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EARTH AIR ARCHITECTURE

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Abstract

The work entitled „Earth Air Architecture“ is one of a series of works created by deepening the general typology of architecture defined by the author in the book „Architecture in Context“ (2011). After inhabiting almost all natural environments on the surface of the Earth, man, for various reasons (scientific, economic, military, adventurous...) stepped into environments that are not 'natural' for his existence: underground (into rocks - architecture carved into rocks), under water (underwater architecture), areas with eternal ice (polar architecture)... The study of architecture in these environments provided the author not only with scientific curiosity but also with immense satisfaction, since through these researches, which he presented in published books, time and time again contributed to his theory of Architecturally Defined Space (ADS), which he defined (1987) in his doctoral dissertation. This work, together with the works Earth Water Air Architecture (Architecture on the Water) and Earth Water Architecture (Underwater Architecture) will provide readers (primarily students of architecture) with valuable information and open a new dioptre of seeing and understanding architecture. Creating architecture in these ('new') environments will require architecture students to have a lot of knowledge that, at first glance, is not of an 'architectural nature', but concerns physics, chemistry, mechanical engineering, electrical engineering (creation of software and hardware, automation, generation of electricity... .), robotics, medicine, psychology, philosophy, religion... Although architects will be part of complex teams of specialized experts, in their hands will be 'big ideas' about architecture as a framework for life.

Keywords: *Architecturally Defined Space (ADS), Earth Air Architecture*

1. Intruduction

„According to the author's understanding of architecture as an Architecturally Defined Space (ADS) with its four basic elements - Environment, Man, Boundaries and Perspectives - a general typology of architecture is proposed according to the way its boundaries (envelopes) are defined, and according to the specifics of global natural environments in which man can realize its existence: on Earth (Earth Architecture, type E) in open space (Space Architecture, type S) and on other celestial bodies (Space Body Architecture, type SB)“ [1,2], (Figure 1).

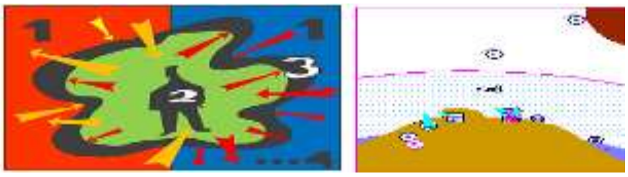

Figure 1. Architecturally Defined Space, ADS (A. Hadrovic, 1987), left and ADP typology (A. Hadrovic, 2011), right

According to Figure 1, Earth Architecture (type E), due to extremely different natural environments, appears in a wide variety of appearances: on the surface of the Earth and partially buried in the ground (Earth Ground Air Architecture, subtype EGA), completely buried in the ground (Earth Ground Architecture , subtype EG), on the surface of water (Earth Water Air Architecture, subtype AWA), underwater (Earth Water Architecture, subtype EW) and completely in the air/atmosphere (Earth Air Architecture, subtype EA). Type EA (Earth Air, or Earth Atmosphere) implies those ADS solutions that are realized in the air/atmosphere, in such a way that all its boundaries are in contact with the air [2] (Figures 3-7). If we follow some living organisms for which the atmosphere is the basic living environment (birds and insects, for example), we must note their anatomical-physiological predispositions that enable them to fly and float in the air, that is, the ability to overcome the Earth's gravity (Figure 2).

Figure 2. Birds hover and fly in the air
Source: http://blog.kootenay-lake.ca/?p=7883, Accessed: July 20, 2023.

An airplane is a highly advanced structure designed by man to meet extremely demanding needs: fast, safe and voluminous transportation of people and assets through the air. The construction of the plane's fuselage and partly the construction of the plane's wings resemble the construction of a car or a bus (Figures 3, 4).

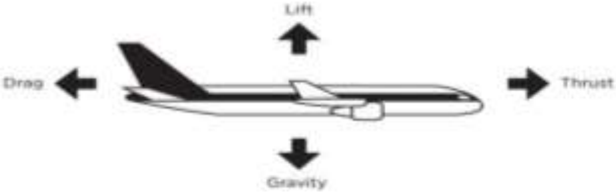

Figure 3. Forces acting on an airplane in flight: gravity, aerodynamic forces (internal and external) and propulsive forces (drive)
Source: https://www.scienceworld.ca/resource/four-forces-flight/, Accessed: July 20, 2023.

Figure 4. Left: The plane rises (and descends) vertically – hovers in the air
Source: https://www.businessinsider.com/f-35b-fighter-jet-hovers-lands-vertically-2016-7, Accessed: July 20, 2023.

Figure 5. A helicopter flies and hovers in the air
Source: https://www.valhallahelicopters.com/blog/back-to-school-how-do-helicopters-work/, Accessed: July 20, 2023.

Figure 6. Drones fly and hover in the air
Source: https://www.digitaltrends.com/cool-tech/drones-with-super-long-flight-times/, Accessed: July 20, 2023.

Figure 7. Man flies (left) and hovers (right) in the air
Source:https://3dprintingindustry.com/news/gravity-industries-strives-for-superhuman-flight-with-3d-printing-boosted-esuit-191975/
Accessed: July 20, 2023.

In the content of the work Earth Air Architecture will be presented the natural environment (atmosphere of the Earth/air), the physical laws that govern between bodies (which fly and float) and the atmosphere/air, the social environment (scientific research and legislation), man (the definitional area of human comfort and psychological-aesthetic dimensions of human presence in the atmosphere/air), boundaries (conceptualization and materialization of envelopes of physical structures that fly and float in the atmosphere/air) and perspectives of structures that fly and float in the atmosphere/air. The physical structures of architecture in its 'classical understanding', which are defined here as 'Hybrid Earth Air Architecture', will also be presented.

2. Environment

“Environment is a fundamental feature of Architecturally Defined Space (ADS). As a complex expression of human struggle, architecture is simultaneously a strictly defined empirical phenomenon that is always realized in a concrete natural environment in which it must survive as a physical structure, resistant to more or less aggressive natural influences. At the same time, many inputs from the social environment give architecture the characteristics of a concrete society in the historical-time period context”[1,3].

2.1. Natural environment

When we talk about the natural environment, we mean „those parts of the visible world that were not created by man and that we can discern with our senses“[1,3]. The term 'nature' refers to all physical phenomena, from microscopic to macroscopic dimensions, from matter and energy to the Universe.

Atmosphere. Earth's atmosphere is a layer of gases held by Earth's gravity that surrounds the planet. The Earth's atmosphere protects life on Earth by creating pressure that enables the existence of liquid water on the Earth's surface, absorbing ultraviolet solar radiation, warming the surface and retaining heat (greenhouse effect) and reducing temperature extremes between day and night (daily temperature variations)[4]. By volume, dry air contains 78.08% nitrogen, 20.95% oxygen, 0.93% argon, 0.04% carbon dioxide and small amounts of other gases. Air also contains a variable amount of water vapor, on average about 1% at sea level and 0.4% in the entire atmosphere (Table: 1). Air composition, temperature and atmospheric pressure vary with altitude. Within the atmosphere, air suitable for use in photosynthesis by land plants and respiration by land animals is found only in the Earth's troposphere.

Table 1: Main components of dry air, by volume

Gas	Volume (A)

Name	Formula	In ppmv [B]	In %
Nitrogen	N_2	780840	78.084
Oxygen	O_2	209460	20.946
Argon	Ar	9340	0.9340
Carbon dioxide (December 2020) [C]	CO_2	415.00	0.041500
Neon	Ne	18.18	0.001818
Helium	He	5.24	0.000524
Methane	CH_4	1.87	0.000187
Krypton	Kr	1.14	0.000114
Not included in the upper dry atmosphere:			
Vodena para[D]	H_2O	0-30.000[D]	0-3 %[E]
notes: (A) volume fraction is equal to mole fraction only for an ideal gas (B) ppmv: parts per million by volume (C) CO2 concentration has been increasing in recent decades (D) Water vapor has about 0.25% mass in the full atmosphere (E) Water vapor varies significantly locally			

Source:http://www.uigi.com/air.html#:~:text=Standard%20dry%20air%2C%20which%20is,recovered%20as%20industrial%20gas%20products, Accessed: July 29, 2023.

The three main components of the Earth's atmosphere are nitrogen, oxygen and argon. Water vapor makes up about 0.25% of the atmosphere by mass. The concentration of water vapor (a greenhouse gas) varies significantly from about 10 ppm by volume in the coldest parts of the atmosphere to as much as 5% by volume in hot, humid air masses, and the concentrations of other atmospheric gases are usually given under dry air conditions (without water vapor). The remaining gases are often called trace gases, among which are greenhouse gases, mainly carbon dioxide, methane, nitrous oxide and ozone. In addition to the already mentioned argon, there are also other noble gases, neon, helium, krypton and xenon. Filtered air includes traces of many other chemical compounds. Many substances of natural origin may be present in locally and seasonally variable small amounts as aerosols in an unfiltered air sample, including mineral and organic dust, pollen and spores, sea spray, and volcanic ash. Various industrial pollutants can also be present in the form of gases or aerosols, such as chlorine (elemental or in compounds), fluorine compounds and elemental mercury vapor. Sulfur compounds such as hydrogen sulfide and sulfur dioxide (SO_2) can be obtained from natural sources or from industrial air pollution. The average molecular weight of dry air, which can be used to calculate density or to convert between mole fraction and mass fraction, is about 28.946 or 28.96 g/mol. This is reduced when the air is humid. The relative concentration of gases remains constant up to approximately 10,000 m above sea level. In general, air pressure and density decrease with altitude in the atmosphere. However, temperature has a more complex profile with altitude and may remain relatively constant or even increase with altitude in some regions. Since the general pattern of the temperature/altitude or lapse rate profile is constant and measurable by instrumented balloon soundings, temperature behavior provides a useful metric for distinguishing atmospheric layers. In this way, the Earth's atmosphere can be divided (called atmospheric stratification) into five main layers: troposphere, stratosphere, mesosphere, thermosphere and exosphere. The altitudes of the five layers are as follows [5]: Troposphere: 0 to 12 km, Stratosphere: 12 to 50 km, Mesosphere: 50 to 80 km, Thermosphere: 80 to 700 km and Exosphere: 700 to 10000 km.

The troposphere is the lowest layer of the Earth's atmosphere. It extends from the Earth's surface to an average altitude of about 12 km, although this altitude varies from about 9 km at the geographic poles to 17 km at the equator, with some variations due to weather conditions (Figure 8). Most conventional air activity takes place in the troposphere, and this is the only layer accessible to propeller-driven aircraft.

The stratosphere is the second lowest layer of the Earth's atmosphere. It lies above the troposphere and is separated from it by the tropopause. This layer extends from the top of the troposphere at approximately 12 km above the Earth's surface to the stratopause at an altitude of about 50 to 55 km (Figure 8). The atmospheric pressure at the top of the stratosphere is approximately 1/1000 of the pressure at sea level. It contains the ozone layer, the part of the Earth's atmosphere that contains relatively high concentrations of this gas. The stratosphere defines a layer in which temperatures rise with increasing altitude. This rise in temperature is caused by the ozone layer absorbing ultraviolet (UV) radiation from the Sun, which limits turbulence and mixing. Although the temperature can be -60 °C at the tropopause, the top of the stratosphere is much warmer and can be close to 0 °C. The stratospheric temperature profile creates very stable atmospheric conditions, so the stratosphere lacks the air turbulence that creates weather conditions so widespread in the troposphere. Consequently, the stratosphere is almost completely devoid of clouds and other weather features. However, polar stratospheric or nacreous clouds are occasionally seen in the lower part of this layer of the atmosphere where the air is coldest. The stratosphere is the highest layer accessible by jet-powered aircraft.

The mesosphere is the third highest layer of the Earth's atmosphere and occupies the area above the stratosphere and below the thermosphere (Figure 8). It extends from the stratopause at an altitude of about 50 km to the mesopause at an altitude of 80–85 km. Temperatures drop with increasing altitude until the mesopause, which marks the top of this middle layer of the atmosphere. It is the coldest place on Earth and has an average temperature of about -85 °C [6]. Just below the mesopause, the air is so cold that even very scarce water vapor at this altitude can sublimate into polar-mesospheric night clouds. These are the highest clouds in the atmosphere and can be seen with the naked eye if sunlight is reflected around them an hour or two after sunset or similar before sunrise. They are easiest to see when the Sun is about 4 to 16 degrees below the horizon. Lightning-induced discharges known as transient lighting events (TLEs) occasionally form in the mesosphere above tropospheric thunderclouds. The mesosphere is also the layer where most meteors burn up upon entering the atmosphere. It is too high above the Earth to be accessible by jet-powered aircraft and balloons, and too low to allow orbiting spacecraft. The mesosphere is mainly accessed by sounding rockets and rocket-powered aircraft.

The thermosphere is the second highest layer of the Earth's atmosphere. It extends from the mesopause (which separates it from the mesosphere) at an altitude of about 80 km to the thermopause at an altitude of 500–1000 km (Figure 8). The height of the thermopause varies considerably due to changes in solar activity. Since the thermopause is located at the lower limit of the exosphere, it is also called the exobase. The lower part of the thermosphere, from 80 to 550 kilometers above the Earth's surface, contains the ionosphere. The temperature of the thermosphere gradually increases with height and can reach up to 1500 °C, although the gas molecules are so far apart that its temperature is not very significant in the usual sense. Air is so thin that a single molecule (oxygen, for example) travels an average of 1 kilometer between collisions with other molecules. Although the thermosphere has a large proportion of high-energy molecules, a person would not be hot in direct contact, because its density is too low to conduct significant amounts of energy into or out of the skin. This layer is completely cloudless and water vapor free. However, non-hydrometeorological phenomena such as aurora borealis and aurora australis are occasionally seen in the thermosphere. The International Space Station orbits in this layer, between 350 and 420 km. Many satellites orbiting the Earth are present on this layer.

The exosphere is the outermost layer of the Earth's atmosphere (the upper limit of the atmosphere). It extends from the thermopause, at the top of the thermosphere at an altitude of about 700 km, to approximately 10,000 km, where it merges with the solar wind (Figure 8). This layer consists mostly of extremely low density hydrogen, helium, and a few heavier molecules, including nitrogen, oxygen, and carbon dioxide closer to the exobase. Atoms and molecules are so far apart that they can travel hundreds of kilometers without colliding with each other. So, the exosphere no longer behaves like a gas, and particles constantly escape into space. These free-moving particles follow ballistic trajectories and can migrate in and out of the magnetosphere or solar wind. The exosphere is too far above the Earth for meteorological phenomena to occur. However, the Earth's auroras - the aurora borealis (northern lights) and the aurora borealis (southern lights) - sometimes occur in the lower exosphere, where they overlap in the thermosphere. The exosphere contains many artificial satellites that orbit the Earth. Within the five main layers above, which are largely determined by temperature, several secondary layers can be distinguished by other properties: **The ozone layer** is located within the stratosphere. In this layer, ozone concentrations are about 2 to 8 parts per million, which is much higher than in the lower layers of the atmosphere, but still very small compared to the main components of the atmosphere. It is mostly found in the lower part of the stratosphere from about 15–35 km, although the thickness varies seasonally and geographically. About 90% of the ozone in the Earth's atmosphere is in the stratosphere. **The ionosphere** is the part of the atmosphere that is ionized by solar radiation. It is responsible for the aurora borealis. During daytime hours, it extends from 50 to 1000 km and includes the mesosphere, thermosphere and parts of the exosphere. However, ionization in the mesosphere largely ceases during the night, so the aurora is usually only seen in the thermosphere and lower exosphere. The ionosphere forms the inner edge of the magnetosphere. It has practical importance because it affects, for example, the propagation of radio waves on Earth.

Physical properties of the atmosphere. Average atmospheric pressure at sea level is defined by the International Standard Atmosphere as 101325 pascals (760.00 Torr; 14.6959 psi; 760.00 mmHg). This is sometimes called a unit of standard atmosphere (atm). The total atmospheric mass is 5.1480 × 1018 kg, about 2.5% less than could be deduced from the average pressure at sea level and the Earth's surface of 51007.2 megahectares, where this part is displaced by the mountainous land of the Earth. Atmospheric pressure is the total weight of air above a unit of surface at the place of its measurement. Therefore, air pressure varies depending on place and time. If the entire mass of the atmosphere had a uniform density equal to the density at sea level (about 1.2 kg per m^3) from sea level up, it would suddenly stop at an altitude of 8.50 km. In fact, mass decreases exponentially with altitude, halving every 5.6 km or by a factor of 1/e every 7.64 km, the average height of the atmosphere on a scale below 70 km. However, the atmosphere is more accurately modeled with a custom equation for each layer that takes into account temperature gradients, molecular composition, solar radiation, and gravity. In short, the mass of the Earth's atmosphere is distributed approximately as follows [7]: 50% is below 5.6 km, 90% is below 16 km, 99.999997% is below 100 km (Kármán line). According to international convention, this marks the beginning of Space in which travelers are considered astronauts. For comparison, the peak of Mount Everest is at 8848 m; commercial aircraft typically cruise between 10 and 13 km where thinner air improves fuel economy; weather balloons reach 30.4 km and more. Even above the Kármán line, significant atmospheric effects such as auroras still occur. Meteors begin to glow in this region, although larger ones may not burn up until they penetrate deeper. The various layers of the Earth's ionosphere, important for the propagation of HF radio waves, begin below 100 km and extend over 500 km. By comparison, the International Space Station and Space Shuttle typically orbit at 350–400 km, within the F-layer of the ionosphere, where they encounter enough atmospheric drag to require relaunches every few months, otherwise they will experience orbital decay leading to a return to Earth. Depending on solar activity, satellites can sense atmospheric drag at altitudes of 700 to 800 km.

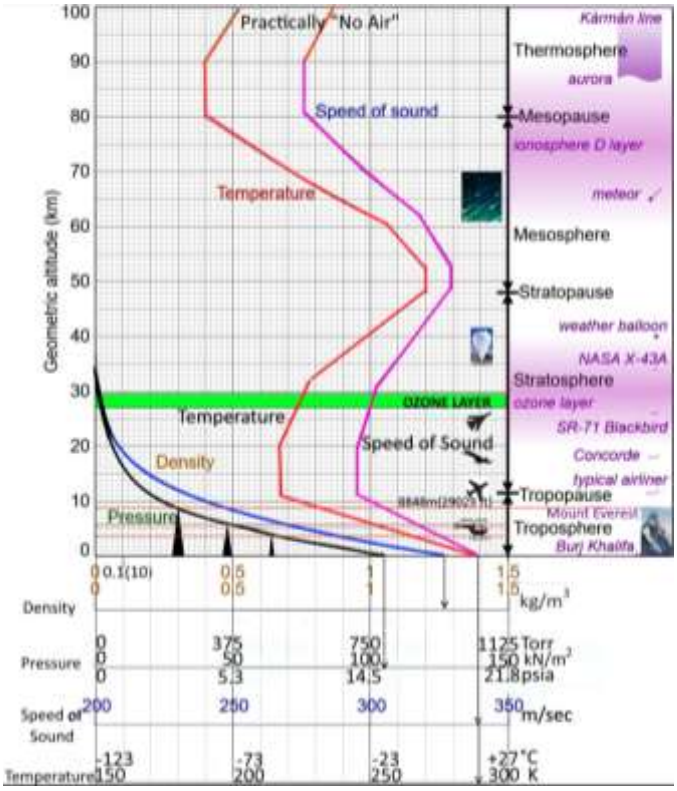

Figure 8. Comparison of the US Standard Atmosphere Chart (1962) geometric height with air density, pressure, sound speed and temperature with the approximate altitudes of various objects
Source: https://ntrs.nasa.gov/api/citations/19630003300/downloads/19630003300.pdf, Accessed: July 29, 2023.

Temperature trends in two thick layers of the atmosphere measured between January 1979 and December 2005 using advanced microwave probes on the National Oceanic and Atmospheric Administration (NOAA) meteorological satellites [8]. The instruments record microwaves emitted by oxygen molecules in the atmosphere. Temperature decreases with altitude above sea level, but variations in this trend begin above 11 km, where temperature stabilizes over a large vertical distance through the rest of the troposphere (Figure 8). In the stratosphere, starting at about 20 km, the temperature increases with height, due to heating within the ozone layer caused by the capture of significant ultraviolet radiation with the Sun's dioxide and ozone gas in this zone. Another region of increasing temperature with altitude occurs at very high altitudes, in the aptly named thermosphere, above 90 km. Since in an ideal gas of constant composition the speed of sound depends only on temperature and not on the pressure or density of the gas, the speed of sound in the atmosphere with altitude takes the form of a complicated temperature profile, and does not reflect changes in density or pressure with altitude.

Air density at sea level is about 1.2 kg/m^3. Density is not measured directly, but is calculated from measurements of temperature, pressure, and humidity using the equation of state of air (a form of the ideal gas law). The density of the atmosphere decreases with increasing altitude. This variation can be approximately modeled using the barometric formula. More sophisticated models are used to predict the orbital decay of satellites. The average mass of the atmosphere is about 5 quadrillion (5×10^{15}) tons or 1/1200000 of the mass of the Earth. According to the U.S. National Center for Atmospheric Research [9], the total mean mass of the atmosphere is 5.1480×10^{18} kg with an annual range due to water vapor of 1.2 or 1.5×10^{15} kg, depending on whether surface pressure or water vapor data are used. The average mass of water vapor is estimated at 1.27×10^{16} kg, and the mass of dry air at $5.1352 \pm 0.0003 \times 10^{18}$ kg.

Optical properties of the Earth's atmosphere. Solar radiation is the energy that the Earth receives from the Sun. Earth also emits radiation back into space, but at longer wavelengths that we cannot see. Part of the incoming and emitted radiation is absorbed or reflected by the atmosphere. In May 2017, it was discovered that light reflections, seen as flickering from a satellite in orbit 1609344 km away, are reflected light from ice crystals in the atmosphere [10]. When light passes through Earth's atmosphere, photons interact with it by scattering. If the light does not interact with the atmosphere, it is called direct radiation and this is what can be seen by looking directly at the Sun. Indirect radiation is light that is scattered in the atmosphere. For example, on cloudy days when one cannot see one's own shadow, the radiation does not reach us directly, but diffused. As another example, due to a phenomenon called Rayleigh scattering, shorter (blue) wavelengths scatter more easily than longer (red) wavelengths. This is why the sky looks blue, you can see scattered blue light. This is also the reason why sunsets are red. Because the Sun is close to the horizon, the Sun's rays pass through higher layers of the atmosphere than normal to reach our eyes. Most of the blue light is scattered, leaving the red light in the setting sun. Different molecules absorb different wavelengths of radiation. For example, O_2 and O_3 absorb almost all wavelengths shorter than 300 nanometers (1 nanometer = 10-9 m). Water (H_2O) absorbs many wavelengths above 700 nm. When a molecule absorbs a photon, the energy of the molecule increases. This warms the atmosphere, but the atmosphere also cools by emitting radiation. The combined absorption spectra of gases in the atmosphere leave 'windows' of low opacity, allowing only certain bands of light to be transmitted. The optical window extends from about 300 nm (ultraviolet-C) to the range that humans can see, the visible spectrum (commonly called light), at about 400–700 nm and continues into the infrared to about 1100 nm. There are also infrared and radio windows that transmit some infrared and radio waves at longer wavelengths. For example, the radio window works from about one centimeter to about eleven meters of wavelength.

Atmospheric circulation is the large-scale movement of air through the troposphere and the means (with ocean circulation) by which heat is distributed around the Earth. The structure of the large-scale atmospheric circulation varies from year to year, but the basic structure remains fairly constant because it is determined by the speed of the Earth's rotation and the difference in solar radiation between the equator and the poles.

Air pollution is the result of the introduction of chemicals into the atmosphere, particles or biological materials that cause harm or discomfort to organisms. Ozone depletion in the stratosphere is caused by air pollution, mainly chlorofluorocarbons and other ozone-depleting substances. The scientific consensus is that anthropogenic greenhouse gases currently accumulating in the atmosphere are the main cause of climate change [11]. On October 19, 2015, NASA launched a website containing daily images of the full side of the Earth illuminated by the Sun. The images were taken from the Deep Space Climate Observatory (DSCOVR) and show the Earth as it rotates during the day. Greenhouse gases consist of:

1. The most important greenhouse gas is water vapor.
2. It is mostly emitted by tropical oceans in response to warming from the Sun. Sunlight heats the surface of the ocean, which is cooled by evaporation. Simply put, the ocean sweats to stay cool. The water vapor then continues its journey through the Earth's hydrological cycle.
3. Some is transported to The Intertropical Convergence Zone (ITCZ) where it rises, condenses into rain and releases stored solar energy. Rain releases latent heat. This warms the air, drives convection in the ITCZ, and is the main source of heat for driving atmospheric circulation.
4. Atmospheric circulation transports heat forward, reducing the temperature contrast between the poles and the tropics.
5. Some condense into puffy clouds. These clouds and convective clouds in the ITCZ reflect sunlight that leads to a cooler Earth.
6. Some remain in the air and absorb the infrared radiation emitted by the Earth. This increases the greenhouse effect leading to a warmer Earth.

The main cause for concern is the relative importance of water in clouds and as water vapor. Is cloud cooling more or less important than vapor warming? Droplets of water vapor and clouds can heat or cool the earth's surface through feedback loops [12] (Figure 9).

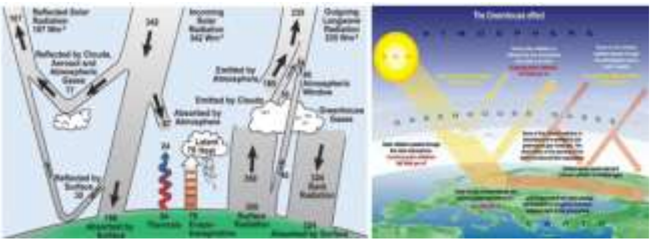

Figure 9. Left: mean annual balance of radiation and heat of the Earth. Right: The Greenhouse effect

Source:https://www.researchgate.net/figure/1-Estimate-of-the-Earths-annual-and-global-mean-energy-balance-Over-the-long-term_fig1_304047576, Accessed: July 29, 2023.

Source: https://web.archive.org/web/20050305042552/http:/www.grida.no/climate/vital/03.htm, Accessed: July 29, 2023.

Bernoulli's principle. In fluid dynamics, Bernoulli's principle states that an increase in fluid velocity occurs simultaneously with a decrease in static pressure or a decrease in potential energy of the fluid. The principle is named after Daniel Bernoulli (1700-1782), who published it in his book Hydrodynamica in 1738. Although Bernoulli concluded that pressure decreases with increasing flow velocity, in 1752 Leonhard Euler (1707-1783) derived Bernoulli's equation in its usual form. The principle is only applicable for isentropic flows: when the effects of irreversible processes (such as turbulence) and non-adiabatic processes (thermal radiation, for example) are small and can be neglected. Bernoulli's principle can be applied to different types of fluid flow, resulting in different forms of Bernoulli's equation. The simple form of Bernoulli's equation is valid for incompressible flows (most liquid flows and gases moving at low Mach number). More advanced forms can be applied to compressible flows at higher Mach numbers. Bernoulli's principle can be derived from the principle of conservation of energy. This means that in a steady flow, the sum of all forms of energy in the liquid along the current is the same at all points of the current. This requires that the sum of kinetic energy, potential energy and internal energy remain constant [13]. Therefore, an increase in fluid velocity - which implies an increase in its kinetic energy (dynamic pressure) - occurs simultaneously with a decrease in its potential energy (including static pressure) and internal energy. If the liquid flows out of the tank, the sum of all forms of energy is equal at all currents because in the reservoir the energy per unit volume (sum of pressure and gravitational potential ρ g h) is the same everywhere. Bernoulli's principle can also be derived directly from Isaac Newton's (1642-1726/1727) Second Law of Motion. If a small volume of fluid flows horizontally from an area of high pressure to an area of low pressure, then there is more pressure behind than in front. This gives a net force to the volume, accelerating it along the streamline. Fluid particles are subject only to pressure and their own weight. If the liquid flows horizontally and along a section of the stream, where the velocity increases it can only be because the liquid at that section has moved from an area of higher pressure to an area of lower pressure; and if its speed decreases, it can only be because it has moved from an area of lower pressure to an area of higher pressure. Consequently, within a fluid flowing horizontally, the highest velocity occurs where the pressure is lowest, and the lowest velocity occurs where the pressure is highest (Figure 10).

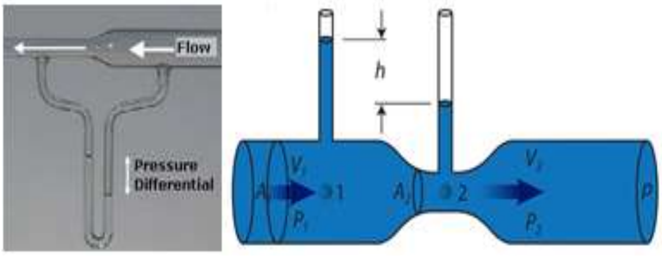

Figure 10. Bernoulli's experiment with liquid

Source: https://www.nasa.gov/sites/default/files/atoms/files/bernoulli_principle_k-4.pdf, Accessed: July 29, 2023.

Balloon magic. Understanding the position and movement of objects during experiments on Bernoulli's principle using a pair of inflated balloons simultaneously suspended a few centimeters apart (Figure 11). By blowing air directly between the balloons, Bernoulli's principle is demonstrated. By blowing air through the tube into the space between the balloons, an environment of faster air flow and thus less pressure is created (according to Bernoulli's principle). The consequence is: the balloons will get closer to each other (pushed by higher air pressure).

Figure 11. Demonstration of Bernoulli's principle

Source: https://www.nasa.gov/sites/default/files/atoms/files/bernoullis_principle_k-4-02-09-17-508.pdf, Accessed: July 29, 2023.

Principles of flying and floating bodies in the Earth's atmosphere. Observing birds in their flight (as well as the way they fly) can complete the understanding of the physical laws that are the basis of flight (Figures 12, 13).

Figure 12. Different positions of the wings (and body as a whole) of the bald eagle (Latin: Haliaeetus leucocephalus)

Source: https://www.allaboutbirds.org/guide/Bald_Eagle/overview, Accessed: July 29, 2023.

Figure 13. Different positions of birds in flight
Source: https://birdfact.com/articles/how-do-birds-fly, Accessed: July 29, 2023

Airplane wings are shaped so that air moves faster over the top of the wing. When the air moves faster, the air pressure decreases (Bernoulli's principle). Therefore, the pressure on the top of the wing is less than the pressure on the bottom of the wing. The difference in pressure creates a force on the wing that lifts the wing upwards [14] (Figure 14).

