BULLETIN

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David Lasser, President C. W. Van Devender, Editor.

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DEFINITION AND HISTORY OF THE ROCKET.

by

G. Edward Pendray.

(An abstract of the first report made to the Society under its research program. Read by Mr. Pendray at the meeting in the Museum of Natural History, November 7, 1930.)

The rocket, as we now know it, is essentially a tubular case, closed at one end, and fitted at the other with a constricted opening or nozzle, and containing a quantity of combustible fuel of such a nature that when combustion begins the gases and flame generated thereby rush through the nozzle. If unrestrained during this state of combustion, a rocket will tend to move with great rapidity in the direction away from the nozzle end -- that is, in a direction opposite to that traveled by the expelled gases. This action is due to the working of the recoil principle, and upon it the value of the rocket depends. In essentials the rocket is an engine without moving parts; the simplest and under proper conditions the most efficient of the various devices for transforming energy into motion. Its discoverer, like the inventor of the wheel and the lever, will probably be forever unknown. We are certain that the principle of the rocket has been known for centuries, perhaps for thousands of years.

For its beginning we must perhaps go back to the ancient Chinese, from whom the rudiments of all pyrotechnic art are believed to have come. The Greeks were also adept at the use of flaming projectiles and other pyrotechnics. The first mention of what was unmistakably a rocket is to be found in a 13th Century collection of recipes known as the Liber Ignium of Marcus Graecus. The later introduction of gunpowder in Europe and the interest in gunnery stimulated the art of fireworks pyrotechny. By the beginning of the 15th Century rockets were used not alone for celebrations but also in warfare, supplementing the crude and unwieldy cannon of the period. From the 15th to the 18th centuries the principal advances in rocket design and fuel were made by the pyrotechnists. Early in the 18th Century the brothers Ruggieri, Italian fireworks artists, were invited to Paris and later to London, where they startled Europe with the beauty, artistry and ingenuity of their displays, incidentally bringing with them their word, rochetta, which has been incorporated in a modified form in our language.

II. The Congreve Rocket and the Napoleonic Wars.

Thus the making of rockets was already a great art and something of a science at the beginning of the 19th Century when Sir William Congreve and his predecessor at the Woolwich Laboratory in England took up the work of adapting them to the needs of war. Congreve was the first scientist of note to take up rocketry. It was largely through his enthusiasm and effort that the rocket in the 19th Century became something more than a toy. In 1805, when Sir Sidney Smith's expedition set out against Boulogne it was accompanied by Congreve and a number of boats specially fitted for firing salvos of rockets. Bad weather balked the first attempt, but

but finally in 1806 Boulogne was bombarded by rocket projectiles. Great numbers of them, discharged in volleys from the special boats, were hurled into the town, where they did great damage, setting fire to houses and spreading terror among the soldiers of the garrison. The Congreve rockets, which were used again in 1807 by the British against Copenhagen, weighed 32 pounds each, of which seven consisted of carcass composition and the remainder fuel. They were three feet, six inches in length and four inches in diameter, and had metal cases and an improved nozzle. The only stabilizing device, however, was the stick fastened to the side like those of ordinary skyrockets. It was 15 feet long and 1-1/2 inches in diameter. Upon landing, the rockets quickly burst, exposing a great mass of flaming surface in the case of incendiary projectiles, or hurling iron and lead pellets like shrapnel.

In 1812 the Field Rocket Brigade was formed and a year later it was sent to join the Allies before Leipsic. So marked were the results that the Rocket Brigade took part in virtually every important subsequent battle against Napoleon, distinguishing itself particularly in the final contest at Waterloo. By the end of the 19th Century military rockets had become obsolete. They were cranky, undependable, inaccurate and more often dangerous to friends than enemies; whereas the rifled bore, breech-loading, independent recoil and smokeless powder gave ordinance and increasing advantage over them.

