The rocket: An old idea, an old challenge

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THE HISTORY of rocketry clearly demonstrates the tortuous path an idea often takes before it comes to fruition.

The first hint of the rocket idea occurs in legends about the flying pigeon of Archytas, a wooden bird built about 360 B.C. Very little is known about it except its renown as a marvel of mechanical ingenuity. When the exaggerations of early writers are discounted and their stories logically analyzed, it seems possible that the pigeon was suspended by a string or rod and made to fly by means of a jet of steam or compressed air.

If lack of detail about the flying pigeon is annoying, there is compensation in the story of the Aeolipile, a jet or reaction engine built by Hero of Alexandria in the 2nd century B.C. One can see in Hero's invention the germ of the idea that developed into the steam engine, the steam and gas turbine, the jet-propelled plane, and the rocket. However, the times were such that Hero's idea was destined to remain only a toy for scholars and philosophers.

Chinese Developments

While Greek rocket development lay dormant, rockets were being developed on the other side of the earth. We have no idea when the work began, since the record is blank for 10 centuries. However, an ancient Chinese manuscript, well illustrated, tells the story of the battle of Pien-King in 1232 A.D. between the Chinese and their Tartar enemies. The account tells how the defenders of the city used "arrows of flying fire." The description and illustrations indicate that these were actually rockets, and not ordinary arrows dipped in pitch. There may have been centuries of effort behind these 13th century battle rockets, but records are scanty and one can only speculate.

During the decades which followed, the Chinese perfected the art of making and using gunpowder, and around 1270, Marco Polo and others brought the idea of gunpowder and its use in rockets back to Europe. It is not surprising to find rockets mentioned in the writings of Roger Bacon and Albertus Magnus at the close of the 13th century. One Marcus Graecus wrote a detailed report on rockets based on these writings, describing them fully.

Just when the first European rockets were used is difficult to say, but by the beginning of the 15th century rockets were widely known. In 1405, a treatise by a German military engineer mentioned three types and advocated their use in warfare. Another military expert, Joanes de Fontana, an Italian, showed real imagination in rocket design. In his book of war instruments are drawings of rockets disguised as rabbits, pigeons, and fish, and equipped with rollers to carry them towards the enemy lines. De Fontana even sketched a rocket car whose design and construction seem practical. There is no indication that his ideas were ever used, but they show the trend of thinking about rockets at that period.

In the 15th century, the cannon and smaller firearms were slowly being brought to perfection. For a while, both cannon and rockets were used, but the advantages of the cannon over the crude rocket soon became evident, and rockets gradually lost their military importance. Even before 1500, rockets had become obsolete as weapons, and for the next three centuries their use in Europe was limited to fireworks and signaling.

The progress of rockets from 1000 to nearly 1700 A.D. was slow. During all this time, there was little or no understanding of how the rocket actually worked. Explanations offered by scholars were confused by the mysticism in which medieval scientific ideas were steeped. Then, in 1687, Sir Isaac Newton gave the world the explanation for the dynamics of the rocket in his famous "Laws of Motion." His theory of action and reaction is not only a 17th century milestone, but also the key to understanding the mechanics of all rockets, from the bazooka to the lunar probe vehicle.

While rocket experimentation in the early 1800's was mostly on war rockets, Claude Ruggieri of Paris developed rockets for carrying rats, mice, and other small animals. These experimental rockets had automatic parachutes which carried the animal safely to earth at the end of its rocket trip. Ruggieri's experiments reached a climax about 1830, when he announced a rocket large enough to carry a ram aloft. The actual flight, however, never came off.

Previously, in 1804, Sir William Congreve and his predecessors at the Woolwich Laboratory in England had again taken up the work of adapting rockets for war use. By 1806, he had developed a product so satisfactory that, in October of that year, during the Napoleonic Wars, he obtained permission to assail the city of Boulogne with boats fitted for firing salvos of rocket projectiles. The Congreve rockets, which were used again in 1807 by the British against the Danes at Copenhagen, weighed 32 lb, with the casing weighing 7 lb and the balance fuel. They were 3 ft 6 in. in length and 4 in. in diam, and had metal cases. The only stabilizing device was a 15-ft stick fastened to the side in the fashion one finds in modern fireworks skyrockets. The rockets proved ballistically inaccurate and were later replaced by others with centrally located sticks—with somewhat better results.