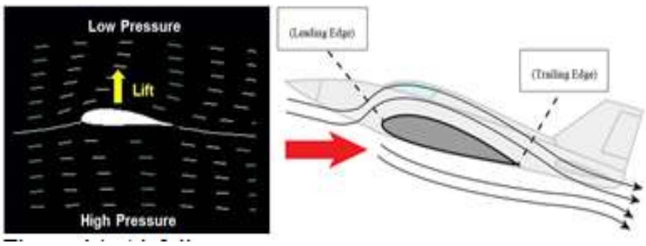

Figure 14. Airfoil
Source: https://www.grc.nasa.gov/www/k-12/UEET/StudentSite/dynamicsofflight.html, Accessed: July 29, 2023.

Sir Isaac Newton (1642-1726/1727) proposed (1665) three laws of motion[1]. These laws of motion help explain how airplanes fly.

1. If the object is not moving, it will not move on its own. If an object is moving, it will not stop or change direction unless something pushes it (This postulate is known as the law of inertia).
2. Objects will move further and faster when they are pushed harder (F = ma. Newton's second law is a quantitative description of the changes that force can produce when a body moves.).
3. When an object is pushed in one direction, there is always resistance of the same magnitude in the opposite direction (Law of action and reaction. This law is important in the analysis of static equilibrium problems, where all forces are balanced, but it also applies to bodies in uniform or accelerated movement.).

Forces of flight. Four forces act on an airplane in flight [14]: lift - upwards, drag - backwards, weight - downwards and thrust - forwards. The relationship between the intensity of these forces determines the position of the aircraft: it stands on the ground, rises (into the air), flies and descends to the ground (Figures 15, 16).

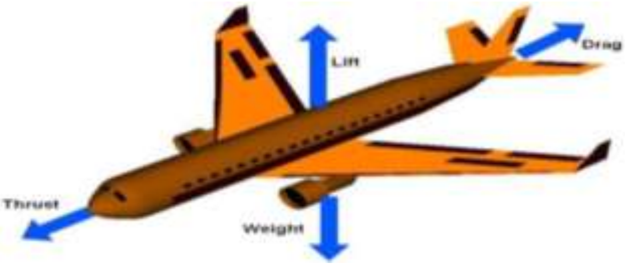

Figure 15. Four forces acting on an airplane in flight: Lift: up, Drag: back, Weight: down, Thrust: forward

Source: https://www1.grc.nasa.gov/beginners-guide-to-aeronautics/four-forces-on-an-airplane/#gallery, Accessed: July 29, 2023.

Figure 16. Parts of the physical structure of the aircraft: ailerons, rudder, elevators
Source: https://www.grc.nasa.gov/www/k-12/BGA/Mike/airplane_parts_act.htm, Accessed: July 29, 2023.

The pilot uses several instruments to control the plane. The pilot controls the engine power using the throttle. Pushing the throttle increases power, pulling it decreases power. Ailerons raise and lower the wings. The pilot controls the roll of the plane by raising one or the other aileron with the control wheel. Turning the steering wheel clockwise raises the right aileron and lowers the left aileron, which rolls the aircraft to the right (Figure 17).

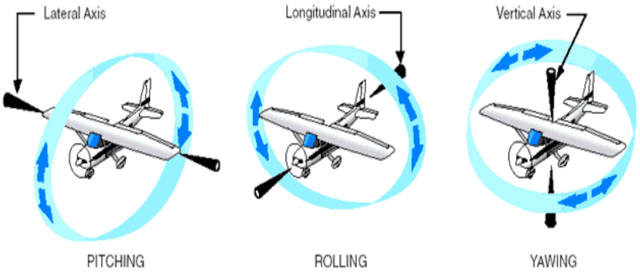

Figure 17. Axes of an airplane
Source: http://www.free-online-private-pilot-ground-school.com/Flight_controls.html, Accessed: July 29, 2023.

The rudder works to control the turn of the airplane. The pilot moves the rudder left and right, with the left and right pedals. By pressing the right rudder pedal, you move the rudder to the right. This turns the aircraft to the right. Used together, the rudder and ailerons are used to turn the airplane. The elevators located on the tail section are used to control the height of the plane. The pilot uses the steering wheel to raise and lower the elevator, moving it forward toward the rear compartment. Lowering the elevator lowers the nose of the plane and allows the plane to descend. By raising the elevator, the pilot can make the plane climb. An airplane pilot pushes the tip of the rudder pedals to apply the brakes. Brakes are used when the plane is on the ground to slow the plane down and prepare it to stop. The tip of the left rudder controls the left brake and the tip of the right pedal controls the right brake. If you look at these movements together, you can see that each type of movement helps control the direction and level of the airplane as it flies.

Sound barrier. Sound consists of air molecules moving. Sound waves travel at a speed of about 750 km/h (340 m/s) at sea level. When an airplane travels at the speed of sound, air waves gather and compress the air in front of the airplane. This compression causes a shock wave to form in front of the plane. In order to travel faster than the speed of sound, the plane must be able to break through the shock wave. When the aircraft moves through the waves, the sound waves spread and this creates a loud noise or

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[1] Newton's laws of motion, three statements describing the relationships between forces acting on a body and the body's motion, first formulated by the English physicist and mathematician Isaac Newton, are the basis of classical mechanics.

sonic boom. A sonic boom is caused by a sudden change in air pressure. When an airplane travels faster than sound, it is traveling at supersonic speed. An aircraft traveling at the speed of sound travels at Mach 1 or about 760 km/h. Mach 2 is twice the speed of sound (Figure 18).

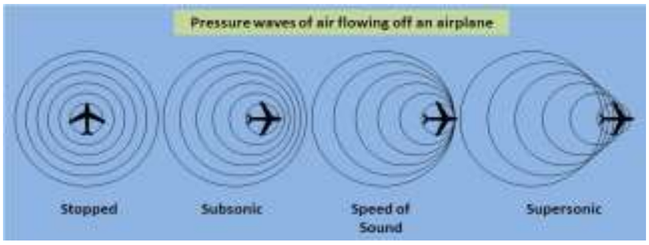
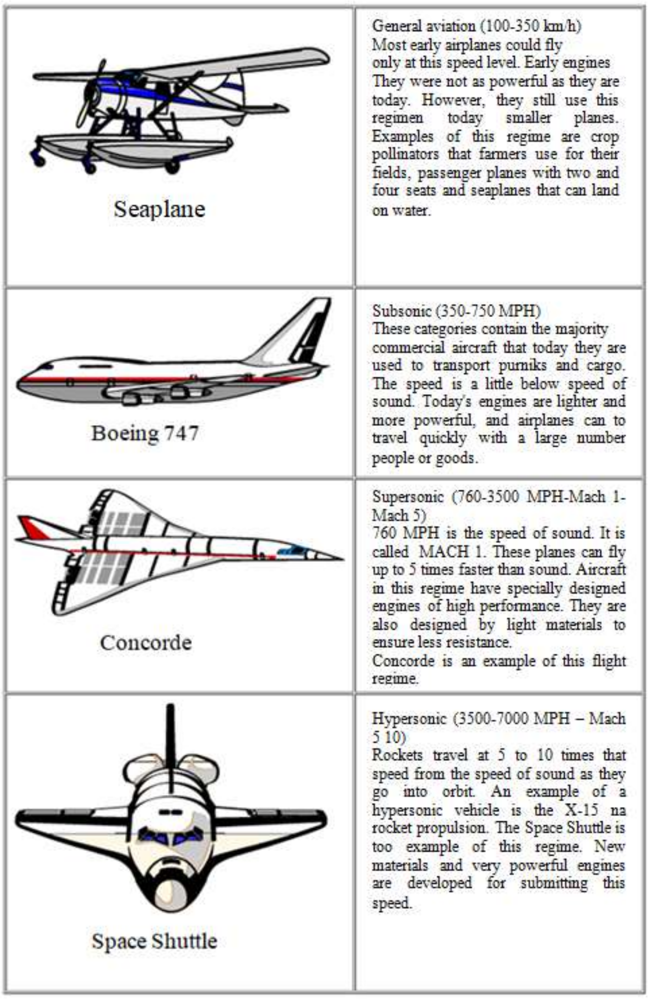


Figure 18. The speed of the plane in relation to the speed of sound
Source:https://aviation.stackexchange.com/questions/14095/when-a-plane-flies-faster-than-the-speed-of-sound-does-the-distance-between-pla, Accessed: July 29, 2023.

Flight modes are also called flight speed, each mode is a different level of flight speed [14] (Figure 19).



Seaplane	General aviation (100-350 km/h) Most early airplanes could fly only at this speed level. Early engines They were not as powerful as they are today. However, they still use this regimen today smaller planes. Examples of this regime are crop pollinators that farmers use for their fields, passenger planes with two and four seats and seaplanes that can land on water.
Boeing 747	Subsonic (350-750 MPH) These categories contain the majority commercial aircraft that today they are used to transport pumiks and cargo. The speed is a little below speed of sound. Today's engines are lighter and more powerful, and airplanes can to travel quickly with a large number people or goods.
Concorde	Supersonic (760-3500 MPH-Mach 1-Mach 5) 760 MPH is the speed of sound. It is called MACH 1. These planes can fly up to 5 times faster than sound. Aircraft in this regime have specially designed engines of high performance. They are also designed by light materials to ensure less resistance. Concorde is an example of this flight regime.
Space Shuttle	Hypersonic (3500-7000 MPH – Mach 5 10) Rockets travel at 5 to 10 times that speed from the speed of sound as they go into orbit. An example of a hypersonic vehicle is the X-15 na rocket propulsion. The Space Shuttle is too example of this regime. New materials and very powerful engines are developed for submitting this speed.

Figure 19. Examples of aircraft with different performances
Source: https://www.grc.nasa.gov/www/k-12/UEET/StudentSite/dynamicsofflight.html, Accessed: July 29, 2023.

The hovering. Some birds have the ability to stay in one place in the air. In fact, they do not 'stand', but by intensive flapping of their wings and body position, they stay 'in one place'. It is hovering (Figure 20). To hover is to stay in the same position in the air without moving forward or backward. Many birds and insects can hover by moving their wings very quickly. Hummingbirds, for example, can stay in the same spot in still air for as long as they like - they are true hoverers. A hovering hummingbird holds its body at a 45-degree angle to the ground and moves its wings in a more or less 'eight' pattern, with the 'eight' lying on its side. Hummingbirds have a highly mobile shoulder joint that allows them to pivot their wing in such a way as to generate lift both backward and forward. The leading edge of the wing leads in both strokes, and on the backstroke it is the underside of the feather that faces up, with the rotation of the shoulder actually turning the wing upside down. In each move, the bird can use part of the energy transferred to the movement of the air by the previous swing of the wings. For example, when walking forward, the air speed of the wing increases as it travels through the air pushed towards the back of the bird by the previous back. The direction of thrust changes between forward and backward strokes, so they cancel each other out. Because the wings beat more than 20 times per second (sometimes up to 80 beats per second), inertia keeps the bird's body essentially motionless. This system makes hummingbirds extremely maneuverable and allows them to hover while extracting nectar from flowers that might otherwise be inaccessible. But hovering flight is quite expensive: about 30% of a hummingbird's total body weight is invested in the muscles that move the wings, while other birds with strong flight have about 20%, and weak flyers can only have about 15%.

Figure 20. Hummingbirds keep their position in the same place - they float in the air
Source: https://birdfact.com/articles/can-birds-fly-backwards, Accessed: July 29, 2023.

Hovering ball demonstration. This experiment demonstrates Bernoulli's principle and Newton's first law of motion. At the same time, it explains the concept of a body floating in the air. The ping-pong ball 'stands' in the air stream created by the hair dryer. The air coming from the hair dryer has a higher speed than the air from the sides of the ball. According to Bernoulli's principle, in the part of the space where the air has a higher speed (in the stream of the hair dryer) there will be less pressure than in the part of the space where the air has a lower speed (from the sides of the ball). Thus, the air from the side "supports" the ball, which remains in the same position (floats) due to the balance of the forces of gravity (a consequence of its mass) and the force of the air current generated by the hair dryer. air floating around the hair dryer? Air coming from the hair dryer (Figure 21).

Figure 21. An experiment that confirms Bernoulli's principle

Source: https://www.nasa.gov/sites/default/files/atoms/files/bernoulli_principle_k-4.pdf, Accessed: July 29, 2023.

A helicopter is a type of aircraft that uses rotating wings for flight. Unlike an airplane or a glider, a helicopter has wings that move. Unlike a balloon, a helicopter is heavier than air and uses an engine to fly. A helicopter's rotating blades, or rotor, allow it to do things that an airplane cannot [15]. In order to fly, an object must have 'lift', a force that moves it upwards. Lifting is usually done using wings. The wings lift because of a relationship called Bernoulli's principle. Bernoulli's principle describes how air speed and air pressure are related. When the speed increases, the pressure decreases, and the opposite is also true. The wings are curved on top and flat on the bottom. This shape is called an airfoil. Because of this shape, the air flow over the top is faster than under the bottom. As a result, there is less air pressure on the wing tip; this causes suction and makes the wing move upwards. Helicopter rotor blades are wings and create lift. An airplane must fly fast to move enough air over its wings to provide lift. The helicopter moves the air above the rotor by turning the blades. A helicopter's rotors allow it to do things a plane can't. Unlike an airplane, a helicopter does not have to move quickly through the air. This fact means that it can be moved straight up or down. Most planes can't do that. A helicopter can take off or land without a runway. It can turn in the air in a way that airplanes cannot. Unlike an airplane, a helicopter can fly backwards or sideways. He can also hover in one place in the air without moving. This makes helicopters ideal for things that a plane can't do. For example, a helicopter can pick up someone with a medical problem up there where there is no runway. It can then land in a small area (on top of a hospital, for example). Helicopters can be used for many things. They can be used as flying ambulances to transport patients. They can be filled with water to extinguish large fires. Military forces use helicopters to attack targets on the ground and move troops. Helicopters are used to supply ships. Helicopters can be used to transport large objects. Helicopters can rescue people in hard-to-reach places like mountains or in rough seas. These uses are just a few of the many things that can be done with helicopters. NASA is conducting research on ways to improve helicopters. Crash tests help make helicopters safer. The new ideas could help engineers create bigger, better and faster helicopters. On one day, helicopters could carry 100 people on trips of 300 miles or more (Figure 22). NASA even studied how to fly helicopters on Mars [15].

Figure 22. Left: NASA uses a four-rotor model helicopter to test how a four-rotor vehicle can be remotely piloted. Right: NASA tested this rotor design in a wind tunnel to investigate ways to make helicopters quieter.
Source: https://www.nasa.gov/audience/forstudents/5-8/features/nasa-knows/what-is-a-helicopter-58.html, Accessed: July 29, 2023.

For decades, engineers have tried to combine the best qualities of helicopters and airplanes to create an aircraft that can hover. As a result, various types of vertical take-off and landing have been produced, some more successful than others. Airplanes and helicopters offer impressive capabilities, but are, at least in some cases, mutually exclusive. Helicopters are capable of vertical takeoff and landing (VTOL), along with hovering. This means they can operate from almost anywhere, independent of airports. Airplanes can't do that because they need runways. But they can carry much more payload and fly much faster than any helicopter. The idea of 'uniting' the characteristics of helicopters and airplanes is not new. Since at least the 1950s, aeronautical engineers have been working on this problem. To date, only a few planes have pulled it out. So far, only four aircraft have succeeded, and each has dealt with engineering problems differently. The engineering behind hovering aircraft is actually quite complex. Airplanes, by definition, need air flowing over their fixed wings to generate lift. When an airplane is hovering, it has no forward speed, so its wings cannot generate lift. Designers and manufacturers have been experimenting with different techniques for decades. The obvious solution is helicopters. They are a tried and true technology that enables vertical take-off and landing (VTOL) and hovering (Figure 23). The helicopter achieves this by generating its lift with rotating rotors instead of fixed wings. However, helicopters have many disadvantages. They can't carry a heavy load and they can't fly very fast. In fact, modern helicopters are limited to about 370.4 km/h top speed, which is far less than desirable for fighter/interceptors. So aircraft designers have a challenge on their hands - how can they create an aircraft as capable and fast as a modern fighter, but that has the benefit of being able to take off and land vertically. This is an important challenge because the ability to control an aircraft from anywhere opens up many more possible operations. Some aircraft are not always capable of vertical take-off and landing in all conditions [16]: CTOL - conventional take-off and landing, functions like a typical aircraft, STOL - short take-off and landing, requires a much smaller runway than a typical aircraft, VTOL - vertical take-off and landing .

Figure 23. Helicopters are the only VTOL aircraft available to civilians
Source: https://aerocorner.com/blog/airplanes-that-can-hover/, Accessed: July 29, 2023.

Methods of achieving vertical lift. Several methods were experimented with to get the aircraft to hover. The idea is basic - use engine power for vertical lift off the ground, then at a safe altitude switch to using engines for forward thrust and wings for lift. This allows you to fly at the speed of an airplane during cruise, but also to achieve vertical take-off and landing. Ryan Aircraft experimented with what is called a 'seated tail'. This aircraft was sitting vertically on the asphalt, and before the launch the pilot was sitting pointed at the sky like a rocket (Figure 24).

Figure 24. Ryan X-13 at Edwards Air Force Base
Source: https://aerocorner.com/blog/airplanes-that-can-hover/, Accessed: July 29, 2023.

A better way to achieve vertical lift was to divert the engine exhaust and thrust in a controlled manner. If the engine is running at full power and creating more thrust than the weight of a fully loaded aircraft, that should be enough power to lift off the ground. The problem with this approach is that it is expensive to build and difficult to fly. However, there have been several successful 'jump-jet' designs that have performed very well. A modern approach to the jump jet is the jet with vertical lift fans that direct the thrust downward. Combined with the exhaust ducts, this can produce the lift needed to get off the ground in a somewhat simplified form. Finally, there are designs where the entire engine is designed to spin. For takeoff and landing, the engines will be vertical. For regular flight, the engines will rotate to a horizontal position. Let's look at a few examples of successful airplanes that have achieved this engineering feat.

The Harrier first entered service in 1969, and some operators still use it today. They are used by the US Marines, as well as others. But its primary users, the British Royal Air Force and Royal Navy, have retired their old Harrier fleets. For all their impressive stats, the Harrier's design is now quite old. During their working life, they were exposed to incredible wear and tear, which required a lot of maintenance and high operating costs. Pilots were also challenging to fly. Hawker Siddeley and British Aerospace built the first generation Harrier. The aircraft was known as the AV-8A Harrier and was operated by the Royal Air Force and US Marines. The Sea Harrier is a derivative designed for the needs of the Royal Navy and the Indian Navy. In the 1980s, McDonnell Douglas, AV-8B, built the second generation Harrier in the USA. When Boeing bought McDonnell Douglas, Hawker came under the company's umbrella. Operationally, the Harrier uses a single Rolls-Royce turbine engine that had four vectored nozzles that could be moved independently from horizontal to slightly ahead of vertical (98 degrees). Being able to rotate the jets slightly forward means that the Harrier can move backwards while hovering. During its forty-plus years of service, 824 Harriers were delivered, making it by far the most popular and successful aircraft capable of hovering (Figure 25).

Figure 25. BAe Harrier GR9
Source: https://aerocorner.com/blog/airplanes-that-can-hover/, Accessed: July 29, 2023.

Another method of vertical descent of the aircraft from the ground is to move the entire engine. The best example of this approach is the tiltrotor V-22 Osprey. It's not exactly a plane, but it's not a helicopter either. Although many others were planned, the Osprey is the world's first operational tilting aircraft. The FAA created a new category of 'lift powered' aircraft for it, anticipating that the technology would one day be used for civilian operations. First launched in 1989, the Osprey program was so fraught with engineering and design problems that the aircraft did not enter operational service until 2007. The design captures the performance of a VTOL helicopter but retains the cruising speed performance of a powerful turboprop aircraft. About 400 aircraft have been delivered so far, and it is operated by the US Marines, Air Force and Navy. The Japan Ground Self-Defense Force also operates a fleet of aircraft. The US Navy currently plans to use the CMV-22B variant for carrier operations. India, Indonesia and Israel are also interested in the V-22 (Figure 26).

Figure 26. Bell Boeing V-22 Osprey
Source: https://aerocorner.com/blog/airplanes-that-can-hover/, Accessed: July 29, 2023.

The operating range of the Osprey is about 900 nautical miles, and they can operate at about 300 knots. The rear ramp can be opened in flight for rappelling and lifting. The latest generation of tiltrotors still under development is the Bell V-280 Valor. This version was designed for the US military as a replacement for their fleet of attack helicopters.

America's newest fighter jet, the Joint Strike Fighter, is designed with the STOVL variant. The F-35B has a single turbine engine with a vectored nozzle and a powered fan that provides vertical lift/descent during takeoff and landing. Much of the technology that went into the F-35B's V/STOL system comes from a partnership between Lockheed Corporation and Yakovlev (Figure 27). The systems that went into the Yak-141, an experimental aircraft that would eventually become the canceled Yak-41, led the way to the F-35B. Many former operators of retired Harriers have begun to transition to the F-35B. Unlike its predecessors, the F-35B is the first VTOL aircraft capable of supersonic speeds. The F-35 program is called the Joint Strike Fighter because there is a version for each service branch tailored to each branch's needs. Only the F-35B has V/STOL capabilities. F-35A-conventional take-off and landing fighter/interceptor for Air Force, F-35B-V/STOL version for Marines and F-35C-carrier based version for Navy use.

Figure 27. Lockheed Martin F-35B "Lightning II"
Source: https://aerocorner.com/blog/airplanes-that-can-hover/, Accessed: July 29, 2023.

2.2 Social environment

A social environment (society) is a group of individuals involved in more or less permanent social interaction or a large social group sharing the same geographic or social territory, usually subject to the same political authorities and dominant cultural expectations. Societies are characterized by patterns of relationships (social relations) among individuals who share a characteristic culture and institutions [1]. A given society can be described as the sum of such relationships between its constituent members. In the social sciences, the larger society often exhibits patterns of stratification or dominance in subgroups. Societies construct patterns of behavior by considering certain actions or speech as acceptable or unacceptable. These patterns of behavior in a certain society are known as social norms [3].

Science of the Earth's atmosphere. The science of the Earth's atmosphere is the study of the Earth's atmosphere and its various physical processes that operate within it. Meteorology includes atmospheric chemistry and atmospheric physics with a strong emphasis on weather forecasting. Climatology is the study of atmospheric changes (both long-term and short-term) that define average climates and their changes over time, due to natural and anthropogenic climate variability. Aeronomy is the study of the upper layers of the atmosphere, where dissociation and ionization are important. The science of the atmosphere has been extended to the field of planetary science and the study of the atmospheres of planets and natural satellites of the Solar System [17]. Experimental instruments used in atmospheric science include satellites, rockets, radiosondes, weather balloons, radars, and lasers. The term aerology (Greek: ἀήρ – aēr and –λογία – oracle) is sometimes used as an alternative term for the study of the Earth's atmosphere. In other definitions, aerology is limited to the free atmosphere, the region above the planetary boundary layer. Early pioneers in the field were Léon Teisserenc de Bort (1855-1913) and Richard Assmann (1845-1918). Atmospheric science, an interdisciplinary field of study combining physics and chemistry components that focus on the structure and dynamics of the Earth's atmosphere. Mathematical tools, such as differential equations and vector analysis, and computer systems are used to evaluate the physical and chemical relationships that describe how the atmosphere works. Atmospheric sciences are traditionally divided into three current areas - meteorology (study and forecasting of weather), climatology (study of long-term atmospheric patterns and their effects) and aeronomy (study of the physics and chemistry of the upper layers of the atmosphere). In meteorology, the research focus is on daily and hourly weather changes in the lower stratosphere and troposphere. Climatology, on the other hand, concentrates more on longer time periods ranging from one month to millions of years and attempts to describe the interaction of the atmosphere with oceans, lakes, land and glaciers. The focus of aeronomy is on the atmosphere from the stratosphere outwards. This field also considers the role that the atmosphere plays in the propagation of electromagnetic communications, such as short-wave radio transmission. Within those three main subject areas, the broad nature of atmospheric science has spawned practitioners who specialize in several different subfields. Kites equipped with meteorographs were used as atmospheric probes in the late 1890s, and in 1907 the U.S. Weather Service recorded the ascent of a kite to 7,044 meters above Mount Weather, Virginia. By the 1920s, radio had replaced the telegraph and the telephone as the main instrument for transmitting weather information. By 1936, a radio-meteorograph (radiosonde) was developed with the ability to send signals about relative humidity, temperature and barometric pressure from an unmanned balloon. An experiment with balloons up to an altitude of about 31 kilometers showed that columns of warm air can rise more than 1.6 kilometers above the Earth's surface and that the lower atmosphere is often stratified, and winds in different layers blow in different directions. During the 1930s airplanes began to be used to observe the weather, and the years from 1945 saw the development of rockets and weather satellites. The Television Infrared Observation Satellite (TIROS), the world's first all-weather satellite, was launched in 1960, and in 1964 the National Aeronautics and Space Administration (NASA) satellite was launched into near-polar orbit.

Atmospheric dynamics studies motion systems of meteorological importance, integrating observations over multiple locations and times as a theory. Common topics studied include phenomena as diverse as thunderstorms, tornadoes, gravity waves, tropical cyclones, extratropical cyclones, jet streams, and global circulations. The goal of dynamic studies is to explain the observed circulations on the basis of the fundamental principles of physics. The goals of such studies include improving weather forecasting, developing methods for predicting seasonal and interannual climate fluctuations, and understanding the impact of human-induced disturbances (increased carbon dioxide concentrations or ozone depletion, for example) on the global climate.

Atmospheric physics is the application of physics to the study of the atmosphere. Atmospheric physicists attempt to model Earth's atmosphere and the atmospheres of other planets using fluid flow equations, chemical models, radiation balance, and energy transfer processes in the atmosphere and beneath the oceans and land. To model weather systems, atmospheric physicists use elements of scattering theory, wave propagation models, cloud physics, statistical mechanics, and spatial statistics, each of which involves high levels of mathematics and physics. Atmospheric physics is closely related to meteorology and climatology, and also covers the design and construction of instruments for the study of the atmosphere and the interpretation of the data they provide, including remote sensing instruments. In the United Kingdom, atmospheric studies are supported by the Meteorological Office. Divisions of the US National Oceanic and Atmospheric Administration (NOAA) oversee research projects and weather modeling involving atmospheric physics. The Arecibo Observatory, also known as The National Astronomy and Ionosphere Center (NAIC) also conducts research into the upper atmosphere. Unlike meteorology, which studies short-term weather systems lasting up to several weeks. It studies the periodicity of weather events over years to millennia, as well as changes in long-term average weather patterns, in relation to atmospheric conditions. Climatologists study both the nature of climate—local, regional, or global—and the natural or human factors that cause climate change. Climatology looks at the past and can help predict future climate change. Phenomena of climatological interest include the boundary layer of the atmosphere, circulation patterns, heat transfer (radiation, convection and latency), interactions between the atmosphere and the ocean and the earth's surface (especially vegetation, land use and topography), and the chemical and physical composition of the atmosphere. Related disciplines include astrophysics, atmospheric physics, chemistry, ecology, physical geography, geology, geophysics, glaciology, hydrology, oceanography, and volcanology.

Aeronomy is the scientific study of the upper layers of the Earth - the atmospheric layers above the stratopause - and the corresponding regions of the atmosphere of other planets, where the entire atmosphere may correspond to the upper atmosphere of the Earth or a part of it. A branch of both atmospheric chemistry and atmospheric physics, aeronomy contrasts with meteorology, which focuses on the layers of the atmosphere below the stratopause. In the atmospheric regions studied by aeronomists, chemical dissociation and ionization are important phenomena. All the planets of the solar system have an atmosphere. This is because their gravity is strong enough to keep the gaseous particles close to the surface. Larger gas giants are massive enough to hold large amounts of light hydrogen and helium gases nearby, while smaller planets lose these gases to space. The composition of the Earth's atmosphere differs from that of other planets because the various life processes that took place on the planet introduced free molecular oxygen. Much of Mercury's atmosphere has been destroyed by the solar wind. The only moon that has retained a thick atmosphere is Titan. There is a thin atmosphere on Triton, and a trace of atmosphere on the Moon. Planetary atmospheres are affected by varying degrees of energy received from the Sun or from their interiors, leading to the creation of dynamic weather systems such as hurricanes (on Earth), planet-wide dust storms (on Mars), Earth-sized anticyclones on Jupiter (called the Great Red Spot). and holes in the atmosphere (on Neptune). At least one extrasolar planet, HD 189733 b, has been claimed to possess such a weather system, similar to the Great Red Spot but twice as large. Hot Jupiter has been shown to lose its atmosphere to space due to stellar radiation, similar to the tails of comets. These planets can have large temperature differences between their day and night sides that produce supersonic winds, although the day and night sides of HD 189733b appear to have very similar temperatures, indicating that the planet's atmosphere effectively redistributes the star's energy around the planet.

Atmospheric research. Some aspects of Earth are easier to explore than others. If we want to study the forest, we go to the forest, if we want to study the river, we go to the river. But what if we want to know what is at the top of the Earth's atmosphere? How to get there, especially in the time before the invention of airplanes and rockets? Exploring the atmosphere was a challenge before the technologies that bring us there like hot air balloons, weather balloons, parachutes and eventually airplanes were developed. Atmospheric measurement technology has also improved over time. It can be said that the scientific study of the atmosphere began in 1643 with the invention of the mercury barometer by Evangelista Torricelli (1608-1647), (Figure 28). Although this phenomenon was observed and discussed by others, including Galileo di Vincenzo Bonaiuti de' Galilei (1564-1642), it was Evangelista Torricelli (1608-1647) who achieved a breakthrough in understanding. At that time, the prevailing opinion was that air was weightless. Instead, the vacuum above the liquid in the barometer tube was thought to act as an attractive force that kept the liquid suspended in the tube. Torricelli challenged this view by proposing the reverse argument. He asserted that air has weight and that the atmosphere exerts pressure on the mercury in the bowl, which balances the pressure exerted by the column of mercury. The vacuum above the mercury in the closed tube, according to Torricelli, had no attractive force and played no part in supporting the column of mercury in the tube. The claim that air has weight, Torricelli realized, could be tested. In elevated places such as mountains, the reduced weight of the atmosphere above would have a lower pressure, so the corresponding height of the column of mercury in the barometer tube should be lower. It seems that Torricelli did not have the opportunity to perform this experiment in his short life, but in the year after his death the experiment was performed in France at the behest of the scientific philosopher Blaise Pascal (1623-1662).

