perform special functions for proper aircraft functioning. These systems include: electrical, hydraulics, oxygen, fuel, flight controls, ice protection, air conditioning.

The function of the aircraft electrical system is to generate, regulate and distribute electrical power throughout the aircraft. New-generation aircraft rely heavily on electrical power because of the wide use of electronic flight instrument systems. Aircraft electrical power is used to operate: aircraft flight instruments, essential systems passenger services. Each of the engines on an aircraft drives an AC generator. The power produced by these generators is used in normal flight to supply the entire aircraft with power. Most often the APUs (auxiliary power unit) power is used while the aircraft is on the ground during maintenance or for engine starting. However, most aircraft can use the APU while in flight as a backup power source.

There are multiple applications for hydraulic use in aircraft, depending on the complexity of the aircraft. For example, hydraulics is often used on small airplanes to operate wheel brakes, retractable landing gear, and some constant-speed propellers. On large airplanes, hydraulics is used for flight control surfaces, wing flaps, spoilers, and other systems. Hydraulic system provides the extra force required to move large control surfaces in heavy aerodynamic loads.

The fuel system is designed to provide an uninterrupted flow of clean fuel from the fuel tanks to the engine. The fuel must be available to the engine under all conditions of engine power, altitude, attitude, and during all approved flight manoeuvres. Two common classifications apply to fuel systems in small aircraft: gravity-feed and fuel-pump systems. Gravity-Feed system utilizes the force of gravity to transfer the fuel from the tanks to the engine. For example, on high-wing airplanes, the fuel tanks are installed in the wings. This places the fuel tanks above the carburetor, and the fuel is gravity fed through the system and into the carburetor. If the design of the aircraft is such that gravity cannot be used to transfer fuel, fuel pumps are installed. For example, on low-wing airplanes, the fuel tanks in the wings are located below the carburetor. Fuel-pump systems have two fuel pumps. The main pump system is engine driven with an electrically driven auxiliary pump provided for use in engine starting and in the event the engine pump fails. The auxiliary pump, also known as a boost pump, provides added reliability to the fuel system. The electrically driven auxiliary pump is controlled by a switch in the flight deck.

Aircraft flight control systems consist of primary and secondary systems. The ailerons, elevator (or stabilator), and rudder constitute the primary control system and are required to control an aircraft safely during flight. Wing flaps, leading edge devices, spoilers, and trim systems constitute the secondary control system and improve the performance characteristics of the airplane or relieve the pilot of excessive control forces.

Anti-icing equipment is designed to prevent the formation of ice, while deicing equipment is designed to remove ice once it has formed. These systems protect the leading edge of wing and tail surfaces, pitot and static port openings, fuel tank vents, stall warning devices, windshields, and propeller blades. Ice detection lighting may also be installed on some aircraft to determine the extent of structural icing during night flights. Most light aircraft have only a heated pitot tube and are not certified for flight in icing. These light aircraft have limited cross-country capability in the cooler climates during late fall, winter, and early spring. Noncertificated aircraft must exit icing conditions immediately.

Most high altitude aircraft come equipped with some type of fixed oxygen installation. If the aircraft does not have a fixed installation, portable oxygen equipment must be readily accessible during flight. The portable equipment usually consists of a container, regulator, mask outlet, and pressure gauge. Aircraft oxygen is usually stored in high pressure system containers of 1,800–2,200 psi. When the ambient temperature surrounding an oxygen cylinder decreases, pressure within that cylinder decreases because pressure varies directly with temperature if the volume of a gas remains constant. The containers should be supplied with aviation oxygen only, which is 100 percent pure oxygen. Industrial oxygen is not intended for breathing and may contain impurities, and medical oxygen contains water vapour that can freeze in the regulator when exposed to cold temperatures. To assure safety, periodic inspection and servicing of the oxygen system should be done.

Theme 7. Functional systems

Practical and laboratory activity

1. What functional systems aircraft does not include?

1. Electrical	2. Oxygen		Correct is
3. Fuel	4. Hydraulic		
5. Explosion warning	6. Flight controls		
7. Air conditioning	8. Ice protection		

2. Anti-icing equipment is designed to:

1. Protect passengers from temperature decrease in cabin		Correct is
2. Protect wings and tail surfaces from ice formation		
3. Provide cooling of the power plant without icing		
4. Unfreeze the lunch for passengers		

3. The secondary control system include:

1. Ailerons		2. Elevator		Correct are
3. Rudder		4. Flaps		
5. Spoilers		6. Slats		
7. Trims		8. Elevons		

4. Choose any airplane you want and fill in the table with systems that airplane include.

Aircraft name	System	System location	System purpose

8.1 Airfoil aerodynamics

A fixed-wing aircraft's wings, horizontal, and vertical stabilizers are built with airfoil-shaped cross sections, as are helicopter rotor blades. Airfoils are also found in propellers, fans, compressors and turbines. Sails are also airfoils, and the underwater surfaces of sailboats, such as the centreboard and keel, are similar in cross-section and operate on the same principles as airfoils. Swimming and flying creatures and even many plants and sessile organisms employ airfoils/hydrofoils: common examples being bird wings, the bodies of fish, and the shape of sand dollars. An airfoil-shaped wing can create downforce on an automobile or other motor vehicle, improving traction.Any object with an angle of attack in a moving fluid, such as a flat plate, a building, or the deck of a bridge, will generate an aerodynamic force (called lift) perpendicular to the flow. Airfoils are more efficient lifting shapes, able to generate more lift (up to a point), and to generate lift with less drag. A lift and drag curve obtained in wind tunnel testing is shown on the figure (fig. 25). The curve represents an airfoil with a positive camber so some lift is produced at zero angle of attack. With increased angle of attack, lift increases in a roughly linear relation, called the slope of the lift curve. At about 18 degrees this airfoil stalls, and lift falls off quickly beyond that. The drop in lift can be explained by the action of the upper-surface boundary layer, which separates and greatly thickens over the upper surface at and past the stall angle. The thickened boundary layer's displacement thickness changes the airfoil's effective shape, in particular it reduces its effective camber, which modifies the overall flow field so as to reduce the circulation and the lift. The thicker boundary layer also causes a large increase in pressure drag, so that the overall drag increases sharply near and past the stall point. The various terms (fig.26) related to airfoils are:

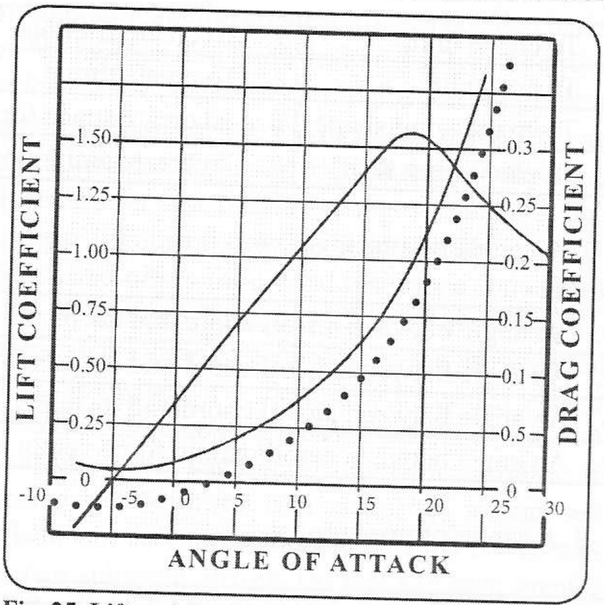


Fig. 25. Lift and drag curves for typical airfoil

The mean camber line is the location of points midway between the upper and lower surfaces.

The chord line is a straight line connecting the leading and trailing edges of the airfoil, at the ends of the mean camber line. The chord is the length of the chord line and is the characteristic dimension of the airfoil section.

The maximum thickness and the location of maximum thickness are expressed as a percentage of the chord.

For symmetrical airfoils both mean camber line and chord line pass from centre of gravity of the airfoil and they touch at leading and trailing edge of the airfoil. The aerodynamic centre is the chord wise length about which the pitching moment is independent of the lift coefficient and the angle of attack.

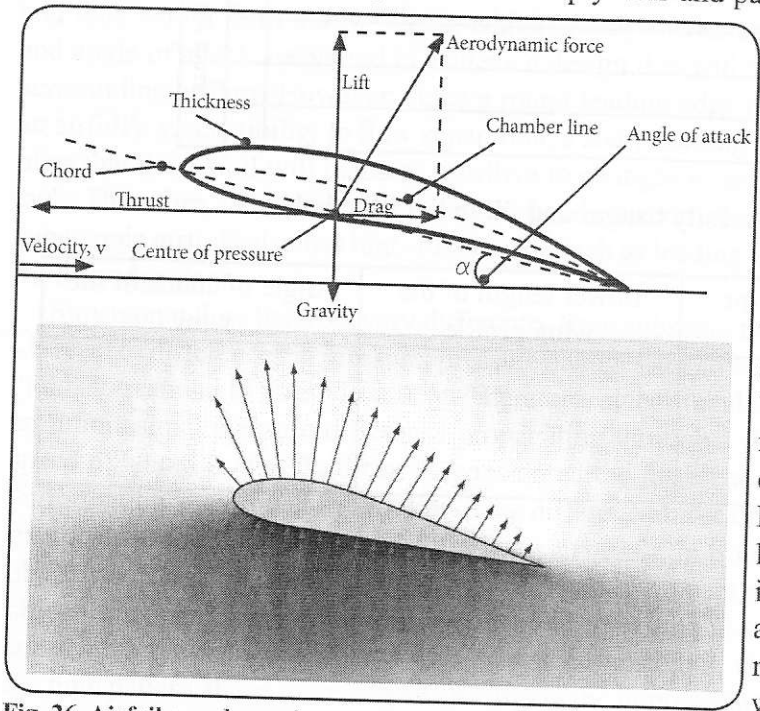


Fig. 26. Airfoil aerodynamics

The centre of pressure is the chord wise location about which the pitching moment is zero. For more detailed information about forces acting on the airfoil refer to the chapter 1.4 - Aircraft. On the lower picture on figure 26 the pressure difference below and under the airfoil is shaded. The areas that are marked with darker shade show the higher pressure and lighter areas show the lower air pressure.