Use of War Rockets

Rockets had now established a place as an auxiliary to, and sometimes a replacement for, field artillery and ship guns of moderate caliber. They distinguished themselves at Walcherin (1807) in the passage of the Adour and at the Battle of Leipzig (1813). Perhaps the most far-reaching achievement of the Congreve war rocket, however, was at the Battle of Bladensburg during the War of 1812. Here, an intensive rocket barrage, directed against Stanbury's American brigade, caused the regiments of Schultz and Ragan to break and flee. This was the signal for a general rout which left the city of Washington unprotected and led to its immediate capture and subsequent burning by the British forces.

A similar barrage was employed the following month during the attempted capture of Fort McHenry in Baltimore Harbor. These rockets, whose "red glare" is so vividly recorded in the "Star Spangled Banner," were not signal flares, but missiles carrying warheads loaded with substantial amounts of explosive—literally, "bombs bursting in air."

For all the improvements he made, however, Congreve was unable to determine a technique for stabilizing his rockets in flight other than his inadequate guidesticks. The need for a more ballistically stable rocket was evident. In some instances, a rocket actually returned to the ship from which it had been fired.

Improved Stability

Finally, in 1850, William Hale found a method to increase the stability of the rocket, and at the same time to replace the awkward guidestick. He inserted three small curved vanes in the path of the jet, causing the rocket to spin rapidly in flight. This idea was adapted, of course, from the rifled artillery shell.

Hale's rockets were used for several years in the dwindling rocket brigades of Europe, but rifling improved artillery so much that the war rocket steadily lost out.

The modern high-altitude rocket, however, owes at least two of its features to Congreve and his successors: The metallic streamlined case and the stabilizing fins or vanes introduced by Hale. To the peacetime rockets of the 19th century it owes another feature—the idea of multiple or step construction, today a vital part of interplanetary rocket design. The latter came about through experimentation with lifesaving line-carrier rockets in an effort to achieve greater distance without too great an expenditure of fuel. In 1835, Colonel Boxer of the Royal Laboratory produced a rocket of great range by joining two ordinary rockets end to end in such a manner that, when the first had burned out, the second commenced burning to prolong the flight of the rocket. This scheme had been suggested earlier by a man named Frazier, who apparently failed to make any practical test of it.

Scientific investigation of rockets did not begin again in earnest until the 1920's, with one notable exception. In 1903, Konstantin Tsiolkovskii, a Russian school teacher and early researcher in astronautics, proposed the revolutionary idea of designing rockets which would use liquid fuels. Although eminent scientists encouraged him, he failed to influence experimental researchers in Russia, and his name remained unknown elsewhere because nobody translated his writings.

One of the first modern publications on rocket theory was Robert H. Goddard's "A Method of Reaching Extreme Altitudes," published in 1919. Dr. Goddard's interest in this aspect of the rocket grew from the demand for a more efficient device for collecting weather data than the slow and cumbersome weather balloon.

In his first laboratory experiments, he definitely proved the fact, then much doubted, that a rocket would work efficiently in a vacuum. Of equal or even greater importance, he worked out in detail the mathematical theory of rocket staging and stated that with this method it was theoretically possible to build a vehicle that would reach the moon.

He first experimented with powder as a propellant and showed that, by adding a tapered nozzle and making the rocket motor strong enough to withstand higher pressures, the efficiency of the rocket could be greatly increased. He also mentioned liquid fuels, but, like Tsiolkovskii, was unsuccessful in his efforts to interest higher authorities.

Although "A Method of Reaching Extreme Altitudes" is recognized today as a major contribution to rocket research, it did not create as much stir as one might suppose. Perhaps its title and treatment created the impression that it was of interest to physicists and meteorologists only. More likely, however, is the fact that its practical value could not be widely appreciated at that time.

Granted Government Funds

Whatever the fate of the paper, Dr. Goddard's experiments did not go unnoticed. During WW I he was granted government funds, under the control of the Smithsonian Institution, to develop long-range rockets for military purposes. With these funds, he and an associate, C. N. Hickman, developed single-charge rockets propelled by double-base powder (40 per cent nitroglycerin and 60 per cent nitrocellulose), and demonstrated them at the Aberdeen Proving Grounds in November 1918. These rockets weighed from $1^1/_2$ to 17 lb, and were fired from lightweight launchers held by hand. Designs of a 4-in. rocket to be fired from airplanes were also demonstrated, but while these demonstrations were in progress, the armistice was signed and development work dropped. The U.S. settled down to demilitarization, and government-supported research on rockets was not seriously resumed until 1940. Dr. Goddard continued his investigations on high-altitude rockets with funds donated by the Guggenheim Foundation.

