

Rockets to access the Near-Earth Space: Sounding Rockets & Launch Vehicles

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The early years

The history of rocketry dates back thousands of years, with early civilizations employing them for warfare and ceremonial purposes. However, it was in the 20th century that rocketry truly began to take shape as a scientific discipline.

The foundations of modern rocketry were laid by visionaries such as Konstantin Tsiolkovsky, Robert H. Goddard, and Hermann Oberth. Their theoretical work and experimental research in the early 20th century paved the way for significant advancements in rocket technology.



The founding fathers; KE Tsiolkovsky, H Oberth and R Goddard
Image courtesy : National academic press

In 1926, Robert H. Goddard launched the world's first liquid-fueled rocket, demonstrating the potential of liquid propellants for achieving higher speeds and altitudes. This breakthrough marked a turning point in the field of rocketry.

During World War II, rockets were used as weapons, with German engineer Wernher von Braun leading the development of the V-2 rocket. After the war, von Braun and a team of German scientists were brought to the United States as part of Operation Paperclip, laying the foundation for the American space program.

Dawn of the space age:

The Space Age truly began on October 4, 1957, when the Soviet Union launched Sputnik 1, the world's first artificial satellite. This event sparked the space race between the United States and the Soviet Union, culminating in the historic Apollo 11 mission in 1969, when Neil Armstrong became the first human to set foot on the moon.

Since then, rocketry has continued to evolve, with advancements in propulsion systems, satellite technology, and the exploration of other celestial bodies. Today, rockets are instrumental in space exploration, satellite deployment, scientific research, and commercial ventures, shaping our understanding of the universe and pushing the boundaries of human achievement.



Neil Armstrong
Image courtesy : NASA



Yuri Gagarin
Image courtesy : Novosti

Basics of rocketry:

Rocketry is the science and technology of designing, building, and launching rockets into space. At its core, rocketry is governed by fundamental principles rooted in Newton's laws of motion and the conservation of momentum. These principles dictate that for every action, there is an equal and opposite reaction.

The basic principle of rocketry involves the ejection of high-speed exhaust gases in one direction, which generates a reaction force propelling the rocket in the opposite direction. This is achieved through the controlled combustion of propellants, either in the form of solid or liquid fuel.

Rockets operate in accordance with Newton's third law of motion, which states that every action has an equal and opposite reaction. As the exhaust gases are expelled at high speeds, the rocket experiences an equal and opposite force, propelling it

forward. The relevant mathematical correlation, known as the rocket equation, was formulated by Tsiolkovsky and is given below.

$$\Delta V = V_e \ln \frac{m_0}{m_f} = V_e \ln R$$

ΔV : The velocity change the rocket's engines can impart.

V_e : The velocity at which exhaust is expelled from the engines.

m_0 : The initial mass of the rocket when full of propellant (also known as *wet mass*.)

m_f : The final mass of the rocket when all propellant is expended (also known as *dry mass*.)

R : The *mass ratio*, or the ratio of wet mass to dry mass.

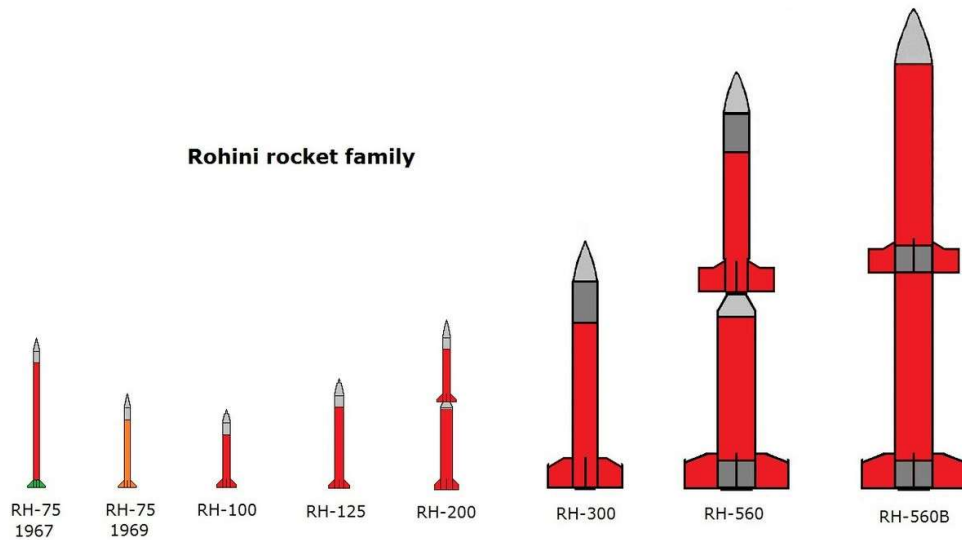
Rocketry has revolutionized our ability to explore space, enabling the launch of satellites, space probes, and even manned missions. It has opened up new frontiers of scientific research, telecommunications, and understanding our universe.

By harnessing the principles of rocketry, we have achieved incredible feats, including lunar landings, satellite networks, and unprecedented discoveries beyond our planet. As technology advances, rocketry continues to play a pivotal role in pushing the boundaries of human exploration and expanding our knowledge of the cosmos.

Space, the vast expanse beyond Earth's atmosphere, holds tremendous mysteries and possibilities for exploration. It is a vacuum devoid of air and gravity, where celestial bodies reside and cosmic phenomena unfold. Space offers unique conditions for scientific research, telecommunications, Earth observation, and human spaceflight.