Theme 8. Aircraft principles of flight

Practical and laboratory activity

1. What is airfoil used for?

1. To create drag	2. To create friction	Correct is
3. To create lift	4. To create thrust	
5. To create wing shape	6. To create space for fuel tank	
7. To carry wing skin	8. To create antigravity	

2. An angle of attack is:

1. An angle between airfoil chord and horizon line in direction to the flow		Correct is
2. An angle between airfoil chord and horizon line opposite to the flow direction		
3. An angle between airfoil chord and its upper surface line		
4. An angle between aerodynamic force vector and airfoil chord		

3. A centre of pressure is:

1. The chord wise location about which the pitching moment is less than zero		Correct is
2. The chord wise location about which the pitching moment is greater than zero		
3. The chord wise location about which the pitching moment is zero		
4. None of the definitions above is correct		

4. During flight, factors that influence the creation of lift at the airfoil profile are:

1. Difference of air temperature			Correct are
2. Difference of air pressure			
3. Difference of air velocities			
4. Difference of profile shapes			

5. Choose any airplane you want in the university hangar and fill in the table below.

Aircraft name	Upper length of the wing profile	Lower length of the wing profile	Angle of attack of the wing

8.2 Types of airfoils

It should be understood that different airfoils have different flight characteristics. Many thousands of airfoils have been tested in wind tunnels and in actual flight, but no one airfoil has been found that satisfies every flight requirement. The weight, speed, and purpose of each airplane dictate the shape of its airfoil. It was learned many years ago that the most efficient airfoil for producing the greatest lift was one that had a concave, or "scooped out" lower surface. Later it was also learned that as a fixed design, this type of airfoil sacrificed too much speed while producing lift and, therefore, was not suitable for high-speed flight. It is interesting to note, however, that through advanced progress in engineering, today's high-speed jets can again take advantage of the concave airfoil's high lift characteristics. Leading edge (Kreuger) flaps and trailing edge (Fowler) flaps, when extended from the basic wing structure, literally change the airfoil shape into the classic concave form, thereby generating much greater lift during slow flight conditions.

On the other hand, an airfoil that is perfectly streamlined and offers little wind resistance sometimes does not have enough lifting power to take the airplane off the ground. Thus, modern airplanes have airfoils which strike a medium between extremes in design, the shape varying according to the needs of the airplane for which it is designed. Figure 27 shows some of the more common airfoil sections. The first (1) airfoil profile was one of the earlier profiles. If we compare it with the later airfoil (3) we can see that later one has more thickness at the lower surface, two subsonic airfoils (5) and (2) have greater lift than supersonic airfoils (4) and (6). Supersonic airfoils generally have a thin section formed of either angled planes or opposed arcs (called "double wedge airfoils" and "biconvex airfoils" respectively), with very sharp leading and trailing edges. The sharp edges prevent the formation of a detached bow shock in front of the airfoil as it moves through the air. This shape is in contrast to subsonic airfoils, which often have rounded leading edges to reduce flow separation over a wide range of angle of attack. A rounded edge would behave as a blunt body in supersonic flight and thus would form a bow shock, which greatly increases wave drag. The airfoils' thickness, camber, and angle of attack are varied to achieve a design that will cause a slight deviation in the direction of the surrounding airflow. However, since a round leading edge decreases an airfoil's susceptibility to flow separation, a sharp leading edge implies that the airfoil will be more sensitive to changes in angle of attack. Therefore, to increase lift at lower speeds, aircraft that employ supersonic airfoils also use high-lift devices such as leading edge and trailing edge flaps.

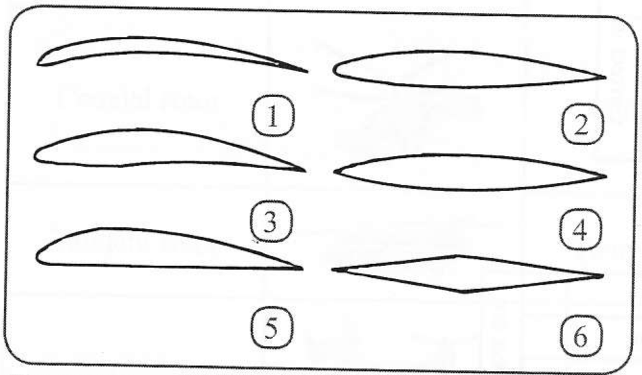


Fig. 27. Types of airfoils

Supersonic flow behaves very differently from subsonic flow. Fluids react to differences in pressure; pressure changes are how a fluid is "told" to respond to its environment. Therefore, since sound is in fact an infinitesimal pressure difference propagating through a fluid, the speed of sound in that fluid can be considered the fastest speed that "information" can travel in the flow. This difference most obviously manifests itself in the case of a fluid striking an object. In front of that object, the fluid builds up a stagnation pressure as impact with the object brings the moving fluid to rest. In fluid travelling at subsonic speed, this pressure disturbance can propagate upstream, changing the flow pattern ahead of the object and giving the impression that the fluid "knows" the object is there and is avoiding it. However, in a supersonic flow, the pressure disturbance cannot propagate upstream. Thus, when the fluid finally does strike the object, it is forced to change its properties - temperature, density, pressure, and Mach number - in an extremely violent and irreversible fashion called a shock wave. The presence of shock waves (fig. 28), along with the compressibility effects of high-velocity fluids, is the central difference between supersonic and subsonic aerodynamics problems.

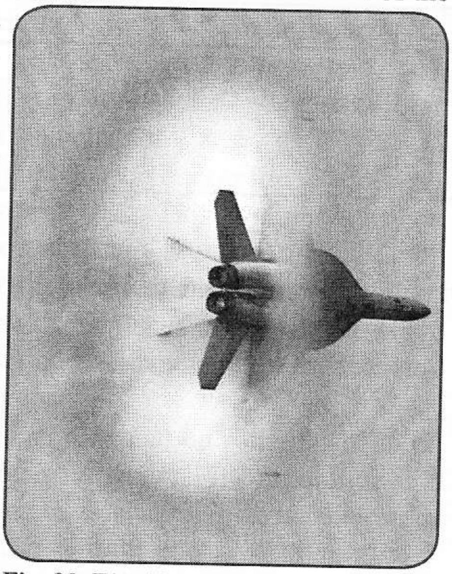
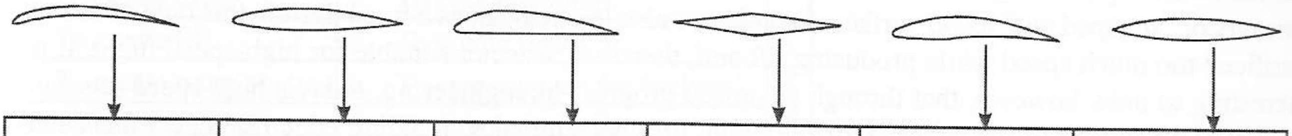


Fig. 28. F/A-18E/F Super Hornet approaching the sound barrier

Practical and laboratory activity

1. In a picture below, a different types of airfoil shapes are presented. Write down, what airfoil is related to subsonic or supersonic shape.



2. A shockwave appears when airplane closes to the:

1. Transonic speed		Correct is
2. Subsonic speed		
3. Supersonic speed		
4. Hypersonic speed		

3. What dictates the airfoil type and shape?

1. Airplane purpose		2. Airplane speed		Correct are
3. Airplane type		4. Designer concept		
5. Wing material		6. Airplane weight		
7. Abilities of production		8. Wind temperatures		

4. Choose any airplane you want in the university hangar and determine its airfoil profile type. Fill in the table.

Aircraft name	Aircraft mass	Aircraft speed	Airfoil type

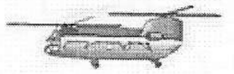
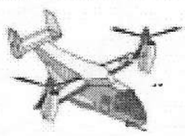
5. Calculate the cross - section area of the chosen airfoil profile. For this take the data from the previous chapter part, and geometrically divide the airfoil profile by more simplest parts.

AREA FOR CALCULATION

9.1 Types of helicopters

A helicopter is a type of rotorcraft in which lift and thrust are supplied by one or more engine driven rotors. In contrast with fixed-wing aircraft, this allows the helicopter to take off and land vertically, to hover, and to fly forwards, backwards, and laterally. These attributes allow helicopters to be used in congested or isolated areas where fixed-wing aircraft would not be able to take off or land. The capability to efficiently hover for extended periods of time allows a helicopter to accomplish tasks that fixed-wing aircraft and other forms of vertical takeoff and landing aircraft cannot perform. A table 7 shows different helicopters by their classification.

Table 7. Helicopters classification.

Rotor configuration	Scheme	Engine type	Purpose	Size
Single-rotor		Light Piston-engined	Aerial photography	Lightweight
Coaxial rotor		Light turbine	Motion picture photography	Medium
Tandem rotor		Twin Engine	Search and rescue	Large
Tiltrotor			Transport	
Intermeshing rotor			Military	

A single rotor helicopter is the most common helicopter. It has one rotor main rotor and one tail rotor to compensate the gyroscopic effect, which will be discussed later in next chapter.

Coaxial rotors are a pair of helicopter rotors mounted one above the other on concentric shafts, with the same axis of rotation, but that turn in opposite directions (contra-rotation). This configuration is a feature of helicopters produced by the Russian Kamov helicopter design bureau.

Tandem rotor helicopters have two large horizontal rotor assemblies mounted one in front of the other. Currently this configuration is mainly used for large cargo helicopters. Advantages of the tandem-rotor system are a larger center-of-gravity range and good longitudinal stability. Disadvantages of the tandem-rotor system are a complex transmission, and the need for two large rotors.

A tiltrotor is an aircraft which uses a pair or more of powered rotors mounted on rotating shafts or nacelles at the end of a fixed wing for lift and propulsion, and combines the vertical lift capability of a helicopter with the speed and range of a conventional fixed-wing aircraft. For vertical flight, the rotors are angled so the plane of rotation is horizontal, lifting the way a helicopter rotor does.

As the aircraft gains speed, the rotors are progressively tilted forward, with the plane of rotation eventually becoming vertical. In this mode the wing provides the lift, and the rotor provides thrust as a propeller.

Intermeshing rotors on a helicopter are a set of two rotors turning in opposite directions, with each rotor mast mounted on the helicopter with a slight angle to the other, in a transversely symmetrical manner, so that the blades intermesh without colliding. The arrangement allows the helicopter to function without the need for a tail rotor. This configuration is sometimes referred to as a synchropter.