During the period from 1920 to 1922, Goddard worked in his spare time with grants from Clark Univ. testing liquid fuels of various types. He came to the conclusion that oxygen and hydrogen were the most powerful reactants but added that ". . . it seems likely that liquid oxygen and liquid methane would afford the greatest heat value of the combinations which could be used without considerable difficulty."

Oberth's Contribution

About this time, the publishing firm of R. Oldenbourg in Munich put out a paper-covered pamphlet of less than 100 pages with the title, "Die Rakete zu den Planetenräumen" (The Rocket into Interplanetary Space) by Hermann Oberth, a professor of mathematics from Transylvania. The introduction began with four numbered paragraphs which read as follows:

"1. The present state of science and of technological knowledge permits the building of machines that can rise beyond the limits of the earth.

"2. After further development, these machines will be capable of attaining such velocities that, left undisturbed in the void of space, they will not fall back to earth; furthermore, they will even be capable of leaving the zone of terrestrial attraction.

"3. Such machines can be built to carry men (probably without endangering their health).

"4. Under certain circumstances, manufacture of such machines might be profitable. Such conditions might develop within a few decades."

Then Oberth added: "In this book, I wish to prove these four assertions. . . ."

The book dealt with more or less general questions of rocket motion, described an assumed high-altitude rocket and concluded with general prophecies about probable achievements. Oberth also described a theoretical spaceship and developed the first sketchy plan for a space station.

The four assertions were subjected to step-by-step mathematical analysis. Rocket flight beyond the atmosphere was dissected mathematically and found to be a problem in fuel consumption. This led to an investigation of the rate at which fuel was consumed, and this was found, in turn, to depend on exhaust velocities. This theoretical reason alone was sufficient to decide in favor of liquid fuels, and particularly gasoline, known to have more than twice the exhaust velocity yielded by ordinary rocket powder.

Oberth did not know about Tsiolkovskii's forgotten articles, in which the Russian schoolteacher had come to the same conclusions. Nor did Oberth or anyone else know that Dr. Goddard was actually experimenting with liquid fuels at that time, under enormous and unnecessary secrecy.

At first, Oberth's book met with some opposition from European scientists, but eventually they accepted his ideas. This encouraged others who had similar ideas to make public their theories. Soon, all Europe was rocket conscious and scientific research got under way. After early attempts to fly rockets ended in failure because of motor difficulties, European scientists began directing their research to the construction of better motors. This research continued openly until the Nazis came into power.

Meanwhile, in the U.S., on March 16, 1926, Dr. Goddard successfully launched the first liquid-fueled rocket at Auburn. The rocket traveled a distance of 184 ft in 2.5 sec which would make the speed along the trajectory about 60 mph. Other short flights of liquid oxygen-gasoline rockets were made in Auburn, one, on July 17, 1929, attracting public attention when someone who witnessed the flight from a distance reported that he had seen a flaming aeroplane. This was the experiment headlined all over the world as "Explosion of a Goddard Rocket."

In his second report, Dr. Goddard stated that this rocket, of the tail-drive type, carried a small barometer and a camera, both retrieved intact after the flight. Additional tests were performed in 1929 and 1930 at Fort Devens, Mass., and later at Mescalen Ranch in New Mexico.

German Society Formed

Meanwhile, a few years earlier, in 1927, the German Rocket Society (actually Verein für Raumschiffahrt, or Society for Space Travel) was formed by a group of amateur rocket enthusiasts, while a few years later, in 1930, the American Rocket Society was formed as the American Interplanetary Society. In the early '30's, both the German and American societies, as well as individuals, performed a number of rocket experiments with varying degrees of success.

As this decade began, Dr. Goddard started his research in the problem of automatically stabilized vertical flight. The first rocket flight with gyroscopically controlled vanes was made on April 19, 1932. Stabilization was achieved by forcing vanes into the blast of the rocket by means of gas pressure controlled by a small gyroscope. In March 1935, another gyro-stabilized flight was carried out, the rocket attaining a height of 4800 ft, flying a horizontal distance of 13,000 ft, and reaching a maximum speed of 500 mph.