Types of rockets

Sounding rockets play a vital role in our exploration of space and the upper atmosphere. These suborbital vehicles are designed to carry scientific instruments and experiments to gather data and conduct research. Unlike orbital rockets, sounding rockets do not achieve a stable orbit but instead provide brief periods of weightlessness and access to regions of the atmosphere and space that are otherwise difficult to study.



Sounding rockets of ISRO

Image courtesy : Wikipedia

Sounding rockets are used to study atmospheric conditions, cosmic radiation, auroras, microgravity environments, and other phenomena. They allow scientists to collect data at altitudes ranging from tens to hundreds of kilometers above the Earth's surface, providing valuable insights into our atmosphere and the space environment.

These rockets are typically single or multi-stage vehicles, designed for specific missions and carrying scientific payloads. They provide a cost-effective means to conduct experiments in space-like conditions without the complexities and expenses associated with orbital missions.

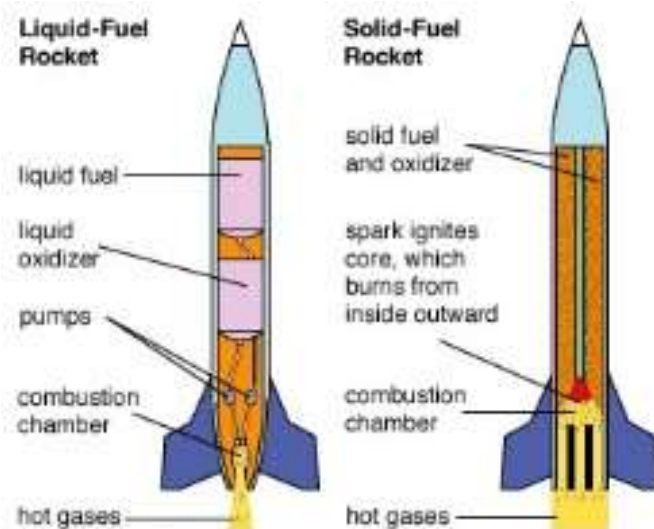
Sounding rockets have played a crucial role in advancing our understanding of Earth's atmosphere, space physics, and astronomy. They continue to be indispensable tools for scientific research, enabling us to explore and unlock the secrets of the higher realms above our planet.

Satellites and launch vehicles are integral components of modern space exploration and technology. Satellites, man-made objects orbiting the Earth, have revolutionized communication, Earth observation, weather forecasting, navigation, and scientific research. Launch vehicles, on the other hand, are the means by which satellites and other payloads are propelled into space.

Satellites come in various forms, including communication satellites, weather satellites, remote sensing satellites, and scientific satellites. They are equipped with instruments and sensors that capture data and transmit it back to Earth. Satellites enable global communication networks, facilitate real-time weather monitoring, monitor environmental changes, aid in disaster management, and provide valuable scientific insights into the universe.

Launch vehicles, also known as rockets, are the vehicles designed to carry satellites and other payloads into space. They consist of multiple stages, each with its own propulsion system. The main stages provide the initial thrust to overcome Earth's gravity, while upper stages fine-tune the trajectory and deliver the payload into the desired orbit. Launch vehicles range in size and capabilities, from small-scale rockets used for scientific experiments to heavy-lift vehicles capable of launching large satellites or even interplanetary missions.

Today launch vehicles of many types are being used by various spacefaring nations across the globe. They employ different types of propulsion systems and other have varying levels of versatility. The design and construction of launch vehicles involve complex engineering and precise calculations and employ multiple stages to generate the required payload velocity.



They must generate enough thrust to overcome gravity and atmospheric resistance, while also ensuring the safety and stability of the payload. Launch vehicles rely on various propulsion systems, including solid rocket motors, liquid rocket engines, and advanced systems such as hybrid engines and ion propulsion.

Typical rocket schemes

Image courtesy : Encyclopaedia Britannica

The launch process involves careful planning and coordination. Mission design determines the trajectory, payload requirements, and launch window. Launch sites are chosen based on geographical considerations and safety regulations. Once the countdown begins, launch vehicles undergo a sequence of operations, including ignition, staging, and payload deployment.

Launch vehicles have played a crucial role in advancing space exploration and technology. They enable the deployment of satellites that improve global communication, enhance weather forecasting accuracy, monitor climate change, and unravel the mysteries of the universe. Additionally, launch vehicles facilitate human spaceflight missions, resupplying space stations, and laying the groundwork for future endeavours, such as lunar and Mars missions.



ISRO launch vehicles , *Image courtesy : ISRO*

In recent years, the space industry has seen the emergence of commercial launch vehicles, fostering competition, innovation, and lower costs. Companies like SpaceX, Blue Origin, and Rocket Lab are revolutionizing the sector, introducing reusable rockets and pushing the boundaries of what is possible in space. This provides new opportunities for the Indian Space segments as well.

Indian Space programme



Dr. Vikram Sarabhai

Image courtesy : ISRO

The Indian Space Program, operated by the Indian Space Research Organisation (ISRO), has made significant strides in space exploration and technology. Established in 1969, it has achieved notable milestones, including launching satellites for communication, Earth observation, and scientific research. The Indian Space Program is renowned for its cost-effective approach and indigenous development of launch vehicles and satellite systems.

Notable missions include the Chandrayaan lunar missions and the Mars Orbiter Mission, which made India the first country to successfully reach Mars in its first attempt. The program continues to expand, paving the way for future advancements in space exploration and satellite technology.

Conclusion

Satellites and launch vehicles have transformed our world, connecting people across the globe, providing critical information, and expanding our knowledge of the universe. As technology advances and new discoveries are made, the potential for further advancements in satellite technology and launch vehicle capabilities holds great promise for the future of space exploration and utilization.