Theme 9. Helicopters

Practical and laboratory activity

1. Check the types of helicopters that does not exist.

1. Single rotor		2. Variable rotor			Correct are
3. Fixed rotor		4. Tandem rotor			
5. Coaxial rotor		6. Rotorless			
7. Tiltrotor		8. Intermeshing rotor			

2. Why is it so important for single - rotor helicopter to have tail rotor also?

1. To compensate the fuel consumption			Correct is
2. To provide the ability to fly forwards and backwards			
3. To provide the helicopter with gyroscopic effect			
4. To compensate the gyroscopic effect			

3. A pair of a helicopter rotors mounted one above the other on concentric shafts, with the same axis of rotation are called:

1. Single	2. Tilt		Correct is
3. Stacked	4. Tandem		
5. Coaxial	6. Fixed		
7. Intermeshing	8. Double		

4. In a university hangar describe all the helicopter types existing there. Fill in the table below.

Helicopter name	Size	Engine type	Rotor configuration

9.2 Helicopter construction

Helicopter design and control principles drastically differ from the airplane (fig. 29). Helicopters have rotary wings that provide lift for the helicopter. To stabilize the helicopter, a stabilizer bar is used. It dampens control inputs to make smoother changes to the rotor system. A swashplate transfers non-moving control inputs into the spinning rotor system. Cowling serves for the aerodynamic covering for the engine. Mast connects the transmission to the rotor system. Transmission which takes power from the engine drives both rotor systems. Engine provides power to the rotor systems. Early helicopter designs utilized custom-built engines or rotary engines designed for airplanes, but these were soon replaced by more powerful automobile engines and radial engines. The single, most-limiting factor of helicopter development during the first half of the 20th century was that the amount of power produced by an engine was not able to overcome the engine's weight in vertical flight.

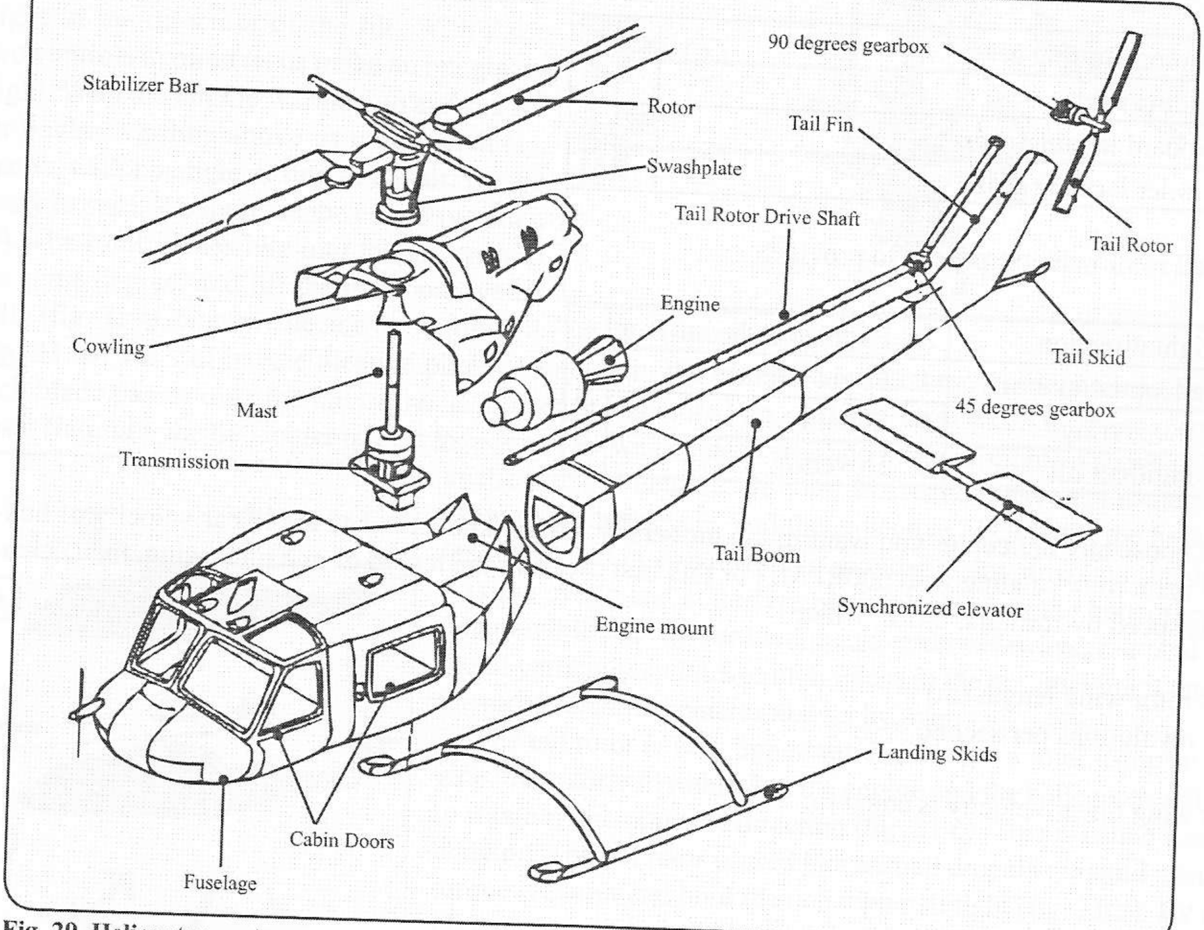


Fig. 29. Helicopter parts.

This was overcome in early successful helicopters by using the smallest engines available. When the compact, flat engine was developed, the helicopter industry found a lighter-weight powerplant easily adapted to small helicopters, although radial engines continued to be used for larger helicopters. Turbine engines revolutionized the aviation industry, and the turboshaft engine finally gave helicopters an engine with a large amount of power and a low weight penalty. The turboshaft engine was able to be scaled to the size of the helicopter being designed, so that all but the lightest of helicopter models are powered by turbine engines today.

The body of the helicopter like an airplane's is called also a fuselage. To allow access to the cabin and cockpit the cabin doors are used. Skids serve as a landing gear that usually have no wheels or brakes. Engine mount - a flexible way to attach the engine to the fuselage. Tailboom, also known as an "empennage" is the tail of the helicopter on which synchronized elevator sits and helps stabilize the helicopter in flight. Tail rotor of the helicopter provides anti-torque and in-flight trim for the helicopter. Tail rotor drive shaft provides power to the tail rotor from the transmission. To transfer power up the vertical fin to the 90 degree gearbox the 45 degree gearbox is used. Vertical fin holds the tail rotor and provides lateral stabilization. Tail skid protects the tailboom when landing.

Practical and laboratory activity

1. What provides lift for helicopters?

		Correct is
1. Rotary wings	2. Wings	
3. Tail rotor	4. Engine	
5. Linear wings	6. Transmission	
7. Swashplate	8. Stabilizer bar	

2. What is the common landing gear type for lightweight helicopter?

		Correct is
1. Pontoon landing gear		
2. Landing skids		
3. Standard landing gear		
4. Crawler landing gear		

3. Tail rotor main purpose is to provide:

		Correct is
1. Flight direction	2. Flight speed	
3. Helicopter take-off	4. Flight altitude	
5. Manoeuvring	6. Stability	
7. Additional lift	8. Hovering	

4. Choose any helicopter you want in the university hangar and calculate the linear velocity of helicopter main rotor rotating with 600RPM. For this first measure the length of one rotor wing, then calculate the speed by formula: $2\pi Rn$, where:

R - rotor wing length (m) =
n - revolutions per second =

Rotor wing linear velocity is equal to:

9.3 Helicopter principle of flight

Flight of a helicopter is governed by the pitch or angle of its rotor blades (fig. 30) as they sweep through the air. For climbing and descending, the pitch of all the blades is changed at the same time and in the same degree. To Climb, the angle or pitch of the blades is increased. To descend, the pitch of the blades is decreased (3). Because all blades are acting simultaneously, or collectively, this is known as collective pitch. For forward, backward and sideways flight an additional change of pitch is provided. By this means the pitch of each blade increases at the same selected point in its circular pathway. This is the cyclic pitch. Tilting the spinning rotor will cause flight in the direction of the tilt. With these two controls in mind let us make an imaginary flight. With the engine warmed up and the rotor blades whirling above us in flat pitch (1), that is, with no angle or bite in the air, we are ready to start. We increase the collective pitch (2). The rotor blades bite into the air, each to the same degree, and lift the helicopter vertically (fig. 31 a). Now we decide to fly forward (fig. 31 b). We still have collective pitch to hold us in the air and we adjust the cyclic pitch so that as each blade passes over the tail of the helicopter, it has more bite on the air than when it passes over the nose. Naturally the helicopter travels forward. Now we decide to stop and hover motionless so we put the cyclic pitch in neutral, the rotor blades now have the same pitch throughout their cycle, and the collective pitch holds the helicopter suspended in space without moving in any direction. In short, it is the cyclic and collective pitch which gives the helicopter its unique ability to fly forward, backwards, sideways, rise and descend vertically and hover motionless in the air , making it one of the most versatile vehicles known by man.

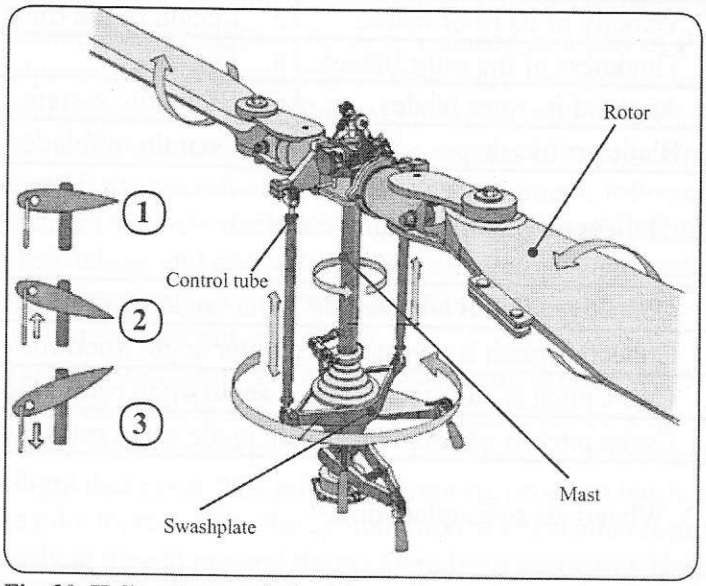


Fig. 30. Helicopter swashplate

The tail rotor is very important. If you spin a rotor using an engine, the rotor will rotate, but the engine and the helicopter will try to rotate in the opposite direction (fig. 31 c). This is called torque reaction. The tail rotor is used like a small propeller, to pull against torque reaction and hold the helicopter straight (fig. 31 d). By applying more or less pitch (angle) to the tail rotor blades it can be used to make the helicopter turn left or right, becoming a rudder. The tail rotor is connected to the main rotor through a gearbox. When using the tail rotor trying to compensate the torque, the result is an excess of force in the direction for which the tail rotor is meant to compensate, which will tend to make the helicopter drift sideways. Pilots tend to compensate by applying a little cyclic pitch, but designers also help the situation by setting up the control rigging to compensate. The result is that many helicopters tend to lean to one side in the hover and often touch down consistently on one wheel first. On the other hand if you observe a hovering helicopter head-on you will often note that the rotor is slightly tilted. All this is a manifestation of the drift phenomenon. The engine simply drive the rotors and did not assist directly with forward flight (like they would with a plane). There is a very small amount of thrust that comes from engine exhaust, but it is so small that it does not effect flight performance.

