AEROSPACE ENGINEERING

9.1 Definition: Aerospace Engineering is the primary branch of engineering concerned with the research, design, development, construction, testing, science and technology of aircraft and spacecraft. It is divided into two major and overlapping branches: aeronautical engineering and astronautical engineering. Aeronautics deals with aircraft that operate in Earth's atmosphere, and astronautics deals with spacecraft that operate outside the Earth's atmosphere. Founded by dreamers and pioneers such as Konstantin Tsiolkovsky, the field reached its maturity with launching of first artificial satellite, first man in space and first step on the Moon.

Aerospace Engineering deals with the design, construction, and study of the science behind the forces and physical properties of aircraft, rockets, flying craft, and spacecraft. The field also covers their aerodynamic characteristics and behaviors, airfoil, control surfaces, lift, drag, and other properties.

Aeronautical engineering was the original term for the field. As flight technology advanced to include craft operating in outer space, the broader term "aerospace engineering" has largely replaced it in common usage. Aerospace engineering, particularly the astronautics branch, is often referred to colloquially as "rocket science", such as in popular culture.

Overview

Flight vehicles are subjected to demanding conditions such as those produced by changes in atmospheric pressure and temperature, with structural loads applied upon vehicle components. Consequently, they are usually the products of various technological and engineering disciplines including aerodynamics, propulsion, avionics, materials science, structural analysis and manufacturing. The interaction between these technologies is known as aerospace engineering. Because of the complexity and number of disciplines involved, aerospace engineering is carried out by teams of engineers, each having their own specialised area of expertise.

The development and manufacturing of a modern flight vehicle is an extremely complex process and demands careful balance and compromise between abilities, design, available technology and costs. Aerospace engineers design, test, and supervise the manufacture of aircraft, spacecraft, and missiles. Aerospace engineers develop new technologies for use in aviation, defense systems, and space.

9.2 History

One of the most important people in the history of aeronautics, Cayley was a pioneer in aeronautical engineering and is credited as the first person to separate the forces of lift and drag, which are in effect on any flight vehicle. Much of the early work leading to the airplane involved gliders, and the 19th century saw dozens of glider experiments. Sir George Cayley expressed the principles of heavier-than-air flight starting in 1804, and in 1856, Jean-Marie Le Bris flew the first manned glider that climbed higher than its launch point. Le Bris did this by having a horse tow the glider along a beach.

The lack of a suitable engine thwarted many early efforts at powered, heavier-than-air flight. The first successful powered flight is credited to Orville and Wilbur Wright. The brothers incorporated the concepts of lift, weight, drag and thrust from a suitably powerful engine, and three-axis control of pitch, roll and yaw. In doing so, the inventors created the first airplane able to take off and climb on its own power, fly for a significant distance and make a controlled landing.

After the invention of fixed-wing airplanes, came the first rotary-wing aircraft, which include autogyros and helicopters. Based on principles first demonstrated in Chinese flying toys dating to 400 B.C., the idea of rotary-wing aircraft inspired many inventors to attempt vertical flight with rotating propellers. A number of small models powered by springs and rubber bands were built, but again, the first true helicopter had to wait for a suitably powerful engine.

Helicopter and autogyro designs progressed incrementally over the next few decades. Juan de la Cierva is credited with inventing the autogyro, a type of aircraft with fixed wings that uses a rotor for lift and a propeller for thrust. His advancements in rotary design led directly to the first modern helicopter, which is generally attributed to Igor Sikorsky in 1942.

Early innovators of powered, lighter-than-air craft included Jules Henri Giffard, who in 1852 flew the first steerable steam-powered airship; Charles Renard and Arthur Constantin Krebs, who in 1884 flew the first powered airship to return to its starting point; and Ferdinand von Zeppelin who built and flew the first rigid airship, in 1900.

The first definition of aerospace engineering appeared in February 1958. The definition considered the Earth's atmosphere and the outer space as a single realm, thereby encompassing both aircraft (*aero*) and spacecraft (*space*) under a newly coined word *aerospace*. In response to the USSR launching the first satellite, Sputnik into space on October 4, 1957, U.S. aerospace engineers launched the first American satellite on January 31, 1958. The National Aeronautics and Space Administration was founded in 1958 as a response to the Cold War.