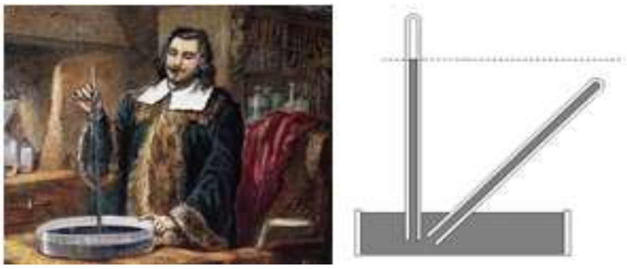


Figure 28. Left: Torricelli uses mercury to demonstrate the principle of the barometer. Right: The Carnot Cycle wonders if Torricelli tilted the barometer tube and observed the disappearance of the space above the mercury. This would indicate that something other than vacuum is keeping the fluid suspended in the tube
Source: https://carnotcycle.wordpress.com/tag/florin-perier/, Accessed: July 29, 2023.

Torricelli's experiment. French salon theoretician Marin Mersenne (1588-1648) traveled (1644) to Italy where he learned about Torricelli's barometer experiment. He brought the news of the experiment with him to Paris, where the young Blaise Pascal (1623-1662) was a regular attendee of meetings in the Mersenne salon. Pascal moved to Paris from the place of his birth and childhood, Clermont-Ferrand. The 1,465m Puy de Dôme was a familiar feature in the landscape he knew as a young man and provided an ideal means of testing Torricelli's thesis. Pascal's son-in-law Florin Périer (1605-1672) lived in Clermont-Ferrand, and after friendly persuasion, Périer climbed the Puy de Dôme with a Torricel barometer, taking measurements as he climbed (Figures 29,30,31).

Figure 29. Puy de Dôme in France, near Clermont-Ferrand
Source: https://carnotcycle.wordpress.com/tag/florin-perier/, Accessed: July 29, 2023.

At the base of the mountain, Périer recorded a living column 26 inches high and 3½ lines. He then asked a colleague to watch this barometer all day to see if there was a change, while he set off to climb the mountain with another barometer. At the summit he recorded a live column of 23 inches and 2 lines, considerably less than the measurement made 1,465 feet below, where the barometer remained stationary. The Puy de Dôme experiment provided convincing evidence that the weight of air, and thus atmospheric pressure, balanced the weight of the mercury column.

Figure 30. Torricelli's experiment was conducted by Florin Périer on Puy de Dôme on Saturday, September 19, 1648.
Source: https://carnotcycle.wordpress.com/tag/florin-perier/, Accessed: July 29, 2023.

This experiment took place when Isaac Newton was only 5 years old and had not yet formulated his famous laws that gave concepts such as mass, weight, force and pressure a systematic, mathematical basis. In the pre-Wotonian world of Torricelli and Pascal, their thinking was based on balancing weights in the familiar sense of merchant scales. The weight of the column of mercury in the barometer tube, acting on the mercury in the bowl, was balanced by the weight of the air acting on the mercury in the bowl. Since the height of the column of mercury was directly proportional to its weight, it was necessary to use the length scale marked on the barometer tube to calculate the weight of the air acting on the mercury in the bowl. It is instructive to compare the language of Robert Boyle (1627-1691) and Isaac Newton (1643-1727) when discussing the barometer in subsequent decades.

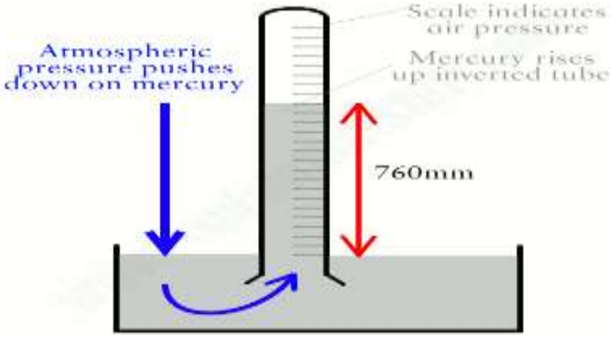


Figure 31. Torricelli's Barometer

Source: https://learn.weatherstem.com/modules/learn/lessons/125/10.html, Accessed: July 29, 2023.

In the second edition of Boyle's New Experiments Physical-Mechanicall from 1662 - which contains the first statement of Boyle's law - the word pressure appears frequently and has a meaning synonymous with weight. In the work Philosophiæ Naturalis Principia Mathematica (English: Mathematical Principles of Natural Philosophy) from 1687, pressure is considered a manifestation of force. Boyle and Newton therefore speak in essentially the same terms because according to Newtonian principles weight is a force.

Newton's principles applied. The key advance in atmospheric science that Newton gave in his Principia was the second law that mathematically expressed force, and thus weight and pressure, through the well-known formula[18,19]:

$\vec{F} = m\vec{a}$ (dimensions MLT^{-2})

The weight of a column of mercury with cross-sectional area A and height h is:

$F = mg = \rho Ahg$

where (ρ) is the mass density of mercury, and (g) is the acceleration due to gravity. The pressure created by the mercury column, which balances the atmospheric pressure, is:

$$P = \frac{F}{A} = \rho gh \text{ (dimensions } ML^{-1}T^{-2}\text{)}$$

Thus P is directly proportional to h.

For a column of live height 1 mm in a standard gravitational field ($g = 9.80665\ ms^{-2}$) at 273 K, P is equal to 133322 pascals. This is a unit of pressure called torr. Thus Pascal and Torricelli are marked in pressure units.

Decrease in temperature with altitude. The appearance of snow above a certain height in elevated places provides clear evidence that the temperature decreases with altitude, at least in that part of the atmosphere where our terrestrial landscape protrudes (Figure 32). There is no doubt that Torricelli, Pascal and other scientific philosophers of their time noticed this phenomenon and thought about it. But the explanation had to wait another two centuries until the beginning of the industrial revolution, ushering in the age of water vapor and the associated science of thermodynamics. The air in the troposphere, the lowest layer of the atmosphere where almost all weather phenomena occur, shows convection currents that constantly transport air from lower regions to higher ones, and from higher to lower regions. When air rises, it expands as the pressure decreases, and thus the work done on the air around it. Thermodynamic principles dictate that this work requires the consumption of heat, which must come from within, since air is a poor conductor and transfers very little heat from the environment. As a result, the rising air cools.

Figure 32. Puy de Dôme covered in snow

Source: https://carnotcycle.wordpress.com/tag/florin-perier/, Accessed: July 29, 2023.

At the top of the Puy de Dôme (1465 meters) the dry air → will be 14 °C cooler than at the foot of the mountain. This explains why snow can appear on the summit while grass is still growing on the lower slopes. In 1787, Horace Bénédict de Saussure (1740-1799) climbed to the top of Mont Blanc to study the atmosphere. Just a year earlier, this craggy peak in the Alps was successfully climbed for the first time. It is the highest point in Europe with an altitude of 4810 meters. Saussure reached the top carrying a barometer and a thermometer and taking measurements along the way. Until then, smaller and more portable instruments were available than the clumsy barometer Pascal and Perier carried with them in 1648. Saussure was a scientist-naturalist, but also a mountaineer. It was a challenging climb. Even though he had to cut his time on the mountain short because he was weakened by altitude sickness, Saussure's measures were very valuable. They showed that the air temperature decreases with height in the atmosphere by about 0.7 ºC per 100 meters. With this data, Hermann Ludwig Ferdinand von Helmholtz (1821-1894) and others concluded that the temperature about 30 km in the atmosphere would be -273 ºC (-460 F). There is no heat at that temperature. It is known as absolute zero. Absolute zero is considered the lowest possible temperature. It has never been found even with modern technologies, although 21st century scientists have come very close. In the 18th century, when Helmholtz was doing his calculations, the temperature that was falling was off the charts. It would be about 60 years before William Thomson/Lord Kelvin (1824-1907) invented a temperature scale that used absolute zero as its zero value. Therefore, when Helmholtz announced that absolute zero might exist, there was great interest among scientists to explore this high atmosphere to find absolute zero. Before the late 1700s, you would have to climb a mountain to explore the high altitudes of the atmosphere. That was before the bubble. French brothers Joseph-Michel (1740-1810) and Jacques-Etienne Montgolfier (1740-1810) invented the hot air balloon in 1783. It is made of burlap with thin layers of paper on the inside held together with 1,800 buttons. On June 3, 1783, they flew for 10 minutes and went perhaps as far as 2,000 meters. With balloons, scientists could begin to explore more than ever before. A year after the historic flight of the Montgolfier brothers, Guyton de Morveau Louis Bernard (1737-1816) and Reverend Bertrand traveled into the atmosphere above Dijon, France, in a hot air balloon with instruments for measuring temperature and pressure. They rose to more than 3,000 meters in the atmosphere, making measurements along the way. Henry Tracey Coxwell (1819-1900) and James Glaisher (1809-1903) delayed their balloon flight on September 5, 1862 due to a storm. They waited in Wolverhampton, England until the storm subsided. Then they climbed through the clouds and into the bright sunlight above (Figure 33). ”A flood of strong sunlight burst upon us with a beautiful cloudless blue sky, and below us lay a magnificent sea of clouds, the surface of which varied from endless hills and mountain ranges and with much snow as tufts rose from it” [20], James Glaisher wrote in his account of the adventure. Coxwell was a skilled balloon pilot. Glaisher was a scientist and equipped the balloon with instruments to measure at different altitudes on the way up into the atmosphere. They made several research expeditions in balloons, but the one they undertook on September 5, 1862 was the only one in which they almost died. They flew higher than anyone had ever flown and it almost cost them their lives.

Figure 33. Henry Tracey Coxwell and James Glaisher had a balloon flight on September 5, 1862
Source: https://scied.ucar.edu/learning-zone/atmosphere/history-discovery-atmosphere, Accessed: July 29, 2023.

Coxwell was gasping for air after climbing about 6 km into the atmosphere. They released the sand allowing the balloon to rise up to 8 km high. The temperature was well below freezing, and Glaisher was still measuring. Coxwell was still panting. They dropped more sand and climbed even higher.

At over 8.84 km in the atmosphere in the hot air balloon basket, Glaisher began to experience the catastrophic effects of cold and altitude. He lost the use of his hands. He couldn't move his legs. And he was aware of all this. ”I vaguely saw Mr. Coxwell and tried to speak but could not” [20], he recalled. Glaisher passed out in the balloon basket. Seeing that Glaisher had passed out, Coxwell knew he had to open the valve allowing the balloon to descend lower in the atmosphere, but his hands were black with frostbite and would not move. Coxwell tugged on the valve cable with his teeth. This made the balloon lower. Both survived, landing in a grassy field 12 km away from where they started. After he was safely on the ground and had regained movement in his arms and legs, Glaisher wondered what data he would have collected if he hadn't passed out at 8.84km. There are limits to our ability to send people in balloons to study the atmosphere. Coxwell and Glaisher learned this the hard way during their ill-fated balloon trip. But when Gustave Hermite (1863-1914) invented the first weather balloon in the 1890s, scientists had a new way to explore the atmosphere without risking lives. One of the first scientists to use weather balloons was Teisserenc de Bort (1855-1913). He sent balloons made of materials such as paper and silk high into the sky above Trappes, France, on the outskirts of Paris. His balloons were not closed. The gas inside them - hydrogen, helium, ammonia or methane - could escape during expansion as the balloon rose in the atmosphere and the air pressure fell. With less gas to lift it, the balloon would eventually fall slowly to the ground. Today's weather balloons send the data they collect back to the ground via radio waves, but the first weather balloons did not have this technology. Instead, de Bort had to watch where the balloon went and follow it until it returned to the ground. An instrument package attached to the balloon recorded all the data collected on the way up. Teisserenc de Bort sent instruments into balloons that recorded temperature and air pressure. He was puzzled when he looked at data from about 200 balloons and discovered that at a certain height in the atmosphere the temperature no longer drops. It remained approximately the same between 8 and 13 km high in the atmosphere. This was puzzling because at the time it was thought that temperature steadily decreased with increasing altitude. On April 28, 1902, Teisserenc de Bort announced to the French Academy of Sciences that he had discovered a layer of the atmosphere in which the temperature remains the same with height. He called that layer of the atmosphere the stratosphere. Richard Assmann (1845-1918), a scientist and physician, was investigating the atmosphere over Germany at the same time that Teisserenc de Bort was investigating the atmosphere over France. Both scientists used instrumented balloons to collect data on how temperature changed with altitude. Both discovered the stratosphere and shared their findings in 1902. Assmann was a member of the Society for the Promotion of Aeronautics. Most members were interested in blimps, balloons, and other means of air travel, but Assmann was interested in using these technologies to study the atmosphere. With the help of the group, Assmann invented rubber weather balloons, which were stronger and flew higher than the paper and cloth balloons of the time. They returned to the ground more easily than fabric and paper balloons. As the rubber balloons would rise in the atmosphere, they would expand as the air pressure decreases. At a certain altitude, the rubber could no longer stretch and the balloon would explode, hence the name Assmann's Expandable and Exploding Balloons. After the balloon exploded, the instruments were lowered to the ground with a small parachute. Richard Assmann flew instruments on his expandable and exploding balloons high in the atmosphere and discovered that the air not only stopped cooling at a certain altitude, but began to warm from 10 to 15 km in the atmosphere. Assmann published his results on May 1, 1902, not knowing that de Bort had presented the same finding at the French Academy of Sciences a few days earlier. Both scientists are responsible for the discovery of the stratosphere.

Cosmic speeds. Exactly ten years after the author's publication of the universal typology of architecture [2], humanity experienced the first stay in space in a private arrangement, the flights of businessman Richard Branson (July 12, 2021), (Figure 34) and Jeff Bezos (July 20, 2021). Richard Branson became the first person to fly into space on a rocket he financed. The supersonic space plane, developed by his company Virgin Galactic, took off early Sunday (July 12, 2021) into the skies over New Mexico, carrying Branson and three crew members. Branson—along with Virgin Galactic employees Beth Moses, Colin Bennett and Sirisha Bandla, and pilots Dave Mackay and Michael Masucci—boarded SpaceShipTwo, the winged, single-rocket engine the company has been developing for nearly two decades. Attached beneath a massive twin-hulled mother ship, named WhiteKnightTwo, the vehicle took to the skies at 8:30 a.m. MT and climbed about 15 km into the air.

Figure 34. V.S.S. Left: Unity with Richard Branson on a flight to the edge of space (July 12, 2021). Right: Photo provided by Blue Origin: Blue Origin's New Shepard rocket (July 20, 2021).
Source: https://www.nytimes.com/live/2021/07/11/science/virgin-galactic-launch-richard-branson, Accessed: July 29, 2023.

The rocket includes passengers Jeff Bezos, the founder of Amazon and the space tourism company Blue Origin, his brother Mark Bezos, Oliver Daemen and Wally Funk. Jeff Bezos, then the richest man in the world, aboard his company Blue Origin's New Shepard, made (July 20, 2021) a suborbital flight as part of a history-making crew—another milestone in the new era of private space travel. The American billionaire and founder of Amazon took off from the West Texas desert site for a trip nine days after

British rival Richard Branson took off on the successful maiden suborbital flight of his rival Virgin Galactic from New Mexico. Speed of the aircraft V.S.S. The Unity with which Richard Branson flew to the edge of the Universe was 4800 km/h (1.33 km/s). For everyday life on Earth, where the highest achieved speed of a Formula 1 car of 372.5 km/h seems fantastic, the speed of Branson's clover (4800 km/h) is almost 13 times higher. Today, the highest speed of passenger planes is achieved by the Boeing 747-8i, about 660 km/h. The highest speed ever achieved by a manned aircraft other than a spacecraft is 7,274 km/h (Mach 6.7) achieved by William John "Pete" Knight (1929-2004), U.S. Air Force, in experimental aviation X-15A-2, on October 03, 1967, in the Mojave Desert, California, USA. Given that this book will be about airplanes (as forms of Air Architecture), we took the previous comparison of the speeds of the aircraft as a logical question: why the aircraft V.S.S. Richard Branson's Unity 'only' reached the edge of the Universe, and why did the X-15A-2 with William John Knight not 'take off' into Space? In order to complete the idea of spacecraft, the Earth with its atmosphere, and the Author's universal typology of architecture, we will briefly refer to the extremely important concept of 'cosmic speed'. In physics (specifically, celestial mechanics), the escape velocity is the minimum velocity required for a free object without propulsion to escape from the gravitational influence of a massive body, thus reaching an infinite distance from it. The escape velocity increases with the mass of the body (the body to escape) and decreases with the distance of the escaping object from the center. The escape velocity therefore depends on how far the object has already traveled, and its calculation at a given distance takes into account the fact that without further acceleration it will slow down during the journey - due to the gravity of the massive body - but will never quite slow to a stop. Cosmic speed is the speed that a body (a natural or artificial satellite, for example) needs to achieve in order to continue moving in a circular path around a celestial body (first cosmic speed), release its gravitational fields and start moving away on a parabolic path (second cosmic speed), that is, released from the gravitational influence of the Sun (third cosmic speed). The centrifugal force of the body that reached the first cosmic speed is equal to the attractive force of the planet. If for some reason, for example, due to a collision with dust particles or gases from the atmosphere, there is no gradual decrease in speed, the body moves forever along the original circular path. The first cosmic speed depends on the gravitational constant of the celestial body (k), its mass (M) and the radius of the circular path (r):

$$v_1 = \sqrt{\frac{k \cdot M}{r}}$$

Although due to the resistance of the atmosphere, satellite paths around the Earth at altitudes of less than 200 km are not possible, the first cosmic speed on the surface of the Earth is theoretically 7.91 km/s, on the surface of the Moon 1.68 km/s, on Mars 3.56 km/s.

The second cosmic speed is also called the release speed, and is vII = vI x , which is 11.15 km/s on the Earth's surface. At this speed, for example, spacecraft (interplanetary probes) must be launched on their way from the Earth to the Moon and the planets of the Solar System. The third cosmic speed for a spacecraft launched from Earth is 16.7 km/s, while the fourth cosmic speed is sometimes called the speed required to leave the Milky Way (about 100 km/s). For this reason, for example, the interstellar spacecraft Voyager I, which, passing by Neptune in 1989, left the solar system at a speed of approximately 30 km/s, will most likely never be able to leave our galaxy. As understanding the importance of the speed of movement of spacecraft in the conditions of the Earth's atmosphere is of fundamental importance for understanding their conceptualization, design and materialization (as a concrete Architecturally Defined Space), a review of cosmic speeds contributes to this understanding and also provides a basis for understanding architecture in Space Architecture - type S of the universal typology of architecture) and architecture on other celestial bodies (Space Body Architecture – type SB of the universal typology of architecture) [21].

International legislation related to the atmosphere. The Earth's atmosphere is a dynamic, ever-changing system that is now recognized as vulnerable to various human-caused damages. Chief among them are ozone depletion and climate change, both of which threaten global-scale effects from damage to the atmosphere itself. At the same time, the atmosphere can also be a means of transmitting other types of damage. Chemical, radiological and biological agents released into the atmosphere accidentally or as waste products of industrial or other processes can be spread by wind and weather over long distances, causing damage to areas far from their origin. These factors (among others) mean that the urgency of regulating the use (and abuse) of the Earth's atmosphere by states is by now clear to everyone. Nevertheless, the regulation of this unique and dynamic space poses numerous challenges to the international order as it developed [22]. International law has long struggled with the problems of shared spaces and shared resources. Questions concerning the right of access, exploitation and sustainability of the resources of common world spaces have long occupied the law of maritime lawyers, and in the past decades the difficulties in regulating the global atmosphere have increasingly burdened international lawyers for the environment. Perhaps the most successful regime of international environmental protection law The Vienna Convention for the Protection of the Ozone Layer [23] and the Montreal Protocol [24] belongs to this common space, as well as what might be (at least to date) the least successful: the climate regime which includes the United Nations Framework Convention on Climate Change [25], the Kyoto Protocol [26] and the Paris Agreement. One of the main challenges affecting the success or failure of regimes dealing with shared spaces is their difficult fit into traditional understandings of state sovereignty. In stark contrast to the archetypal case of regulating issues that are entirely within the competence of states, the principle of sovereignty is pulled in different directions in response to questions concerning the division of rights and obligations among states, while at the same time affirming the rights of states to access resources of common law, the rights of states to preservation of the common good and the impossibility of any jurisdiction regulating the use of the state without their consent. The overlapping sovereign/common spaces encompassing the atmosphere at the Earth's surface, with the atmosphere at once referring to the territory of the state and common to all, results in a very complex regulatory landscape.

3. Man

„On the life scale of each person, the image of the 'objective world' changes, and he himself changes, his 'software and hardware' with which he perceives objective reality and forms his judgments about it. It is the result of the natural default of the world“. This is a quote from the author's book „Man, something or nothing“ (2019) [27], which has a philosophical content, but is suitable as a pretext for this chapter of the book, whose content is of an empirical-scientific nature.

Comfort assurance requirements. When it comes to humans, it is very important to know that there is an exact and measurable range of external influences (elements of the natural environment) that humans experience as physiologically pleasant. Outside of that (optimal) range, a person feels more or less discomfort, which sometimes rises to, for him, a deadly level. At the global level, the issue of human thermal comfort is regulated by appropriate standards.

The following standards are the most relevant:

- ISO 7730:1994 Moderate Thermal environments - Determination of the Predicted Mean Vote (PMV) and Predicted Percentage Dissatisfied (PPD) indices and specification of the conditions for thermal comfort. This standard has been revised: ISO 7730: 2005
- ASHRAE 55 (2007), including a calculation methodology based on the PMV/PPD ratio. CEN 15251(2005): Criteria for indoor conditions including thermal conditions, indoor air quality, lighting and noise.

The CEN standard defines minimum ventilation requirements, minimum and maximum indoor air temperatures that are included in the energy calculation. PMV (Predicted Mean Vote) index - evaluates the level of (dis)pleasure → predicts the subjective evaluation of the pleasantness of living in the environment by a group of people (determined from complex mathematical expressions according to ISO 7730) PPD (Predicted Percentage of Dissatisfied) index → predicts the percentage of dissatisfied people (determination from a simple mathematical expression, a function of PMV). Knowledge of the 'defining areas of human physiological comfort' [28] is of elementary and essential importance for architecture. The basic task of architecture, in fact, is to ensure the physiological comfort of man within the limits that he himself designs and builds. Only after fulfilling this requirement, we can continue to search for the realization of other dimensions of architecture. This elementary dimension of architecture was more or less understood throughout its entire past, but it was often neglected, at the expense of some other architectural values. It could even be said that the biggest internal conflict in architecture has always been between its elementary purpose and the architects' desire to communicate that purpose in a beautiful way. It seems that the just-mentioned conflict was at the same time the greatest internal strength of architecture, which led it towards the realization of new values. Man paid the highest price for this internal antagonism in architecture through energy costs (heating and cooling), or, as we have already seen, by endangering the natural environment in the last instance. Architecture necessarily had to turn to the principles of bioclimatic organization, and that path in the 21st century became global. Definitional areas of human physiological comfort within the boundaries of the Architecturally Defined Space have been well researched, and as given values, they have been translated into national, regional and world standards81. The most important dimensions of the environment, the intensities of which determine human comfort, can be classified into three basic areas: The field of thermodynamics in architecture, The field of lighting in architecture, and The field of architectural acoustics.

In the scope of the field of thermodynamics in architecture, the most important quantities whose intensity determines the area of human comfort are: Temperature of the outside air (t_e), Temperature of the air inside the room (t_i), including the vertical gradient of the air temperature inside the room, Temperature of the internal surfaces of the external fence surfaces (υ_j), Relative humidity of the outside air (φ_e), Relative humidity of the air inside the room (φ_i), Air flow speed (c_z), CO_2 concentration and Odor concentration [28].

In the area of lighting in architecture, the most important quantities whose intensity (quality) determines the area of human comfort are: Spectral composition of light. Light color climate, Light color temperature (T, in K), Luminous flux (luminous flux, W/s), Luminous intensity (intensity, cd), Illumination (lx). Evenness of illumination, Brightness (luminescence, cd/m^2). Brightness distribution. Glare limitation, Phototechnical properties of materials and surfaces: reflection (ρ), absorption (α), transparency (τ), refraction (index of refraction, n) [28].

In the area of architectural acoustics, the most important quantities whose intensity (quality) determines the area of human comfort are: Intensity (W/m^2), power (W) and density of sound energy (Ws/m^3), Level of sound pressure, intensity and power of sound (Db), Types of sound impulse, Sound resonance, Sound interference, Directional characteristics of a sound source, Doppler effect, Phenomena that threaten sound propagation (reflection, diffraction, absorption, refraction), Reverberation. Flatter echoes in the room, Echo of the room. Reverberation time (s), Room volume (m^3). Specific acoustic volume of the room (m3/person), Noise [28]. The speed of sound is the distance traveled by a sound wave per unit time during propagation through an elastic medium. At 20 °C, the speed of sound in air is about 343 meters per second. It depends a lot on the temperature, as well as on the medium through which the sound wave propagates. In colloquial speech, the speed of sound refers to the speed of sound waves in air. However, the speed of sound varies from substance to substance: usually sound travels slowest in gases, faster in liquids and fastest in solids. For example, while sound travels at a speed of 343 m/s in air, it travels at a speed of 1481 m/s in water (almost 4.3 times faster) and 5120 m/s in iron (almost 15 times faster). In an extremely rigid material, such as diamond, sound travels at 12,000 meters per second - about 35 times the speed of air and about the fastest it can travel under normal conditions. Considering the natural environment in which Air Architecture is established, air with all its performance is provided by the air conditioning system. The same conditioned air is used to pressurize the cabin of the aircraft.

Aesthetic and psychological requirements. In the Environment chapter, there was talk about the appearance of Air Architecture structures that float or fly in the air, without any supports on the ground. Hence, given the common perception and understanding of architecture as structures that 'have foundations' (whether they are exposed to pressure, which is also common, or 'uprooted') the physical structures of Air Architecture have no foundations, therefore, they are not fixed - they are mobile. Hence, this type of architecture is generally understood as 'air transportation means'. However, according to its conceptualization, horizontal and vertical plan, construction and materialization, provision of cryptoclimate (climate of closed spaces), these structures have all the performances that determine the Architecturally Defined Space (ADS) in the usual natural environments on Earth, on the ground, mostly. Balloons are structures that were created and used for a long time as a reason for adventures. Later, by getting to know the specific environment high above the Earth's surface, balloons began to be used in scientific expeditions to study the Earth's atmosphere, to monitor certain elements (and factors) that determine the climate of a narrower or wider area on Earth, and the planet Earth as a whole. Today, flexible balloons are especially used in the tourist offer, as one of the cheapest and most efficient ways of seeing the landscape from a 'bird's eye' perspective.

Zeppelins (flexible structures with a rigid structure) were in the beginning exclusive means of transport (even on intercontinental routes), highly equipped and luxurious, whose decoration was equal to luxury hotels. Later they were also used for military purposes. These apparently brilliant structures had a serious 'weak point' - the non-resistance of their envelope to fire. This weakness (after several serious breakdowns) put them out of use. Rigid (flying) Air Architecture - structures (various types of airplanes and helicopters) have an extremely wide range of uses: passenger transportation (in short, also on intercontinental routes), transportation of various goods (including extremely bulky and heavy loads, such as tanks or transporters on example), atmospheric monitoring, observation and recording of all parts of the Earth's surface, various military functions, medical expeditions, firefighting, rescuing people and property due to natural disasters... A special type of rigid flying structures (drones), in addition to a wide range of utilitarian functions, they are also used to record the surface of the Earth, and these recordings (video and photos) have a special aesthetic dimension. The latest flights of individuals to the edge of the Universe, under private direction, confirm people's immanent need for adventure. In this case, it is about confirming the property status of these people (mostly they are among the richest individuals in the world) and the possibility of organizing a special aesthetic-psychological event that broadens such people's horizons and prepares them for new endeavors. People's need to see the natural environment, quickly, safely and from an aerial view, generated many technical solutions of aircraft (Figures 35,36,37).

Figure 35. Various solutions of small aircraft

Figure 36. Various solutions (and functions) of drones

Figure 37. Photos taken using a drone (drone camera)

The primordial desire of man to fly in the air, which was recorded in the myth of Daedalus and Icarus and the stories about the flying carpet from One Thousand and One Nights, as well as in some other Eastern myths, became a reality [29,30]. In April 1934, a number of American newspapers printed a photograph distributed by the International News Photo agency showing a man flying through the air using his lung power. That man was identified as German pilot Erich Kocher (Figure 38).

Figure 38. German pilot Erich Kocher flies using a simple device whose rotor drives the pilot Kocher's breath ('lung engine'), 1934. The event, as a sensation, was reported by The New York Times (April 13, 1934)
Source: http://hoaxes.org/af_database/permalink/man_flies_by_own_lung_power, Accessed: July 29, 2023.

Figure 39. In 2006, Swiss pilot Yves Rossy became the first and only man in the history of aviation to fly a jet-powered wing. This jetpack led to Yves being nicknamed Airman, Jetman, Rocketman and Fusionman according to the steps of his project
Source: https://www.news18.com/photogallery/tech/its-a-bird-its-a-plane-its-a-flying-man-835831.html, Accessed: July 29, 2023.

Captions accompanying the photo explain that Kocher wore a chest-mounted device consisting of a box and two horizontal rotors. By blowing into the box he could make the rotors turn. This created enough suction in front of him to propel him through the air. He also wore skis on his legs as landing gear, and fins on his back for steering. Today, there are a large number of various technical solutions that allow a person to fly in a perfectly controlled manner (Figures 39, 40, 41).

Figure 40. Left: French inventor Franky Zapata flew over the English Channel with a jet-powered hoverboard on Sunday, August 4, 2019. Right: A man with a jet pack 915 meters above Los Angeles, 2020.

Source: https://www.cnet.com/culture/french-green-goblin-crosses-english-channel-on-hoverboard/, Accessed: July 29, 2023.

Figure 41. Left: David Mayman, CEO of Jetpack Aviation, demonstrates (September 2, 2020) his jetpack in Sydney. Center and right: The mysterious jet guy is actually a human-shaped drone that flies up to a height of several kilometers, Los Angeles, 2021. After test flights (now controlled from the ground), the soldier's silhouette will soon be a living human.

Source:https://www.smh.com.au/traveller/travel-news/jetpack-sighting-near-los-angeles-airport-airline-pilots-report-man-flying-20200902-h1qfqm.html, Accessed: July 29, 2023.