III. Rockets in Peace; the Lifesaving Step-Rocket.

The modern high-altitude rocket owes at least two of its features to Congreve and his successors; the metallic, streamlined case and the stabilizing fin or vans, introduced by Hale. To the peaceful rockets of the 19th Century it owes another -- the idea of the multiple or step construction that may some day be a vital part of interplanetary rocket design. The first application of the rocket as a line carrier in life saving was made by the Cornishman Trengrouse, in 1807. The chief problem from the first was the achievement of distance without too great an expenditure of fuel. In 1855 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 burnt out the second came into action. This scheme had been suggested earlier by a man named Frezier, who apparently failed to make any practical test of it.

IV. Dr. Goddard and the High-Altitude Rocket.

The period of modern rocket research begins with the work of Dr. Robert H. Goddard, of Clark University. The idea of using rockets to reach great altitudes and even interplanetary spaces, goes back as far as 1660, but it remained for Dr. Goddard to make the first experiments and to write the first scientific work on the subject. His report, apparently prepared two or three years earlier, was published by the Smithsonian Institute in 1919, to be followed in 1923 by the book of Professor Hermann Oberth of Mediasch, in Transylvania; in 1924 by that of Max Valier, of Munich; and in 1925 by the study of Dr. Walter Hohmann, of Essen, and the monumental work of Robert Esnault-Pelterie, of France, who gave the new science of Astronautics its name.

Dr. Goddard, in his first laboratory experiments, backed by a small grant from the Smithsonian Institution, definitely proved the fact -- then much doubted-- that the rocket would work efficiently in a vacuum. Of equal or greater importance, he worked out in detail the mathematical theory of the multiple or step rocket, and stated that it was without doubt theoretically possible to build a rocket by this method that would reach the moon. Publication of his report caused a great sensation among scientists and the newspaper-reading public. Dr. Goddard turned back to his work with intense competition on the part of the Germans, Austrians and French to spur him on, in addition to his own zeal for discovery.

V. Contributions of Europeans to Rocketry.

(a) The most dashing and courageous, if not the most popular, of these was Max Valier. His offering to the development of rockets consisted first of experiments, in partnership with Fritz von Opel, tending to adapt the recoil principle to automobiles, sleds and aircraft. His most important work, however, was done with Dr. Paul Heylandt, in experiments with liquid fuels. Their first recoil motor, announced in 1929, weighed seven pounds and could develop 40 horsepower on a fuel of liquid oxygen, alcohol and benzine. By April of this year they had improved it so that, with the addition of only four pounds of weight they had been able to generate maximum output of 220 horsepower. On May 17, 1930 the motor exploded and Valier was killed -- the first martyr to the growing science of astronautics.

(b) Only one European has made achievements of sufficient importance to rank him with Dr. Goddard. He is Professor Hermann Oberth, now thirty-six years old. In 1928 or early 1929 Oberth joined forces with the UFA Film Company under an agreement by which the company guaranteed to finance the building of a rocket in return for technical aid in filming a drama called "The Girl in the Moon." Oberth selected a small island in the Baltic and plans were drawn up for building the rocket there. This rocket has not yet been completed. According to United Press dispatches from Berlin it is six feet high and ten inches in diameter, constructed of steel with an outer covering of magnesium to protect it against changes in diameter. Oberth told reporters that the fuel, consisting of hydrogen and oxygen, would burn for 80 seconds and that he hoped it would accelerate sufficiently to give the rocket a speed of 4,000 yards a second.

VI. Goddard's shot of July 17, 1929.

In 1920 Dr. Goddard began experimenting with liquid fuels for rockets -- probably the first scientist anywhere to do so. By 1928 he had perfected a nozzle suitable for handling it, and had experimentally determined upon a mixture of hydrogen and oxygen as the best fuel. Several small shots prior to the summer of 1929 were made at Auburn, Mass., with these inventions and when they proved satisfactory he set to work at Worcester to make a final test of the fuel and method in a rocket which he hoped would reach an impressive altitude carrying a camera and a delicate barometer and landing by means of a parachute. It was this test which startled Worcester in the famous "shot of July 17."