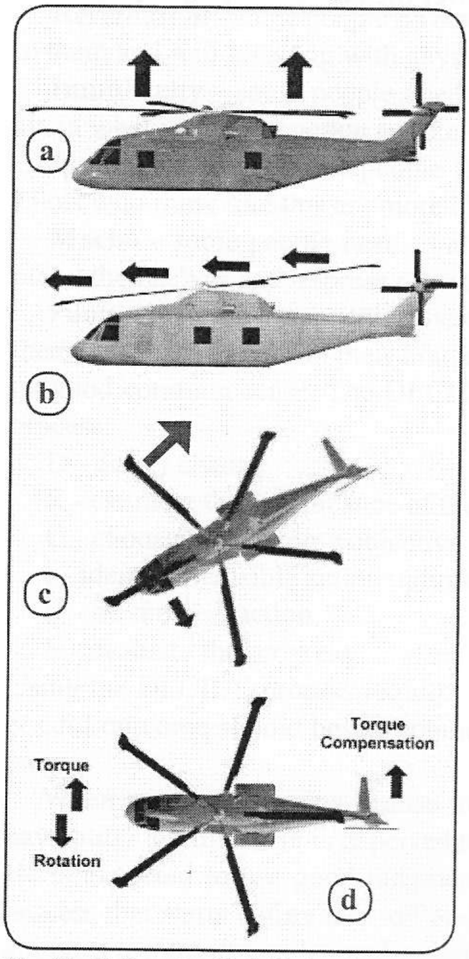


Fig. 31. Helicopter flight behaviour

Helicopters

Practical and laboratory activity

1. Flight of the helicopter is governed by:

1. Velocity of its rotor blades	2. Length of the rotor blades	Correct is
3. Thickness of the rotor blades	4. Engine	
5. Angle of its rotor blades	6. Hydraulic system	
7. Blade profile shape	8. Quantity of blades	

2. Helicopter flies forward because:

1. Collective pitch is adjusted by lesser angle when rotor blade passes over the tail		Correct is
2. Collective pitch is adjusted by greater angle when rotor blade passes over the tail		
3. Cyclic pitch is adjusted by lesser angle when rotor blade passes over the tail		
4. Cyclic pitch is adjusted by greater angle when rotor blade passes over the tail		

3. What does swashplate do?

1. Collective pitch is adjusted by lesser angle when rotor blade passes over the tail		Correct is
2. Collective pitch is adjusted by greater angle when rotor blade passes over the tail		
3. Cyclic pitch is adjusted by lesser angle when rotor blade passes over the tail		
4. Cyclic pitch is adjusted by greater angle when rotor blade passes over the tail		

4. What helicopter part is used to compensate the torque reaction?

1. Main rotor	Correct is
2. Tail rotor	
3. Stabilizer bars	
4. Engine	

10.1 Flight operation: pilots

Aeronautical knowledge, skill and judgment have been considered the three essential faculties that pilots must possess to be professional in the execution of their duties. The knowledge and skill have been taught in ground school and flight training programs, but decision making skills have usually been considered a trait that pilots innately possess or that is acquired through experience. In fact, good decision making skills can also be taught. Training in decision making skills is being introduced as a part of the pilot training program. Pilots can learn good judgment just as thoroughly as they learn the mechanical concepts and basic skills of flying. But what is good judgment? It is the ability to make an instant decision which assures the safest possible continuation of the flight. Pilot judgment is the process of recognizing and analyzing all available information about oneself, the aircraft and the flying environment, followed by the rational evaluation of alternatives to implement a timely decision which maximizes safety. Pilot judgement thus involves one's attitudes toward risk-taking and one's ability to evaluate risks and make decisions based upon one's knowledge, skills and experience. A judgment decision always involves a problem or choice, an unknown element, usually a time constraint, and stress.

The causal factor in about 80% to 85% of civil aviation accidents; is the human element, in other words, pilot error, a poor decision or a series of poor decisions made by the pilot-in-command. This concept is known as the poor judgment chain. One poor decision increases the probability of another and as the poor judgment chain grows, the probability of a safe flight decreases. The judgment training program teaches techniques; for breaking the chain by teaching the pilot to, recognize the combination of events that result in an accident and to deal with the situation correctly in time to prevent the accident from occurring. How a pilot handles his or her responsibilities as a Pilot depends on attitude. Attitudes are learned. They can be developed through training into a mental framework that encourages good pilot judgment. The pilot decision making training program is based on recognition of five, hazardous attitudes:

Anti-authority - this attitude is common in those who do not like anyone telling them what to do.

Resignation - some people do not see themselves as making a great deal of difference in what happens to them and will go along with anything that happens.

Impulsivity - some people need to do something, anything, immediately without stopping to think about what is the best action to take.

Invulnerability - some people feel that accidents happen to other people but never to themselves. Pilots who think like this are more likely to take unwise risks.

Macho - some people need to always prove that they are better than anyone else and take risks to prove themselves and impress others.

Pilots who learn to recognize these hazardous attitudes in themselves can also learn how to counteract them, can learn to control their first instinctive response and can learn to make a rational judgment based on good common sense. The DECIDE acronym was developed to assist a pilot in the decision making process.

D - detect change.
E - estimate the significance of the change.
C - choose the outcome objective.
I - identify plausible action options.
D - do the best action.
E - evaluate the progress.

Using the DECIDE process requires the pilot to contemplate the outcome of the action taken. The successful outcome should be the action that will result in no damage to the aircraft or injury to the occupants.

When a pilot receives a license to fly, he is being given the privilege to use public airspace and air navigation facilities. He is expected to adhere to the rules and to operate an aircraft safely and carefully. He is expected to use good judgment and act responsibly. Decision-making is a continuous adjustive process that starts before take-off and does not stop until after the final landing is made safely. Positive attitudes toward flying, learned judgment skills, will improve a pilot's chances of having a long and safe flying career.

Practical and laboratory activity

1. What are the five hazardous attitudes?

		Correct is
1. Anti-authority	2. Resignation	
3. Stupidity	4. Invulnerability	
5. Impulsivity	6. Rage	
7. Courage	8. Macho	

2. Decision - making is the process that:

	Correct is
1. Starts before take-off and does not stop until after the final landing is made safely	
2. Starts after take-off and does not stop until after the final landing is made safely	
3. Starts before take-off and stops until the final landing is made safely	
4. Stops before take-off and does not start until after the final landing is made safely	

3. What acronym was developed to assist the pilot in the decision making process?

		Correct is
1. DECRYPT	2. DECLASSIFY	
3. DECIDE	4. DECOR	
5. DECADE	6. DECODE	
7. DECREASE	8. DEDICATE	

4. Decode the acronym that was developed to assist the pilot in decision making process.

Letter	Notion

10.2 Flight service: crew

Today's flight and cabin crews are much different than they were during the early years of commercial aviation. The captain of the aircraft was once considered "God" and his decisions were always the "right" ones. There was little, if any, input from the other pilots because they assumed the captain knew what he was doing. It was also considered somewhat disrespectful to question the decisions of a superior. Part of this thinking had its genesis from the military. At one time the military was the biggest producer of pilots, and along with military training came a good dose of machismo, ego, and autocratic decision-making processes (many military fighters were single pilot aircraft and therefore lacked the redundancy of, and decision inputs from, another crew member). This attitude did not transfer well into civilian cockpits. The problems began to manifest in pilot error related airline accidents that claimed hundreds of lives:

- 1978, United 171 ran out of fuel over Portland, Oregon and no one noticed until it was too late.
- 1972, Eastern 401 gradually descended into the Everglades as all three crew members became fixated on a landing light indication and the autopilot became disengaged.
- 1982, Air Florida 90 was not properly de-iced and crashed shortly after takeoff from Washington, D.C. In addition, standard operating procedures were violated by an inexperienced flight crew.
- 1985, Delta 191 was caught in an unreported windshear on final approach to the Dallas/Fort Worth airport.

It was obvious that something needed to be done to address the human aspect of flying an aircraft. Airlines were noticing that although pilots were technically competent, their people skills were deficient. In other words, the captain could fly a perfect Instrument Landing System (ILS) approach, but could not work in a synergistic environment to effectively accomplish tasks. This can create a potentially dangerous and antagonistic situation.

Approximately 25 years ago, one major airline took notice and began implementing "people skills" training as part of technical flight training. It became known as Crew Resource Management (CRM). Formerly known as Cockpit Resource Management, CRM has its roots at United Airlines, where in 1980, a formal training program was set up to concentrate on human factors in the cockpit. The reason for the change from "cockpit" to "crew" resource management training was because the training eventually branched out to include not only the pilots but also flight attendants, mechanics, dispatchers, management personnel, or in fact anyone who had a responsibility for the safe completion of a flight.

Crew resource management or Cockpit resource management (CRM) is a procedure and training system in systems where human error can have devastating effects. Used primarily for improving air safety, CRM focuses on interpersonal communication, leadership, and decision making in the cockpit. The training originated from a NASA workshop in 1979, which found that the primary cause of most aviation accidents was human error. CRM training encompasses a wide range of knowledge, skills and attitudes including communications, situational awareness, problem solving, decision making, and teamwork; together with all the attendant sub-disciplines which each of these areas entails. CRM can be defined as a management system which makes optimum use of all available resources - equipment, procedures and people - to promote safety and enhance the efficiency of operations. CRM is concerned not so much with the technical knowledge and skills required to operate equipment but rather with the cognitive and interpersonal skills needed to manage resources within an organized system. In this context, cognitive skills are defined as the mental processes used for gaining and maintaining situational awareness, for solving problems and for making decisions. Interpersonal skills are regarded as communications and a range of behavioural activities associated with teamwork. In many operational systems as in other walks of life, skill areas often overlap with each other, and they also overlap with the required technical skills. Furthermore, they are not confined to multi-crew craft or equipment, but also relate to single operator equipment or craft, which invariably need to interface with other craft or equipment and various other support agencies in order to complete a mission successfully.

