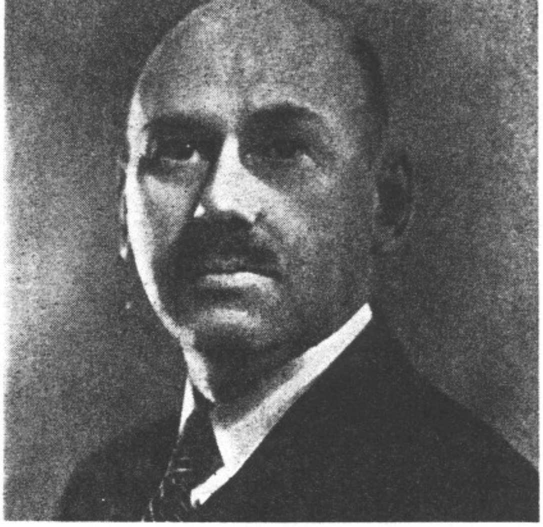
Three Astronautical Pioneers — I

Robert H. Goddard
an autobiography



"It is difficult to say what is impossible, for the dream of yesterday is the hope of today and the reality of tomorrow."

—Robert H. Goddard

Background

Today's major achievements in the fields of rocketry and space flight stem to a large extent from the writings and teaching of three astronautical pioneers—Robert H. Goddard (1882–1945), an American; Hermann Oberth (1894–), a German; and Konstantin E. Tsiolkovskii (1857–1935), a Russian.

Some time ago, Astronautics was fortunate enough to obtain a brief but fascinating autobiography of Tsiolkovskii which had not previously been published in English. The manuscript was accepted for publication, but it was felt that the picture would be incomplete without similar autobiographies of Dr. Goddard and Prof. Oberth, and efforts were immediately undertaken to see if these could be obtained.

Through the good offices of Esther C. Goddard, widow of Dr. Goddard and an ARS Honorary Member, a previously unpublished autobiography of the American rocket pioneer (written in 1927,) was obtained, and excerpts from this autobiography appear here. Taking Dr. Goddard from his early years to the time when the Smithsonian Institution published "A Method of Reaching Extreme Altitudes," they reveal in detail the motivating forces which got him interested in rocketry and space flight, and indicate for the first time the extent of his far-reaching early work. Mrs. Goddard has also been kind enough to supply the photos and facsimiles of Dr. Goddard's notebooks which appear on these pages.

The complete autobiography, as well as a vast amount of additional material from Dr. Goddard's own files, will be used as background in a definitive biography now being written by Milton Lehman, to be published by Farrar, Strauss and Cudahy next year.

Tsiolkovskii autobiography, as well as a new autobiography of Prof. Oberth especially prepared for Astronautics, *will appear within the next few months.*

Owing to the widespread interest which is certain to arise later regarding space navigation, or interplanetary studies, it seems worthwhile to note the development of the writer's ideas and experiments upon the subject, together with a few personal facts which bear more or less upon this matter.

My earliest recollection of a scientific experiment dates back to when I was four or five years old, in Roxbury, Mass. I had heard of electric sparks being produced by a person who scuffed along a carpet, and I had seen electricity produced by a Leclanche battery, so one day I obtained the zinc from one of these batteries and scuffed along the gravel walk. Next, I mounted a low fence and jumped. Then I repeated the experiment, scuffing over a longer distance, and endeavored to convince myself I had jumped higher. My mother caught sight of this investigation and called out to me to be careful because it might work and I might go sailing away, without being able to come back. After this warning, I hid the zinc rod and never repeated the experiment.

An event of some interest occurred when I was taking impromptu examinations for the purpose of entering Roxbury Latin School. A number of my playmates planned on taking these examinations, and had been studying for them for some time, unknown to me. I remember that I entered into the spirit of the thing as far as I could, and earnestly endeavored to pass.

However, it was not with great surprise that I received a notice from the headmaster a few days later that I had not passed with entering grades. But I was surprised to learn, when I called on him, that, if it was any satisfaction to me, I had beaten them all in both mental and written arithmetic.

It was the first inkling I ever had that I was even of average ability in mathematics. Hitherto, arithmetic had merely been a subject in which I was continually making mistakes and achieving poor or unsatisfactory grades. I learned the principles easily enough and secured a variety of answers to the long problems in multiplication and division, although these answers seldom included the correct solution.