Dr. Goddard had erected a steel tower forty feet high in his accustomed proving ground, providing it with small rails to guide the rocket from its base to its apex. The rocket was nine feet long and 28 inches in diameter. Despite confusing reports it was apparently not a step-rocket but was so constructed that the liquid fuel was exploded in a rapid series of blasts instead of continuously. When the rocket was touched off the rear of the explosions were heard for two miles. The newspapers in their first reports declared that the rocket had exploded and that the experiment had been a failure. It was only after some days that Goddard succeeded in making it clear that the attempt had instead been a brilliant success. Liquid fuel had been used successfully for th first time in an actual rocket flight. Though the altitude reached had not been as great as expected, the apparatus had worked perfectly and the parachute had brought the shell and its delicate instruments, which included a camera and a barometer, back to earth undamaged. Not without reason was the shot of July 17 compared by Dr. Abbot of the Smithsonian Institution with the first flight made by Dr. Langley's heavier-than-air machine over the Potomac in 1896. It might better be compared with the completion of the first working steam engine, or with some other fundamental invention that caused a subsequent social revolution. No one can say what the effect will be when the penetration of interplanetary space, which by this exploit now seems almost within our grasp, becomes a possibility.

VII. Dr. Goddard's Present Plans, and Conclusion.

Thus the practical work of getting a liquid-fuel rocket actually into the air was a contribution of America, as were the three most fundamental achievements of modern rocketry. These, as listed by Dr. Abbot a year ago, were: (1.) The discovery of the correct-angle gas orifice. (2.) The successful introduction of continuously-burning liquid propellants, and, (3.) The mathematical theory of the multiple rocket, together with the first practical measurements and tests in the fundamentals of rocket propulsion.

One of the most important immediate results of Dr. Goddard's successful shot of July 17 was that it called the attention of a financier to his work. In all, from 1919 to 1929, the Smithsonian Institution had spent about $12,000, and this was the cost -- aside from funds Dr. Goddard himself contributed -- of the advances the American scientist had made up to this year. In July, 1930, Daniel Guggenheim, who is now dead, made a fund of $100,000 available to continue the work. The report is that plans are now being made to build a huge rocket, with stabilizing devices, landing apparatus and compartment for scientific instruments, that will go 50 to 200 miles, perhaps reaching the extreme limit of the atmosphere. It has been announced that the next experimental shots and perhaps the great shot, will be made near Roswell, New Mexico, where Goddard has discovered atmospheric conditions more nearly the ideal than those of Worcester.

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GERMAN SOCIETY BUSY.

The "Verein fur Raumschiffahrt," or the German Interplanetary Society, of which Professor Hermann Oberth is president, sends the following letter, through its secretary, Willy Ley:

> "The officers of the German Interplanetary Society have succeeded in securing near Berlin a suitable rocket flying field, a large field on which the starting supports for the different rockets were set up. There are likewise several buildings, which are now being equipped with machinery, so that next year we can work on a very large scale.
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> "In the meantime important rocket experiments have been performed by the technicians of the Society, the engineers Nebel and Riedel, -- experiments dealing with the combustion of liquid fuels (gasoline) with liquid oxygen; experiments on the ignition of liquid rockets; on the stabilizing of rockets in flight; on the arranging of the fuel chambers, and on the rocket parachute, which brings the burned out rocket safely back to earth.
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> "It is a great pleasure for us to be able to say that all these experiments, despite their great difficulty, have been successful. Ignition, stabilizing and the releasing of the parachute were problems which came out successfully with our experimental apparatus. Details about these experiments will be given in our next bulletin, but we merely want to inform America by these few lines that the German Interplanetary Society has not gone to sleep and that our work has brought the world another step nearer the final goal. This goal is the space ship, as our president, Prof. H. Oberth has shown in the film for which he was advisor, 'The Girl in the Moon.'"

THE MECHANICS OF ROCKET FLIGHT.

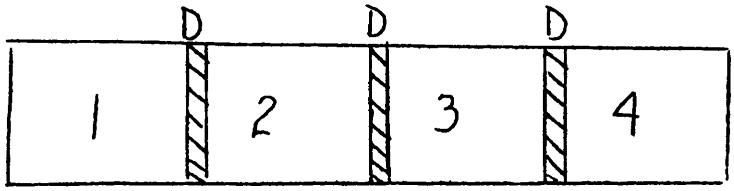
By Laurence E. Manning.