Practical and laboratory activity

1. What technician training program was implemented?

1. MRM	2. CRB	Correct is
3. HRM	4. CRS	
5. CSM	6. CRM	
7. CMR	8. CSR	

2. How does the technician training program decode?

3. _____ can be defined as:

1. Management system which makes optimum use of all available resources - equipment, procedures and people to promote safety and enhance the efficiency of operations		Correct is
2. Management system for which is not necessary optimum use of all available resources - equipment, procedures and people to promote safety and enhance the efficiency of operations		
3. Management system which makes optimum use of all available resources - equipment, procedures and people but does not promote safety and enhance the efficiency of operations		
4. Management system which does not make optimum use of all available resources - equipment, procedures and people to promote safety and enhance the efficiency of operations		

10.3 Maintenance: technicians

Over the years, considerable progress have been made to Crew Resource Management (CRM). One of the reasons is that errors made by pilots are highly visible and have immediate consequences on safety. In addition, pilots are also seen as the last line of defence against errors. For these reasons, research on activities such as communication and teamworking skills initially focused on pilots. In contrast, errors made by maintenance personnel are latent and thus Maintenance Resource Management (MRM), the maintenance version of CRM has received considerably less attention. In their efforts to enhance safety, the aviation industry as a whole have recognised that there is a need to minimise errors across all facets of aviation. Because of this, the trend nowadays is to move further in their approach to reduce errors. Thus human factor programmes have expanded to include people in all facets of aviation such as air traffic controllers and of course maintenance personnel.

Maintaining aircrafts is a complex and demanding endeavour. It consist of numerous interrelated human and machine components. The complexity of such interface mean that errors are likely to be introduced and ways to detect errors and deal with them are needed. The safety of the flying public is first and foremost dependent on the proper functioning of the aircraft and its components. In any maintenance process, it is the ability of maintenance personnel to work together that determines its success. The very nature of the industry is such that engineers and mechanics will often need to work together, therefore communication and team working skills are important. Although most errors in the maintenance environment are latent, they cannot be ignored as they have the potential to contribute towards fatal consequences in flight. Once an aircraft leaves the hangar, the sound functioning of all systems on board will be one of the important precursors to whether a flight will get from one point to another safely. Indeed, maintenance plays such an crucial role in flight safety that it is the responsibility of the aircraft's owner or operator to ensure that they are properly maintained. In United States, studies have shown that maintenance factors is a contributing factor in 18% of all accidents. History is abound with notorious examples (table 8) of how maintenance errors contribute to accidents.

Table 8. Accident examples due to maintenance personnel.

Airline	Location	Date	Cause
Aloha Airlines Flight 243	Hawaii	28 April 1988	Fuselage failure in flight caused by inspection failure.
United Airlines Flight 232	Iowa	19 July 1989	Inspection failure which led to uncontrolled engine failure and loss of flight controls.
Continental Express Flight	Texas	11 September 1991	Separation of horizontal stabilizer. Maintenance personnel did not replace screws on it.
Northwest Airlines	Tokyo	01 March 1994	Engine separation caused by incomplete assembly.

What is common is all these cases is the there is an urgent need for changes in aspects of the organisation relating to human performance. Increasing diligence in maintenance will probably have prevented these accidents. In addition MRM will help airlines avoid significant financial burdens imposed by loss of lives, flight delays, cancellations, turn backs and diversions. MRM was developed from CRM after the fuselage of Aloha Airlines Flight 243 was ripped off in flight and had to amek an emergency landing. Investigations led to attention being turned to maintenance errors as a potential cause of accidents. MRM and maintenance human factors training are thus developed. MRM does not just stop at the operational level; the mechanics and engineers. It is for staff at all levels of an organisation. Essentially, it orientates the entire organisation towards a safe and error free performance. It creates awareness about what human factor elements are and how they affect performance. The overall objective is to integrate maintenance technical skills, interpersonal skills and human factor knowledge in a way that increases communication effectiveness and enhance safety. Since MRM has got its roots in CRM, they share common goals such as: improve communication skills, end authoritative attitudes in supervisory staff, improve team working skills, improve assertiveness among mechanics, provide people with human factors knowledge. In addition, MRM also helps managers understand how their decisions affect workers' behaviours.

Practical and laboratory activity

1. What maintenance training program was implemented?

1. CRM	2. MRC	Correct is
3. RMM	4. MCR	
5. MRM	6. MRR	
7. RMR	8. CMR	

2. How does the maintenance training program decodes?

3. What functions does ______ perform?

10.4 Air traffic control

Air Traffic Control is divided into two main types of operation: visual control operations done at aerodromes by tower controllers (fig. 32), and instrumental operations done by radar and oceanic controllers. Instrumental operations are not necessarily based on or near aerodromes (e.g. all radar control over New Zealand is carried out from a single location).

Tower controls the landing, take-off and runway operations of aircraft, ensuring the separation of aircraft in the aerodrome. Most activity in the tower is done visually. Radar controls aircraft in the air. Thus, radar vectors arriving aircraft to the vicinity of airports before handing it to Tower. They also take charge of aircraft from Tower right after take off. In Oceanic operations, traffic control is carried out through satellites (GPS, or Globally Positioning Systems). Air traffic operations are similar to radar control except that Oceanic control vectors aircraft between international airspaces. Oceanic hands control over and takes control over national Radar controllers.

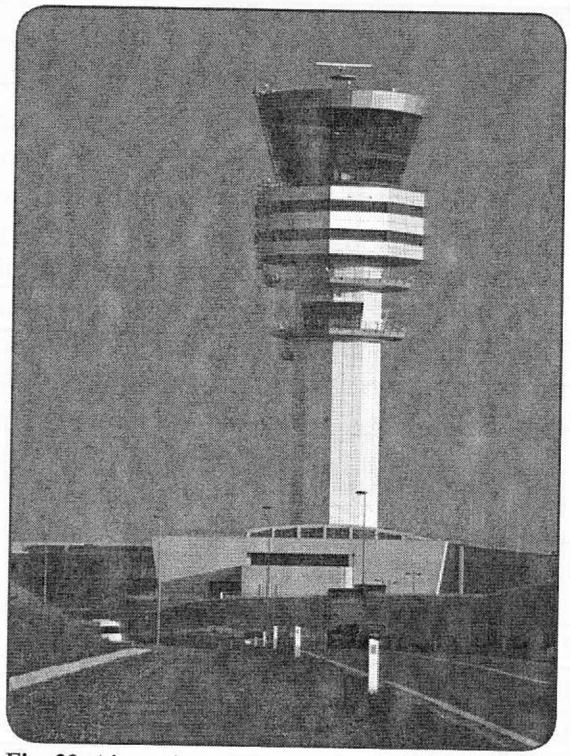


Fig. 32. Air traffic control tower

The humans in the ATC system are a matter of concern particularly in the case of meeting the desired efficiency levels. The desired efficiency cannot be achieved if there is poor coordination of humans and the automation and new technology. In this case, the study of human factors is crucial because it helps in the effective and efficient integration of human and automated technologies to bring them into a workable solution. In other words, the study of human factors in air traffic control makes it easy for the humans to coordinate with the various new technologies, decision support tools and other new forms of automated technology used in the different areas of Air Traffic Control in order to achieve a desired performance outcome. Maintaining safety in aviation is a major issue in human factors. The flow of information is a critical aspect and must be clear and ambiguous. Entrusting power and responsibility to a person in the vital area of flight operations such as Air Traffic Control where there are pivotal decisions regarding the flight to be made needs a serious thought. The main goal of the Air Traffic Control System is to carry out the safe and efficient flow of traffic from an origin to a destination point . It is the main task of air traffic controllers to reach these goals of safety and efficiency which is not easy. It involves them to go through a complicated series of procedures, judgements, plans, decisions, communications and coordinated activities. Besides the obvious communication and coordination between air traffic controllers and pilots, the communication and coordination between and within the air traffic control is also very important in terms of improving safety and efficiency. For example- when an aircraft leaves from an area to another, there is a shift of responsibility from one controller where the plane left to the other one where the plane is.

Air travel has increased dramatically since the U.S. federal government deregulated the airline industry in the 1970s. However, the construction of new airports and runways has not kept pace with the increase in air traffic. This has put excessive pressure on the air traffic control system to handle the nearly 50,000 flights per day, a number projected to increase in the near future. To handle these flights and avoid delays and collisions, the FAA and NASA have developed modern software, upgraded existing host computers and voice communications systems and instituted full-scale GPS (global positioning system) capabilities to help air traffic controllers track and communicate with aircraft. The FAA is currently redesigning U.S. airspace to make more room for increased traffic. For example, the U.S. military has freed previously restricted airspace off the coast of North Carolina for use by commercial aircraft. These efforts should help ease traffic and minimize delays in the short term; however, increasing airport capacity by building new runways and airports is ultimately the way to handle the problem.

Practical and laboratory activity

1. Air Traffic Control is divided into two main types of operation:

1. Radio	2. Sensual	Correct is
3. Acoustic	4. Magnetic	
5. Visual	6. Electric	
7. Locator	8. Instrumental	

2. Tower controls:

1. Landing, take-off and runway operations of aircraft		Correct is
2. Only landing		
3. Only take-off		
4. Only runway operations		

3. What did FAA and NASA develop to handle a huge amount of flights per day?

1. Modern software, upgraded existing host computers and voice communications systems and instituted full-scale GPS		Correct is
2. Modern training system, and voice communications systems.		
3. Modern computers.		
4. Modern ATC towers with new equipment.		