4. Boundaries: architecture as a framework of life

In accordance with the already mentioned earlier concept of architecture as an Architecturally Defined Space (ADS), Boundaries (3) are the one (of the four basic) element of ADS that, with its concept and materialization, reflects the result of harmonizing the requirements of Man (2), on the one hand, and the conditions of the concrete Environment (1), on the other hand [1] (Figure 1). As man is a very complex being, and as the possible combinations of conditions of the concrete environment are practically unlimited, the possible physical appearance of the boundaries of ADS is also unlimited. The boundary that demarcates the complex system of needs in the environment is also built by other living beings, sometimes with such skill that not even humans can achieve (termite mounds, bee combs, bird's nests, cobwebs...). However, despite their perfection, we do not consider such borders to be architecture, since architecture is the exclusive creation of man. According to the presented definition of borders, one could carelessly conclude that borders are created 'automatically' by matching the demands of man and the input of the environment. Some examples of vernacular (traditional) architecture around the planet Earth almost confirm this. However, since architecture is created by humans, and each one is different from the other in a population of several billions, the 'solutions to the same architectural task' obtained by any number of architects will be different. Moreover, the same architect, at different times, will give different answers to the same architectural task. The just-mentioned complexity and controversy characteristic of architecture are those specificities that distinguish architecture from the world of other sciences, arts and philosophy and make it a total human creation [31]. Type EA (Earth-Atmosphere) includes those ADS solutions that are realized in the atmosphere (Earth), in such a way that all its boundaries are in contact with the air. If we follow some living organisms for which the atmosphere is the basic living environment (birds and insects, for example), we must note their anatomical-physiological predispositions that enable them to fly and float in the air, that is, the ability to overcome the Earth's gravity. Since man, as the most perfect living being, has the desire to master these abilities as well (for which he is not predestined due to his anatomical and physiological predispositions), he learned the physical laws of flying and hovering, and devised technical solutions that provide him with these possibilities as well. These solutions are to a certain extent the inverse of ADS solutions realized in a complete water environment, but they also have their own specifics. Being man-made solutions, they are always tied to the Earth's soil, that is, their establishment in the atmosphere is limited to a certain period of time. For now, we recognize two basic ways of establishing ADS in the atmosphere [31]:

1. Flexible structures (or structures in a combination of rigid and flexible elements) that are maintained in the air by the balance of buoyancy force and Earth's gravity; the buoyant force is initiated by a light, hot gas (hydrogen, helium or air) in a voluminous, flexible balloon; in the rigid part of the structure is the utilitarian part of the ADS (Figures 42,43).
2. Rigid, heavy, structures that are maintained in the air by more or less powerful engines, based on the principle of the balance of the drive force (generated by the engine) and the Earth's gravity (Figures 43, 44).

Figure 42. Flexible structure: balloon

Source: https://stock.adobe.com/search?k=hot+air+balloons+mountain, Accessed: July 29, 2023.

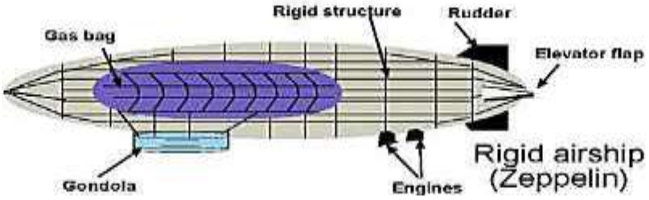


Figure 43. Flexible-rigid structure: Count Ferdinand von Zeppelin's balloon, 1899.

Source: https://www.thoughtco.com/ferdinand-von-zeppelin-1992701, Accessed: July 29, 2023.

Figure 44. Rigid structures: a helicopter hovering in the air (left) and an airplane in flight (right)

Source: https://science.howstuffworks.com/transport/flight/modern/helicopter9.htm, Accessed: July 29, 2023.
Source: https://www.rd.com/article/how-high-do-planes-fly/, Accessed: July 29, 2023.

Similar to man-made structures in water (underwater (EW) type of architecture), and in the case of structures that are maintained in the air (Air Architecture (EA) type of architecture) the principle of their organization is based on Archimedes' principle: any body immersed in a liquid (or gas) apparently loses its weight as much as the volume of displaced liquid (gas). And while in the case of underwater (EW) architecture, the basic practical problem is how to anchor a structure submerged in water (due to the large buoyancy force - the weight of the displaced liquid), in the case of Air Architecture (EA), the problem is how to make as large as possible the volume of the structure which, due to the thrust force (proportionality of the weight of the displaced air to the volume of the structure), would lift the structure into the air against the force generated by the Earth's gravity. Air Architecture's flexible structures (balloons and zeppelins) work exclusively on this principle. In addition, they can have systems (usually motors) that can move them horizontally, with additional parts of the physical structure to control the direction of movement. The rigid structures of Air Architecture (various types of airplanes and helicopters), although subject to Archimedes' principle (which is negligible in their case), take off, fly and land on the surface of the Earth under other principles.

Flexible structures. As stated in the Introduction of this paper, flexible structures (or structures in a combination of rigid and flexible elements) are those structures that are maintained in the air by the balance of buoyancy force and Earth's gravity; the buoyant force is initiated by a light, hot gas (hydrogen, helium or hot air) in a voluminous, flexible balloon; in the rigid part of the structure is the utilitarian part of the ADP.

Hot gas balloon. A hot air balloon is a lighter-than-air aircraft that consists of a bag, called an envelope, that contains heated air (Figures 45, 46). Below is a suspended gondola or wicker basket (in some long-distance or high-altitude balloons, a capsule) that carries passengers and a heat source, in most cases an open flame caused by burning liquid propane. The heated air inside the envelope makes it buoyant because it has a lower density than the cooler air outside the envelope. Like all aircraft, hot air balloons cannot fly outside the atmosphere. The envelope does not need to be sealed at the bottom, since the air inside the envelope has approximately the same pressure as the surrounding air. In modern sports balloons, the envelope is generally made of nylon fabric, and the balloon inlet (closest to the burner flame) is made of a flame-resistant material, such as Nomex. Modern balloons are made in many shapes, such as rocket ships and the shapes of various commercial products, although the traditional shape is used for most non-commercial and many commercial applications [32].

Figure 45. Hot air balloon

Source: https://www.daysoftheyear.com/days/hot-air-balloon-day/, Accessed: July 29, 2023.

Figure 46. Tourists view Cappadocia (Turkey) from a hot gas balloon

Source: https://www.hurriyetdailynews.com/balloon-ride-consortium-under-scrutiny-in-cappadocia-144035, Accessed: July 29, 2023.

The hot air balloon is the first successful human-carrying flight technology. The first manned balloon flight was made by Jean-François Pilâtre de Rozier (1754-1785) and François Laurent d'Arlandes (1742-1809) on November 21, 1783 in Paris, in a balloon created by the Montgolfier brothers (Joseph-Michel Montgolfier (1740-1810) and Jacques-Étienne Montgolfier (1745-1799), (Figure 47). The first hot air balloon to fly in America was launched from the Walnut Street Jail in Philadelphia on January 9, 1793 by French aviator Jean Pierre Blanchard (1753-1809). Hot-air balloons that can be powered by air, rather than simply flying with the wind, are known as thermal airships. The forerunner of the hot-air balloon was the sky lantern. Zhuge Liang (181-234) of the kingdom Shu Han, during the Three Kingdoms era (220-280), used these aerial lamps for military signaling.In the 18th century, the Portuguese-Brazilian Jesuit priest Bartolomeu de Gusmão (1685-1724) conceived an aerial apparatus called the Passarola, which was the predecessor The purpose of the Passarola was to serve as an airship to facilitate communication and as a strategic device. In 1709, the House of João V (known as Magnanimous/Generous, 1689-1750) decided to finance Bartolomeu de Gusmão's project after a Jesuit priest's petition, and unmanned demonstrations were performed at the Casa da India in the presence of João V, Queen Marie Anne of Austria (Maria Anna Josepha Antonia, 1738-1789), Italian Cardinal Michelangelo Conti, two members of the Portuguese Royal Historical Academy, one Portuguese diplomat and one chronicler. This event attracted the attention of Europe. A later article dated October 20, 1786, published in the London Daily Universal Register, stated that the inventor was able to soar aloft with his prototype. Also in 1709, a Portuguese Jesuit wrote Manifesto summário para os que ignoram poderse navegar pelo elemento do ar (A short manifesto for those who are not aware that it is possible to sail through the element of air); he also left blueprints for a manned airship. The famous balloonist Julian Nott (1944-2019) in the 1970s; hypothesized that the formation of the Nazca Lines geoglyphs two millennia ago may have been guided by Nazca leaders in a balloon, possibly the earliest hot air flights in human history. In 1975, to support this theory, he designed and piloted the prehistoric Nazca balloon, using only the methods and materials available to the pre-Inca Peruvians, 1,000 years ago. French brothers Joseph-Michel and Jacques-Étienne Montgolfier developed a hot-air balloon in Annonay, Ardeche, France, and demonstrated it publicly on September 19, 1783, making an unmanned flight lasting 10 minutes. After experiments with unmanned balloons and flights with animals, the first balloon flight with humans on board, a tethered flight, was performed on October 15, 1783, by Jean-Francois Pilatre de Rozier (1754-1785), who performed at least one bound flight from the courtyard of the Reveillon workshops in Faubourg Saint-Antoine. Later that day, Pilatre de Rozier became the second man to ascend into the air, reaching an altitude of 26 m, the length of a tether. The first free flight with passengers was made a few weeks later, on November 21, 1783. King Louis XVI (Louis-Auguste, 1754-1793) originally decreed that convicted criminals would be the first pilots. The first military use of hot air balloons occurred in 1794 during the Battle of Fleurus, when the French used the l'Entreprenant balloon for observation.

Figure 47. Jean-François Pilâtre de Rozier and François Laurent, Marquis d'Arlandes, ascend in a Montgolfier balloon at Château de la Muette, Paris, on November 21, 1783.
Source: https://www.britannica.com/biography/Montgolfier-brothers, Accessed: July 29, 2023.

Jean-Pierre Blanchard became the first person to fly in a hot air balloon in various countries, including the USA, the Netherlands and Germany. His most significant flight crossed the English Channel in the direction of Dover Castle accompanied by Dr. John Jeffries, which happened on January 7, 1785 [33]. In 1808, Blanchard fell from a balloon over The Hague and died. His wife continued his interest, but she also died a decade later in a balloon, at a fireworks festival that ignited the hydrogen in the balloon (Figure 48).

Figure 48. Jean-Pierre Blanchard: hot air balloon flight across the English Channel
Source: http://www.ltaflightmagazine.com/the-first-aerial-crossing-of-the-english-channel/, Accessed: July 29, 2023.

Modern hot air balloons with a built-in heat source were developed by American innovator Ed Yost (1919-2007), beginning in the 1950s; his work resulted in the first successful flight on October 22, 1960 [34] (Figure 49). The first modern hot air balloon built in the United Kingdom (UK) was the Bristol Belle, built in 1967. Currently, hot air balloons are used primarily for recreation.

Figure 49. Pilot Ed Yost on board "Raven 1"
Source: https://www.sdpb.org/blogs/images-of-the-past/sioux-falls-and-the-birth-of-the-modern-hot-air-balloon/, Accessed: July 29, 2023.

Hot air balloons can fly to extremely high altitudes. On November 26, 2005, Vijaypat Singhania (1938-) set the world altitude record for the highest hot air balloon flight, reaching 21027 m [35] (Figure 50). It took off from downtown Mumbai, India and landed 240 km south in Panchal. The previous record of 19,811 m was set by Per Lindstrand (1948-) on June 6, 1988 in Plano, Texas.

Figure 50. Hot air balloon flight by Indian Vijaypat Singhani
Source: https://www.rediff.com/money/2008/apr/05vij4.htm, Accessed: July 29, 2023.

On January 15, 1991, the Virgin Pacific Flyer balloon completed the longest flight in a hot air balloon, when Per Lindstrand (born in Sweden, but settled in Great Britain) and Richard Branson from Great Britain flew 7671.91 km from Japan to northern Canada [36] (Fig. 3.10). With a volume of 74,000 cubic meters, the balloon envelope was the largest ever built for a hot air craft. Designed to fly in transoceanic jets, the Pacific Flyer recorded the highest ground speed for a manned balloon at 394 km/h. The record with the longest duration was set by Swiss psychiatrist Bertrand Piccard (grandson of Auguste Piccard) and Briton Brian Jones, flying in Breitling Orbiter 3 (Figure 51). It was the first trip around the world in a balloon [37].

Figure 51. Richard Branson and Per Lindstrand: with Virgin Pacific Flyer they had (January 15, 1991) the longest flight in a hot air balloon
Source: https://balloon.hu/new/2017/01/15/the-virgin-pacific-flyer-started-in-1991-to-the-pacific-crossing/, Accessed: July 29, 2023.

The balloon left Château-d'Oex, Switzerland on March 1, 1999, and landed at 1:02 a.m. on March 21 in the Egyptian desert 500 km south of Cairo. Two men traveled a record distance, demonstrating endurance, traveling for 19 days, 21 hours and 55 minutes. Steve Fossett (1944-2007), flying solo, broke the record for the shortest round-the-world flight on July 3, 2002, on his sixth attempt, in 320 hours and 33 minutes. Fedor Konyukhov (1951-) circumnavigated the world independently in his first attempt in a hybrid hot air/helium balloon from July 11 to 23, 2016 for a time of 268 h 20 min [38] (Figure 52).

Figure 52. Left: Bertrand Piccard and Brian Jones, flying the Breitling Orbiter for the 3rd longest flight (01-21 March 1999). Right: Russian adventurer Fedor Konyukhov stands in front of his balloon as it is inflated in Northam, Australia
Source: https://luxurylondon.co.uk/culture/entertainment/bertrand-piccard-environmentalist-interview/, Accessed: July 29, 2023.

A manned hot air balloon uses a single-layer fabric gas bag (the lifting 'envelope'), with an opening at the bottom called the mouth or throat (Figure 53). On the envelope is a basket or gondola for transporting passengers. Mounted above the basket and centered in the mouth is a 'burner', which injects a flame into the envelope, heating the air in it. The heater or burner is powered by propane, a liquefied gas stored in pressure vessels, similar to the cylinders of high-pressure forklifts. The envelope - the balloon part of the flying machine, is designed to contain the hot air coming from the burner and lift the whole machine into the air. It is made of ripstop nylon or dacron. The panels are sewn together and have structural load straps sewn into them to carry the weight of the gondola or basket. The envelope has a crown ring on top - an aluminum ring that holds a hole in the top that is used to release hot air from the balloon when the pilot wants to reduce altitude. The gores and the envelope are sewn by hand or with an industrial sewing machine, and three types of stitches are used for this: double-fold seam - two rows of parallel stitches; straight seam - straight parallel sewing; and zigzag parallel stitching with a double fold of fabric. After the entire envelope is sewn, it is coated with a sealant under pressure so that it does not leak air. Printing is done after coating if there is a need for it [39].

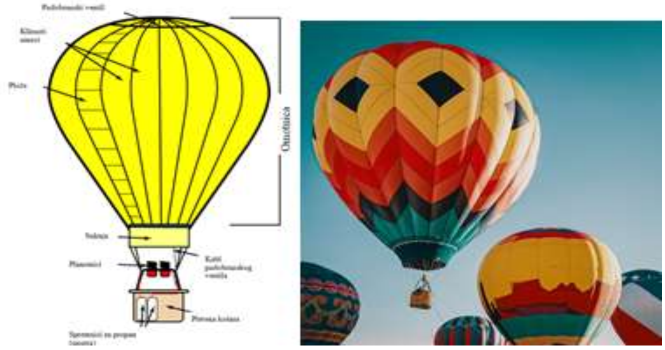


Figure 53. Structure of a hot air (gas) balloon
Source:
https://www.chm.bris.ac.uk/webprojects2003/hetherington/final/Hot_air_balloon_parts.html, Accessed: July 29, 2023.

The hot air balloon is partially inflated with cool air from a gasoline powered fan, before propane burners are used for final inflation. During the manufacturing process, the material is cut into panels and sewn together with structural load straps that carry the weight of the gondola or basket. The individual parts, which extend from the throat to the crown (top) of the envelope, are known as the upper parts. Envelopes can have as few as 4 steps or as many as 24 or more. Envelopes often have a crown ring on top. This is a ring of smooth metal, usually aluminum, approximately 30 cm in diameter. Vertical load bands from the envelope are attached to the crown ring. At the bottom of the envelope, vertical loading strips are sewn into loops that are connected to cables (one cable per loading strip). These cables, often called fly wires, are connected to the basket by carabiners. The most common technique for sewing panels together is called a French drop or double stitch. Two pieces of fabric are folded over each other at their common edge, possibly with a loading strap, and sewn together with two rows of parallel seams. Other methods include the straight lap stitch, in which two pieces of fabric are held together simply by two rows of parallel stitches, and the zigzag, where a parallel zigzag stitch holds a double fold of fabric together. The fabric (or at least part of it, the top 1/3, for example) can be coated with a sealant, such as silicone or polyurethane, to make it airtight. Degradation of this coating and corresponding loss of impermeability often ends the effective life of the envelope rather than weakening the fabric itself. Heat, moisture and mechanical wear and tear during installation and packaging are the primary causes of degradation. When the envelope becomes too porous for flight, it can be pulled back and discarded, or perhaps used as a 'rag bag' - inflated cold and open for children to walk through. Fabric reupholstering products are becoming available on the market. A range of envelope sizes are available. The smallest balloons without a basket for one person (called ”Hoppers” or ”Cloudhoppers”) have only 600 m^3 envelope volume; for a perfect sphere, the radius would be about 5 m. On the other side of the scale, balloons used in commercial tours could carry more than twenty people, with an envelope of up to 17,000 m^3. The most frequently used size is around 2800 m^3, which enables the transport of 3 to 5 people. The top of the balloon usually has some sort of vent that allows the pilot to release hot air to slow the climb, start the descent, or increase the rate of descent, usually for landing. Some hot air balloons have swivels, side vents that, when opened, cause the balloon to rotate. Such openings are particularly useful for balloons with rectangular baskets, to facilitate alignment of the wider side of the landing basket. The most common type of upper air vent is a disc-shaped flap called a chute, invented by Tracy Barnes. The fabric is joined around the edge with a series of 'vent lines' that meet in the middle. These 'vent lines' are themselves connected to the control line leading to the basket. The parachute hatch is opened by pulling the control line. When the control line is released, the pressure of the remaining hot air pushes the vent fabric into place. The parachute hatch can be opened briefly in flight to initiate a rapid descent. (The slower descent begins by allowing the air in the balloon to cool naturally). The hatch opens fully to collapse the balloon after landing.

Baskets are usually made of wicker or rattan. These materials have proven to be light, strong and durable enough for balloon flight. Such baskets are usually rectangular or triangular in shape. They vary in size from large enough for two people to large enough to carry thirty. Larger baskets often have internal partitions for structural support and passenger separation. Small holes can be woven into the sides of the basket to serve as footrests for passengers climbing in or out. Baskets can be made of aluminum, especially a collapsible aluminum frame with a fabric skin, to reduce weight or increase portability. They can be used by unmanned pilots on the ground or attempting to set altitude, duration or distance records. Other special baskets include fully enclosed nacelles used for attempts around the world and baskets consisting of little more than a seat for the pilot and perhaps one passenger.

Burner. The burner unit gasifies the liquid propane, mixes it with air, ignites the mixture, and directs the flame and exhaust gases into the mouth of the envelope. Burners differ in output power; each will generally produce 2 to 3 MW of heat, with twin, triple or quad burner configurations installed where more power is required. The pilot activates the burner by opening the propane valve, known as the jet valve. The valve may be spring-loaded so that it closes automatically, or it may remain open until the pilot closes it. The burner has a control light for igniting the propane/air mixture. The control light can be ignited by the pilot with an external device, a flint or lighter, or with a built-in piezoelectric spark. If multiple burners are present, the pilot can use one or more at once, depending on the desired heat output. Each burner has a metal propane coil that passes through the flame to preheat the incoming liquid propane. The burner unit can be hung by the mouth of the envelope or firmly supported over the basket. The burner unit can be mounted on a gimbal to allow the pilot to direct the flame and avoid overheating the jacket material. The burner may have a secondary propane valve that releases propane more slowly and thus creates a different sound. This is called a whisper burner and is used to fly over livestock to reduce the chance of spooking them. It also produces more of a yellow flame and is used for night rides because it lights up the inside of the envelope better than the primary valve.

Propane fuel tanks are usually cylindrical pressure vessels made of aluminum, stainless steel, or titanium with a valve at one end to feed the burner and fill with fuel. They can have a fuel gauge and a pressure gauge. Common tank sizes are 38, 57 and 76 liters. They can be intended for vertical or horizontal use and can be mounted inside or outside the basket. The pressure required to push the fuel through the pipeline to the burner can be achieved by vapor pressure of the propane itself, if it is warm enough, or by introducing an inert gas, such as nitrogen. The tanks can be preheated with electric heat strips to produce sufficient vapor pressure for cold weather flying. Heated tanks are usually wrapped in an insulating blanket to preserve heat during deployment and flight.

The balloon can be equipped with various instruments that help the pilot. These typically include an altimeter, a rate of climb (vertical speed) indicator known as a variometer, envelope (air) temperature, and ambient (air) temperature. A GPS receiver can be useful for indicating ground speed (traditional airspeed indicators on aircraft would be useless) and heading.

An increase in the temperature of the air inside the envelope makes it less dense than the surrounding (ambient) air. A balloon floats because of the buoyant force acting on it. This force is the same force that acts on objects when they are in water and is described by Archimedes' principle. The amount of lift (or buoyancy) provided by a hot air balloon depends primarily on the difference between the temperature of the air inside the envelope and the temperature of the air outside the envelope. For most envelopes made of nylon fabric, the maximum internal temperature is limited to approximately 120 °C. The melting point of nylon is significantly higher than this maximum working temperature (about 230 °C), but higher temperatures cause the strength of the nylon fabric to degrade faster over time. With a maximum operating temperature of 120 °C, balloon wraps can generally be used for between 400 and 500 hours before the fabric needs to be replaced. Many balloon pilots operate their envelopes at temperatures well below the maximum to extend the life of the envelope material.

The density of air at 20 °C is about 1.2 kg/m^3. The total lift for a 2800 m^3 balloon heated to 99 °C would be 723.5 kg. This is sufficient to create neutral buoyancy for the total mass of the system. A slightly higher temperature would be required for ascent, depending on the desired ascent speed. In reality, the air inside the envelope is not at the same temperature, as shown in the accompanying thermal image, so these calculations are based on averages. For typical atmospheric conditions (20 °C), a hot air balloon heated to 99 °C needs about 3.91 m^3 of envelope volume to lift 1 kilogram. The exact amount of lift depends not only on the internal temperature mentioned above, but also on the external temperature, altitude and humidity of the surrounding air. On a warm day, the balloon cannot rise as much as on a cold day, because the temperature required for launch will exceed the maximum sustainable nylon fabric. Also, in the lower atmosphere, the lift provided by a hot air balloon decreases by about 3% per 1000 m of altitude gained.

Standard hot air balloons are known as Montgolfier balloons and rely solely on the buoyancy of hot air provided by the burner and contained within the envelope. This style of balloon was developed by the Montgolfier brothers, and had its first public demonstration on June 4, 1783 with an unmanned flight lasting 10 minutes, followed by manned flights later that year.

Zeppelin. A Zeppelin is a type of rigid airship named after the German inventor Count Ferdinand von Zeppelin (German: Ferdinand Adolf Heinrich August Graf von Zeppelin, 1838-1917) who pioneered the development of rigid airships in the early 20th century (Figures 54-70). Zeppelin's terms were first formulated in 1874 and developed in detail in 1893. They were patented in Germany in 1895 and in the USA in 1899. After the extraordinary success of the Zeppelin design, the word zeppelin began to be commonly used to denote all rigid airships. Zeppelins were first flown commercially in 1910 by Deutsche Luftschiffahrts-AG (DELAG), the world's first revenue airline. By the middle of 1914, DELAG had transported over 10,000 passengers paying tickets on more than 1,500 flights. During the First World War, the German army used Zeppelins extensively as bombers and scouts.

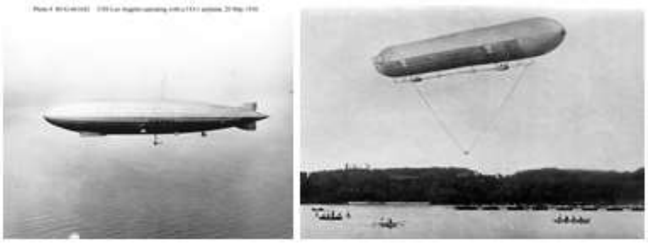


Figure 54. Left: USS Los Angeles, a United States Navy airship built in Germany by the Luftschiffbau Zeppelin (Zeppelin Airship Company). Right: First flight of LZ 1 over Lake Constance (Bodensee) in 1900

Source: welweb.org/ThenandNow/images/g461642.jpg, Accessed: July 29, 2023.

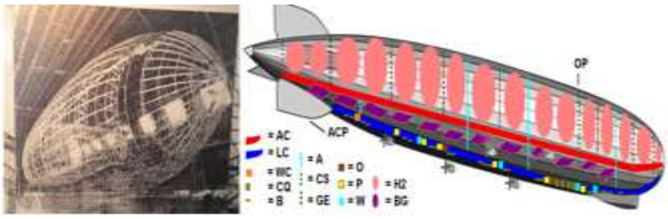


Figure 55. Left: Construction of the Zeppelin. Right: Pink ovals show hydrogen cells inside LZ 127, magenta elements are Blaugas cells.

Source: https://www.cnet.com/pictures/when-zeppelins-ruled-the-skies-photos/, Accessed: July 29, 2023.

Figure 56. Left: Wreckage of LZ 4. Right: Wreckage of Zeppelin L31 shot down over England on September 23, 1916.

Source: thisdayinaviation.com/tag/lz-4/, Accessed: July 29, 2023.

Figure 57. Left: Hindenburg in flames in 1937. Right: Count Zeppelin under construction

Source:https://www.militarytimes.com/news/your-military/2017/05/05/the-airship-hindenburg-bursts-into-flames-original-1937-ap-story/

Accessed: July 29, 2023.

Source:

https://www.sciencephoto.com/media/515943/view/airship-construction, Accessed: July 29, 2023.

The defeat of Germany in 1918 temporarily slowed down the airship business. Although DELAG established a regular daily service between Berlin, Munich and Friedrichshafen in 1919, the airships built for this service eventually had to be surrendered under the terms of the Treaty of Versailles, which also prohibited Germany from building large airships. An exception was made to allow one airship to be built for the United States Navy, saving the company from extinction. In 1926, restrictions on the construction of airships were lifted, and with the help of donations from the public, work began on the construction of the LZ 127 Graf Zeppelin. This revived the company's fortunes, and during the 1930s the airships Graf Zeppelin and the larger LZ 129 Hindenburg operated regular transatlantic flights from Germany to North America and Brazil. The Art Deco column of the Empire State Building was originally designed to serve as a mast for mooring Zeppelins and other airships, although high winds were found to make this impossible and the plan was abandoned. The Hindenburg disaster of 1937, along with political and economic issues, hastened the demise of the Zeppelin. The main feature of the Zeppelin design was a rigid fabric-covered metal frame made of transverse rings and longitudinal supports containing a series of individual gas bags [40,41]. The advantage of this design was that the aircraft could be much larger than non-rigid airships, which relied on a slight positive pressure inside a single pressure envelope to maintain its shape. The frame of most Zeppelins is made of duralumin (a combination of aluminum and copper, as well as two or three other metals - its exact content has been a secret for years). Early Zeppelins used rubberized cotton for gas bags, but most later craft used gold coin leather, made from cattle intestines.

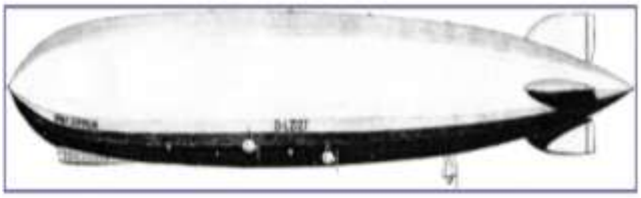


Figure 58. Graf Zeppelin. The ship is a long, thin cylinder, 236.5 meters long and 30 meters in diameter, with the nacelle located far forward, so that it could be dropped under the hull where it began to rise towards the bow. The height of the ship from the bottom of the gondola to the top of the hull was 34 meters

Source: https://www.airships.net/lz127-graf-zeppelin/graf-zeppelin-design-technology/, Accessed: July 29, 2023.

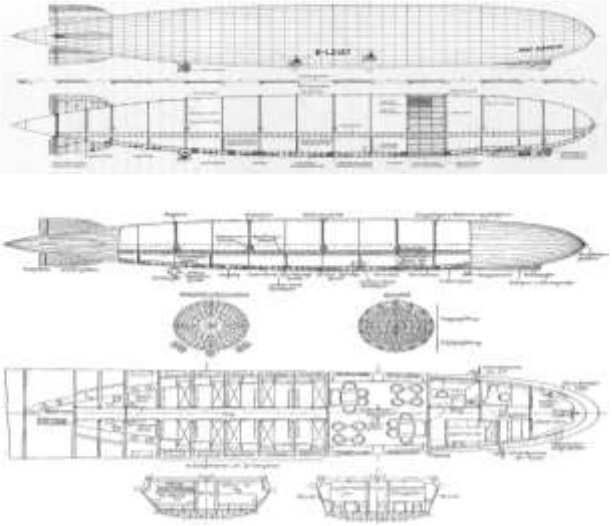


Figure 59. Graf Zeppelin profile, showing rings, gas cells and main elements

Source: https://www.airships.net/lz127-graf-zeppelin/graf-zeppelin-design-technology/, Accessed: July 29, 2023.

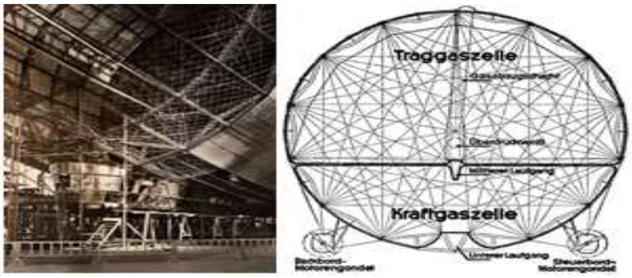


Figure 60. Left: Graf Zeppelin under construction, showing duralumin frames, 15 meters away. Right: cross section through the Graf Zeppelin

Source: https://www.airships.net/lz127-graf-zeppelin/graf-zeppelin-design-technology/, Accessed: July 29, 2023.