In the spring of 1898, perhaps because the sky appeared so attractive, I spent considerable time thinking how delightful it would be to have a small balloon attached to a thread which I could fly like a kite. An ordinary rubber or silk balloon, however, held no attraction. It had to be a permanent balloon, which would not require refilling. The obvious thing was therefore a balloon of thin aluminum filled with hydrogen.

Manufacture Proved Difficult

Attempts to manufacture thin sheet aluminum proved very unsatisfactory, but, after putting out the fire in the kitchen stove with my ladle of aluminum several times, I finally succeeded in obtaining some 1/100 sheet aluminum, which I formed into a pillow-like shape, sealing the edges with litharge and glycerine. Then followed the filling with hydrogen. A local drug store clerk caught my enthusiasm and spent most of one rainy morning helping me to fill the balloon. He also caught a very severe cold, but I was too excited to do that. Unfortunately, the balloon would not rise because the aluminum was too thick.

I imagine my innate interest in mechanical things was inherited from a number of ancestors who were machinists. At any rate, an event happened about this time which was destined to provide me with all the scientific speculative material I could desire. In January 1898, there appeared daily for several months in the *Boston Post* the story, "Fighters from Mars, or The War of the Worlds, In and Near Boston." This, as well as the story which followed it, "Edison's Conquest of Mars," by Garrett P. Serviss, gripped my imagination tremendously. Wells' wonderful true psychology made the thing very vivid, and possible ways and means of accomplishing the physical marvels set forth kept me busy thinking.

At that time, my Uncle George was living in the same house with us at Worcester, Mass. He could do wonderful little things about the house with wire and pieces of zinc, and his neat little workshop and

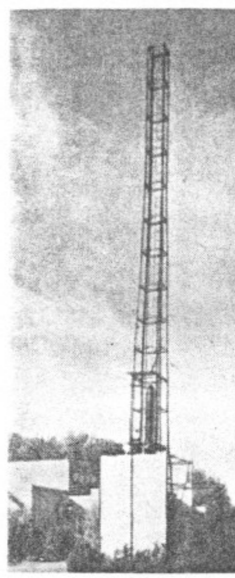
Roswell Museum to Open Goddard Wing This Month