(The paper of which this is an abstract was read by Mr. Manning at the meeting of the Scoeity on November 21. Mr. Manning's paper, the second report under the Society's research program, was accompanied by several illustrations, the simplest of which are reproduced here.)

1. Recoil Propulsion.

There is in space no matter against which to push. Ordinary means of physical propulsion are therefore useless. The only physical law which can at present be utilized to obtain powered navigation in space is that of the recoil. In its simplest terms this is familiar to everyone who has fired a shotgun without properly cleaning its barrel. I will attempt to give a more detailed analogy, however, since up to the time of Goddard's experiments in 1919 there was doubt even in scientific circles as to whether power could be obtained in a vacuum.

Let us suppose four cubes of equal weight stuck together with a glue of dynamite to form a long narrow apparatus, four times as long as wide. In cube No. 1 we place our pay-load. The whole is set out in space and the problem is to move cube No. 1 to the left.



An explosion of the dynamite between cubes 2 and 3 divides the vehicle in half. Obviously both halves will fly apart at an equal rate of speed. But we are only interested in cube No. 1, which has moved to the left as desired. Now another explosion is caused between cubes 1 and 2 and these two quarters fly apart -- cube 2 is jettisoned and cube 1, in which is our payload, is forced at still greater speed toward the left. Though inefficient in the extreme this is true rocket propulsion and it is obvious that it would operate in airless space. A more scientific expression of the law upon which it is based would be that the center of gravity of the whole vehicle (in this case the dynamite between cubes 2 and 3) remains unchanged in position by the explosion, due to the inertia of mass.

2. Possible Types of Rocket Motors.

The design of the motor depends, of course, upon the fuel to be used. If a solid fuel can be obtained with sufficient expulsion speed,such a simple design as has been proposed by Walter Hohmann might be possible. He would have a pyramid of solid fuel -- a monolith requiring no containers but being of itself sufficiently rigid to hold together. At the top is the passenger chamber in which the entire pay-load is placed. The fuel commences burning at the bottom and gradually consumes itself, leaving the passenger chamber free in space traveling at the required speed. Conceivably such a solid fuel might exist, but it seems at present improbable. The hopes of rocket experts at the present time lie in the direction of various liquid fuels, requiring a much more complicated construction of rocket.

It is first necessary to build a container for the fuel. This will assume different shapes and have different requirements for various fuels. Properly speaking, it is not a part of the motor. The motor itself consists of a fuel feed, an explosion chamber and an exhaust tube. The type of explosion chamber must dictate the form of the whole motor, and there are two possible types:

(a) An equal pressure motor. In this there is a constant pressure in the explosion chamber. There is a constant explosion and a constant rush of gas or vapor through the exhaust. It is necessary to keep the explosion chamber supplied with fuel, and to do this in spite of the enormous pressure requires a forced feed. Two methods are apparent: 1. the fuel chambers are under sufficient pressure all the time, in which case they must be strong enough to stand it, or 2. some form of pump is used to inject regularly the necessary fuel.

(b) An explosion rocket is also possible. In this the fuel is exploded in the chamber and the gas rushes out of the exhaust. There is now little or no pressure in the chamber and a new charge is brought in to be exploded in its turn. Here also two methods of feed are possible. The fuel may be under constant pressure, controlled by a valve which shuts off the supply during the actual explosion, or there may be a method of mechanically feeding the fuel as cartridges are fed into a machine gun. A brief reflection upon the problem indicates that the more even and steady the motive force the less is the strain put on the rocket structure and the occupants, as well as the greater the motive efficiency. For this reason if the second or explosive rocket type is to be successful the explosions must be extremely frequent -- several each second. With this premise granted there is no difference in practical efficiency, at least so far as mechanical theory is concerned.