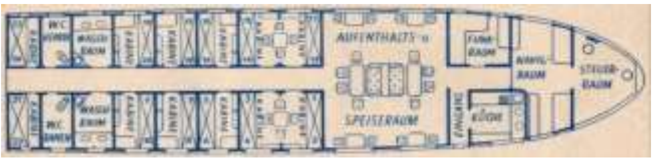


Figure 61. Deck plan of the Graf Zeppelin gondola

Source: https://ar.pinterest.com/pin/466052261441564116/, Accessed: July 29, 2023.

Figure 62. Salon and dining room on the Graf Zeppelin [41]

Source: https://www.airships.net/lz127-graf-zeppelin/interiors/, Accessed: July 29, 2023.

Figure 63. From left to right: passenger corridor on Graf Zeppelin, passenger cabin (day) and passenger cabin (night)

Source: https://www.airships.net/lz127-graf-zeppelin/interiors/, Accessed: July 29, 2023.

Figure 64. Left: Ladies' toilet room on the Graf Zeppelin. Right: Graf Zeppelin control room

Source: https://www.airships.net/lz127-graf-zeppelin/interiors/, Accessed: July 29, 2023.

Figure 65. Left: Graf Zeppelin file. Right: Graf Zeppelin radio room

Source: https://www.airships.net/lz127-graf-zeppelin/interiors/, Accessed: July 29, 2023.

Figure 66. LZ-127 Graf Zeppelin drops water ballast during landing

Source: https://www.airships.net/lz127-graf-zeppelin/graf-zeppelin-design-technology/, Accessed: July 29, 2023.

Figure 67. Left: One of the Graf Zeppelin's two port engine nacelles, under construction. Right: Five nacelles of the Graf Zeppelin under construction

Source: https://www.airships.net/lz127-graf-zeppelin/interiors/, Accessed: July 29, 2023.

Modern zeppelins are kept aloft by the inert gas helium, eliminating the danger of burning, as illustrated by the Hindenburg (Figures 68, 69, 70). It has been suggested that modern zeppelins can be powered by hydrogen fuel cells. Zeppelin NTs are often used for sightseeing; for example, D-LZZF (k/n 03) was used to celebrate the birthday of Edelweiss by performing flights over Switzerland in Edelweiss livery, and is now used, weather permitting, on flights over Munich.

Figure 68. Left: Original wine list from Hindenburg. Right: A life-size replica of part of the Hindenburg's internal structure

Source: https://www.cbsnews.com/pictures/when-zeppelins-ruled-the-skies/, Accessed: July 29, 2023.

Figure 69. Left: A replica of one of the bedrooms in the Hindenburg. Although it was a giant airship, it originally carried only 72 passengers. Right: A replica of one of the toilets on the Hindenburg. Passengers on any plane today would not consider this bathroom to be decades old

Source: https://www.cbsnews.com/pictures/when-zeppelins-ruled-the-skies/, Accessed: July 29, 2023.

Figure 70. Left: Replica of the saloon on the Hindenburg. Right: Replica of the reading room on the Hindenburg

Source: https://www.cbsnews.com/pictures/when-zeppelins-ruled-the-skies/, Accessed: July 29, 2023.

Rigid, heavy, structures. As stated in the INTRODUCTION of this book, rigid, heavy structures are those Earth Air Architecture solutions that are maintained in the air by more or less powerful engines, based on the principle of the balance of the driving force (generated by the engine) and the Earth's gravity.

A plane. Aircraft (including airplanes) are transportation devices designed to move people and cargo from one place to another. They come in many different shapes and sizes depending on the aircraft's mission. Airplane as ADS. The aircraft shown in Figure 71 is a turbine powered aircraft that was chosen as a representative aircraft.

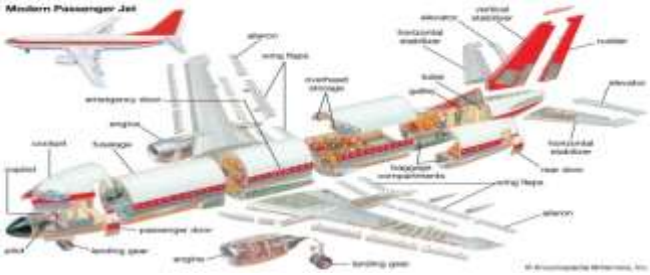


Figure 71. Passenger plane parts

Source: https://www.britannica.com/technology/airplane/Civil-aircraft#ref528050, Accessed: July 28, 2023.

In order for the plane to fly, it is necessary to lift the weight of the plane itself, fuel, passengers and cargo. The wings generate most of the lift to keep the aircraft in the air. To generate lift, the aircraft must be "pushed" through the air. Air resists movement in the form of aerodynamic drag. Modern aircraft use ailerons on the tips of the (main) wings to reduce drag. Turbine engines, located under the wings, provide thrust to overcome drag and propel the aircraft forward through the air. Smaller aircraft (slow speeds) use propellers for the propulsion system instead of turbine engines [42]. To control and maneuver the aircraft, smaller wings are located on the tail of the aircraft. The tail usually has a fixed horizontal piece, called the horizontal stabilizer, and a fixed vertical piece, called the vertical stabilizer. The task of the stabilizer is to ensure the stability of the aircraft, so that it flies straight. The vertical stabilizer prevents the 'nose' of the plane from swaying from side to side, which is called yaw. The horizontal stabilizer prevents the nose from moving up and down, which is called pitch. On the rear side of the wing and stabilizer there are small moving parts that are hinged to the fixed parts. Changing the rear of the wing will change the intensity of the force produced by the wing. The ability to change forces gives the ability to control and maneuver the aircraft. The articulated part of the vertical stabilizer is called the rudder; used to turn the tail left and right when viewed from the front of the fuselage. The articulated part of the horizontal stabilizer is called the elevator; used to turn the tail up and down. The outer wing part of the wing is called the aileron; it is used to roll the wings from side to side. Most aircraft can also roll from side to side using spoilers. Spoilers are small panels used to disrupt the flow over the wing and to change the force intensity by reducing lift when the spoiler is deployed. The wings have additional hinges, rear parts near the body called flaps. The flaps are lowered during takeoff and landing to increase the amount of force produced by the wing. On some aircraft, the front part of the wing will also be removed. Slats are used during takeoff and landing to generate additional force. Spoilers are also used during landing to slow down the plane. The fuselage or body of the plane holds all the parts together. Pilots sit in the cockpit at the front of the fuselage. Passengers and cargo are transported in the rear of the hull. Some aircraft carry fuel in the fuselage, while others carry fuel in the wings. The aircraft configuration in Fig. it is chosen only as an example. Some aircraft may be configured quite differently from this aircraft. The Wright brothers' 1903 flyer had pusher propellers and elevators on the front of the plane. Fighter aircraft often have jet engines built into the fuselage, rather than in pods suspended under the wings. Many fighter aircraft combine the horizontal stabilizer and elevator into a single stabilizing surface. There are many possible aircraft configurations, but each configuration must provide the four forces necessary for flight. All non-military aircraft are civilian. This includes private and business jets and commercial aircraft. Private jets are personal aircraft used for recreational flying, often single-engine monoplanes with non-retractable landing gear. Business jets are used to generate income for their owners and include everything from small single-engine aircraft used for pilot training or to transport small packages over short distances to four-engine executive jets that can span continents and oceans. Business jets are used by salesmen, prospectors, farmers, doctors, missionaries and many others. Their primary purpose is to make the best use of top executives' time by freeing them from flight schedules and flight operations. They also serve as an executive prerequisite and as a sophisticated incentive for potential customers. Other business aircraft include those used for agricultural operations, traffic reporting, forest firefighting, medical evacuation, pipeline surveillance, cargo transportation, and many other applications. Commercial aircraft are used for regular passenger and cargo transportation between selected airports. Their sizes range from single-engine cargo carriers to the Airbus A380 and speeds below 320 km/h to supersonic ones, such as the Anglo-French Concorde, which was in service from 1976 to 2003 (Figure 72).

Figure 72. Concorde - a supersonic passenger transport that first flew in 1969 and entered commercial service in 1976. The British Aircraft Corporation and Aérospatiale of France built the aircraft, which was powered by four Rolls-Royce/SNECMA engines.
Source: https://www.britannica.com/technology/commercial-aircraft, Accessed: July 29, 2023.

Aircraft can be categorized according to their configurations. One measure is the number of wings, and styles include monowing, with one wing (that is, on both sides of the fuselage); biplanes, with two wings, one above the other; and even, although rarely, triplanes and quadriplanes. An aircraft with tandem wings has two wings, one placed in front of the other. The wing plan is the shape seen from above. Delta wings are formed in the shape of the Greek letter delta (Δ); these are triangular wings that lie approximately at right angles to the fuselage. The supersonic Concorde had delta wings. The swept wings are angled, usually at the back and often at an angle of about 35°. Forward-swept wings are also used on some research craft. Some aircraft have wings that can be adjusted in flight to attach at different angles to the fuselage; they are called variable incidence wings. Variable geometry (swing) wings can change the swing (wing angle relative to a plane perpendicular to the longitudinal axis of the aircraft) of their wings in flight. These two types have primarily military applications, as does the swept wing, in which the wing is attached at an angle of about 60° as an alternative to the standard symmetrical wing sweep (Figure 73). Another configuration limited to military aircraft is the so-called flying wing, a tailless aircraft that has all its elements contained within the wing structure (as in the Northrop B-2 bomber). Unlike a flying wing, lift-body aircraft (such as the US space shuttle) generate partial or full lift by the shape of the fuselage rather than the wing, which is greatly reduced or omitted altogether.

Figure 73. NASA's M2-F2 Lift Body Research Vehicle, 1965 This experimental craft was designed to demonstrate how lift body spacecraft would perform in Earth's atmosphere between reentry and landing.
Source: https://www.britannica.com/technology/commercial-aircraft, Accessed: July 29, 2023.

Another way to categorize aircraft is by the type of equipment used for takeoff and landing. In a conventional aircraft, the gear consists of two primary wheels under the front of the fuselage and the rear wheel. The opposite configuration is called a tricycle, with one nose wheel and two main wheels farther back. The aircraft with two main landing gear assemblies in the fuselage and wing tip guard wheels has cycling equipment. Large aircraft, such as the Boeing 747, incorporate multiple bogies (several wheels arranged in different configurations) into the landing gear to distribute the weight of the aircraft and facilitate storage after takeoff (Figure 74).

Figure 74. A Boeing 747 preparing to land at Amsterdam Schiphol Airport guided by runway approach lights. Runway lights and approach lights guide pilots to a safe landing and are essential for flights at night or during low visibility.
Source: https://www.britannica.com/technology/commercial-aircraft, Accessed: July 29, 2023.

Several aircraft use skis or other structures to take off or land on a water surface. This includes seaplanes that are equipped with pontoons for working on water; flying ships, in which the hull also serves as a hull for water navigation; amphibians, which are equipped to land and take off from land and water. The demands placed on naval aircraft used on aircraft carriers require heavier construction to withstand the stresses of catapult launches and stall-abrupt landings. The landing gear mechanisms were also strengthened, and a tail hook was installed to activate the arresting gear, a system also used on heavy military aircraft. The take-off and landing method also differs between aircraft. Common solutions generate speed (for lift) on the airstrip before takeoff and land on a similar flat surface. In the design of the aircraft, various means intended for short takeoff and landing (STOL) were used. These range from optimized wing, fuselage and landing gear designs as in the World War II Fieseler Storch (which featured automatic Handley Page slots, extendable flaps and long-travel undercarriage) to a combination of wing area, large flap area, and the use of large propellers to direct airflow over the wing as in the pre-war Crouch-Bolas, or even such specialized innovations as the large U-shaped channels in the wings as in the Custer Channel Wing aircraft. Vertical take-off and landing (VTOL) aircraft include helicopters, tilt rotors, and "jump jets," which lift off the ground in a vertical motion. Single-stage-to-orbit (SSTO) aircraft can take off and land on conventional runways, but can also be flown on an orbital flight path. There are several types of engines used to achieve thrust.

Piston engines. The internal combustion piston engine is often used, especially for smaller aircraft. There are different types, based on the arrangement of the cylinders. Horizontally opposed engines have four to six cylinders lying flat and arranged two or three on each side. In a radial engine, the cylinders (ranging from 5 to as many as 28, depending on engine size) are arranged in a circle around the crankshaft, sometimes in rows of two or more. Once the dominant type of piston engine, they are now only produced in limited quantities. Four to eight cylinders can be aligned one behind the other in an in-line engine; the cylinders can be upright or inverted, with the inverted crankshaft above the cylinders. In-line V-type engines are also used, with cylinders arranged in three, four or six rows. An early type of engine in which a propeller is attached to a body of cylinders, which rotate around a stationary crankshaft, is a rotary engine. Modern rotary engines are modeled after the Wankel principle of the internal combustion engine.

Automotive and other small engines have been modified for use in domestic and ultralight aircraft. These include two-stroke, rotary and small versions of the conventional horizontally opposed type. Early in the history of aviation, most aircraft engines were liquid-cooled, first water, then a mixture of water and ethylene glycol, with air-cooled rotary engines being the exception. After Charles Lindbergh's epic 1927 transatlantic flight, a trend toward radial air-cooled engines began for reasons of reliability, simplicity, and weight reduction, especially after modernized fairings (the covers that surround aircraft engines) were developed to moderate airflow and aid cooling. Designers continued to use liquid-cooled engines when low frontal drag was an important factor. Due to advances in engine cooling technology, there has been a minor trend back to liquid-cooled engines for greater efficiency.

Aircraft engines. The gas turbine engine has almost completely replaced the piston engine for aircraft propulsion. Jet engines achieve thrust by ejecting combustion products in a jet at high speed. A turbine engine that passes all the air through the combustion chamber is called a turbo jet. Because its basic design uses rotating rather than reciprocating parts, the turbojet is far simpler than a reciprocating engine of equal power, weighs less, is more reliable, requires less maintenance, and has far greater potential for power generation. It uses fuel faster, but the fuel is cheaper. In the simplest terms, a jet engine takes in air, heats it up, and expels it at high speed. Thus, in turbojet air, outside air is sucked in at the entrance to the engine (induction), compressed approximately 10 to 15 times in a compressor consisting of rotor and stator blades (compression) and introduced into the combustion chamber where igniters ignite the injected fuel (combustion). . The resulting combustion produces high temperatures (760 to 1,040 °C). The expansive hot gases pass through a multi-stage turbine that turns the air compressor through the coaxial shaft and then into the exhaust nozzle, creating thrust from the high-velocity gas stream that is ejected out the back (exhaust). A turbofan is a turbine engine that has a large, low-pressure fan in front of the compressor section; low-pressure air is allowed to bypass the compressor and turbine, mix with the jet stream, increasing the mass of accelerated air. This system of slower movement of large volumes of air increases efficiency and reduces fuel consumption and noise (Figure 75, left). A turboprop is a turbine engine connected by a reduction gearbox to a propeller. Turboprop engines are usually smaller and lighter than a piston engine, generate more power and burn more but cheaper fuel (Figure 75, right).

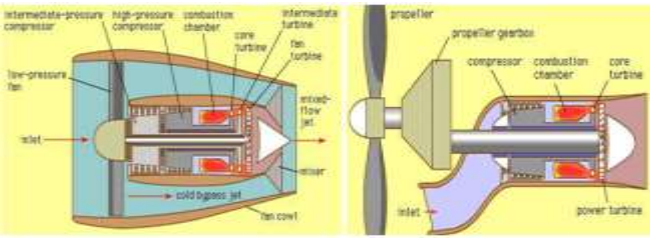


Figure 75. Left: Large bypass turbofan with two coil core and mixed flow jet. Right: A turboprop engine driving a single-rotation propeller as propulsion.

Source: https://www.britannica.com/technology/commercial-aircraft, Accessed: July 29, 2023.

Propfans jet engines without fans, achieve extremely high bypass air flow using a wide-chord propeller driven by the jet engine. Rockets are purely reactive engines that usually use a fuel and oxidizer in combination. They are used primarily for research aircraft and as launch vehicles for spacecraft and satellites.

A ramjet is an engine that takes in air and after accelerating to high speeds acts like a turboreactor without the need for a compressor or turbine. A scramjet (supersonic combustion ramjet) engine is designed for speeds greater than Mach 6, mixing fuel with air flowing through it at supersonic speeds; it is intended for hypersonic aircraft (Figure 76).

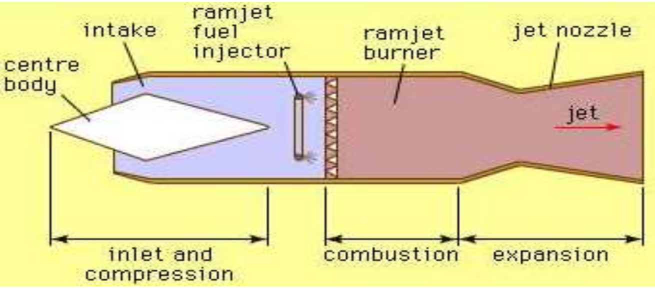


Figure 76. Arranging ramjet. A type of jet engine in which the air drawn in for combustion is compressed solely by the forward motion of the aircraft

Source: https://www.britannica.com/technology/commercial-aircraft, Accessed: July 29, 2023.

Structural assembly of a typical passenger plane. A historical perspective provides an understanding of how the current state of composite hull manufacturing has developed. It also provides insight into what the future state of composite hull manufacturing might look like. Figure 77 is a familiar graph showing the increase in the use of composites in military and commercial aircraft over time. The initial applications of carbon fiber reinforced composites (CFRP) in commercial and military aircraft were limited mainly to non-structural applications such as turnstiles and flight control surfaces. Structural applications for military aircraft began to emerge in the 1980s, as the use of composites increased to more than 20% of aircraft weight. As the industry continued to mature, the material and processes became better understood and cost-effectiveness improved to the point where commercial aircraft manufacturers incorporated the technology into the latest generation of wide-body and other new aircraft [43].

Figure 77. The use of composites

Source: https://www.intechopen.com/chapters/64957, Accessed: July 29, 2023.

Research and development of high-performance composite materials and processes for aerospace applications in the US was first conducted in the 1940s at Wright-Patterson Air Force Base in Dayton, Ohio. The focus of this early research was primarily for military applications. This research has continued ever since, and the Air Force Research Laboratory (AFRL), supported by industry, academia and other government agencies, such as the Defense Advanced Research Projects Agency (DARPA) and the Department of Energy (DOE), continues to play a leading role in the development of advanced materials for military applications. The National Aeronautics and Space Administration (NASA) began research in the late 1960s dedicated to the development of high-performance composites for commercial aircraft and space vehicles. Over the years, NASA has worked with industry and academia to develop affordable technologies to improve the safety and performance of aircraft and launch vehicles. A common feature of the AFRL- and NASA-sponsored programs was a 'building block' approach to R&D programs that progressed through a series of steps, each increasing in complexity and cost over the previous step. In general, programs started at the coupon level and considered a wide range of samples to narrow down the selection of design approaches, construction materials, tooling, and manufacturing processes to fabricate and test coupons, subcomponents, and ultimately complete components. Unlike the technology readiness levels used to describe new technologies today, this approach was used successfully in programs such as the Lignin-derived Activated Carbon Fibers (LACF) program in the late 1980s and NASA's Advanced Composites Technology (ACT) program in the mid-1990s. The B-2 Stealth Bomber program also took place during the 1980s and provided many lessons learned related to the production of large composite primary structures. For the B-2, survivability performance was one of the primary reasons for the extensive use of carbon fiber composites—cost and productivity were not the most critical factors. Boeing was the prime subcontractor on the program and built the wing skins using Automated Tape Laying (ATL). This program presented an opportunity to demonstrate the productivity that was possible using automated lamination processes such as ATL and AFP. Another program that directly benefited from the ACT program is the V-22. Composites have been used extensively and aggressively in helicopters more than any other type of aircraft because weight is such a critical factor. The V-22 uses composites for the wings, fuselage skin, canopies, side fairings, doors and nacelles. AFP technology is used to create the rear fuselage in one piece. Both Bell and Boeing are also incorporating hardened airframe fuselage structures into their parts of the program, using solid silicon mandrels. Large Aircraft Composite Fuselage (LACF) program. The LACF program was partially implemented by Northrop and sponsored by the Wright Air Force Laboratory (AFWAL) during the 1980s. The program was part of an effort focused on manufacturing technology for the linear production of large composite airframes from primary construction. The multi-phase program was aimed at defining and demonstrating production methods for curing reinforced hull panels using: (1) existing, qualified material systems, (2) automated skin fabrication, (3) internal mold line (IML) controlled tooling, (4) non-autoclave hardening technology. Like many similar terms, in the 1980s "linear" manufacturing was a code word for "lean", and non-autoclaves are now called Operations procedures Outside the Autoclave (OOA). The program followed a four-phase approach. Among the lessons learned as a result of Phases III and IV were economies of scale, scale, and speed. This included cutting and layering time to make the boards and removing the paper backing, and management issues affecting the laying of the pull and the preparation of the wire laminate (Figure 78). The second lesson involved a better understanding of the hardening of the longitudinal „I" beams on the large hull plate skin. One nice feature of the „I" beam construction is that the tools are not trapped after curing, and the channel details that form the „C" of the „I" beam can be removed to any length. Disadvantages were also apparent, including the number of laminate preforms and tooling details required to construct the "I" beam versus the simplicity of the hat stiffener. Northrop has developed the technology to manufacture a hull-reinforced skin hat to support the YF-23 (Figure 79).

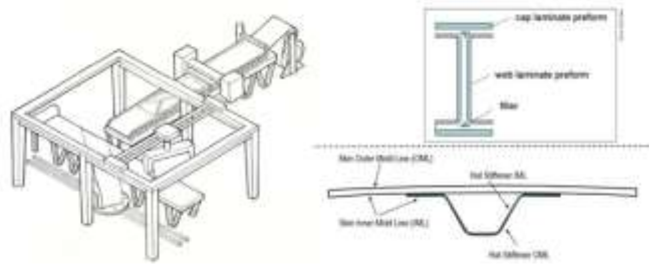


Figure 78. Left: Laminate Cross Ply Machine. Right: "I" beam opposite the hat stiffener

Source: https://www.intechopen.com/chapters/64957, Accessed: July 29, 2023.

One of the critical problems to be solved was the removal of the tool from the mandrel to stiffen the hat from the hardened part. The hull tooling was controlled by Outer Mold Lines (OML) and made of Carbon-fiber-reinforced polymers (CRFP) prepreg to match the Coefficient of Thermal Expansion (CTE) parts. The resin system used to make the tools was bismaleimide (BMI), and the tools were autoclaved on machined monolithic original graphite tools. Hat stiffeners that run longitudinally against the leather are cured using a silicone mandrel developed by Northrop using Rubbercraft as a supplier.

Figure 79. YF-23 fuselage structure

Source: https://www.intechopen.com/chapters/64957, Accessed: July 29, 2023.

The silicone-based solid mandrel system included a solid rubber mandrel, a butterfly fence, and a final resin dam. The silicone mandrel is designed to be removed from the cured part after pulling and extending the mandrel to reduce the cross-section enough to release it from the part. The butterfly cap is designed to consistently control the OML of the hat stiffener. It has also helped to greatly simplify the bagging process allowing a wider range of operators to be used instead of relying on only a highly skilled mechanic. The final dam was designed to be inexpensive and disposable and would replace much of the complexity of the inner packaging process by sealing off the hardener hat to prevent resin from escaping during the curing cycle (Figure 80). This is not a difficult process, but it is critical and tedious.

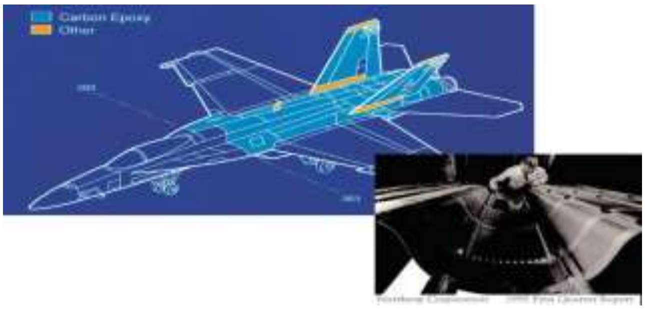


Figure 80. Solid mandrel system
Source: https://www.intechopen.com/chapters/64957, Accessed: July 29, 2023.

Northrop later applied this hat stiffener fabrication technology to the fuselage of the F/A-18E/F as Boeing's prime subcontractor on the program (Figure 81).

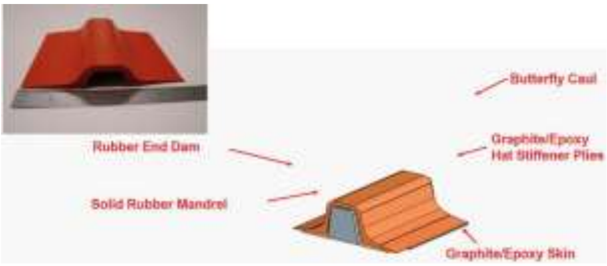


Figure 81. F/A-18E/F Fuselage Structure
Source: https://www.intechopen.com/chapters/64957, Accessed: July 29, 2023.

During this time period, many research and development programs recognized that liquid molding processes present the possibility of using resins and fibers in their least expensive state by removing prepregs from the manufacturing process. Other benefits include minimizing material waste, simplifying raw material storage and supporting non-autoclave manufacturing processes. The development of mesh-shaped damage-resistant textile preforms and the development of innovative tooling concepts for liquid forming supported this opportunity. The Advanced Composites Technology (ACT) program incorporated processes such as Resin Transfer Molding (RTM) and pultrusion into the development effort. The technologies have advanced to practice processes with the 787 and A350 programs using fluid molding and textile preform technology to create fuselage frame elements. Advanced Composites Technology (ACT) program. The goal of the ACT fuselage program was to develop a composite primary structure for commercial aircraft with 20-25% lower costs and 30-50% less weight than an equivalent metal structure. The Advanced Technology Composite Aircraft Structure (ATCAS) program was carried out by Boeing as prime contractor under the auspices of NASA's ACT program and focused on fuselage structures. A large team of industrial and university partners also supported the program. The primary goal of the ATCAS program was to develop and demonstrate an integrated technology that enables the cost-effective use of composite materials in future aircraft fuselage structures. The area selected for study was identified as Section 46 on Boeing's wide-body aircraft (Figure 82). This section contains many of the structural details and manufacturing challenges found throughout the fuselage. This includes variations in design details to deal with heavy loads on the front end and lower fuselage sections. The loads are reduced towards the rear end and upper part of the fuselage, allowing transitions in the thickness of the structure adapted to the structural load.

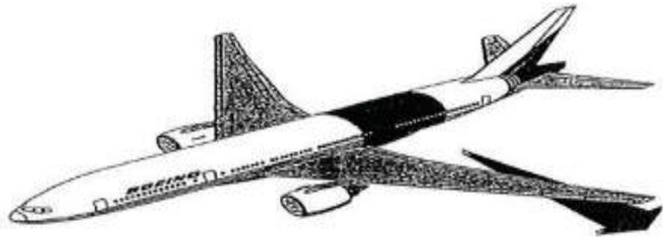


Figure 82. ACT part of the fuselage
Source: https://www.intechopen.com/chapters/64957, Accessed: July 29, 2023.

A quadrant plate approach was chosen for the study as shown in Figure 83. The cross section is divided into four segments, crown, keel and left and right side plates. The four-quadrant perimeter plate approach was chosen with the idea of reducing assembly costs by reducing the number of longitudinal joints. This built assembly approach is the basis of metal aircraft manufacturing and is similar to the approach Airbus has chosen for most of the A350 fuselage.

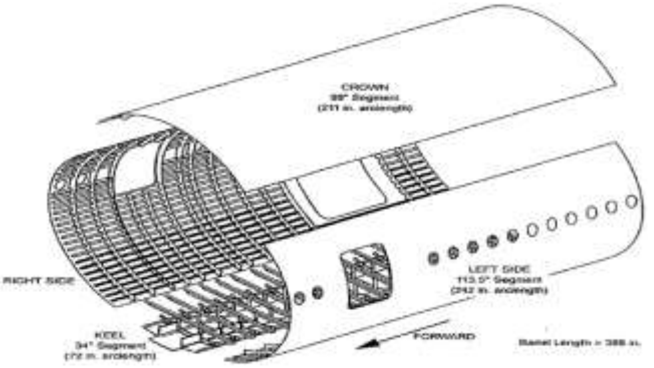


Figure 83. ACT Quadrant Plates
Source: https://www.intechopen.com/chapters/64957, Accessed: July 29, 2023.

The development of production processes and design trade studies contributed to the development of Cost Optimization Software for Transport Aircraft Design Evaluation (COSTADE), which enabled the definition and evaluation of the cost-effectiveness and productivity of various designs. Included in the program were evaluations of the tooling, materials, and process controls required for future tube production like the one Boeing selected for the 787. The structural concepts studied included stiffened skin structures achieved by independent or combinations of curing, co-bonding, gluing, and mechanical attachment of stringers and frames to monolithic or sandwich plates. A coronal section study selected fiber mounted skin laminated on an IML controlled mandrel for placement and the skin was subsequently cut into individual panels and transferred to OML drying tools. Hat fasteners used solid silicone mandrels placed longitudinally against the IML diaphragms. The recommended optimized panel design involved gluing together the stiffened frame elements while simultaneously stiffening the hat stiffeners and skin. The hardened frames were demonstrated using knitted textile preforms and Resin Transfer Molding (RTM). One of the main challenges of the crown plate concept was the integrity of the connection between the pre-attached frames attached to the leather plate which was stiffened with hardened hat strings. Alternative concepts considered by the team during the review process included mechanically attached Z-section frames instead of jointed J-sections. The mechanically attached frame approach greatly reduces the complexity of the IML tooling required to attach the hat stiffener and frame connection.

This especially applies to the intersections of the frame and the hat. Flexible closure panels and custom reusable bags became part of the tooling system required to achieve a fully integrated skin/spar/frame structure. Productivity issues are complicated by the blind nature of the IML skin, which is completely covered by flexible molds and a reusable bag system. The structural layout shown in Figure 84 is very similar to the configurations that ended up on both the 787 and A350 programs.