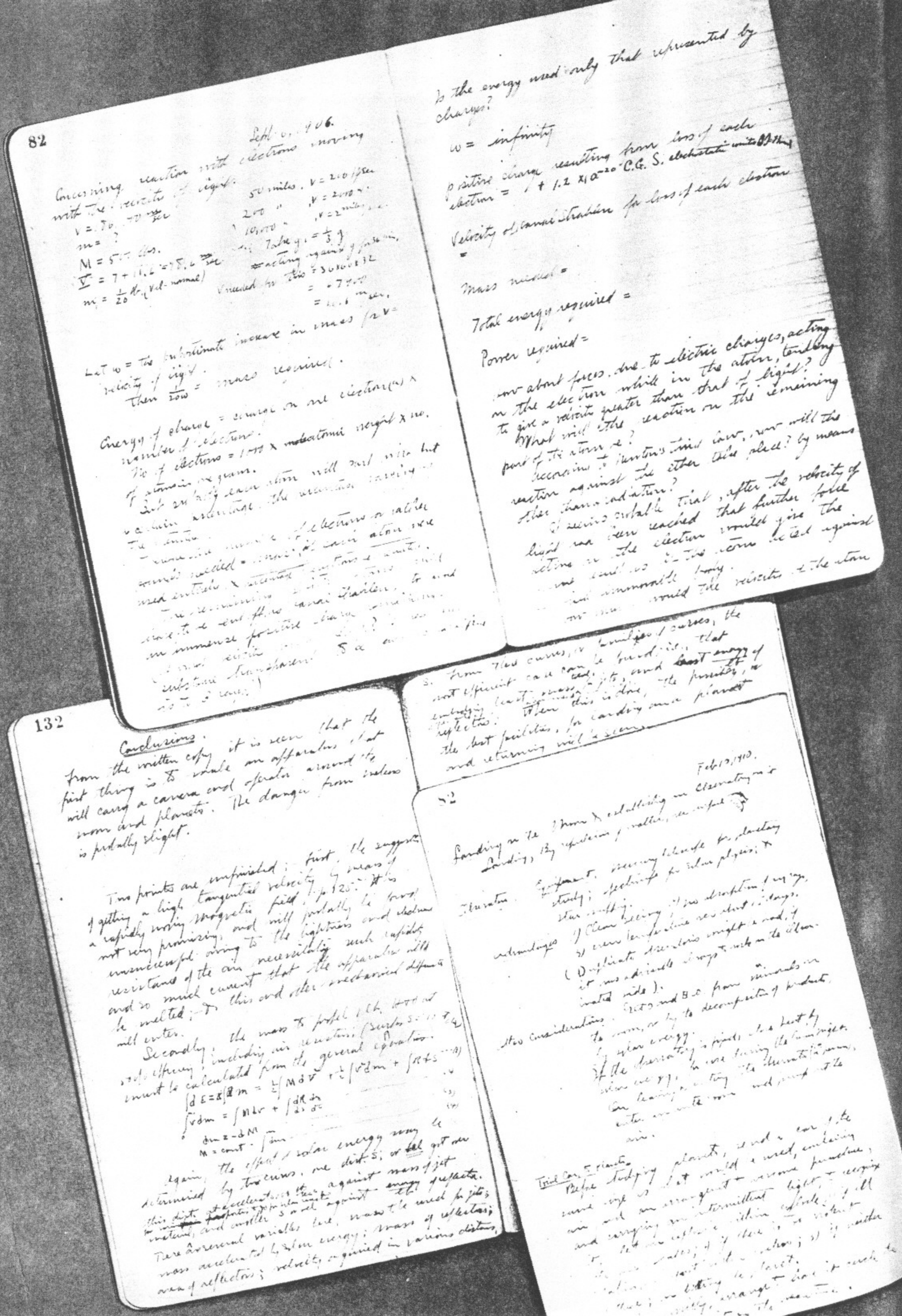
The Goddard Memorial Wing of the Roswell (N. M.) Museum will be opened to the public April 25 following special dedication ceremonies. Mrs. Robert H. Goddard, Army Under Secretary Hugh Milton, Sen. Clinton P. Anderson (D., N. M.), Harry Guggenheim and a host of leading figures in rocketry and astronautics are expected to attend.

Both indoor and outdoor exhibits are planned and these are now being readied by the museum staff, headed by Director David Gebhard. The indoor exhibit will trace Dr. Goddard's experiments from around 1914 to his untimely death in 1945, concentrating on work done in the Roswell area. Materials exhibited will be supplemented by large photo-murals showing the Goddard rockets being built, tested, and fired. Other exhibits will trace the history of rocketry from his death to the present. The launching tower and observation tower used by Dr. Goddard in his Roswell experiments have been emplaced on the museum grounds, while a newly built courtyard will house the larger rockets and equipment.

A good part of the material to be exhibited was donated to the museum by Mrs. Goddard and the IAS. Funds for the necessary construction were made available through a grant from the Daniel and Florence Guggenheim Foundation.

Above, the Roswell Museum, with new Goddard wing at right. Highlights of outdoor exhibit are the launching tower (right) and some of the larger Goddard rockets (below)




82
Sept. 6, 1906.
Concerning reaction with electrons moving with the velocity of light.
Is the energy used only that represented by charges?
w = infinity
Velocity of Canal Strahlen for loss of each electron
Mass needed =
Total energy required =
Power required =
132
Conclusions.
From the written copy it is seen that the first thing is to make an apparatus that will carry a camera and operate around the moon and planets. The danger from meteors is probably slight.
Two points are unfinished: first, the suggestion of getting a high tangential velocity by means of a rapidly moving magnetic field
Secondly, the mass to propel
Feb 13, 1910.
82
Landing on the Moon & establishing an Observatory
Landing, By reflection of matter
Other Considerations.

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tool cabinet in the shed was an unending feast to my eyes. This was the situation when, on the afternoon of Oct. 19, 1899, I climbed a tall cherry tree at the back of the barn and, armed with a saw and hatchet, started to trim the dead limbs from the tree. It was one of those quiet, colorful afternoons of sheer beauty which we have in October in New England, and, as I looked toward the fields to the east, I imagined how wonderful it would be to make some device which had even the *possibility* of ascending to Mars, and how it would look on a small scale if sent up from the meadow at my feet.