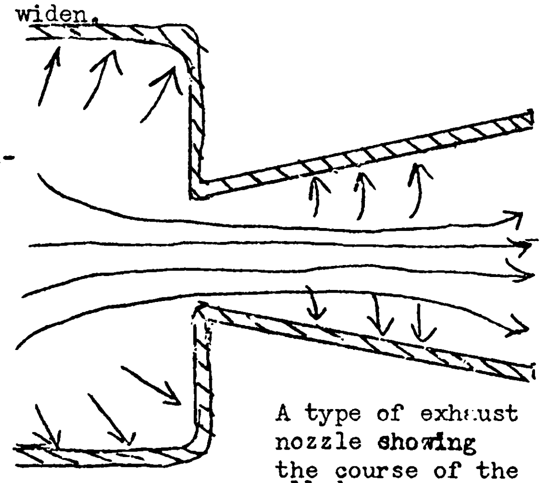
The first problem confronting us is that of safety. Fuels must be so handled that there is no danger of the whole fuel cargo being set into combustion at once. For this reason a detonating gas or fuel could hardly be used in an equal pressure rocket with the fuel in continuous forced feed into the combustion chamber. No screen could prevent back-firing into the mass of the fuel. One of Professor Oberth's designs uses two gases -- hydrogen and oxygen. The oxygen is heated by passing it through coils surrounding the explosion chamber. When it reaches 700 degrees Centigrade it is sprayed into the explosion chamber under pressure. The hydrogen is vaporized and sprayed upon the heated stream of oxygen in the chamber. Immediate and continuous combustion occurs, and with safety, for hydrogen and oxygen are neither explosive separately. No detonating gas exists except that in the explosion chamber itself.

3. Other problems of design.

The weight of the fuel container, particularly if it proves necessary to install a cooling plant to maintain liquid oxygen at the necessary low temperature, becomes of great importance. If built as a single unit, it would be exceedingly inefficient when the fuel is partially exhausted. The ideal would be a container that shrank as the fuel was exhausted. The nearest we can come to this ideal might be a series of comparatively small fuel containers each of which is detached and discarded when its contents become exhausted. For solid fuels the problem is much simpler. Goddard suggested in 1919 a smokeless powder loaded in cartridges and fed machine-gun fashion into the explosion chamber. This is extremely safe and efficient, except that the weight of the cartridges would be clearly waste. This waste might be overcome by having the cartridges on an endless belt passing back into the fuel chamber after firing and being there automatically reloaded. This same principle might be adapted to liquid fuels, and might even render possible a detonating gas fuel providing the empty cartridges were cooled before passing back into the fuel container for reloading. There would be a distinct advantage in such a motor, since it would not be necessary to force fuel into the explosion chamber against the enormous pressure existing there. It would render possible an explosion type motor with extremely frequent explosions.

The ideal shape of exhaust can be computed, but as it is a purely mathematical calculation it cannot be considered here. It will be sufficient to say that it must be smaller at the start of the tube than the explosion chamber above it, and gradually widen to permit as free an expansion of the gases as possible, as well as take advantage of the work involved in that expansion. The exhaust gases expand with extreme rapidity, and the exhaust walls widen, providing inclined planes against which the expansion pushes. This push is translated into a forward motion of the rocket itself.

Oberth says, in a rocket of considerable size, the ideal form of exhaust is manifold. One large exhaust subject to terrific pressure would be difficult and weighty in construction. If many smaller exhausts are used it becomes much simpler to provide the necessary structural strength without undue weight. The pressure must be as great as possible in proportion to the pressure in the explosion chamber for the sake of efficiency.



A type of exhaust nozzle showing the course of the expelled gases

4. Oberth's Model Rocket "B"

Mr. Manning accompanied his paper with a drawing and detailed explanation of Oberth's theoretical Model "B" Rocket, which it is impossible to reproduce in the Bulletin. The report itself is on file with the librarian of the Society, where it may be consulted by members and others interested in its subject matter. The "B" model consists of two steps -- an alcohol rocket and a liquid hydrogen rocket, with the chamber for instruments or passengers in the nose of the ship. The main features of the alcohol rocket (which is almost identical in principle and design with the liquid hydrogen one) are the containers for alcohol and liquid oxygen, the feed and pumping systems, the atomizers for spraying the alcohol and oxygen into the explosion chamber, the explosion chamber itself, the exhaust and the cooling system. To construct the "neck" of the exhaust out of material that is fireproof and heat-resisting would require enormous weight, since at this point the heat is greatest. Oberth's design provides for comparatively thin walls at this point and behind the walls are cooling chambers filled with a liquid, the composition of which is not specified.