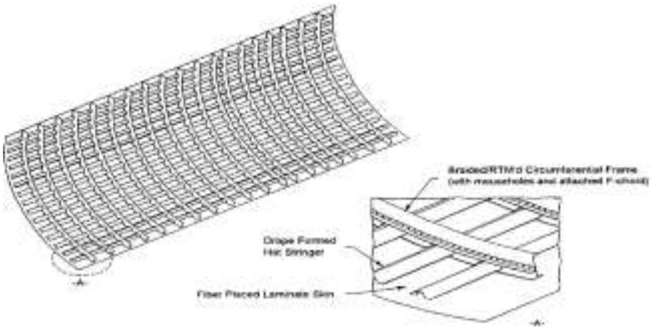


Figure 84. Structural layout of the ACT crown plate
Source: https://www.intechopen.com/chapters/64957, Accessed: July 29, 2023.

The program studied the pultrusion process for the production of leather bands. Continuous Resin Transfer Molding (CRTM) developed by Ciba-Geigy is one of the promising technologies studied. Improved process control and reduced waste are among the perceived benefits; the maturity of the process, the constant series of sections and the costs associated with secondary bonding or co-bonding are among the disadvantages. Airbus looked into automating string manufacturing using both pultrusion and RTM, but felt limited by aspects of both processes. In response, Airbus developed its own version of pultrusion RTM. Sl. 3.58. shows equipment completed in 2011 used for process development and qualification. This hybrid fabrication approach allows the use of laminate preforms instead of being limited to unidirectional reinforcements like traditional pultrusion and supports continuous manufacturing instead of batch processing associated with traditional RTM. Instead of dipping a stack of preforms into a vat of resin, they are fed into an RTM tool that is open at both ends. To overcome resin extrusion at both ends of the open tool, Airbus developed an epoxy resin with a parabolic temperature/viscosity curve together with resin suppliers. At 120 °C, the viscosity of the resin is very low with high flow characteristics, but at room temperature and at 180 °C and above, it is very viscous (Figure 85). The inlet to the tool is cooled so the resin is too viscous to flow out; the middle is heated to achieve resin flow and hardening; finally more heat is added to increase the viscosity of the resin to prevent flow and reduce the curing pressure [43].

Figure 85. Airbus equipment for continuous pultrusion
Source: https://www.intechopen.com/chapters/64957, Accessed: July 29, 2023.

Automatic fiber placement. Even in the early days of development, industry leaders believed in the possibility of higher lay rates using AFP than was possible with hand lay, but the capabilities and scale the industry has achieved today are astounding. Almost as astonishing as how the industry has transformed itself from a technology that saves raw material costs to one that enables large aircraft structural components. In the late 1980s and early 1990s, Northrop and ATK/Hercules worked on several joint Air Force-sponsored projects involving the development and application of fiber deployment. The technology was in its infancy as ATK was developing drag placement (as it was originally more commonly referred to) from its roots in thread winding technology. The top prize in the early days was $5 per pound. Highly modular carbon fiber and $15 per kilogram of high-performance high-temperature resin instead of the $60 cost of prepreg. The wet process of passing the fibers through a resin bath before being placed on the placement mandrel has never been able to achieve the quality and consistency required by the design. This same process was used in the manufacturing process of large wind blades and reminds us how challenging the approach can be. Additionally, the wind blade manufacturing industry learned some valuable lessons from those early days about 'building as cheaply as possible' using the lowest cost materials you can handle. Although these early knives were built with lower manufacturing costs, it can be argued that many of these knives failed very early in their life cycle and required expensive repairs or replacement to generate electricity. If the blade cannot be turned because it has fallen off, it does not produce any electricity at the expense of repair or replacement. The technology not only did not realize the cost savings of dry fibers and wet resin, but was forced to adopt prepreg technology into the process - namely dealing with the backing paper and adding the cost of unidirectional prepreg tape by requiring it to be cut into prepreg traction. At the time of the ATCAS program, the AFP process was still evolving from what was originally intended to be a significantly lower raw material cost, starting with a dry fiber/wet resin process instead of the expensive unidirectional fiber prepreg. The basic process chosen by the ATCAS program to make the fuselage skin was AFP using prepreg traction. Dry fiber/wet resin traction evolved into traction prepreg in an attempt to improve process consistency. The process was selected based on several factors, including the potential to reduce material costs (compared to prepreg tape), the potential to achieve high lay rates on contoured surfaces, and the potential to efficiently support a significant amount of layer tailoring. In addition, the fact that no backing paper is required for the traction material eliminated the perceived risk of major machine downtime. Compared to the quality and consistency of parts made from prepreg tape, traction preg and subsequent traction prepreg, it was not acceptable. Variability in the quality of the resulting panels would require compensation in the part design, resulting in weight penalties. However, this did not turn out to be fatal for the technology, but the place for traction was reinvented (Figure 86).

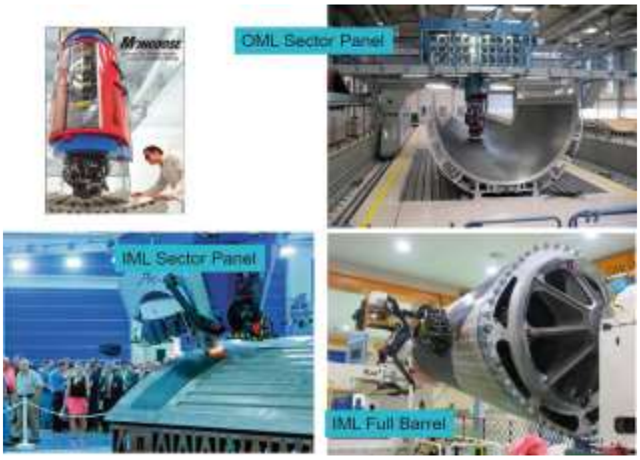


Figure 86. AFP process and tools

Source: https://www.intechopen.com/chapters/64957, Accessed: July 29, 2023.

There have been many studies of the AFP process that have helped shape and improve the features and capabilities that exist in today's equipment offerings. But the ACT program allowed Boeing to better understand, study, define and refine the process to guide technology development based on the needs of the user community. Everything from gluing the initial layers to the surface of the tool, to overlaps and gaps in the laminate; the most efficient ways to handle window/door cutouts, laminate thickness transitions, layup for flat, curved, cylindrical and channel parts, etc. etc. What ended up in production on the 787 was not a direct result of that ACT program, but the ACT program created a pathway for subsequent AFP development for monitoring and improvement.

Tools. One clear thread throughout the development of the composite hull fabrication process that was recognized and considered very early on was tooling. The fabrication of large composite hull structures is also made possible by the tooling required to support it. The industry's ability to produce tools using specific materials and built to the size, scale and accuracy required by aerospace and defense applications were critical factors. Large-scale machining, laser measurement systems and innovative thinking supported the transition to today's composite hull manufacturing capabilities. The ACT program has shown that the productivity of large, integrated, composite hull structures is highly tool dependent to ensure skin hardening, hardened or bonded tool compatibility with frames and frames. Management of these elements is necessary to minimize gaps and interference fits between dried detail components. Understanding the effect of build-up tolerances, warpage, liquid and hard shim allowances, and fastener pull forces creates the ability to calculate the impact on structural layout and fuselage weight, parts manufacturing cost and risk, and fuselage assembly and integration time. These elements become even more critical as fuselage size grows to the proportions of the 787 and A350. One important note was the need for the mat tooling to be removable after curing and flexible enough to accommodate variations in skin thickness—particularly the "jerk" or up-and-down transitions on each of the frame frames. These requirements forced the team to use silicone or flexible laminate mandrels - reusability was also a key consideration. The shafts had to be stiff enough to handle or be used as spindles for drapery or vacuum molding; durable and able to withstand a 177°C autoclave curing cycle and still conform to the shaping and tailoring of the leather layers; and can be removed after hardening. Although the use of silicone mandrels and flexible IML tooling has proven to be adequate for controlling the shape, quality, and attachment location of hats, it is also recognized that silicone mandrels present many challenges in scale-up and production scenarios. Boeing began developing hat-shaped silicone bubbles that applied autoclave pressure to the bubble throughout the cure to ensure even pressure throughout the array. After hardening, the pressure in the bladder is released, allowing the bladder to be removed. At the same time, Rubbercraft worked with engineers on the C-17 program to develop and manufacture inflatable silicone bladders for use on the replacement compound tail (Fig. 3.60). In 1991, a complex tail was integrated into the program on aircraft 51. Rubbercraft produced silicone blisters with FEP film molded onto the OML blisters used in the IML tooling to attach the hat fasteners to the skin of the horizontal stabilizers. The design of the tooling, bubbler, and cap closure enabled the production of bubbles with significant excess length that supported multiple curing cycles despite dimensional shrinkage of the bubble in the longitudinal direction. Reuse over multiple curing cycles is key to the cost effectiveness of an inflatable bladder system. Product improvement of rubber products focused on bladder attributes that supported increasing the number of cure cycles for which the bladder could be used (Figure 87).

Figure 87. Left: C-17 horizontal stabilizer. Right: Inflatable bubble

Source: https://www.intechopen.com/chapters/64957, Accessed: July 29, 2023.

As Boeing developed flexible IML tools for curing hat ropes and joint frames on the ACT program, they evolved from one-piece overall molds to separate, individual flexible seals made of graphite/epoxy fabric with a layer of Viton® fluoroelastomer and an outer layer of FEP film. Fluoroelastomer has been shown to be more resistant to epoxy resin and therefore more durable than silicone or other rubbers. An additional benefit - but perhaps not yet so understood at the time - is the additional permeability resistance offered by both FEP film and Viton rubber. This helps reduce the amount of autoclave gas inside the bladder from entering the laminate through the permeability of the bladder system. Development of the fluoroelastomer bladder continues today in support of new programs and applications. A comparison of OML and IML treatment tool approaches shows some trade-offs that must be considered. OML tools are less complex, less expensive, can be run as soon as the aircraft OML is established, and are more forgiving of changes than the IML tool. The IML tool requires less work and risk to locate and maintain stiffeners and other elements, and is much easier to bag (Figures 88, 89).

Figure 88. Left: OML sector toolbar. Source: Premium Aerotec. Right: IML tool
Source: https://www.intechopen.com/chapters/64957, Accessed: July 29, 2023.

Figure 89. Left: IML and OML treatment tools. Right: IML and OML tools
Source: https://www.intechopen.com/chapters/64957, Accessed: July 28, 2023.

Large autoclaves. One possibility that supports the evolution of the current state of composite hull production is large autoclaves. There is much research, both historical, ongoing and planned for the future, development efforts focused on OOA materials and processes (or the non-autoclave, as it was called in the 1980s), with the goal of removing that monument, the autoclave. The goal is noble (and not new), and development efforts are making great progress and will one day in the future represent a significant (if not all) part of the complex structure on commercial passenger aircraft - just not today. We are already seeing components made from the liquid forming process being used in specific applications and families of parts and components on aircraft like the 787 and A350, just not yet primary fuselage panels and fuselage supports. The maturity, forgiving nature and low risk of basic autoclave drying systems made it easy for programs like the 787 and A350 to progress knowing that it would take enough time and money to build autoclaves to meet the program's needs. No new technology is required, just the scope and incorporation of improvements being made by the autoclave industry, such as management systems and operational efficiency. Spirit even built its own on-site liquid nitrogen plant to service its large autoclaves (Figure 90).

Figure 90. Autoclaves. Source: Spirit, DLR
Source: https://www.intechopen.com/chapters/64957, Accessed: July 29, 2023.

NDE/I/T technology. The use of composites for high performance applications requires the ability to identify and ultimately eliminate structural defects that occur during manufacturing, assembly, service or maintenance. The entire field of Nondestructive Evaluation (NDE) continued to develop in parallel with the growth of the application of composite structures. It is both an enabling technology and one that is driven by the market and needs. NDE of composites is a mature technology and has been used successfully for many years, however, today's and tomorrow's composite structures have grown in both scale and complexity. New and improved Nondestructive Testing (NDT) methods and technologies are needed to improve detection capabilities, meet growing inspection needs, and address future Nondestructive Inspection (NDI) requirements. NDT methods currently used in aerospace applications span a wide range of technologies, from a simple coin-tapping test to fully automated, computerized systems that can inspect very large parts (Figure 91).

Figure 91. Ultrasound examination
Source: https://www.intechopen.com/chapters/64957, Accessed: July 29, 2023.

Many of the newer NDI methods are 'wide area' inspection methods, which allow for more uniform and faster coverage of the test surface which can improve productivity and reduce human error. Technical advances in computing power and commercially available multi-axis robots and/or gantry systems now facilitate a new generation of scanning machines. Many of these systems use multiple end-effector tools that deliver improvements in review quality and productivity. Ultrasound is the current NDE method of choice for the inspection of large fiber reinforced airframe structures. Over the past 2 decades, all aircraft manufacturers and their top suppliers have used ultrasonic scanning machines that use common techniques to perform these inspections. A limitation of ultrasound examination may be the requirement to use a joint between the probe and the test piece. VACRS (Variable Automatic Measurement and Recovery System) has helped change the way ultrasound examinations of very large areas are performed. The VACRS system uses a lightweight fabrication and delivery/recovery system that allows C-scans to be performed with large ultrasound arrays without large water requirements. Works with Boeing's Mobile Automated Scanner (MAUS®) and other scanning systems on the market. Shearography and thermography are relatively fast, non-contact methods that do not require splicing or complex scanning equipment. Laser shearography was originally applied to aircraft construction in 1987 by Northrop Grumman on the B-2 bomber. Since then, laser shearography has emerged as an advanced, fast and efficient screening method. An enabler for the wider application of bonded structure in commercial aircraft will be improved cost and capability related to quantifying the integrity of structural bonds in real time. Adhesive bonds slowly degrade over time and are highly dependent on surface preparation. On older aircraft, the only indicator of bond integrity is age, environmental exposure and statistics - not actual bond condition. The ability to detect weak adhesive bonds, before they come off, will lead to greater part integration and a reduction in the number of fasteners and everything involved in creating holes in hardened composite parts. Military air vehicle platforms are more aggressive in this pursuit, and the pay-for-performance mindset, lower production rates, and program size, visibility, and goals allow for greater flexibility in implementing related structures. The commercial world is different and just like the widespread use of composite material on new aircraft, this will not happen unless there are compelling economic benefits and very low risk.

Airbus A350 XWB. The composites community in Europe was equally active. There have been many research and development programs focused on the design and manufacture of high performance composites. The results of this work, along with many lessons learned from the historical programs, have been incorporated into the approach taken on the A350XWB program (XWB stands for eXtra Wide Body). The A350's composite fuselage manufacturing approach is not as uniform as the method Boeing chose on the 787. The A350 contains one integral tube section, the tail, manufactured in Spain using an approach similar to that used by Boeing and its partners on the 787 (Figure 92). The rest of the A350 fuselage follows a more conventional panel assembly approach, but uses some unique manufacturing processes along the way. The use of AFP, invar tools and longitudinally embedded omega (like the Greek letter Ω) stiffeners, more traditionally called hat stiffeners, are also common in the programs. The panel approach used on the A350 supports large section lengths and this is reflected in section 15 which is approximately 20m long. The way the omega stiffeners are incorporated into the fuselage panels varies quite a bit between sections and suppliers.

Figure 92. Left: Airbus A350. Right: A350 fuselage and tail panel. Source: Airbus
Source: https://www.intechopen.com/chapters/64957, Accessed: July 29, 2023.

Spirit is a common key supplier of both programs, and the approaches to construction share some key characteristics. Spirit manufactures the A350's 15 section and uses the sector plate approach that is common throughout the fuselage. Spirit cures the omega using an IML-controlled layup/curing tool with a rigid composite seal plate to control the aerodynamic smoothness of the OML surface. Uncured omega stiffeners are laminated, shaped and placed in troughs processed with the invar tool. Inflatable rubber bubbles sit on top of the omega laminate and fill the gap between the omega and the AFP skin that is laminated on top of the assembly. The part is dried in an autoclave and the rubber bubbles are removed after curing leaving a hardened and now hollow omega on the board (Figure 93).

Figure 93. A350 fuselage side panel. Source: Spirit
Source: https://www.intechopen.com/chapters/64957, Accessed: July 29, 2023.

The remainder of the A350 fuselage structure uses joint bonding to incorporate omega stiffeners into the fuselage skin (Figure 94). Approved omega stiffeners are placed on the green AFP skin with a layer of adhesive film between the elements, and then cured in an autoclave (Figure 36). During the co-bonding cycle, the tubular pouches are located within the cured stiffener and are open to pressure in the autoclave during the curing/co-bonding cycle to ensure that the pre-cured string does not collapse or become damaged under autoclave pressure (Figure 95).

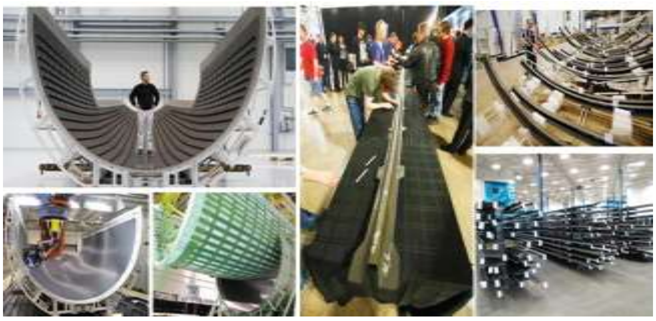


Figure 94. Left: A350 fuselage panel. Source: CTC Stade. Right: A350 advance omega wires
Source: Deseret News, Jeffrey D. Allred; CW/Fotografije: Jeff Sloan
Source: https://www.intechopen.com/chapters/64957, Accessed: July 29, 2023.

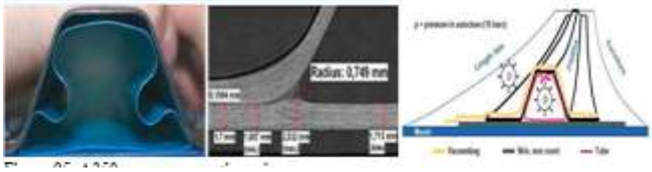


Figure 95. A350 omega connecting wire
Source: https://www.intechopen.com/chapters/64957, Accessed: July 29, 2023.

Like the 787 program, fluid molding processes are used to create fuselage frames that are mechanically attached to the skin. The structural arrangements and assembly methods used by both programs are extremely similar. One significant difference (if not the most significant) is the integration of the frame with the fuselage. The 787 features a 'mouse hole' in the frame that nests around the hat stiffener and is attached directly to the fuselage skin IML. Boeing can do this because the 787's IML surface is a machined surface with features that have controlled heights and locations. Both programs use hull frames made with a closed molding process that machine the surface that joins the skin. On the 787 this creates surface contact with machined surfaces creating a very predictable assembly. The components fit together and can be manufactured because at the beginning of the program he paid the design price for assembly (Figure 96).

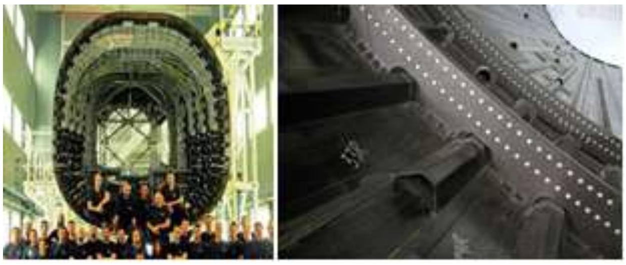


Figure 96. Left: A350 fuselage. Right: 787 fuselage
Source: Borga Paquito

A350 fuselage frames are attached only to the omega stiffener crowns using secondary clips. Airbus did not attempt to attach the frames directly to the skin because the IML fuselage skin is not a controlled surface. It is a bagged surface that could use sealing plates to create a uniform pressure and smooth surface, but the IML surface 'floats' depending on factors such as bags, resin discharge and initial prepreg resin content. Just as the OML of each 787 fuselage 'floats' and varies from aircraft to aircraft, depending on the same factors. Airbus uses a standard carbon fiber-reinforced buckle molded from a thermoplastic material to absorb skin manufacturing tolerances in the assembly process (Figures 97,98).

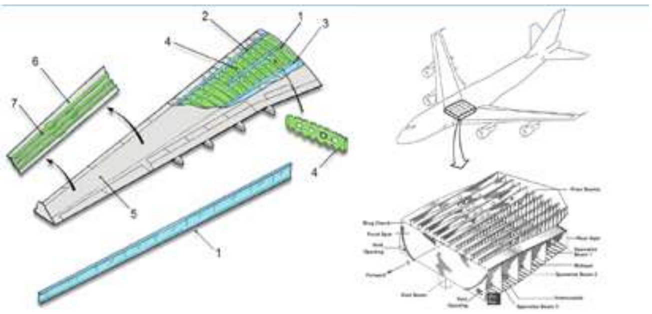


Figure 97. Left: Construction of a commercial aircraft wing box: 1. Center spar, 2. Front spar, 3. Rear spar, 4. Rib, 5. Skin plate, 6. Underside of membrane, 7. Strings. Right: Constructive assembly of the plane's physical structure

Source:https://www.researchgate.net/figure/Construction-of-wing-box-of-a-commercial-aircraft-1-center-spar-2-front-spar-3_fig1_244989196, Accessed: July 29, 2023.

Figure 98. Interior of the wing of the C-130 Hercules transport aircraft

Source: https://www.researchgate.net/figure/Inside-the-wing-of-the-C-130-Hercules-transport-aircraft-14_fig4_244989196 Accessed: July 29, 2023.

Future developments/trends. There are several recently developed commercial aircraft, such as the Bombardier C series, Mitsubishi's MRJ and Comac's C919, which all share a similar overall airframe architecture to the 787 and A350. However, none of these aircraft feature a fully composite fuselage. The advantages of composites on large aircraft with wide bodies are confirmed by the short service history of the 787, and the even shorter history of the A350. The debate over achieving the same gains in smaller aircraft continues for next-generation single aisles. Wide-body aircraft spend most of their lives cruising at 12 km altitude, and the structure is tailored to pressure loads and structural needs - this ensures adequate thickness for good damage-resistant designs. A fuselage design for single-aisle aircraft could be more efficient based on cabin pressure and structural loading alone. But in order to provide designs that will tolerate many more takeoffs and landings, and are also hazardous in service, such as baggage and catering carts, dropped tools and equipment, hail and bird strikes, the fuselage panels must be thicker and heavier, sacrificing weight . Wings are one area of composite implementation on one-pass upgrades and new aircraft of the future. The Boeing 777X incorporated a compound wing into its design. The composite sash allows for a very high degree of tailoring of the laminate and can be designed and built for maximum efficiency. This creates a sleek wing that is amazing to look at in flight, but feels alarmingly thin compared to conventional metal aircraft wings. But compound wings for high rates present challenges. Production rates of 12-14 per month for wide bodies have been shown to be achievable. Building complex wings to support production rates of 60 aircraft per month for narrow bodies is not. The costs associated with course tools alone can be daunting. Remarkable advances in OOA technology could help provide a solution. Bombardier has chosen an OOA process for the C-series wings, and the MRJ uses an OOA system for the wing's vertical tail box, a similar process to what United Aircraft (Russia) has announced for its MS-21 wing. However, there are complex issues to resolve that will affect the timeline for using OOA systems on the next generation of commercial monoplane (one pair of wings) aircraft and airframes. The industry is risky, and OOA systems are in their infancy compared to autoclave systems. The autoclave process has proven to be very tolerant of variations that exist in raw materials, auxiliary materials, supply chain manufacturing processes, and through the manufacturing of final parts. The effect of production variability is well understood and incorporated into efficient designs that contain minimal penalties for the unknown or less well understood. The same will not be the case with OOA systems until more lessons are learned. Many of these lessons will continue to come from military applications that are more aggressive in adopting new technologies. The benefit to the military is usually not the cost; the benefit to the commercial world is always the price. On a slightly longer timeline affecting future composite hull construction are sensors and technologies related to structural health monitoring (SHM). This is a very large area with increasing interest from many OEMs for many applications in many industries, including aerospace, automotive and power generation. Advances in this technical arena could be one of the next revolutionary changes or 'step changes' (as opposed to evolutionary) for the advancement of the industry. Advanced sensor technology could replace many NDT applications by supporting in-situ 'structural health monitoring'. Installed on or within composite structures, such systems would continuously monitor the component and detect degradation and damage as they occur. This could eliminate the possibility of damage being overlooked and reduce costly downtime in manual inspections. The future of SHM and other smart composite structures includes morphing technology that changes the shape of a part in flight to create optimal flight conditions. Built-in sensing, computing and actuation, new frontiers are emerging for structures that autonomously adapt their properties to changing flight conditions. Similar developments include multifunctional composite-laminates that not only provide lightweight, load-bearing structures, but also perform additional functions, such as energy harvesting and storage. More than 100 presentations on multifunctional composites were presented at the 20th International Conference on Composite Materials (July 19-24, 2015, Copenhagen, Denmark). 3-D printing is another emerging technology that will influence the future of composite hull construction. It is already having an impact on prototyping, early design and development, and application of tools. Small, highly complex parts will follow the path created by 3-D printed metal parts. Bigger applications are sure to follow. Nanotechnology can also be developed as a viable stand-alone technology or perhaps integrated with 3-D printing. Extraordinary innovations are certainly on the horizon.

Passenger plane air conditioning system. The air conditioning system is supplied with air processed through two packages that regulate air flow and temperature as needed. The air conditioning system of the aircraft mixes warm and cold air to achieve the desired temperature. Aircraft types differ, but the principles and operation of the air conditioning system are the same in all aircraft. The primary parts of the air conditioning system have the following functions [44]: Control the flow of fresh air for air pressure and ventilation, Control the temperature of the flight area and passenger cabin, Recirculate the air in the cabin for ventilation. The air conditioning package enables the cooling of the exhaust air for the air conditioning of the flight and the passenger compartment. The air conditioning system is based on the Air Cycle Machine (ACM) cooling device, which is mainly used in turbine-powered aircraft. An air cycle system is often referred to as an air conditioner package or package. Typically, air conditioning packages are located to the left and right of the wing to the body near the main landing gear of the aircraft. The packs remove excess heat from the bleed air entering the packs from the aircraft's bleed system and bring air into the cabin at the desired temperature. The main components of the air conditioner are: Package valve (flow control and shut-off valve (FCSOV) controls the flow of exhaust air to the package), Primary heat exchanger. Cools engine/exhaust air from APU, Secondary heat exchanger. Removes heat of compression of ACM, Air Cycle Machine (ACM). ACM consisting of a compressor and turbine mounted on the same shaft, Condenser. The condenser uses the cooling exhaust air from the turbine to cool the inlet exhaust air to a temperature low enough (below the dew point) for moisture condensation to occur, Reheater (the reheater is used to raise the temperature of the air before it reaches the turbine inlet to evaporate the remaining droplets of water to protect the turbine), Water extractor (the water extractor removes water from the moisture produced by the condenser), Water spray nozzle. It is located at the entrance to the secondary heat exchanger and sprays water discharged from the water vacuum on it to increase the cooling capacity of the heat exchanger. Air supply for batch operation. The air cycle air conditioning system is supplied with air using the aircraft's pneumatic system. On the other hand, the pneumatic system is supplied by air vents on each engine compressor compartment or from the APU pneumatic supply. Bleed air from the pneumatic manifold is directed to the primary Packs heat exchanger. Operation of the air conditioner package. When the bleed air passes through the primary heat exchanger, the air removes some of the heat. This partially cooled exhaust air goes to the compressor section of the air cycle machine. The compressor section increases the pressure and temperature of the partially cold exhaust air. This compressed air goes to the secondary heat exchanger. Air from the ACM compressor outlet flows through the secondary heat exchanger. The reciprocating flow of ram air removes heat before the air enters the ACM turbine inlet. When the aircraft is on the ground, the ACM rotor fan creates a low pressure zone. In this way, the air is extracted through the heat exchangers and through the plenum to the impeller fan. Then, the rotor fan sends air through the diffuser and out the air outlet. When the aircraft is in flight, air pressure flows down the plenum and exits the fan bypass valve. Discharge air leaving the secondary heat exchanger passes through the hot side of the preheater. The air that first passes through the preheater is cooled by cooler air from the condenser. The temperature of the exhaust air rises as it passes through the preheater a second time and enters the turbine section of the air cycler. The preheater increases the temperature of the air in the air conditioner package before it enters the turbine of the air cycler. This increases the efficiency of the turbine. The air cycle machine (ACM) reduces the temperature of the air by expanding it through the turbine. The air leaving the turbine passes through the cold side of the condenser. The air flow from the condenser passes through the water vacuum cleaner. The condenser reduces the temperature of the air in the air conditioning package below the dew point, changing the water vapor into a liquid. Water vacuum cleaners remove moisture. This moisture goes into the water spray nozzle. A water spray nozzle sprays water into the air channel. This cools the air stream of the frame by evaporation and increases the cooling efficiency. Air distribution in the airplane cabin. The main air distribution system in the aircraft receives air from the air conditioning package, conditioned air on the ground and the recirculation system. A mixture manifold collects and mixes air from any combination of sources. The flight compartment receives conditioned air from the left package and mixed manifold. The flight compartment receives conditioned air from the right pack if the left pack is inoperative. The passenger air conditioning distribution receives air from the mixed manifold. The air passes through the vertical ducts and along the side walls to the overhead distribution duct.

Air recirculation in the cabin. The recirculation system uses two fans to move air from the passenger compartment to the mixture manifold. This system reduces the amount of air that the packages need to supply. This part of the air conditioning system recycles approximately 50% of the cabin air for ventilation. This reduces the amount of fresh air from the pneumatic ventilation system. The left and right fans and recirculation filters are the primary components. Modern airplanes use high-efficiency air filters that capture more than 99.9% of the air in the filtered air. They are similar to those used in hospital operating rooms.

Temperature control. The temperature control system has overheating switches in the supply channels. Overheat switches provide an indication and stop operation when the temperature is outside the limit. Passenger cabin and duct temperature bulbs that monitor and send temperature data to the cabin control panel. Air temperatures are displayed on the temperature control panel. Air from the pneumatic system adds heat to the zone that needs warmer air. This warm bypassed air must be mixed with the cold air produced by the air cycle system, so that the air delivered to the cabin has a comfortable temperature. This is achieved with a mixing valve. The temperature controller compares the actual temperature signals received from the various sensors with the desired temperature input. The output signal is sent to the valve in the air cycle air conditioning system. This valve has different names, depending on the aircraft manufacturer and the design of the environmental control system (mixing valve, temperature control valve, air intake valve, for example). It mixes the warm exhaust air that has bypassed the cooling process of the air cycle with the cold air it produces (Figures 99,100).