It seemed to me then that a weight, whirling around a horizontal shaft and moving more rapidly above than below, could furnish lift by virtue of the greater centrifugal force at the top of the path. In any event, I was a different boy when I descended the ladder. Life now had a purpose for me. Later in the year, I started making wooden models in which lead weights were to furnish lift by moving back and forth in vertical arcs, or strike against metal pieces as they whirled around horizontal axes. These naturally gave negative results, and I began to think there might be something after all to Newton's Laws, which I had read in Cassell's "Popular Educator," given to me by my father.

Newton's Third Law was accordingly tested, both with devices suspended by rubber bands and by devices on floats, and the said law verified conclusively.

This, however, did not put a stop to my interest, but made me realize that, if a way to navigate space were to be discovered, or invented, it would be the result of a knowledge of physics and mathematics. Not having had a course in physics, and having had a course in algebra in the English High School in which I had not particularly distinguished myself, I resolved forthwith to enter the new South High School in Worcester and shine in these subjects.

This proved easy in physics, at the hands of a very delightful and capable teacher. In mathematics, however, there was my previous distaste of the subject to overcome. I resolved nevertheless to lead the class in geometry and managed to do so despite the presence in the class of an exceedingly bright girl who was a natural mathematician. The plan which brought success was the making of a very painstaking book of original geometrical propositions. Any proposition I could think of I would try to prove, and then bring the result to my very patient and encouraging teacher. Some of the propositions occurred later in the course and some did not, but they made it a pleasure to think about geometry, which, perhaps, was the important thing.

Work at the attractive new school, with its complete equipment and enthusiastic teachers, was a pleasure. In December 1901, during my first year, I wrote a short article on the Navigation of Space and submitted it to *Popular Science Monthly*. The article mentioned how the idea of firing several cannons, arranged like a nest of beakers, had been proposed, and quoted figures on the frequency of meteors in space, which objects might make a collision likely. The article was not accepted.

During my two later years at the school, I spent a good deal of time considering the possibility of obtaining propulsion by a kind of machine gun device in which bullets were fired downward. I also experimented with gyroscopes under the erroneous impression that the tendency for the gyroscope to remain in one plane might be used to give a resultant force, just as a light card, in the air, can resist turning in such a way as to give a resultant force.

By the time I graduated from high school, I had a set of models which would not work and a number of suggestions which, from the physics I had learned, I now knew were erroneous. Accordingly, one day I gathered together all the notes I could find and burned them in the little wood stove in the dining room.

Dream Would Not Down

But the dream would not down, and inside of two months I once again caught myself making notes of further suggestions, for even though I reasoned with myself that the thing was impossible, there was something inside me which simply would not stop working.

At about this time, I bought a number of green cloth-covered notebooks with numbered pages, and started to make a systematic record of suggestions, setting down the date of each as it occurred. I had the advantage during this period of the excellent physics courses given by Worcester Polytechnic Institute.

The suggestions were very diversified, and concerned all sorts of possibilities. A summary of 26 methods, involving means in space, means taken with the apparatus, and means sent from the earth, was written Dec. 28, 1909. A brief outline of the most interesting suggestions will show that the fresh start made with these notebooks was worthwhile:

Large mass of explosive (CONTINUED ON PAGE 106)

Pages from Dr. Goddard's famous notebooks, dated from Sept. 6, 1906, to 1910, reveal references to ion propulsion, high energy propulsion systems utilizing solar energy collectors and lightweight propellants, and landing and establishing an observatory on the moon.

Goddard Autobiography

(CONTINUED FROM PAGE 27)

to raise 1-lb final mass to great heights, with slow propulsion in the atmosphere (April 4, 1908).

Multiple rockets (Jan. 24, 1909).

Liquid H, O, N_2O_4 and CH_6 for rocket propulsion (June 9, 1908).

Continuous propulsion produced by liquids burning under pressure (June 11, 1908).

General theory of hydrogen and oxygen rocket (Aug. 10, 1910).

Reaction by streams of ions to furnish rocket propulsion (Sept. 6, 1906).