10.5 Airport service

Humans play a central role in ramp activities. They do a wide variety of jobs necessary for safe and efficient ramp operations. Occasionally, however, a worker does not or is not able to do his or her job correctly or in the required time. These human performance failures can result in a number of unwanted consequences, such as personal injury, aircraft damage, equipment damage, or flight delays. Two major categories of human performance failures associated with ramp operations are errors and violations of company policies, processes, or procedures. We often refer to these violations as procedural noncompliance. Although errors are unintentional deviations from the expected action or behaviour, the worker who violates policies, processes, or procedures, does so intentionally. Wellintentioned individuals often commit violations trying to finish a job, and not simply for comfort or to reduce workload. During ramp operations, there is an assumption that workers will follow the policies, processes, and procedures as written. When this assumption is broken, it places the whole basis of the safety system at risk. In some cases, workers may commit violations because of factors dictated by his or her immediate situation, such as time pressures, insufficient staff, or unavailability of tools or equipment. In other cases, violations have become common practice and have become almost automatic. These routine types of violations have become the work group's normal practice, or norms - "everybody does it." Management knows about and unofficially condones routine violations, making these violations more of a management issue than an individual worker issue. In rare cases, a worker will break rules while disregarding the consequences. Event investigation data show that violations are often contributing factors to errors, but that sometimes errors and violations work together to cause an event. For example, a worker makes an error and then violates a procedure by not conducting a final check designed to find the error. We must eliminate violations in order to ensure safe and efficient ramp operations - regardless of the type of violation.

Injury prevention

Injury prevention is a critically important part of an airport operations human factors program. Many of the causal factors for employee injuries are similar to those contributing to aircraft damage. Generally, preventing one also will prevent the other. Ergonomics is the name for the component of human factors related to the physical body and associated task and equipment design. Sprains and strains make up the majority of injury types for baggage and freight handlers. Establishing an ergonomics program as part of your human factors program will significantly reduce the number of injuries.

Human factor training

Research and experience have shown that human factors training can address many of the issues that contribute to events. Training provides the knowledge to understand important principles and procedures and to integrate them into the work environment. Training can promote awareness and affect attitude. It reduces costs associated with human performance issues.

Fatigue/Alertness management

Proper rest contributes to your health and emotional well-being. Proper rest is a critical prerequisite to safe and efficient performance in all aspects of airport operations. Whether you are lifting bags, operating ramp equipment, or interacting with customers, proper rest is important. Many factors can cause fatigue, including physical and mental exertion, and lack of proper sleep. We can also call fatigue issues "alertness" issues, because alertness includes a wide range of factors associated with human fitness for duty. Airport operations personnel who have worked extended hours recall that they were fatigued more than they remember the work they performed. The entire workforce is susceptible to errors induced by fatigue.

Event investigation

The purpose of an event investigation process is to manage the risks from events caused by human actions that may affect flight safety, personal injury, and equipment damage. An error is a human action that unintentionally deviates from the required, intended, and expected action. A violation is a human action that intentionally deviates from company or regulatory policies or procedures. Event investigations help organizations identify and understand multiple contributing factors to errors and violations. Examples include hard-to-understand procedures, time pressures, task interruptions, poor communication, and a variety of additional workplace and life conditions. The identification of contributing factors provides an organization with a specific focus to prevent future events. Often, event investigation systems are part of a company's overall safety management system.

Practical and laboratory activity

1. Why human performance failures occur?

2. What is the purpose of human factor training?

1. Training can promote awareness and affect attitude		Correct is
2. Training can increase level of knowledge		
3. Training provides fast reaction		
4. Training provides correct task performance		

3. What are the basic methods of reducing the occurrence of unwanted consequences?

1. Injury prevention		2. Better education		Correct is
3. Human factor training		4. Fatigue/Alertness management		
5. Instruments accessibility		6. Frequent inspection		
7. Event investigation		8. Adherence of rules		

11.1 Knowledge bases and Databases

Computer information and communication technologies became a necessary aid applied for different purposes in the area of aerospace systems. Knowledge-based systems become more and more popular for the decision making support purposes. The most important aspect of a knowledge base is the quality of information it contains. The best knowledge bases have carefully written articles that are kept up to date, an excellent information retrieval system (search engine), and a carefully designed content format and classification structure.

A knowledge base (abbreviated KB) is a special kind of database for knowledge management, providing the means for the computerized collection, organization, and retrieval of knowledge. Also a collection of data representing related experiences, their results are related to their problems and solutions. Knowledge based systems are artificial intelligent tools working in a narrow domain to provide intelligent decisions with justification. Knowledge is acquired and represented using various knowledge representation techniques rules, frames and scripts. The basic advantages offered by such system are documentation of knowledge, intelligent decision support, self learning, reasoning and explanation.

A database is an integrated collection of logically-related records or files consolidated into a common pool that provides data for one or more multiple uses. One way of classifying databases involves the type of content, for example: bibliographic, full-text, numeric, image. Other classification methods start from examining database models or database architectures. Software organizes the data in a database according to a database model. A database model or database schema is the structure or format of a database, described in a formal language supported by the database management system, In other words, a "database model" is the application of a data model when used in conjunction with a database management system. Databases function in many applications, spanning virtually the entire range of computer software. Databases have become the preferred method of storage for large multiuser applications, where coordination between many users is needed. So, having such excellent possibilities, databases can be used almost in all fields of life, science and mãnagement.

Databases and knowledge bases has got many applications in aviation sphere. They are used for storage of accident statistics, aircraft repair records, aircraft and systems condition monitoring, diagnostics and prognostics. Faults often exhibit themselves as a deterioration trend in the turbomachine performance for example and eventually lead to the need to perform expensive repair and overhaul activities. Timely detection of incipient faults enables preventive maintenance and has significant economic importance. The overall areas of condition monitoring, diagnostics, trending, and prognostics for such faults are known in industry as PTM (Predictive Trend Monitoring). Accurate and reliable detection and parameter estimation of incipient faults requires detailed and thorough understanding and knowledge of the equipment. Trend monitoring is defined as using engine operational data to find symptoms of damage, deterioration, or excessive wear, trend monitoring has been around in some form since the mid-1970s. New hardware technology that captures more engine data points and sophisticated software that finds more subtle trends-and thus finds potential problems sooner-are making trend monitoring even more valuable now than in decades past. Trend monitoring consists of two basic components: engine data usually supplied by the OEM's engine control unit (ECU), and trend monitoring software or service supplied by the OEM or a third party. Nearly all turbine aircraft engines include an electronic ECU that adjusts fuel flow according to a set of parameters obtained from temperature and pressure probes and flow meters. Many of these parameters are recorded during certain engine events, such as engine startup and shutdown. The ECU also records additional parameters, such as the number of hours the engine has run, the number of start cycles, and any engine faults. Many ECUs allow this data to be downloaded into either OEM-provided software or to generic spreadsheets for later analysis.

On-board diagnostic systems, often called OBD systems, refer to a computer component used to monitor an engine and engine performance in an airplane. The system is similar to what's available in modern automobiles. An OBD records error codes that a mechanic can read to troubleshoot problems. OBD systems enable modern aircraft to record nearly everything that happens during flight. Commercial helicopters use similar technology to military Chinooks that monitors flight time, vibration and engine temperature. This takes human error and numbers rounding out of the equation for scheduled parts maintenance.

Theme 11. Information technologies in aviation

Practical and laboratory activity

1. What information technologies for storing and retrieving data you know?

1. Databases	2. Analyzing bases	Correct is
3. Storage bases	4. Retrieving bases	
5. Computational bases	6. Knowledge bases	
7. Modelling bases	8. Monitoring bases	

2. Definition of the notion for storing and retrieving data is:

1. An integrated collection of logically-related records or files consolidated into a common pool that provides data for one or more multiple uses		Correct is
2. An integrated collection of logically-related records or files consolidated into a different pools that provide data for one or more multiple uses		
3. An integrated collection of logically-related records or files consolidated into a common pool that provides data only for one use		
4. A non-integrated collection of logically-related records or files that provides data for one or more multiple uses		

3. What is PTM?

1. Predictive Technical Monitoring		Correct is
2. Proactive Technical Monitoring		
3. Performance Technical Monitoring		
4. Predictive Trend Monitoring		

11.2 Computer based training systems

Computer based training systems or e-learning comprises all forms of electronically supported learning and teaching. The information and communication systems, whether networked or not, serve as specific media to implement the learning process. The term will still most likely be utilized to reference out-of-classroom and in-classroom educational experiences via technology, even as advances continue in regard to devices and curriculum. E-learning is essentially the computer and network-enabled transfer of skills and knowledge. E-learning applications and processes include web-based learning, computer-based learning, virtual classroom opportunities and digital collaboration. Content is delivered via the Internet, intranet/extranet, audio or video tape, satellite TV, and CD-ROM. It can be self-paced or instructor-led and includes media in the form of text, image, animation, streaming video and audio.

Flight simulation is used extensively in the aviation industry for the training of pilots and other flight crew in both civil and military aircraft. It is also used for the training of maintenance engineers in aircraft systems, and has applications in aircraft design and development, also in aviation and other research.

Several different types of devices are utilized in modern flight training. These range from simple Part-Task Trainers (PTTs) that cover one or more aircraft systems to Full Flight Simulators (FFS) with comprehensive aerodynamic and systems modelling. This spectrum encompasses a wide variety of fidelity in both physical cockpit characteristics and quality of software models, as well as various implementations of sensory cues such as sound, motion, and visual systems. In many professional flight schools, initial training is conducted partially in the aircraft, and partially in relatively low cost training devices such as FNPTs and FTDs. As the student becomes familiar with basic aircraft handling and flight skills, more emphasis is placed on instrument flying, cockpit resource management (CRM), and advanced aircraft systems, and the portion of flight training conducted in these devices increases significantly. Finally, for more advanced aircraft-specific training, Full Flight Simulators (FFS) are used, particularly as part of conversion to the Commercial Air Transport (CAT) aircraft that the pilot will eventually fly. For many commercial pilots, most aircraft orientation and recurrent training is conducted in high level FTDs or FFS. In comparison to training in an actual aircraft, simulation based training allows for the training of manoeuvres or situations that may be impractical (or even dangerous) to perform in the aircraft, while keeping the pilot and instructor in a relatively low-risk environment on the ground. For example, electrical system failures, instrument failures, hydraulic system failures, environmental system failures, and even flight control failures can be simulated without risk to the pilots or an aircraft.