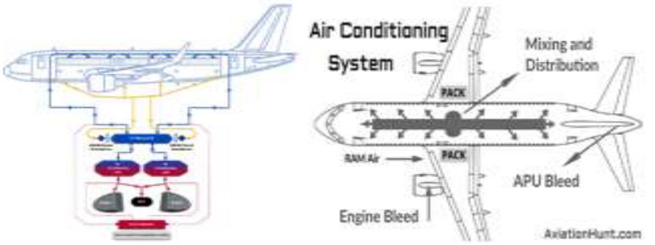


Figure 99. Left: Schematic representation of the air delivery system in the aircraft. Right: The air conditioning system in the plane. Pattern geometry: (a) and (c) single yarn patterns. (b) and (d) samples of SEN.
Source: https://www.aviationhunt.com/aircraft-air-conditioning-system/, Accessed: July 28, 2023.

Figure 100. Air purification in the aircraft cabin (HEPA filters, since the 1990s)
Source:https://www.aircraftinteriorsinternational.com/industry-opinion/how-hepa-filters-have-been-purifying-aircraft-cabin-air-since-the-1990s.html#prettyPhoto/0/, Accessed: July 28, 2023.

Interior decoration of a passenger plane. The airline company Emirates has shown its newest passenger plane that will soon start servicing Logan Airport. The massive A380 is so big that Massport spent $30 million renovating Terminal E to accommodate it. Emirates operates more Airbus A380 aircraft, the largest passenger aircraft in the world, than any other airline [45]. The A380 can carry up to 853 passengers (depending on seat configuration), with its massive two-deck layout. It provides Emirates with ample space not only for seats, but also for amenities such as showers and lounges. In addition, the air in the aircraft cabin is recycled every two minutes, while advanced lighting systems provide mood and ambient features. Emirates economy seats are 46 cm wide and up to 86 cm high. The wingspan of the massive aircraft, which can weigh as much as 575 tons, is about 80 meters. Emirates recently introduced economy blankets on its A380 aircraft made entirely from recycled plastic bottles, alongside economy comfort kits with eye masks, earplugs, toothbrush, toothpaste and socks. The layout of the double-decker aircraft of airlines such as Emirates, Etihad and Korean Air can incorporate lounges. The Emirates onboard lounge, which is reserved for first and business class passengers, even has a bartender. Emirates Business Class on the A380 has split-flat seats that can be laid flat (Figure 101). Includes sliding doors with electronic control for privacy. The seat pitch in business class is 112 cm, while the seat width ranges from 47 to 53 cm. First class passengers will also find a dressing table with drawers and an illuminated mirror. Also, personal wardrobe, personal mini-bar and in-flight dining table. In the first class cabin there are two shower-baths with walnut and marble interior. Emirates was the first airline to purchase the A380. It is also operated by Singapore Airlines (SIA1, SINGY), Qantas, Air France, Lufthansa (LHAB, LHA), Korean Air, China Southern Airlines (ZNH), Malaysia Airlines, Thai Airways International, British Airways, Asiana Airlines, Qatar Airways and Etihad Airways [45].

Figure 101. The largest passenger plane in the world (A380)
Source: https://www.aerotime.aero/22921-inside-worlds-largest-passenger-plane, Accessed: July 29, 2023.

The President of the United States must be willing to travel anywhere in the world. Modern presidents have access to a variety of transportation options—including flying on Air Force One. Technically, Air Force One is used to describe any aircraft carrying the president—but since the mid-20th century, it's been common practice to refer to specific aircraft equipped to transport the commander-in-chief. Today, the name refers to one of two highly customized Boeing 747-200B series aircraft carrying tail codes 28000 and 29000. The aircraft's aviation designation is VC-25A. Air Force One is one of the most recognizable symbols of the president, evoking countless references not only in American culture, but around the world. Decorated with the words "United States of America", the American flag and the seal of the President of the USA, its presence is undeniable wherever it is seen in the world. Capable of mid-air refueling, Air Force One has unlimited range and can carry the president wherever he needs to travel. Onboard electronics are hardened to shield against electromagnetic pulses, and Air Force One is equipped with advanced secure communications equipment, allowing the aircraft to function as a mobile command center in the event of an attack on the US. Inside, the President and his entourage enjoy 4,000 m2 of floor space on three levels, including the expansive Presidential Suite, which has a large office, toilet and conference room. Air Force One includes a medical suite that can function as an operating room, with a doctor on board at all times. The plane's two food preparation galleries can feed 100 people at once. Air Force One has accommodations for those accompanying the president, including senior advisers, Secret Service officers, traveling press and other guests. Several cargo planes usually fly ahead of Air Force One to provide the president with the services he needs in remote locations. Air Force One is maintained and operated by the Presidential Airlift Group, part of the White House Military Office (Figure 102). The Airlift Group was founded in 1944 as the Presidential Pilot Office at the direction of President Franklin Delano Roosevelt (1882-1945). For the next 15 years, various elite-powered aircraft served the President until President Dwight David „Ike“ Eisenhower (1890-1969) flew to Europe on a Boeing 707 Stratoliner, VC-137A, in

August 1959. In 1962, President John Fitzgerald Kennedy (1917-1963) became the first president to fly in a jet specially built for presidential use - a modified Boeing 707. Several more jets were used over the years, and the first of the current aircraft was delivered in 1990. year, during the administration of President George Herbert Walker Bush (1924-2018).

Figure 102. Air Force One (Plane of the President of the USA)
Source: https://www.youtube.com/watch?v=NvyCqgrzOYc, Accessed: July 29, 2023.

Helicopter. A helicopter is a type of aircraft (rotorcraft or rotary) in which lift and thrust are provided by horizontally rotating rotors (on a vertical axis). This allows the helicopter to take off and land vertically, hover and fly forward, backward and sideways. These attributes enable the use of helicopters in congested or isolated areas where fixed-wing aircraft and many forms of VTOL (vertical take-off and landing) aircraft cannot operate [46] (Figure 103). Due to the operational characteristics of the helicopter - its ability to take off and land vertically, and to hover for long periods of time, as well as the ability to control the aircraft in conditions of low flight speed - it was chosen to perform tasks that were previously not possible with other aircraft, or required a lot of time or work on the land. Today, helicopter uses include, but are not limited to, transportation of people and cargo, military use, construction, firefighting, search and rescue, tourism, medical transportation, law enforcement, agriculture, news and media, and aerial observation. A helicopter used to transport cargo attached to long cables or slings is called a crane. Aerial cranes are used to place heavy equipment, such as radio transmission towers and large air conditioners, on top of tall buildings or when the object must be lifted in a remote area, such as a radio tower erected on top of a hill or mountain. Helicopters are used as aerial cranes in the logging industry to lift trees from terrain where vehicles cannot travel and where environmental concerns prohibit road construction. These operations are called longlines because of the long, single line used to transport cargo.

Figure 103. Left: Modern helicopter Airbus H130 (pilot and two passengers). In the middle: CH-47F Chinook transport helicopter (USA). Right: Combat helicopter AH-64 Apache (USA)
Source: https://www.militarytoday.com/helicopters/top_10_transport_helicopters.htm, Accessed: July 29, 2023.

The largest single non-combat helicopter operation in history was the disaster management operation following the 1986 Chernobyl nuclear disaster. Hundreds of pilots were involved in air and observation missions, making dozens of flights a day for several months.

„Helitack“ is the use of helicopters to fight wildland fires. Helicopters are used for aerial firefighting (water bombing) and can be equipped with water tanks. Heliobuckets, like the Bambi bucket, are usually filled by submerging the bucket in lakes, rivers, reservoirs or portable tanks. Tanks installed in helicopters are filled from a hose while the helicopter is on the ground, or water is drawn from a lake or reservoir through a suspended snorkel while the helicopter is hovering over the water source. Helitack helicopters are also used to deliver firefighters descending into inaccessible areas and to supply firefighters. Common firefighting helicopters include variants of the Bell 205 and the Erickson S-64 Aircrane helitanker. Although most early designs used more than one main rotor, the configuration of a single main rotor (monocopter) accompanied by a vertical anti-torque tail rotor became the most common helicopter configuration. Twin-rotor helicopters (bicopters), in tandem or cross-rotor configurations, are also used due to their greater payload than single-rotor designs. Today, coaxial rotor helicopters, tiltrotor aircraft and complex helicopters are flying. Four-cylinder helicopters (quadcopters) were introduced as early as 1907 in France, and other types of multicopters were developed for specialized applications, such as unmanned aerial vehicles. The English word 'helicopter' is adapted from the French word 'hélicopét', coined by Gustave Ponton d'Amécourt in 1861, and derived from the Greek words ἕλιξ – helix = spiral, vortex and πτερόν - pteron = wing). The rotor system is the rotating part of the helicopter that generates lift. It can be mounted horizontally, like the main rotors, providing vertical lift, or it can be mounted vertically, like a tail rotor, to provide horizontal thrust to oppose the torque from the main rotors. The rotor consists of a mast, a head and rotor blades. The mast is a cylindrical metal shaft that extends upward from the gearbox. At the top of the mast is where the rotor blades are attached, called the head. Main rotor systems are classified according to how the rotor blades are attached and move relative to the head. There are three basic types: hingeless, fully hinged and sliding; some modern rotor systems use a combination of these. Most helicopters have a single main rotor, but the torque generated by its aerodynamic drag must be countered by an opposing torque. The design Igor Ivanovich Sikorsky (Íгорь Ивáнович Sikońskij, 1889-1972) decided on for his VS-300 was a smaller tail rotor. The tail rotor pushes or pulls the tail to counteract the effect of the torque, and this has become the most common configuration for helicopter design, usually at the end of the tail boom [47]. Some helicopters use other anti-torque controls instead of a tail rotor, such as duct fans (called Fenestron or FANTAIL) and NOTAR. NOTAR provides torque similar to the way a wing develops lift by using the Coandă effect on the tail lever. The use of two or more horizontal rotors rotating in opposite directions is another configuration used to counteract the effects of torque on the aircraft without relying on the tail rotor to counter the torque. This allows power to be normally diverted to fully apply the tail rotor to the main rotors, increasing the aircraft's energy efficiency and lift capacity. There are several common configurations that use the counter-rotating effect to the advantage of rotorcraft: Tandem rotors are two rotating rotors with one mounted behind the other, Transverse rotors are a pair of rotating rotors mounted transversely at the ends of fixed wings or support structures. Now used on tiltrotors, some early model helicopters used them, Coaxial rotors are two rotating rotors placed one above the other with the same axis, Interlocking rotors are two counter-rotating rotors placed close to each other at enough of an angle that the rotors intertwine across the top of the aircraft without collision, Quadcopters have four rotors often with parallel axes (sometimes rotating in the same direction with tilted axes) commonly used on model airplanes. Jet tip designs allow the rotor to push through the air and avoid torque generation. The number, size and type of engine(s) used on a helicopter determine the size, function and capabilities of that helicopter. The earliest helicopter engines were simple mechanical devices, such as rubber bands or spindles, which relegated the size of helicopters to toys and small models. Half a century before the first airplane flight, steam engines were used to advance the understanding of helicopter aerodynamics, but limited power did not permit manned flight. The introduction of the internal combustion engine at the end of the 19th century became a turning point for the development of helicopters as engines that were powerful enough to enable helicopters capable of lifting people began to be developed and produced. Early helicopter designs used custom engines or rotary engines designed for aircraft, but these were soon replaced by more powerful automobile engines and radial engines. The single most limiting factor in helicopter development during the first half of the 20th century was that the amount of power produced by the engine was unable to overcome the weight of the engine in vertical flight. 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 power unit 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 for use in helicopters, which began with the Kaman K-225 in December 1951, finally gave helicopters a high-powered, light-weight engine. Turboshafts are also more reliable than reciprocating engines, especially when producing the sustained high levels of power required by a helicopter. The turboshaft engine was able to be adapted to the size of the helicopter being designed, so that all but the lightest helicopter models today are powered by turbine engines. Special jet engines developed to drive rotors from the rotor tips are called tip jets. Tip jets driven by a remote compressor are called cold tip jets, while those powered by exhaust gases are called hot tip jets. An example of a cold jet helicopter is the Sud-Ouest Djinn, and an example of a hot tip jet helicopter is the YH-32 Hornet. Some radio-controlled helicopters and smaller, helicopter-type unmanned aerial vehicles use electric motors or motorcycle engines. Radio-controlled helicopters can also have piston engines that use fuels other than gasoline, such as nitromethane. Some turbine engines commonly used in helicopters can also use biodiesel instead of jet fuel. There are also human powered helicopters.

Historical development of helicopters. The earliest references to vertical flight came from China. From around 400 BC. Chinese children played with flying bamboo toys [48]. This bamboo helicopter turns by rolling a stick attached to the rotor. The spinning creates lift, and the toy flies when released (Figure 104).

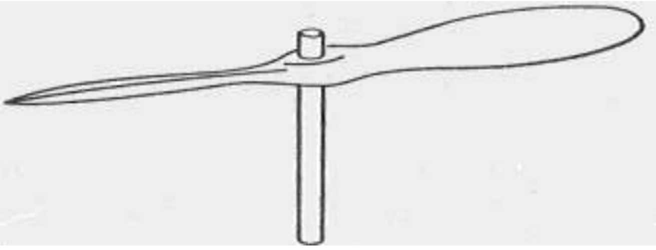


Figure 104. Chinese top

Source: https://aerospaceweb.org/design/helicopter/history.shtml, Accessed: July 29, 2023

.Designs similar to Chinese toy helicopters appeared in some Renaissance paintings and other works. In the 18th and early 19th centuries, Western scientists developed flying machines based on a Chinese toy. In the early 1480s, when the Italian Leonardo da Vinci (1452-1519) created a design for a machine that could be described as an 'aerial screw', progress towards vertical flight was noted (Figure 105). His notes suggested that he was building small flying models, but there was no indication that any provision would prevent the rotor from rotating the craft. As scientific knowledge increased and became more accepted, people continued to pursue the idea of vertical flight.

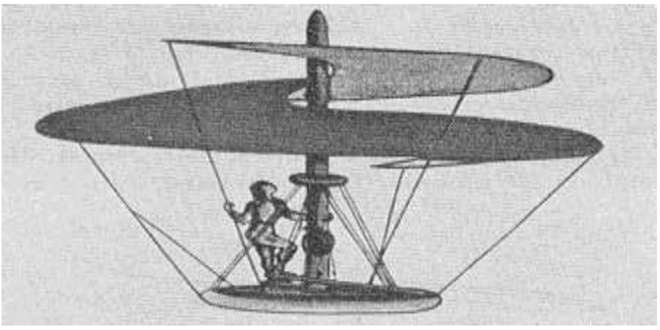


Figure 105. Leonardo da Vinci's helicopter, 15th century

Source: https://aerospaceweb.org/design/helicopter/history.shtml, Accessed: July 29, 2023.

In July 1754, Mikhail Vasilyevich Lomonosov (Михаил Васильевич Lomonosov, 1711-1765) developed a small coaxial model modeled after the Chinese tip, but powered by a coiled spring device and showed it to the Russian Academy of Sciences [49]. It was powered by a spring, and was proposed as a method for raising meteorological instruments (Figure 106).

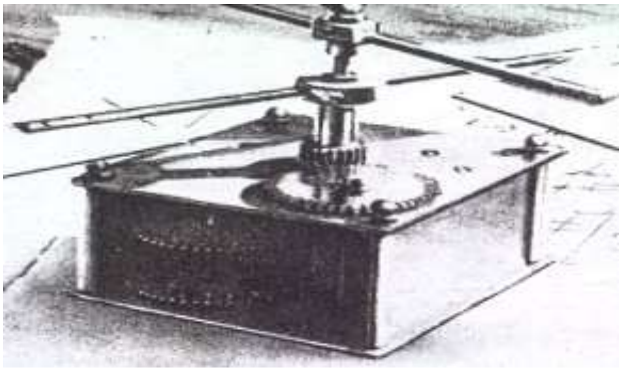


Figure 106. "Aerodynamic" by Mikhail Vasilyevich Lomonosov (1754)

Source: http://www.aviastar.org/helicopters_eng/lomonosov.php, Accessed: July 29, 2023.

In 1783, Christian de Launoy and his mechanic Bienvenu used a coaxial version of the Chinese tip in a model consisting of a counter-rotating Turkish flight feather as a rotor blade, and in 1784 demonstrated this to the French Academy of Sciences [50] (Figure 107, left). Sir George Cayley, influenced by his childhood fascination with the Chinese flying tip, developed a feather model, similar to that of Launoy and Bienvenu, but powered by rubber bands (Figure 107, right). By the end of the century, he had advanced the use of sheet tin for rotor blades and power springs. His records of his experiments and models would become influential to future aviation pioneers. Alphonse Pénaud (1850-1880) would later develop toy helicopters with a coaxial rotor model in 1870, also powered by rubber bands. One of these toys, given to them by their father, would inspire the Wright brothers to realize their dream of flight.

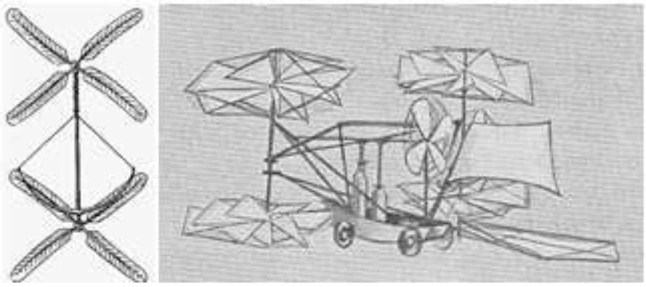


Figure 107. Left: "Helicopter" by Christian de Launoy and his mechanic Bienven (1783). Right: "Helicopter" by Sir George Cayley (1796)
Source: https://aerospaceweb.org/design/helicopter/history.shtml, Accessed: July 29, 2023.

In 1861, the word 'helicopter' was coined by Gustave de Ponton d'Amécourt (1825-1888), a French inventor who demonstrated a small steam-powered model (Figure 108, left). Although hailed as an innovative use of a new metal, aluminum, the model never got off the ground. D'Amecourt's linguistic contribution would survive to eventually describe the vertical flight he envisioned. Steam power was also popular with other inventors. In 1878, the unmanned vehicle of the Italian Enrico Forlanini (1848-1930), also powered by a steam engine, rose to a height of 12 meters, where it hovered for about 20 seconds after vertical takeoff (Figure 108, right). Emmanuel Dieuaide's steam-powered design had rotating rotors driven through a hose from a boiler on the ground (Figure 109, left). In 1887, a Parisian inventor, Gustave Trouvé (1839-1902), built and operated an electric model helicopter (Figure 109, right).

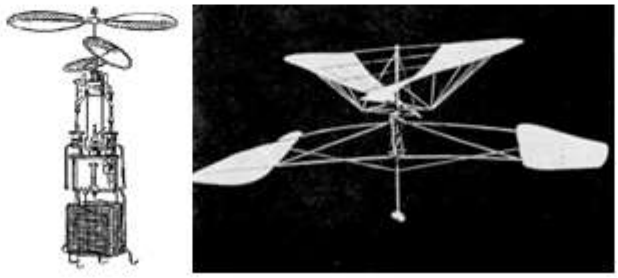


Figure 108. Left: Gustave de Ponton d'Amécourt's helicopter (1865). Right: Enrico Forlanini's helicopter (1878)
Source:http://www.century-of-flight.freeola.com/Aviation%20history/helicopter%20history/Early%20Helicopter%20Technology.htm
Accessed: July 29, 2023.

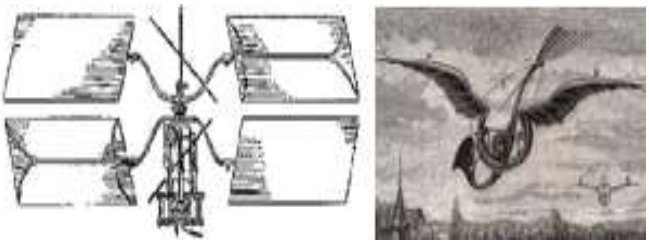


Figure 109. Left: Emmanuel Dieuaide's helicopter design. Right: Gustave Trouvé's electric helicopter (1881)
Source:http://www.century-of-flight.freeola.com/Aviation%20history/helicopter%20history/Early%20Helicopter%20Technology.htm Accessed: July 29, 2023.

In July 1901, the first helicopter flight of Hermann Ganswindt (1856-1934) took place in Berlin-Schöneberg; this was probably the first powered heavier-than-air flight carrying humans. A film covering the event was made by Max Skladanowsky (1863-1939) but remains lost. In 1885, James Gordon Bennett, Jr. (1841-1918) gave Thomas Alva Edison (1847-1931) $1,000 (the equivalent of $29,000 today) to conduct experiments in the development of flight. Edison built a helicopter and used stock market paper to create a cannon gun, which he used to try to start an internal combustion engine (Figure 110, left). The helicopter was damaged by the explosion, and one of its workers was badly burned. Edison reported that based on his experiments, an engine with a ratio of three to four kilograms per horsepower produced would be required. Ján Bahýľ (1856-1916), a Slovak inventor, adapted an internal combustion engine to power his model helicopter that reached a height of 4.3 meters in 1901 (Figure 110, right). On May 5, 1905, his helicopter reached a height of 4 meters and flew over 1500 meters [51]. In 1908, Edison patented his own design of a gasoline-powered helicopter with boxes attached to the mast by cables for the rotor, but it never flew.

Figure 110. Left: Thomas Alva Edison's helicopter (1880). Right: Ján Bahýľ's helicopter
Source: https://www.wired.com/2007/12/gallery-helicopter/, Accessed: July 29, 2023.

Spanish aeronautical engineer and pilot Juan de la Cierva (1895-1936) invented the autogyro in the early 1920s, becoming the first practical rotorcraft (Figure 111). In 1928, de la Cierva successfully flew across the English Channel from London to Paris. In 1934, the autogyro became the first rotorcraft to successfully take off and land on the deck of a ship [52]. In the same year, the autogyro was used by the Spanish military during the rebellion in Asturias, making it the first military deployment of a rotocraft. Autogyros were also employed in New Jersey and Pennsylvania to deliver mail and newspapers before the invention of helicopters. Although it lacks true vertical flight capabilities, the autogyro work forms the basis for helicopter analysis.

Figure 111. Autogiro Juan de la Cierva (1928)
Source: https://www.bbvaopenmind.com/en/technology/visionaries/juan-de-la-cierva-and-the-autogyros-invention/, Accessed: July 29, 2023.

Heinrich Focke (1890-1979) of Focke-Wulf bought a license from the Cierva Autogiro Company. In return, Cierva Autogiro was granted a cross-license to build Focke-Achgelis helicopters [53]. Focke designed the world's first practical twin-rotor transverse helicopter, the Focke-Wulf Fw 61, which first flew in June 1936. The Fw 61 flew above 2,400 m at a speed of 190 km/h (Figure 112).

Figure 112. Helicopter Focke-Wulf Fw 61 Heinrich Focke (1936)
Source: http://www.helistart.com/helicopters/Focke-Wulf/Fw-61, Accessed: July 29, 2023.

Construction assembly of the helicopter. Sikorsky[2] and several of his contemporaries brought the technical rigor to the field that finally made vertical flight safe, practical and reliable. As Igor Ivanovich Sikorsky continued to refine his helicopter designs, he worked out the basic requirements that any such machine needed to have in order to be successful, including: A suitable engine with a high power-to-weight ratio, A mechanism to counteract the effects of rotor torque, Suitable controls to the aircraft could be operated reliably and without catastrophic failures, Lightweight structural frame, Means to reduce vibrations. Many of the basic parts seen on the modern helicopter arose from the need to meet one or more of these basic requirements (Figure 113). Main rotor blade. The main rotor blade performs the same function as an airplane's wings, providing lift as the blades rotate—lift is one of the critical aerodynamic forces that keep an airplane aloft. The pilot can affect lift by changing the rotor's revolutions per minute (rpm) or its angle of attack, which refers to the angle of the rotating wing relative to the oncoming wind.

Stabilizer. The stabilizer bar is located above and across the main rotor blade. Its weight and rotation dampen unwanted vibrations in the main rotor, helping to stabilize the craft in all flight conditions. Arthur Young, designer of the Bell 47 helicopter, is credited with inventing the stabilizer bar.

Rotor mast. Also known as the rotor shaft, the mast connects the transmission to the rotor assembly. The mast rotates the top plate and blades.

Transfer. Just like in a motor vehicle, the helicopter transmission transmits power from the engine to the main and tail rotors. The main gearbox reduces the speed of the main rotor so that it does not turn as fast as the motor shaft. The second gearbox does the same for the tail rotor, although the tail rotor, being much smaller, can spin faster than the main rotor.
Engine. The engine generates power for the aircraft. Early helicopters relied on reciprocating gasoline engines, but modern helicopters use gas turbine engines like those found in commercial aircraft.

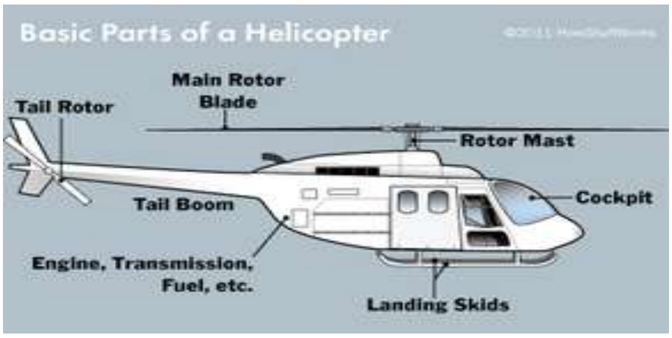


Figure 113. Basic parts of a helicopter
Source: https://science.howstuffworks.com/transport/flight/modern/helicopter3.htm, Accessed: July 28, 2023.

The materialization of the envelope of a typical helicopter is shown in Figures 114-118. The primary building materials are graphite epoxy, Kevlar epoxy and Nomex and aluminum honeycomb. The graphite epoxy came in unidirectional and woven forms and used the Narmco 5240 low-flow resin system. The low-flow resin system eliminated the need for the cumbersome flow control agents associated with earlier low-viscosity resin systems. Other materials include Rohacell foam in the rear pillars, ballistic foam to support the fuel tank and aluminum mesh for lightning protection. The weight of the frame was 82% composite material. Metal components were limited to fire-resistant engine decks, small parts, brackets and hardware [54]. Figure 114 shows different conductive coating systems that were evaluated for electrical properties. Conductive coatings are applied to the outer skin to protect against lightning strikes.

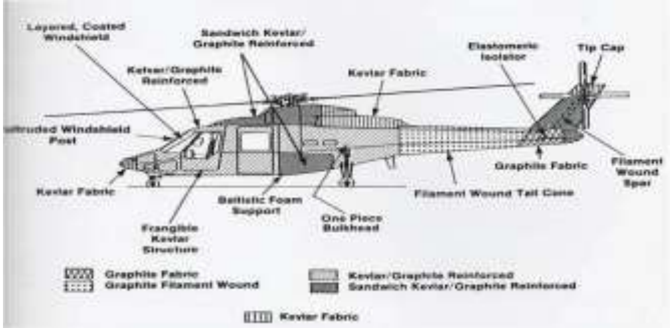


Figure 114. Materials for the frame (Sikorsky S-75 ACAP Helicopter)
Source:https://sikorskyarchives.com/home/sikorsky-product-history/helicopter-innovation-era/sikorsky-s-75-advanced-composite-airframe-program-acap/, Accessed: July 29, 2023.

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[2] Sikorsky Aircraft is an American aircraft manufacturer headquartered in Stratford, Connecticut. It was founded (1923) by the famous aviator Igor Ivanovič Sikorsky (1889-1972) and was among the first companies to produce helicopters for civil and military use. Formerly owned by United Technologies Corporation (UTC), in November 2015 Sikorsky was sold to Lockheed Martin.

Figure 115. Left: S-75 in final assembly. Right: The lower skin of an S-75 helicopter

Source:https://sikorskyarchives.com/home/sikorsky-product-history/helicopter-innovation-era/sikorsky-s-75-advanced-composite-airframe-program-acap/, Accessed: July 29, 2023.

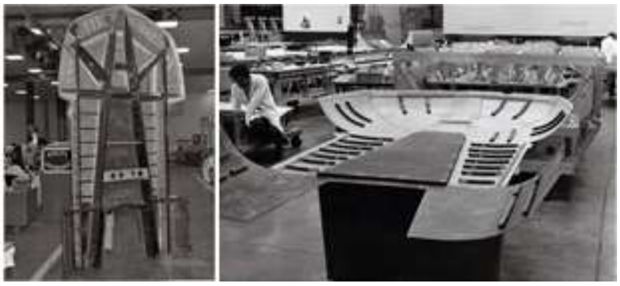

Figure 116. Left: S-75 helicopter roof structure assembly. Right: S-75 helicopter cabin roof skin

Source:https://sikorskyarchives.com/home/sikorsky-product-history/helicopter-innovation-era/sikorsky-s-75-advanced-composite-airframe-program-acap/, Accessed: July 29, 2023.

Figure 117. Left: Pre-hung cargo door system. Middle: Left: One-piece tail tip structure. Right: Filament winding of the skin on the tail

Source:https://sikorskyarchives.com/home/sikorsky-product-history/helicopter-innovation-era/sikorsky-s-75-advanced-composite-airframe-program-acap/, Accessed: July 29, 2023.

Figure 118. Interiors of various types of helicopters

Source: https://edition.cnn.com/travel/article/private-helicopters/index.html, Accessed: July 29, 2023.