Between this time and the outbreak of WW II there was only silence from the formal strongholds of science and engineering in this country. At a time when research was seriously undertaken in Britain and Germany, the U.S. seemingly abandoned interest in rocketry. Nothing was heard from Goddard except a list of patents. After Pearl Harbor, it became known that he had resumed work for the Navy, mainly, it appeared, on devices for rocket-assisted takeoff for aircraft. Under grants from the Guggenheim Foundation, Goddard was also pioneering a liquid-fueled gyro-controlled rocket very similar to the German V-2 dropped on London in 1944.

The Germans and the English had begun to develop rocket weapons several years before WW II. In 1933, Germany began the first experimental work at Peenemuende with the 330-lb A-1 rocket. They followed it in 1934 with the A-2, which reached a height of 6500 ft. Then about 1937, a research and development station was founded at Peenemuende. A whole series of rockets was designed and intensive effort devoted to their practical construction. These projects were indicated by the symbols A-1 to A-10, the best known being the A-4, or V-2, the work of Walter Dornberger, Wernher Von Braun and their collaborators.

In October 1942, the first successful launching of the V-2 rocket took place. The rocket weighed over 12 tons, was 46 ft long and about 5 ft in diam. The fuel, consisting of 7600 lb of alcohol and 11,000 lb of liquid oxygen, burned for about 65 sec and produced a thrust of about 68,000 lb. With this thrust, the V-2 could reach a maximum height of 60–70 miles. It is interesting to note that the last rocket in the German series, the A-10, though not an operational vehicle at the time, was designed as an ICBM for use against eastern American cities.

British investigations, begun in 1934, were mainly directed toward anti-aircraft rockets utilizing cordite powder (nitroglycerine and nitrocellulose). These fin-stabilized barrage rockets reached altitudes of 20,000 ft and carried several pounds of high explosives. The British were the first to fit some of their invasion boats with barrage rockets, and thousands of them were fired during the invasion of France.

Developments in the U.S. did not get under way in earnest until 1940, when Dr. Hickman, a Bell Telephone Laboratories physicist who had worked with Dr. Goddard as a graduate student in 1918, wrote to Frank Jewett, head of Bell Labs and president of the National Academy of Sciences, outlining the advantages and uses of rockets, especially as applied to the new blitz techniques which the Germans had developed. Dr. Jewett then persuaded the National Defense Research Committee to sponsor a program under the direction of Dr. Hickman and Army Capt. L. A. Skinner, an experimenter with rockets from 1933 to 1940.

Bazooka Rocket Developed

Under the direction of these men, the bazooka rocket was developed. The bazooka was about 21 in. long, weighed a little more than 3 lb and was fired from a $4^1/_2$-ft launcher. Designed as an anti-tank weapon, with a hollow-charge warhead weighing less than 2 lb, it was capable of penetrating 4–6 in. of steel.

At about the same time, the Air Force and Navy also began to support rocketry. By virtue of guiding light from Theodore von Karman and Frank J. Malina, the Air Force pushed the development of jet-assisted takeoff (JATO) units at the Guggenheim Aeronautical Laboratory of the California Institute of Technology and the Jet Propulsion Laboratory, founded by von Karman and Malina. The Navy, through the urging of C. C. Lauritsen, undertook development of a variety of barrage and aircraft rockets, first at CalTech and later at the vast desert expanse of the U.S. Naval Ordnance Test Station in the nearby Mojave Desert.

Studies of jet propulsion and rocket development spread rapidly from such centers of enlightenment to groups in universities, industry, and government. WW II saw in consequence a rapid growth in rocket technology in this country. Unfortunately, the main stream of work and interest ran little beyond a limited military goal, with emphasis on small- and medium-caliber artillery rockets and JATO units.

The history of rocketry since the end of WW II is too well-known to warrant repetition at this time. In the past year and a half, U.S. and Soviet achievements in the astronautics and missile fields have made the potential of the rocket vehicle for peace as well as war obvious to all.

With artificial earth satellites, lunar and planetary probes, and, in the not-too-distant future, manned space vehicles a reality, rather than a dream, the idea of rocketry has come to full bloom. And, just as it has through its long history constituted a challenge to Man, it continues to offer an ages-old choice: Accept the challenge and survive, by bending the idea to useful ends—or perish.