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MOON FLIGHT BROADCAST.

A trip to the moon in the year 2050 was described by John Q. Stewart, Associate Professor of Astronomical Physics at Princeton University, in a recent talk over the Columbia Broadcasting System. Professor Stewart's broadcast, which was printed in the science section of the New York Herald-Tribune for Sunday, November 9, took the form of a description, in the present tense, of the start of the moon ship and its landing on the moon. Television having of course been perfected long before 2050, the listeners-in were presumed to be able to see the events as they were described.

From a scientific viewpoint Professor Stewart's description of the space ship and of the method used by the explorers on the moon in communicating with Earth, are of interest. The future space ship was pictured as a sphere 110 feet in diameter, made of tungsten alloy, carrying 67 men and supplies of air, water and food, and equipped with heating and refrigerating plants. Propulsion was obtained by the recoil of cannon from which nearly three tons of lead was fired per second at a muzzle speed of 200 miles per second.

To describe the landing of the space ship on the moon six days after the start, Professor Stewart had the announcer stationed at Mt. Wilson Observatory in California with a 500-inch telescope at his command. The space ship, he says, required four days to reach the moon's orbit and another two days in circling the moon about fifty times in the process of slowing down in order to make a landing. A few minutes after the ship landed communication was established with Earth over a beam of light, and the voice of one of the exploring party was picked up on the microphone and broadcast to all parts of the Earth. Perhaps the most significant part of Professor Stewart's fanciful talk was his statement that the "Hop-Off-The-Earth," as he named the moon ship, cost two billion dollars to construct.

RESEARCH PROGRAM UNDER WAY

In this issue of the Bulletin are published abstracts of reports made to the Society on the first two divisions of its research program, which has as its general subject, "The Rocket as a Vehicle for Interplanetary Travel." Following the papers on the history and mechanics of rockets the reports due are successively: "Rocket Fuels," "The Rocket as a Projectile," "The Construction of a Rocket Vehicle," (in two parts,) "The Utilization of the Rocket," (in two parts), "Physiological Implications of Rocket Flight," "Avenues in Which Research is Necessary," "Social Implications of Rocket Development," "Sources and Acknowledgments," and "Index and Appendices." As far as space permits abstracts of all these papers will be published in the Bulletin.

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TO THE MOON 15 YEARS SAYS PELTERIE

It will be possible, said Robert Esnault-Pelterie to the French Academy of Sciences recently, to travel to the moon and return, 15 years from now. From the great progress being made in solving the fundamental problems of astronautics, M. Pelterie is convinced that a practical design for a space ship is on the way.

The mixture of oxygen and hydrogen, Pelterie believes, is capable of performing the task of lifting a space ship to the moon, carrying at least one passenger. As a preliminary to a space flight, M. Pelterie would seek capital to build a rocket ship capable of traveling from Paris to New York in 24 minutes! If he could find a patron of science who is willing to donate $2,000,000 to the necessary preliminary experiments, M. Pelterie feels that all the problems barring the way to space could be solved and within 15 years man would be "rocketing" his way into the great unknown.

It is expected that M. Pelterie will come to America early in 1931 and will state his program for the space flight at a lecture before the American Interplanetary Society. M. Pelterie is himself a patron of the art of astronautics by establishing the Rep-Hirsch prize for the best contribution each year to the space flight problem. In 1928 this prize was awarded to Hermann Oberth for his design of a ship expelling gases at a speed of 5,000 yards per second. M. Pelterie is also the author of "Astronautics "a complete scientific treatise on the entire subject of interplanetary flying.

Meetings of the New York members of the American Interplanetary Society are held on the first and third Fridays of each month at the American Museum of Natural History, 77th Street and Central Park West. Persons interested in the aims of the Society are invited to attend and to write to the secretary, C.P.Mason, 302 West 22nd Street, New York City, for information about the various classes of membership, including active, associate and special, which are open to men and women who possess the necessary qualifications.