Unmanned aerial vehicles. An unmanned aerial vehicle (UAV) is an aircraft without human pilots, crew or passengers. Unmanned aircraft are an integral part of the Unmanned Aircraft System (UAS), which additionally includes a controller on the ground and a communication system with the unmanned aircraft. An unmanned aircraft can fly under the remote control of a human operator, as a Remotely-Piloted Aircraft (RPA), or with different degrees of autonomy, such as the assistance of an autopilot, to fully autonomous aircraft that do not have the possibility of human intervention. Drones were originally developed during the twentieth century for military missions too dangerous for humans. As control technologies improved and costs fell, their use expanded into many non-military applications. These include aerial photography, product delivery, agriculture, policing, infrastructure inspections, science, smuggling and drone racing. The term unmanned aerial vehicle has been used since the early days of aviation, applying to remote-controlled target aircraft used for practice firing from battleship guns, such as the Fairey Queen of the 1920s and the de Havilland Queen Bee of the 1930s. Later examples included the Airspeed Queen Wasp and the Miles Queen Martinet, before the eventual replacement by the GAF Jindivik. The term remains in common use. An unmanned aerial vehicle (UAV) is defined as „a powered aircraft that does not carry a human operator, uses aerodynamic forces to lift the vehicle, can fly autonomously or be remotely piloted, can be expendable or recovery, and can carry a lethal or non-lethal payload“ [55]. UAV is a term usually applied to military cases. But missiles with warheads are not considered unmanned aerial vehicles because the vehicle itself is a munition. The term Unmanned Aircraft System (UAS) was adopted by the United States Department of Defense (DoD) and the Federal Aviation Administration (FAA) in 2005 under their Unmanned Aircraft Systems Roadmap 2005–2030. The International Civil Aviation Organization (ICAO) and the British Civil Aviation Authority have adopted this term, which is also used in the European Union's Single European Sky ATM Research Joint Undertaking (SESAR) 2020 air traffic management work plan. This term emphasizes the importance of elements other than the aircraft. It includes elements such as ground control stations, data links and other auxiliary equipment. A similar term is Unmanned-Aircraft Vehicle System (UAVS), Remotely Piloted Aerial Vehicle (RPAV), Remotely Piloted Aircraft System (RPAS). Many similar terms are in use: 'unoccupied' and 'uninhabited' are occasionally used as gender-neutral alternatives to 'unmanned'. In addition to software, autonomous drones use a host of advanced technologies that enable them to carry out their missions without human intervention, such as cloud computing, computer vision, artificial intelligence, machine learning, deep learning, and thermal sensors. Under new regulations that came into effect on June 1, 2019, the Canadian government adopted the term Remotely Piloted Aircraft System (RPAS) which means „a set of configurable elements consisting of a remotely piloted aircraft, its control station, command and control connections and all other system elements needed during the flight“ [56]. The relationship of unmanned aerial vehicles to remotely piloted aircraft models is not clear. UAVs may or may not include model aircraft. Some jurisdictions base their definition on size or weight; however, the US FAA defines any flying craft as an unmanned aerial vehicle regardless of size. For recreational purposes, an unmanned aerial vehicle is a model aircraft that has video, autonomous capabilities, or both. The earliest recorded use of an unmanned aircraft for warfare occurred in July 1849, serving as a balloon carrier (the forerunner of the aircraft carrier) in the first offensive use of air power in naval aviation. The Austrian forces besieging Venice tried to launch about 200 incendiary balloons into the besieged city. Balloons were launched mostly from land; however, some were also launched from the Austrian ship SMS Vulcano. At least one bomb fell in the city; however, due to a change in wind after launch, most of the balloons missed their target, and some returned via the Austrian lines and the launch ship Vulcano. Significant development of unmanned aerial vehicles began in the early 1900s, originally focused on providing practical training objectives for military personnel. The earliest attempt at an unmanned aerial vehicle was the „Aerial Target" designed (1916) by Archibald Montgomery Low (1888-1956) [57], (Figure 119). Low confirmed that Geoffrey de Havilland's monoplane was the one that flew under control using his radio system on March 21, 1917. Other British unmanned development followed during and after the First World War leading to a fleet of over 400 de Havilland 82 Queen Bee aerial targets entering service in 1935.

Figure 119. Aerial Target drone designed (1916) by Archibald Montgomery Low

Source: https://shvachko.net/?p=1378&lang=en, Accessed: July 29, 2023.

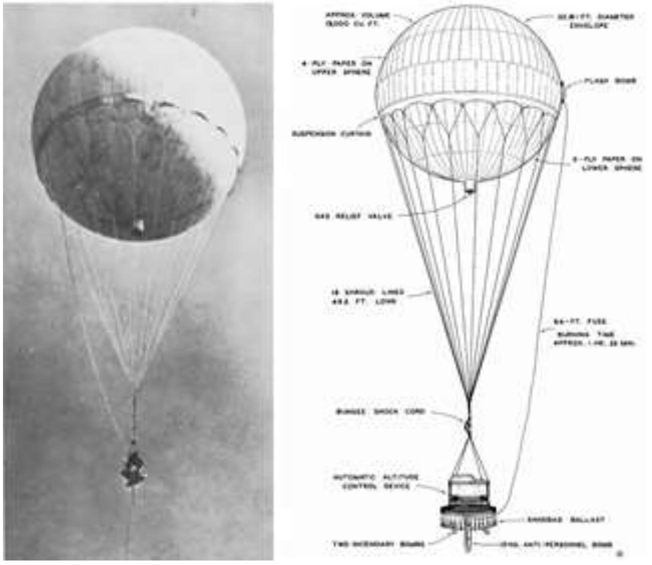

Figure 120. Left: Japanese Paper Bombing Balloon (A 37180C). Right: General arrangement of a Japanese paper balloon for bombing

Source: https://web.mst.edu/~rogersda/forensic_geology/Japenese%20vengenance%20bombs%20new.htm, Accessed: July 29, 2023.

Figure 121. Left: The Americans quickly inflated the Japanese balloon to inspect its components. This balloon was recovered intact near Alturas, California on January 10, 1945 (US Army photo, SC-226135). Right: A malfunctioning ballast release mechanism caused this balloon to land without dropping bombs near Tremonton, Utah, on February 23, 1945.

Source: https://time.com/6276685/japanese-balloon-bomb-history-world-war-ii/, Accessed: July 29, 2023.

Figure 122. Rusted hydrogen production tanks are all that remain of a former balloon launch (US Army photo, SC 284185)

The first measurable remotely controlled vehicle was developed (1935) by movie star and model airplane enthusiast, Reginald Denny [58] (Fig. 3.116).

Figure 123. Paul Whittier (left) and actor Reginald Denny prepare their RP-1 for flight in 1935 (Righter Family Archives)

Source: https://www.historynet.com/drones-hollywood-connection/?f, Accessed: July 29, 2023.

Modern drones. As applicable technologies matured and miniaturized in the 1980s and 1990s, interest in unmanned aerial vehicles grew within the upper echelons of the US military. In the 1990s, the US Department of Defense awarded the contract to AAI Corporation together with the Israeli company Malat. The US Navy purchased the AAI Pioneer unmanned aerial vehicle jointly developed by AAI and Malat [59]. Many of these drones served in the 1991 Gulf War. Unmanned aerial vehicles have demonstrated the possibility of cheaper, more capable combat machines, deployable without risk to the crew (Figure 124). The first generations primarily involved surveillance aircraft, but some carried armaments, such as the General Atomics MQ-1 Predator, which launched AGM-114 Hellfire air-to-surface missiles.

Figure 124. IAI/AAI RQ-2 Pioneer
Source: https://www.designation-systems.net/dusrm/app2/q-2.html, Accessed: July 29, 2023.

As of 2012, the United States Air Force (USAF) employed 7,494 unmanned aerial vehicles - nearly one in three USAF aircraft. The Central Intelligence Agency (CIA) also operated drones. By 2013, at least 50 countries were using drones. China, Iran, Israel, Pakistan, Turkey, for example, have designed and built their own varieties. The use of drones continued to increase. Due to their wide spread, there is no comprehensive list of UAV systems (Figure 125).

Figure 125. Turkish drone "Bayraktar" (left) and American drone "MQ-9 ripper" (right)
Source: https://www.hurriyetdailynews.com/no-damage-to-turkish-drone-maker-from-canadian-move-bayraktar-163954
Accessed: July 29, 2023.

The development of smart technologies and improved power systems have led to a parallel increase in the use of unmanned aerial vehicles for consumer and general aviation activities. As of 2021, quadcopter drones exemplify the widespread popularity of hobby radio-controlled aircraft and toys, however the use of drones in commercial and general aviation is limited by a lack of autonomy and new regulatory environments requiring line-of-sight contact. Position and movement sensors provide information about the state of the aircraft. Extroceptive sensors process external information such as measuring distance, while exproprioceptive sensors correlate internal and external states. Non-cooperative sensors can independently detect targets and are used to ensure separation and avoid collisions. Unmanned aerial vehicles (UAVs) include digital electronic speed controllers (which control engine revolutions) connected to motors and propellers, servomotors (mostly for airplanes and helicopters), weapons, payload actuators, LEDs, and speakers. The purpose of the flight beam is to collect data from sensors, control motors to ensure the stability of the unmanned aerial vehicle, and to facilitate ground control and communication during mission planning. UAVs are real-time systems that require rapid response to changing sensor data. This is why drones rely on single-board computers for their computing needs. Examples of such single-board computers include Raspberry Pis, Beagleboards, for example. Protected NavIO, PXFMini, for example, or designed from scratch, such as NuttX, preventive-RT Linux, Xenomai, Orocos-Robot operating system or DDS-ROS 2.0. The open source assembly for civil use includes: ArduCopter, CrazyFlie, KKMultiCopter, MultiWii, BaseFlight (forked from MultiWii), CleanFlight (forked from BaseFlight), BetaFlight (forked from CleanFlight), iNav (forked from CleanFlight), RaceFlight (forked from CleanFlight), OpenPilot, dRonin (forked from OpenPilot), LibrePilot (forked from OpenPilot), TauLabs (forked from OpenPilot), Paparazzi, PX4 autopilot (Figures 126,127).

Figure 126. Basic parts of an unmanned aerial vehicle
Source:https://www.researchgate.net/figure/Main-components-of-a-UAV-system-Even-though-reliable-autopilots-exist-the-main-selected_fig1_224057242, Accessed: July 29, 2023.

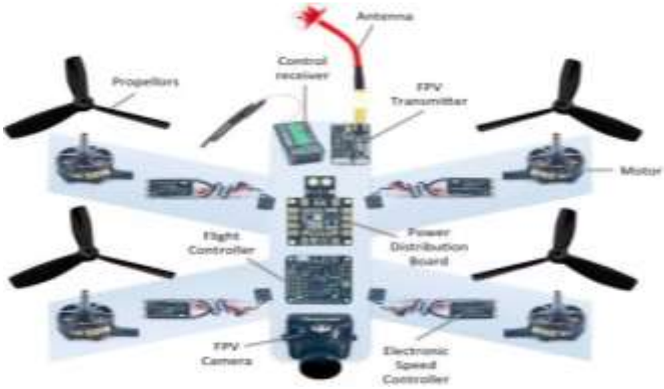

Figure 127. Basic parts of a typical drone
Source: https://frameworkfilms.net/facts/fpv-drone-build, Accessed: July 29, 2023.

Application of unmanned aerial vehicles in architecture and construction. The technological development of unmanned aerial vehicles is leading the construction industry to adapt these devices to save time and costs during construction work. It is known that some construction works, such as the management of river structures, bridge deterioration monitoring and inspection, have been carried out using unmanned aerial vehicles [60]. Drones simplify and improve the execution process. Today, unmanned aerial vehicles are used as „free cranes“ for the delivery of various building elements during the construction of architectural and construction structures. Efficient monitoring and review of activities in construction projects is also useful in terms of saving time and money for contractors (Figure 128). Unmanned aerial vehicles (drones) are perfect tools for recording terrain, landscapes (forests, lakes, cities...) for the purpose of monitoring important for scientific research, but also practical data collection related to planning and designing. Photographs taken with a drone have, in addition to specific aesthetic qualities, exceptional documentary value.

Figure 128. Left: UAV-based camera in river (lake) monitoring. Right: UAV-based camera for structural damage assessment

Source: https://www.researchgate.net/figure/Remote-water-sampling-15_fig1_340261420, Accessed: July 29, 2023.

Unmanned aerial vehicles have a wide range of applications that deviate from their currently more conventional military use. New applications have been found in the fields of medicine, agriculture, delivery and construction of architectural structures. Because drones are relatively small, can be equipped with cameras and can be controlled remotely, they can be used to visually inspect buildings in areas that are difficult to access or pose a risk to human health and safety. Back in June 2014, an abandoned house in Camden, New Jersey, USA, was inspected using the architect's own drone. Architectural visualizations or architectural renderings of a construction project are important (sometimes crucial) in allowing others to see the properties of the proposed design. Drones equipped with cameras can be used to obtain actual aerial images of the project location, so that architectural visualization can be integrated. English architect Norman Foster organized a 'journey' (2016) of a drone through the interior of the Hearst Tower in New York, which he designed (2006). Once he got the permit, a drone equipped with professional-grade cameras flew inside the building. The video was published by Hearst Corporation [61] (Figure 129).

Figure 129. Architect Norman Foster at the Hearst Tower in New York uses a drone to film the interior of the building

Source: https://www.pagerpower.com/news/five-applications-of-drones-in-design-construction-real-estate/, Accessed: July 29, 2023.

The author of this work used photos taken by a drone in his book "My approach to designing mosques" (2017) [62], (Figures 130-133).

Figure 130. Left: Mosque in Tarcin (1989-2007). Right: Adil Bey Mosque in Sarajevo (1994-1999)

Source: Vladimir Obradovic (2017)

Figure 131. Mosque in Binjezevo near Hadzici (1989-2006)

Source: Vladimir Obradovic (2017)

Figure 132. Left: Islamic Center in Novi Travnik (2000-2015). Right: Kuwait Mosque in Sarajevo (2006)

Source: Vladimir Obradovic (2017)

Figure 133. Left: City mosque in Breza (2002-2017). Right: Mosque in the Rakitnica village on the Bjelašnica plateau (2008)

Source: Vladimir Obradovic (2017)

Realtors have already started using drones to 'capture' attractive images of houses and buildings they are trying to sell. There is also a very real possibility that videos will start to be used as well. First Person View (FPV) drone racing is a competition in which pilots fly drones equipped with cameras while wearing goggles that transmit live video from the drones so that they feel as if they are flying from inside the drone (Figure 134). The goal is to finish the complex race as quickly as possible and ahead of the other pilots in the heat. Drone racing started in Germany in 2011 with many amateur pilots gathering for semi-organized races in Karlsruhe. Competitions are held in stadiums around the world.

Figure 134. Drone racing

Source: https://seekdroneonline.wordpress.com/, Accessed: July 29, 2023.

All of these uses of drones are limited by commercial drone regulation, policy and licensing.

Hybrid Earth Air Architecture. Man looks at the sky admiring that world from the beginning, from the Earth he threatens changes in it, trying to understand and connect them with the environment and life on Earth. One of his latent desires was to fly, and to observe the Earth's surface from an aerial perspective so that, flying through the air, he would bypass the difficult physical obstacles imposed on him by the terrain configurations on the Earth's surface. There are many fantastic stories (myths) in history related to this human need (Figures 135-137). Some of them are the myth of Daedalus and his son Icarus and the myth of the flying carpet. These myths have inspired many artists (painting, sculpture, music, literature, animated films...) in creating their works. Some of the large number of paintings (from different historical periods) have as their theme the myth of Daedalus and Icarus (Figure 135).

Figure 135. Left: Carlo Saraceni (1580/1585-1620): The Fall of Icarus. In the middle: Giuseppe Cesari (1568-1640): Daedalus and Icarus. Right: Jacob Peter Gouwy: The Fall of Icarus
Source: https://www.flickr.com/photos/70125105@N06/10957702113, Accessed: July 29, 2023.
Source: https://www.bridgemanimages.com/en/cesari/daedalus-and-icarus-ceiling-painting/oil-on-canvas/asset/69593 Accessed: July 29, 2023.
Source: https://www.pinterest.com/pin/1061653312128169249/, Accessed: July 29, 2023.

Figure 136. Ethiopian fresco depicting the Queen of Sheba
Source: https://traveltoeat.com/wp-content/uploads/2012/11/wpid-Photo-Nov-25-2012-722-PM.jpg, Accessed: July 29, 2023.

Sl. 3.137. The magic flying carpet from The Fool and One Night (some of the many illustrations)
Source: https://nazmiyalantiquerugs.com/blog/magic-flying-carpet-rug-aladdin/, Accessed: July 29, 2023.

As architecture is the framework of life, it is simultaneously a reflection of the natural and social environment and a materialized image of man, both the man who uses it (its client) and the man (the architect) who creates it. Some architects have the need for their architecture to leave the observer with the impression that it is floating in the air, to impress with its construction and design. The architectural realizations presented here clearly demonstrate this. However, this kind of architecture cannot be characterized as Earth-Air Architecture, that is, architecture in the air (type EA according to the typology of the authors of this book), but as Earth-Ground-Air Architecture (type EGA). Namely, these architectural realizations, regardless of the fact that most of their physical structure is 'in the air', have supports on the ground, which is why they are identical to the usual architectural realizations of the EGA type of architecture. For this reason, the author named this architectural realization Hybrid Earth Air Architecture. A distinct cultural force in Ontario, OCADU's push to expand comes with growing national recognition of the creative industries' contribution to the modern Canadian economy. The decision to employ Alsop was based on significant results in the design of cultural buildings of lasting efficiency and attractiveness that also offered an iconic representation of the client's body as the school entered a new era. The Sharp Center for Design project unites the existing brick structures under the 'table', the park to the west and McCaul Street to the east (Figure 138). A view of the park was preserved for OCADU's neighbors across McCaul Street, who participated in the consultation process. The park will also benefit from the regeneration of the area and, once restored, will be home to contemporary sculpture and school events. In addition to teaching and administrative spaces, the project includes gallery spaces, design and research centers, salons and meeting rooms, special craft and metalwork workshops, and areas for design criticism. The faculty fulfills its aspirations to revive a neglected part of the city by inviting the public to visit the galleries and café areas in the new building. OCAD contributes to the recognizable design and revitalization of public areas of the city's neighborhoods, both indoor and outdoor [63]. A pure parallelepiped with two floors stands on a series of columns and the main communication core ('hidden' in the existing building) and seems to float in the air, especially at night.

Figure 138. Sharp Center for Design, Toronto, Canada, 2004 (architects: Alsop Architects)
Source: https://archello.com/project/the-sharp-centre, Accessed: July 29, 2023.

The idea of the minimalist construction of The Air Home is to create a sense of weightlessness of the architecture with a view of the ocean (Figure 139). The physical structure of the building is wedged in the rock and stands slightly in front of the cliff, evoking a sense of 'impossible architecture'. However, the building, which is placed on a vertical reinforced concrete wall and secured by a recycled concrete foundation, is absolutely balanced. The central wall occupies a small interior space and at the same time includes most of the engineering and communications, maximizing the view of the Atlantic Ocean [64]. Privacy is achieved with an integrated system of window curtains around the perimeter. The minimalist interior is an open concept of 48 m^2. There is only essential furniture in the cabin. The warm beige theme provides homey vibes and comfort regardless of the weather and ocean 'mood' outside. Functional zones - living room, kitchen, bedroom and bathroom - invisibly cling to each other. It is a combination of modern style with geometric shapes and lively design: straight lines, rounded sofa shapes, round lamps, straw boards as a wall surface, rough-hewn logs, ceramic decor, low dining chairs. All furniture is grounded to avoid overlapping the dramatic view. The privacy of the bathroom is preserved by using special glass with transparency adjustment. The project was developed as a holiday home for a surfer, who is no stranger to conflict with the powerful elements of nature - the air. As the archetype of this cabin, the architect Victoria Yakusha took an ancient lighthouse that stood steadfastly on the very edge of the land and marked a safe passage for ships.

Figure 139. The Air Home, Portugal, Atlantic Coast, 2020 (architects: YD / Yakusha Design)
Source:
https://www.visualatelier8.com/architecture/2020/6/yakusha-design-air-home, Accessed: July 29, 2023.

Poland Zalewski Architecture Group designed a walking balcony suspended in the middle of a dark courtyard in Gliwice, Poland (Figure 140). This is one of the ideas to change the sad courtyard, which is overlooked every day through the windows of the office on the 3rd floor. The path of the suspended corridor is winding, meandering, does not lead directly to the goal, surprises, relaxes, gives contact with nature. It bends freely and intertwines with itself - it enables a relaxing walk 'from office to office'. The longing for a bit of greenery led the architects to treat the road as a big pot. The architects filled it with grass that can grow as it pleases - after all, it's just a road. The dark courtyard - the well, which was the core of the problem - actually became the inspiration for the solutions. The method of assembly imposed itself. The supports - the walls of the houses - just had to come from all sides. The shading of the neighbors was reduced by reaching the very idea of the path - which, in addition to being winding, is also very narrow. It is therefore an 80 cm wide strip of greenery suspended in the air. From the bottom it appears even narrower due to the polished metal palate [65].

Figure 140. A walking balcony suspended in the middle of a dark courtyard, Gliwice, Poland, 2015 (architects: Zalewski Architecture Group)
Source:
https://www.urdesignmag.com/architecture/2015/02/16/zalewski-architecture-group-designed-a-path-suspended-in-the-air/
Accessed: July 29, 2023.

In Japan, houses were created capable of rising several centimeters above the ground in the event of an earthquake and remaining in such a position until the end of the earthquake (Figure 141). This technology was developed in the last decade - however, it only received attention in Japan after the devastating earthquake in 2011. The system, developed by the designers of Air Danshin Systems Inc., assumes the presence of a powerful air cushion that allows the house to float above the ground at the right time, if necessary. A sensitive sensor can detect the onset of seismic activity in advance. It gives a signal that activates the air compressor, and it takes a few seconds to fill the air with a special cushion between the house itself and the foundation. The thickness of such a pillow is only a few centimeters, but it is quite enough to reduce the damage from an earthquake many times over. After the earthquake, the house sits on a special frame around the perimeter of the basement. In Japan, about a hundred houses have already been built using the new technology.

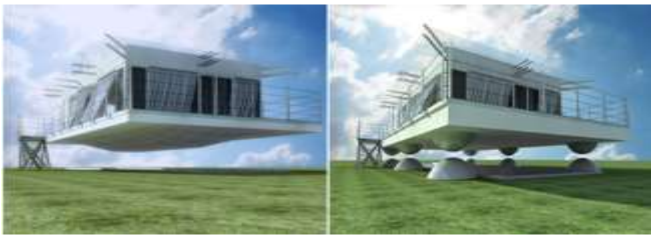

Figure 141. House on air cushions, Japan, 2011 (architects: Air Danshin Systems Inc.)
Source: https://stroyka.md/en/news/v-yaponii-sozdali-doma-paryashchie-v-vozdukhe, Accessed: July 29, 2023.

Hovering over the courtyard of Prague's DOX Center for Contemporary Art, 'Gulliver' is the latest addition to the city's burgeoning cultural scene (Figure 142). It was designed by the Czech architect Martin Rajniš. The physical structure of this object is in the form of an ellipsoid (which in its appearance is associated with a balloon-Zeppelin) built of a 42-meter-long steel-wood structure. The facility was opened in 2021 as a permanent new literary center. The architect used the shape of an airship as a symbolic reminder of a more optimistic time - of technological progress from the beginning of the 20th century and the artistic avant-garde. The actual structure connects both the high-tech architecture and the artistic events inside. The 10-meter-wide ship, made of wooden planks and covered with a curved plastic shield, will serve as a space for readings and public discussions about literature - fiction, poetry and critical writing - related to the themes of DOX exhibitions, which usually offer a critical view of certain aspects contemporary human situations.

Figure 142. DOX Center for Contemporary Art, Prague, (architect: Martin Rajnis)
Source:
https://www.architectmagazine.com/technology/architectural-detail/gulliver-lands-at-the-dox-centre-for-contemporary-art_o
Accessed: July 29, 2023.

One of the downsides of living in a big city is the lack of space. Overcrowded train carriages, shoebox apartments and traffic jams are regular reminders that space is a rare luxury in the most populated hubs. But what if we could rise above it all, leaving the crowds and traffic behind for a peaceful haven in the urban sky? This is the amazing premise of the Rising Oases project by Professor Georges Kachaamy, head of the Center for Research, Innovation and Design at the American University in Dubai (AUD), (Figure 143). Kachaamy's floating architecture, more than a decade in development, is one of the star attractions on display at Dubai Design Week from 11 to 16 November 2019. Rising Oases outlines a possible future where there are platforms within the city where people can disconnect. from everyday restrictions. During its evolution, architecture crawled out of caves, settled on the ground, climbed stilts, floated on water, stood tall, and even danced. Now many argue that it is high time for him to move forward and take on some of his multiple and upcoming probabilities. While many predict a direction toward the virtual realm, automation, and digital fabrication, Dr. Georges Kachaamy, associate professor of architecture at the American University in Dubai, has been conducting ongoing research that depicts architecture of a different kind. A kind of architecture that levitates, floats in the air and separates from the ground. His architectural projects under the name „Rising Oases“ include Gravity Defiance Architecture, which was exhibited in Venice and Dubai. The exhibition presented visualizations and physical models of architectural prototypes that defy gravity. His projects are a series of chained built environments that include natural resources (light, wind, water, flora, fauna...). These are places of well-being on a human scale that offer the possibility of separating from the city and reconnecting with nature on a higher plane. Like lotuses rising from the mud and oases thriving in the desert, these objects are floating beacons of separation and symbols of omnipresence, unity and rejuvenation. The architecture is inspired by the four main sources of water: spring, pond, waterfall and river. Each object incorporates one of these sources and is levitated on a different plane from that of the city using a revolutionary technology that allows it to generate architecture that challenges itself, defies gravity and rises [66].

Figure 143. Rising Oases, 2019 (architect: Georges Kachaamy)
Source: https://www.archdaily.com/915221/levitate-an-architecture-of-a-different-kind, Accessed: July 29, 2023.

5. Conclusion (Perspectives)

Perspectives of Earth Air Architecture (architecture in the atmosphere/air) can be seen in the light of perspectives of architecture in general [2,21]. Perspectives in architecture, regardless of which historical period it is about, have their constant as well as a series of more or less variable dimensions appropriate to the specific time and space, that is, to the natural and social environment. The constant perspective in architecture is related to man, that is, confirmation of his true values. At the same time, some requirements of architecture according to human needs are universal and timeless and, as such, are prescribed by standards at the world, regional or national level. It is about the so-called definition area of human comfort in the field of thermodynamics, acoustics and lighting [21]. The perspectives of Earth Air Architecture are based on the principles discussed in chapters 2. Man, and 3. Limits. Actual realizations will be conditioned by the progress of technique and technology, that is, they will be dictated by the social environment. Compared to the perspectives of architecture built on the ground (with or without partial burial), types EA (Earth Air) and EGA (Earth Ground Air), the perspectives of Earth Air Architecture seem more complex and 'further'. Namely, while the physical structures of architecture on the ground can survive without any 'service' (inflow of energy, for example), when people do not use them, Earth Air Architecture cannot survive without the permanent generation of energy that keeps it flying or floating in the air. This specificity makes it 'temporary architecture', architecture 'in situ' for a certain period of time. Similar to Earth Air Architecture solutions ('zero energy house', 'energy plus house', for example) where the physical architectural structure survives using renewable energy sources (where Solar energy is among the most important), and in Earth Air Architecture perspectives, similar concepts can be used that would make it more 'permanent'. This concept especially applies to Earth Air Architecture hybrid solutions. Thoughts on the concepts of Earth Air Architecture perspectives, we have seen, go back a long way. Here we will present some newer concepts whose perspectives do not seem so 'distant' to us. Arata Isozaki, a Japanese architect and winner of the 2019 Pitzker Prize, is known not only for his prolific portfolio of works built all over the world (more than a hundred), but also for his constant contribution to the theory of urbanism, including texts and proposals. It is precisely in the field of urbanism that he developed is one of his most interesting unbuilt projects: a futuristic master-plan, known as "City in the Air", in the Shinjuku district of Tokyo, Japan [67] (Figure 144). At the end of the Second World War, an avant-garde architectural and urbanist movement, known as Metabolism, appeared in Japan - a country undergoing complete material and spiritual renewal. Japanese architects began to explore the relationship between man and the built environment. Metabolism emphasized the concept of biological growth in architecture, implying that the city, as well as its structures, are living organisms that evolve together. Architecture is now understood as a being in constant transformation, a movement that can reflect a dynamic reality in its design. Metabolists broke away from much of the established international discourse after World War II. They moved away from an architecture defined by functional programming and toward one focused on human association and mobility, thinking about how to create utopian cities after the destruction of war. Arata Isozaki (1931 – 2022), who was 12 years old when Hiroshima and Nagasaki were bombed, understood urban history as a circular existence. A vision that moves from construction to destruction and vice versa, emphasizing actions such as natural disasters and wars that can destroy entire cities. In Process of Incubation (1962), Isozaki reflects: „The ruins that made up my childhood environment were created by acts of sudden destruction ... wandering among them instilled in me an awareness of the phenomenon of obliteration rather than a sense of the transience of things“ [67]. Although Isozaki was never formally part of the Metabolist group, his first vision in the 1960s was associated with the movement. In 1962, he created a futuristic proposal based on the idea of the metamorphosis of the city: City in the Air. The City in the Air project is a capsule suspended in the air over cylindrical and modular megastructures. These structures allow the expansion and reorganization of the urban space, by adding or removing capsule units to meet the needs of the inhabitants in real time. Meanwhile, the foundations of the towers resembled huge craters left by bombs, referencing the plumes of smoke raised during the US bombing of Japan during World War II. For Arata Isozaki, the city is destined for destruction. The ruin is the future of our city, and the future is the ruin itself. In the process of incubation, he says: „Future cities are themselves ruins. Our modern cities... are destined to live only a fleeting moment. Give up their energy and return to the inert material. All our suggestions will be buried. The incubation mechanism is re-established. That will be our future“ [67]. At the time the City in the Air was proposed, Tokyo limited the maximum building height to 31 meters. Isozaki said: “Tokyo is hopeless... I leave everything below 30 meters to others. If they think they can fix the mess in this town, let them try. I will think about architecture and the city above 30 meters. An empty space of 10 square meters is all I need on the ground. I will raise a pillar there, and that pillar will be both a structural pillar and a channel for vertical circulation“ [67]. Almost 60 years since its creation, City in the Air is the timeless work of Arata Isozaki. Popularized thanks to black-and-white photomontage that has survived in the age of the Internet, the project is a declaration of architectural principles: flexible, mobile and capable of meeting the constant needs and demands of its users.

Figure 144. City in the Air, Shinjuku district in Tokyo, Japan (architect: Arata Isozaki)

Source: https://www.archdaily.com/912738/the-city-in-the-air-by-arata-isozaki, Accessed: July 29, 2023.

Human behavior has a major impact on atmospheric components and global climate change. In history, there have been many serious air pollution events around the world, such as the smog in the Meuse River Valley in Belgium in 1930, which caused 63 deaths. In 1952, photochemical smog in London killed 4,000 people in four days. In recent decades, there have been constant droughts, floods, high temperatures, rain and sandstorms, which is closely related to changes in the components of the atmosphere due to human activities. In the 21st century, even if governments and scientific institutes have shown growing concern about environmental problems, without public awareness of environmental protection, it is still not so optimistic in improving atmospheric pollution. There is a reason why scientific approaches to improving the natural environment are too far removed from everyday life. Therefore, for a better presentation of scientific work, it is important to alert the public.

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