The other side of aerospace engineering is rocketry and spacecraft. The most famous pioneers in this field were Robert Goddard, who constructed and successfully launched the first liquid-fueled rocket; Werner von Braun, who developed the first ballistic missile and went on to become the first director of NASA's Marshall Flight Center; and Konstantin Tsiolkovsky, who is considered the Russian father of rocketry.

Several astronauts were aerospace engineers, including Kalpana Chawla, the first Indian-born woman in space, who died in the space shuttle Columbia disaster; and Neil Armstrong, the first man on the moon. Armstrong himself once said: "I am, and ever will be, a white socks, pocket protector nerdy engineer."

Other well-known aerospace engineers include Boback Ferdowski, the "Mohawk Guy," who serves as flight director of NASA's Mars Curiosity rover mission, and Burt Rutan, whose company, Scaled Composites, designed SpaceShipOne, the first nongovernment manned spacecraft.

9.2 What does an aerospace engineer do?

Aerospace engineers design aircraft, spacecraft, satellites and missiles, according to the BLS. In addition, these engineers test prototypes to make sure that they function according to plans. These professionals also design components and subassemblies for these craft; those parts include engines, airframes, wings, landing gear, control systems and instruments. Additionally, engineers may perform or write the specifications for destructive and nondestructive testing for strength, functionality, reliability, and long-term durability of aircraft and parts.

Here are some recent developments of note in aerospace engineering:

- Many aerospace innovations are making their way into automobile technology, such as thermoelectric generators, which use heat to make electricity, and hydrogen fuel cells, which take hydrogen gas and mix it with oxygen to generate useful electricity, heat and water.
- A team of engineers has developed an algorithm that can convert brain waves into flight commands. The team hopes to make mind-controlled

aircraft a reality.

- Researchers are deliberately setting fires on the International Space Station to study "cool-burning" flames, which could lead to more-efficient car engines that contribute less pollution to the environment.

Today's aerospace engineers still work with the basic concepts of aerodynamics, and must also have a working knowledge of aircraft power plants such piston engines, turbo props and jets, the BLS said.

Astronautical engineers must also understand additional concepts, such as spacecraft propulsion systems, which include solid- and liquid-fuel rockets, along with ion drives. Manned missions require life support systems to provide air, food, water, temperature control and waste handling, so spaceflight engineers must also be familiar with these concepts.

Aerospace engineering requires in-depth skills and understanding in physics, mathematics, aerodynamics and materials science. These professionals must be familiar with advanced materials such as metal alloys, ceramics, polymers and composites, the BLS said. This knowledge allows engineers to predict the performance and failure conditions of designs before they are even built.

More and more, aerospace engineers rely on computer-aided design (CAD) systems for quick and easy drafting and modification of designs and 3D visualization of finished parts and assemblies. Computer simulations have become essential for performing virtual testing of engines, wings, control surfaces, and even complete aircraft and spacecraft under all possible conditions they might encounter.

According to Robert Yancey, vice president of Aerospace Solutions at Altair Engineering, Inc., "Simulation is having a greater impact on defining concept designs. This is requiring design engineers, who traditionally do not have skills in simulation, to start to develop some competency in simulation." Computer simulations have greatly reduced the dangers to test pilots and the cost of failed missions.

9.3 Where do aerospace engineers work?

Aerospace engineers generally work in professional office settings. They may occasionally visit manufacturing and testing facilities where a problem or piece of equipment needs their personal attention, according to the BLS. Aerospace engineers work mostly in manufacturing industries and in the federal government. Additionally, a select few aerospace engineers are chosen to work on the International Space Station.

Most aerospace engineering jobs require at least a bachelor's degree in engineering. Many employers, particularly those that offer engineering consulting services, also require certification as a professional engineer. Promotion to management often requires a master's degree, and engineers need ongoing education and training to keep up with advances in technology, materials, computer hardware and software, and government regulations. Additionally, many aeronautical engineers belong to the American Institute of Aeronautics and Astronautics (AIAA).

Some aerospace engineers work on projects related to national defense and thus must obtain security clearances, according to the BLS.

According to Salary.com, as of July 2014, the salary range for a newly graduated aerospace engineer with a bachelor's degree is $52,572 to $73,535. The range for a midlevel engineer with a master's degree and five to 10 years of experience is $73,823 to $114,990, and the range for a senior engineer with a master's degree or doctorate and more than 15 years of experience is $93,660 to $147,582. Many experienced aerospace engineers with advanced degrees are promoted to management positions where they can earn even more.