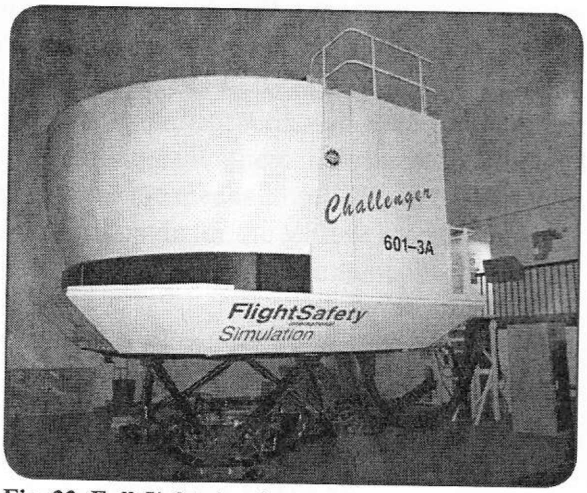


Fig. 33. Full flight simulator

A Full flight simulator (FFS) duplicates relevant aspects of the aircraft and its environment, including motion (Fig. 33). This is typically accomplished by placing a replica cockpit and visual system on a motion platform. A six degree-of-freedom (DOF) motion platform using six jacks is the modern standard, and is required for the so-called Level D flight simulator standard of civil aviation regulatory authorities such as FAA in the USA and EASA in Europe. Since the travel of the motion system is limited, a principle called 'acceleration onset cueing' is used. This simulates initial accelerations well, and then returns the motion system to a neutral position at a rate below the pilot's sensory threshold in order to prevent the motion system from reaching its limits of travel. Flight simulator motion platforms used to use hydraulic jacks but electric jacks are now being used. The latter do not need hydraulic motor rooms and other complications of hydraulic systems, and can be designed to give lower latencies (transport delays) compared to hydraulic systems. Level D flight simulators are used at training centres such as those provided by Airbus, Flight Safety International, CAE, BoeingTraining and Flight Services (ex-Alteon) and at the training centres of the larger airlines. In the military, motion platforms are commonly used for large multi-engined aircraft and also in helicopters, except where a training device is designed for rapid deployment to another training base or to a combat zone.

Practical and laboratory activity

1. What methods are used for training pilots and other crew?

1. Books		Correct is
2. Flight simulators		
3. Computer tests		
4. Video lessons		

2. What is E-learning?

3. What aid duplicates relevant aspects of the aircraft anf its environment?

1. Fast flight simulator	2. Full fiction supercomputer	Correct is
3. Full flight supercomputer	4. Flight fiction simulator	
5. Fictional flight simulator	6. Fast fictional simulator	
7. Full fiction simulator	8. Full flight simulator	

11.4 E-documents

An *electronic document is any electronic media content (other than computer* programs or system files) that are intended to be used in either an electronic form or as printed output.

Originally, any computer data were considered as something internal - the final data output was always on paper. However, the development of computer networks has made it so that in most cases it is much more convenient to distribute electronic documents than printed ones. And the improvements in electronic display technologies mean that in most cases it is possible to view documents on screen instead of printing them (thus saving paper and the space required to store the printed copies).

Electronic Flight Bag (EFB) is an electronic information management device that helps flight crews perform flight management tasks more easily and efficiently with less paper. It is a general purpose computing platform intended to reduce, or replace, paper-based reference material often found in the Pilot's carry-on Flight Bag, including the Aircraft Operating Manual, Flight Crew Operating Manual, and Navigational Charts (including moving map for air and ground operations). In addition, the EFB can host purpose-built software applications to automate other functions normally conducted by hand, such as performance take-off calculations.

The EFB gets its name from the traditional pilot's Flight Bag, which is typically a heavy (up to 40 lb/18 kg or more) documents bag that pilots carry to the cockpit. The Electronic Flight Bag is the replacement of those documents in a digital format. EFB weights are typically 1 to 5 pounds (0.5 to 2.2 kg), about the same as a laptop computer, and a fraction of the weight and volume of the paper publications. There are numerous benefits for using an EFB but specific benefits vary depending on the size of the operation, type of applications used, the existing content management and distribution system, the type of applications deployed. Some common benefits include: weight savings by replacing the traditional flight bag, reduced medical claims from handling traditional flight bags, reduced cost, and increased efficiency by reducing or eliminating paper processes. There are also claims of increased safety and reducing pilot workload.

EFB devices can display a variety of aviation data or perform basic calculations (including performance data and fuel calculations.). In the past, some of these functions were traditionally accomplished using paper references or were based on data provided to the flight crew by an airline's "flight dispatch" crew.

As personal computing technology became more compact and powerful, with extensive storage capabilities, these devices became capable of storing all the aeronautical charts for the entire world on a single three-pound (1.4 kg) computer, compared to the 80 lb (36 kg) of paper normally required for worldwide paper charts. New technologies such as real-time satellite weather and integration with GPS have further expanded the capabilities of Electronic Flight Bags. However, for large commercial airlines, the primary problem with EFB systems is not the hardware on the aircraft, but the means to reliably and efficiently distribute content updates to the airplane. And now there is an EFB made for the VFR & recreational IFR Pilot, by the name of VFRpad. The VFRpad has maps, plates, AFD, planning & weather apps, plus a full aviation GPS.

The EFB may host a wide array of applications, categorized in three software categories:

Type A

Static applications, such as document viewer (PDF, HTML, XML formats);

Electronic checklists (ECL);

Flight Crew Operating Manuals, and other printed documents like airport NOTAM;

Flight performance calculation;

Type B

Non-interactive electronic approach charts or approach charts that require panning, zooming, scrolling;

Head-down display for Enhanced Vision System (EVS), Synthetic Vision System (SVS) or video cameras;

Real-time weather data display, including weather map;

Type C

Can be used as a Multi-function display (MFD); In at least one case as part of an Automatic Dependent Surveillance-Broadcast system.

Practical and laboratory activity

1. What is an electronic document?

2. An electronic flight bag is used to:

1. Store different information about flight tasks		Correct is
2. Record different flight data in order to retrieve it after flight		
3. Perform flight tasks more easily and efficiently with less paper		
4. None of the answers is correct		

3. What are the advantages of the electronic flight bag?

11.4 CAD/CAE systems

Modern computer technology enables the designer to manage the enormous number of design, material, and process applications available when designing with composites for example. In the past, the designer had to limit the material, process, and design choices to those that were familiar. Now, with the help of a computer, one can develop a number of design concepts, quickly evaluate them against established functional and performance criteria in a wide range of materials and processes, and make the necessary design modifications. Finished drawings and specifications can be provided with increased accuracy and confidence-often in less time than ever before possible. For example, if one dimension is changed that alters many other dimensions, all the dimensions will be changed automatically by the computer at the same time the initial changes are made.

Computer-aided engineering (CAE) is the broad usage of computer software to aid in engineering tasks. It includes computer-aided design (CAD), computer-aided analysis (CAA), computer-integrated manufacturing (CIM), computer-aided manufacturing (CAM). CAE areas covered include:

- Stress analysis on components and assemblies using FEA (Finite Element Analysis);
- Thermal and fluid flow analysis Computational fluid dynamics (CFD) (Fig. 34);
- Kinematics;
- Mechanical event simulation (MES).
- Analysis tools for process simulation for operations such as casting, molding, and die press forming.
- Optimization of the product or process.

In general, there are three phases in any computer-aided engineering task:

- Pre-processing - defining the model and environmental factors to be applied to it. (typically a finite element model, but facet, voxel and thin sheet methods are also used)
- Analysis solver (usually performed on high powered computers)
- Post-processing of results (using visualization tools).

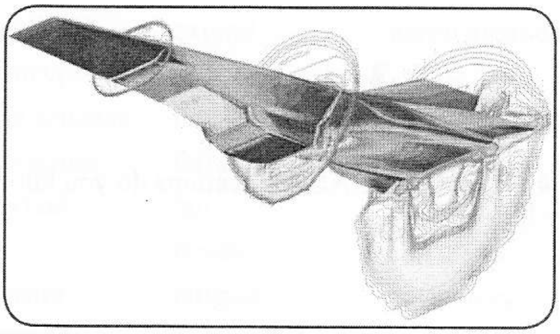


Fig. 34. NASA Hyper-x at MACH 7 - computational fluid dynamics image.

Computer-aided design (CAD), is the use of computer technology for the process of design and design-documentation. Computer Aided Drafting describes the process of drafting with a computer. CAD software, or environments, provides the user with input-tools for the purpose of streamlining design processes; drafting, documentation, and manufacturing processes. CAD output is often in the form of electronic files for print or machining operations. The development of CAD-based software is in direct correlation with the processes it seeks to economize; industry-based software (construction, manufacturing, etc.) typically uses vector-based (linear) environments whereas graphic-based software utilizes raster-based (pixelated) environments.

CAD is an important industrial art extensively used in many applications, including automotive, shipbuilding, and aerospace industries, industrial and architectural design, prosthetics, and many more. Current computer-aided design software packages range from 2D vector-based drafting systems to 3D solid and surface modellers. Mo-dern CAD packages can also frequently allow rotations in three dimensions, allowing viewing of a designed object from any desired angle, even from the inside looking out. Some CAD software is capable of dynamic mathematical modelling, in which case it may be marketed as CADD - computer-aided design and drafting. CAD is used in the design of tools and machinery and in the drafting and design of all types of buildings, from small residential types (houses) to the largest commercial and industrial structures (hospitals and factories). CAD is mainly used for detailed engineering of 3D models and/or 2D drawings of physical components, but it is also used throughout the engineering process from conceptual design and layout of products, through strength and dynamic analysis of assemblies to definition of manufacturing methods of components. It can also be used to design objects. CAD has become an especially important technology within the scope of computer-aided technologies, with benefits such as lower product development costs and a greatly shortened design cycle. CAD enables designers to lay out and develop work on screen, print it out and save it for future editing, saving time on their drawings.