Use of solar energy in connection with electrostatic repulsion (July 1907).

Cooling of nozzle by liquid H and O (April 6, 1909).

Raising an explosively propelled apparatus to a great initial height by balloons (June 1907).

Camera sent around distant planets and returned to earth (June 19, 1908) and guided by the intensity of gravity at predetermined points of its path (June 24, 1908).

Steering automatically by photosensitive cells (Oct. 15, 1908).

Explosive sent to dark side of new moon giving specially colored light (Dec. 26, 1908) and observed as monochromatic light, on a Frauenhofer line, along with use of monochromatic light in locating a rocket returning from outer space (Jan. 21, 1908).

Circling a planet to decrease speed before landing (June 24, 1908).

Use of planes on rockets (April 6, 1909).

Production of H and O on the moon (February 10, 1910).

Automatic signaling from a planet (Aug. 18, 1908).

Means for neutralizing effect of decrease of gravity on an operator (Nov. 27, 1910).

Ion Experimentation

As a result of the ideas concerning the breaking up of atoms artificially by impact, of ions moving at very high speeds, and the motion of ions in closed paths, I experimented with a vacuum tube in which ions moved in closed paths due to a magnetic field while at Clark Univ., and later demonstrated the tube at the Physics Seminar at Princeton Univ., afterward obtaining a U.S. patent on the method (May 4, 1915, No. 1,137,964), entitled "Method of and Means for Producing Electrically Charged Particles."

Also, as a result of the attempt to obtain "reaction against the ether," or, in other words, reaction against a displacement current in free space, I obtained Patent No. 1,159,209, issued Nov. 5, 1915, entitled "Method of and Apparatus for Producing Electrical Impulses or Oscillations." This consisted of a means of obtaining forced vibrations of any frequency by means of an oscillating cathode ray beam, and resulted from a Wehnelt cathode ray tube, constructed at Clark Univ.

This idea led to some consequences which were highly important in shaping my later work. After having obtained my Ph.D. from Clark, choosing as a thesis the explanation of crystal rectifiers—not because I was particulary interested, but because I felt my previous studies on the conductivity of powders at Worcester Polytechnic Institute would be a help—I spent an additional year at Clark as an honorary fellow in physics, living on what I had saved while teaching for a year at WPI.

Two Interesting Essays

While at WPI, I wrote two essays of some interest. One, on the balancing of aeroplanes by use of the gyroscope, incidentally suggested bending of the wings in steering. The other, entitled "Traveling in 1950," concerned an idea for traveling in airtight cars in a vacuum, supported above and out of contact with a roadbed, and propelled by the action of magnets in the bottom and walls of both car and tunnel, there being an acceleration of 32 fps^2 during the first half of the journey and a deceleration of equal amount during the last half. A fundamental and important principle set forth in this essay was the continued acceleration of a body by forces which changed from attraction and repulsion as the body passed by the source of the force.

While at WPI, also, I wrote in 1907 a rather long article on the possibility of applying heat from radioactive changes in obtaining interplanetary transportation, the device being equivalent to a rocket. This was never published, and I still have the letter of rejection from W. W. Payne, the editor of Popular Astronomy at the time.

Before leaving for Princeton, the various methods were outlined in a careful discussion, and the theory of the multiple-charge rocket, conceived in 1908–09, was roughly outlined, along with the use of a lightweight solar energy engine, considered in 1907.

While at Princeton in 1912–13, I spent the evenings working on the theory of rocket propulsion, assuming that, with smokeless powder, and hydrogen and oxygen, an efficiency of 50 per cent could be secured. This I later found by experiment to be true. During the day I worked on an interesting physical problem not then explained by electrical theory—the positive result of force on a material dielectric carrying a displacement current.

While recuperating from a serious illness in May of 1913, I wrote the material for the two U.S. patents which cover the essentials of rocket propulsion, namely No. 1,102,653, dated July 7, 1914, and No. 1,103,503, July 14, 1914.