9.4 What is the future of aerospace engineering?

The BLS projected the employment of aerospace engineers to grow 7 percent between 2012 and 2022, slower than the average for all occupations. However, "there should be many opportunities for highly qualified applicants, particularly those who have kept abreast of the latest developments in technology," the BLS said. "Having good grades from a highly rated institution should give a job seeker an advantage over the competition."

9.5 Elements

Some of the elements of aerospace engineering are:

- Fluid mechanics – the study of fluid flow around objects. Specifically aerodynamics concerning the flow of air over bodies such as wings or through objects such as wind tunnels (see also lift and aeronautics).

- Astrodynamics – the study of orbital mechanics including prediction of orbital elements when given a select few variables. While few schools in the United States teach this at the undergraduate level, several have graduate programs covering this topic (usually in conjunction with the Physics department of said college or university).
- Statics and Dynamics (engineering mechanics) – the study of movement, forces, moments in mechanical systems.
- Mathematics – in particular, calculus, differential equations, and linear algebra.
- Electrotechnology – the study of electronics within engineering.
- Propulsion – the energy to move a vehicle through the air (or in outer space) is provided by internal combustion engines, jet engines and turbomachinery, or rockets (see also propeller and spacecraft propulsion). A more recent addition to this module is electric propulsion and ion propulsion.
- Control engineering – the study of mathematical modeling of the dynamic behavior of systems and designing them, usually using feedback signals, so that their dynamic behavior is desirable (stable, without large excursions, with minimum error). This applies to the dynamic behavior of aircraft, spacecraft, propulsion systems, and subsystems that exist on aerospace vehicles.
- Aircraft structures – design of the physical configuration of the craft to withstand the forces encountered during flight. Aerospace engineering aims to keep structures lightweight.
- Materials science – related to structures, aerospace engineering also studies the materials of which the aerospace structures are to be built. New materials with very specific properties are invented, or existing ones are modified to improve their performance.
- Solid mechanics – Closely related to material science is solid mechanics which deals with stress and strain analysis of the components of the vehicle. Nowadays there are several Finite Element programs such as MSC Patran/Nastran which aid engineers in the analytical process.
- Aeroelasticity – the interaction of aerodynamic forces and structural flexibility, potentially causing flutter, divergence, etc.
- Avionics – the design and programming of computer systems on board an aircraft or spacecraft and the simulation of systems.
- Software – the specification, design, development, test, and implementation of computer software for aerospace applications, including flight software, ground control software, test & evaluation software, etc.
- Risk and reliability – the study of risk and reliability assessment techniques and the mathematics involved in the quantitative methods.

- Noise control – the study of the mechanics of sound transfer.
- Aeroacoustics – the study of noise generation via either turbulent fluid motion or aerodynamic forces interacting with surfaces.
- Flight test – designing and executing flight test programs in order to gather and analyze performance and handling qualities data in order to determine if an aircraft meets its design and performance goals and certification requirements.

The basis of most of these elements lies in theoretical physics, such as fluid dynamics for aerodynamics or the equations of motion for flight dynamics. There is also a large empirical component. Historically, this empirical component was derived from testing of scale models and prototypes, either in wind tunnels or in the free atmosphere. More recently, advances in computing have enabled the use of computational fluid dynamics to simulate the behavior of fluid, reducing time and expense spent on wind-tunnel testing. Those studying hydrodynamics or Hydroacoustics often obtained degrees in Aerospace Engineering.

Additionally, aerospace engineering addresses the integration of all components that constitute an aerospace vehicle (subsystems including power, aerospace bearings, communications, thermal control, life support, etc.) and its life cycle (design, temperature, pressure, radiation, velocity, lifetime).

Taught courses

Aerospace engineering may be studied at the advanced diploma, bachelor's, master's, and Ph.D. levels in aerospace engineering departments at many universities, and in mechanical engineering departments at others. A few departments offer degrees in space-focused astronautical engineering. Some institutions differentiate between aeronautical and astronautical engineering.

In popular culture

The term "rocket scientist" is sometimes used to describe a person of great intelligence since "rocket science" is seen as a practice requiring great mental ability, especially technical and mathematical ability.

The term is used ironically in the expression "It's not rocket science" to indicate that a task is simple.

Strictly speaking, the use of the word "science" in "rocket science" is a misnomer since science is about understanding the origins, nature, and behavior of the universe; engineering is about using scientific and engineering principles to solve problems and develop new technology. However, the media and the public often incorrectly use "science" and "engineering" as synonyms.