Practical and laboratory activity

1. What means CAD?

1. Computer automated design	2. Computer automated drawing	
3. Computer aided design	4. Computer aided drawing	Correct is
5. Computer animated design	6. Complex automated design	
7. Computer animated description	8. Computer animated drawing	

2. What is the purpose of the CAE, describe its advantages and disadvantages.

3. What is the difference between CAD and CAE?

4. What CAD/CAE applications do you know?

Vocabulary

A

abrasion wear	абразивный износ
acceleration	ускорение
actuator	исп. механизм
advancement	достижение
aerodynamic force	аэродин. сила
aerodynamics	аэродинамика
aerospace	аэрокосмический
aileron	элерон
air conditioning	возд. кондиц.
air traffic control	упр. возд. движ.
aircraft	воздушное судно
airfoil	профиль крыла
airline	авиалинии
airship	воздушное судно
alloy	сплав
altitude	высота
aluminium	алюминий
angle of attack	угол атаки
anhedral	отриц. V
anti-authority	борьба с властью
atmosphere	атмосфера
attach	прикрепить
attempt	попытка
auxiliary power unit	вспом. блок питания
aviation	авиация

B

baloon	воздушный шар
banking	крен
barrier	барьер
bending	изгиб
biplane	биплан
blade	лопатка двиг.
bomber	бомбардировщик
boundary	граничный
breakage	поломка
bulkhead	шпангоут
bureau	бюро

C

cabin	кабина
CAD	автом. проект.
CAE	автом. разраб.
camber	дужка крыла
canopy	купол
capable	способный
carbon	углерод
carbon fiber	ушлеволокно
cargo	груз
center of pressure	центр давления
chord	хорда крыла
civil	гражданский
cleanup	зачистка
climb	подъем
coaxial rotor	коаксиальный ротор
collision	столкновение
combat	бой
combustion chamber	камера сгорания
compensate	компенсировать
composite	композитный
compression	компрессия
concave	вогнутый
configuration	конфигурация
consumption	расход топлива
control	управление
convex	вогнутый
copper	медь
corrosion	коррозия
cowling	обтекатель
crack	трещина
crew	экипаж
cross section	поперечное сечение

D

damage	повреждение
dashpot	амортизатор
database	база данных
defense	защита
deflect	отражать
degree of freedom	степень свободы мех.
dent	вмятина
descend	снижение
design	конструкция
develop	разработка
diagnostics	диагностирование
diameter	диаметр
dihedral	полож. V
disposal	устранение
dissipate	рассеивать
double-bubble	двойной пузырь
double-decked	двухэтажный
downward	вниз
drag	возд. сопротивление
drag coefficient	коэф. в.с.
drastic	радикальный
dynamic lift	дин. подъемная сила

E

e-document	эл. документ
elevator	руль высоты
engine	двигатель
engineering	конструирование
equipment	оборудование
exert	влиять, оказывать
exhaust	выхлоп
extend	вытягиваться

F

fabric	ткань
failure	отказ, сбой
fan	вентилятор
fasten	скрепить
fatigue	усталость
fighter	истребитель
filament	нить, волокно
flap	закрылок
flight	полет
flight controls	рули управления
fluid	жидкость
flying wing	летающее крыло
former	каркас
frame	скелет, конструкция
fuel	топливо
fuselage	фюзеляж

G

gearbox	коробка передач
glider	планер
gravity	гравитация
gull type	тип "чайка"

H

hardness	твердость
hatch	люк
hazard	опасность
heavier-than-air	тяжелее воздуха
height	высота
helicopter	вертолет
high pressure compressor	компр. выс. давления
high pressure turbine	турбина выс. давления
hinge	шарнир
honeycomb	сотовый наполнитель
horizontal stabilizer	гориз. стабилизатор
horizontally opposed	оппозитный
human factor	человеч. фактор
hydraulic	гидравлический
hypersonic	гиперзвуковой

I

ice protection	против. обледенит.
immerse	погружать
impulsivity	импульсивность
increase	увеличивать
information technologies	инф. технологии
injury	повреждение
inline engine	рядный двиг.
install	устанавливать
intake	впускной
intention	намерение
interior	интерьер
intermeshing rotor	пересекающ. ротор
investigation	расследование
invulnerability	неуязвимость

J

jam	заклинить
jet	реактивный
jetplane	реакт. самолет
joint	соединенный
judgement	решение

K

kevlar	кевлар
kinematics	кинематика
kite	возд. змей
knowledge base	база знаний

L

lack	нехватка
landing	приземление
landing gear	шасси
landing skids	лыжное шасси
latency	скрытое состояние
launch	запуск
leading edge	передняя кромка
leakage	утечка
lean	уклоняться
lifecycle	жизненный цикл
lift coefficient	коэф. под. силы
lift force	подъемная сила
lightweight	легкий
load	нагрузка
longeron	лонжерон
longitudinal	продольный
low pressure compressor	комп. низкого давления
low pressure turbine	турб. низкого давл.

M

mach number	число маха
magnesium	магний
maintain	поддерживать
maintenance	техобслуживание
malfunction	неисправность
maneuverability	маневренность
manganese	марганец
manned	управляемый
manufacturer	производитель
mast	мачта
military	военный
missile	ракета
molybdenum	молибден
monoplane	моноплан
motion	движение
multiplane	мультиплан

N

nacelle	гондола двиг.
narrow	узкий
network	комп. сеть
nickel	никель
nitrogen	азот
nozzle	азот

O

occurrence	происшествие
oil	масло
oxygen	кислород

P

parasol	парасоль
passenger	пассажир
piloted	пилотируемый
piston	поршневой
pitch	уклон
pitch angle	угол наклона
plane	самолет
pontoon	понтон
power plant	силовая устаовка
precursor	предшественник
pressure	давление
pressurize	герметизировать
production	производство
propeller	пропеллер
prototype	прототип
punch	пробитый
puncture	проколотый
purpose	назначение

Q

R

radial engine	радиальный двиг.
radome	обтекатель
ram	таранить
range	дальность
rapid	мгновенный
reinforced	упрочненный
relation	отношение
reliability	надежность
research	исследование
reservoir	резервуар
resignation	отказ
resist	сопротивляться
resultant force	результирующая сила
retract	убирать шасси
rib	нервюра

risk	риск
rivet	заклепка
rocket	ракета
rod	шток
roll	крен
rotary engine	роторный двиг.
rotor	ротор
ramjet	прямоточный
rudder	руль направления

S

safety	безопасность
sandwich	бутерброд
scratch	царапина
seal	изоляция
shaft	вал
shear	сдвиг
shock absorber	амортстойка
significant	значительный
simulation	симуляция
single	единичный
skid	лыжи
skill	навык, опыт
skin	обшивка
slat	предкрылок
slip	скользкий
solid	сплошной
sound	звук
sound barrier	звук. барьер
spanwise	поперечный
spar	лонжерон
spoiler	спойлер
stabilize	стабилизировать
stabilizer bar	стаб. попопер. устойчив.
stagnation	застой
stall	срыв потока
static lift	статическая п.с.
steam	пар
steel	сталь
stress	напряжение
stringer	стрингер
structural	структурный
strut	подпора
subsonic	дозвуковой
superior	превосходство
supersonic	сверхзвуковой
surface	поверхность
sustain	поддерживать
swashplate	автомат перекоса

T

tail rotor	хвостовой ротор
tail unit	хвост самолета
take-off	взлет
tandem rotor	двойной ротор
tears	разрывы
technician	техник
technology	технология
tension	натяжение
thrust	тяга
tiltrotor	изм. наклон ротор
tire	шина
titanium	титан
torque	крут. момент
traction	волочение
traffic	движение тр.
trailing edge	задняя кромка
transmission	трансмиссия
transonic	околозвуковой
transport	транспорт
trend	тенденция
triplane	триплан
turbofan	турбовентиляторный
turbojet	реактивный дв.
turboprop	турбовинтовой
turboshaft	турбовальный

U

undercarriage	шасси
unmanned	беспилотный
unveil	открывать (тайну)

V

vanadium	ванадий
vehicle	транспорт
vertical	вертикальный
vertical stabilizer	верт. стабилизатор
volumetric	объемный
VTOL	верт. взл. и пос.

W

wide	широкий
wind tunnel	аэродин. труба
wing	крыло
wing tips	законцовки крыла
wire	провод
wood	древесина

X

Y

yaw	рыскание

Z

Links and sources

Links	Page
http://en.wikipedia.org/wiki/Aviation_history	4
http://en.wikipedia.org/wiki/Boeing	6
http://en.wikipedia.org/wiki/Short_Brothers	
http://en.wikipedia.org/wiki/Antonov	
http://en.wikipedia.org/wiki/Aircraft	10
http://en.wikipedia.org/wiki/Fuselage	12
http://www.planemath.com/activities/pmenterprises/fuselage/fuselage1.html	14
http://adg.stanford.edu/aa241/fuselayout/fusesection.html	
http://www.tpub.com/content/aviation/14018/css/14018_34.htm	16
http://www.tpub.com/content/aviation/14018/css/14018_567.htm	18
http://inventors.about.com/od/astartinventions/ig/Parts-of-an-Airplane-/wings.htm	22
http://www.tpub.com/content/aviation/14018/css/14018_16.htm	26
http://www.grc.nasa.gov/WWW/k-12/VirtualAero/BottleRocket/airplane/elv.html	30
http://en.wikipedia.org/wiki/Undercarriage	34
http://en.wikipedia.org/wiki/Aircraft_engine	40
http://en.wikipedia.org/wiki/Aircraft_engine	42
http://www.madehow.com/Volume-1/Jet-Engine.html	44
http://en.wikipedia.org/wiki/Airfoil	48
http://avstop.com/ac/flighttrainghandbook/airfoildesign.html	50
http://en.wikipedia.org/wiki/Helicopter	52
http://en.wikipedia.org/wiki/Helicopter	54
http://en.wikipedia.org/wiki/Helicopter_flight_controls	56
http://www.helis.com/howflies/ontheair.php	
http://www.pilotfriend.com/training/flight_training/human/decisions.htm	58
http://en.wikipedia.org/wiki/Human_factors	
http://en.wikipedia.org/wiki/Air_traffic_control	64
http://www.atcvantage.com/docs/FAA_HF_OPs_MANUAL_AO.pdf	66
http://en.wikipedia.org/wiki/Database	68
http://en.wikipedia.org/wiki/E-learning	70
http://en.wikipedia.org/wiki/Electronic_document	72
http://en.wikipedia.org/wiki/Computer-aided_design	74

Навчально-методичне видання

ГАЛСТЯН Артем Арменович
ЖУРАВЛЬОВА Лариса Андріївна

ОСНОВИ АВІАЦІЇ І КОСМОНАВТИКИ

Методичні рекомендації до виконання лабораторних робіт (англійською мовою)

Технічний редактор Н. М. Угляренко

Підписано до друку 23.08.2011 року. Формат 60х84 1/8
Друк офсетний, наклад 200 прим. Зам. №75
Надруковано СПД ФО Маруфі Р.А.
тел.: 044 237-54-16, 063 237-54-16
www.enterprint.com.ua
Свідоцтво №10014044

Видавництво ПП НВЦ Профі
Свідоцтво про державну реєстрацію серія ДК №790 від 29.01.2002р.