These two patents are worthy of special attention, in passing, for they give as nearly as possible an answer to the question as to what the "Goddard Rocket" is. The types of propellant that have given satisfactory results on the small-scale models have been so varied, and the methods of feeding successive portions of combustible or explosive materials into a combustion chamber have also been so varied, and yet proved so satisfactory, that I hesitate to limit myself to one particular apparatus and type of propellant. I prefer instead to consider the three broad principles covered in the claims of these two patents, namely (1) the use of a combustion chamber and nozzle; (2) the feeding of successive portions of propellant, liquid or solid, into the combustion chamber, giving either a steady or discontinuous propulsive force; and (3) the use of multiple rockets, each discarded in succession as the propellant it contains is exhausted.

1914—Work on Propellants

In the fall of 1914, while teaching part-time at Clark, I worked out the theory and calculations for smokeless powder and hydrogen and oxygen completely, and began experiments on the efficiency of ordinary rockets. Curiously enough, the initial mass needed to send 1 lb to infinity for hydrogen and oxygen at 50 per cent efficiency, namely, 43.5 lb, was close to that estimated roughly at 45 lb on Jan. 31, 1909.

Recognition of the importance of hydrogen and oxygen as a propellant, and the comparative ease of manufacture of liquid hydrogen and oxygen in comparatively inaccessible places where there was ice and snow and low temperatures, led to U.S. Patent No. 1,154,009, "Apparatus for Producing Gases." A further realization of the importance of repelling charged particles at a very high potential, and of light means for producing this potential, led to Patent No. 1,363,037, "Method of and Means for Producing Electrified Jets of Gas."

The experimental work which checked the conclusions set forth in this patent was carried out at Clark by two students during 1916–17, with the result that, at 20 lb pressure, a blast of air produced from 5000 to 10,000 v from 110 v d.c.

The chief experiments on which I myself worked in 1915–16 were concerned with the measurement of efficiency of common rockets, and of steel rockets provided with nozzles, the latter experiments being repeated, in part, in vacuo. These experiments were carefully written up and, together with photographs, were bound in a book entitled "A Method of Reaching Extreme Altitudes." The aim was to secure funds sufficient to permit the development and construction of a rocket having a large proportion of propellant to total weight. The use of smokeless powder appeared to offer the least experimental difficulty, and no other propellant was therefore mentioned.

The calculations for projection to an "infinite" distance were included, but, to avoid the appearance of too much speculation, it was considered best to suggest the sending of a mass of flash powder to the surface of the new moon, rather than to specify interplanetary navigation. The use of solar energy in decreasing transit time between planets was also omitted, as was use of the moon as a halfway station, and also the production of hydrogen and oxygen under pressure by electrolysis.

Nevertheless, as a hint of further possibilities, the following remark was made at the end of the manuscript:

"There are, however, developments of the general method under discussion which involve a number of important features not herein mentioned, which could lead to results of much scientific interest."

Smithsonian Lent Encouragement

A letter sent to the Aero Club of America regarding this manuscript brought no reply, but a similar letter addressed to the Smithsonian Institution gave some encouragement, and was accompanied by the request that the manuscript be sent for examination by a committee. This committee reported favorably, and a request for $5000 for the construction of a model was granted.

Work was carried on chiefly in the Magnetic Laboratory at WPI, but in part also at Clark. With the entrance of the U.S. into the World War in 1917, it seemed desirable to have the development undertaken as a war proposition, and after considering several plans, I went to Washington in the winter of 1917 and obtained the necessary support. From that time until June, the work was continued at WPI, and from June until nearly November, it was carried on at the Mt. Wilson Observatory shops in Pasadena, Calif.

With the devices developed and tested, and their possibilities, this document is not concerned. It is, perhaps, sufficient to say that, before the signing of the Armistice, a small multiple-charge rocket, using a few cartridges had been tested, operated satisfactorily and traveled straight—a distance of 60 or 80 ft.

On returning to Clark, Dr. Webster, Director of the Physical Laboratories, became interested in what I had done, and said that the matter should be published. He even went so far as to say that if I didn't publish a paper on rockets, he would. Under this stimulation, I asked the Smithsonian to publish the manuscript I had previously sent them, thinking this to be preferable to dividing the paper into several parts and publishing these in separate journals. They agreed to do so, provided it came out of my appropriation for rocket development. I agreed to do this, and the manuscript was published in the Smithsonian Miscellaneous Collections for 1919.

Inasmuch as I believed that some of the matters upon which I had worked should be mentioned in this publication, I included, in the form of supplementary notes, a discussion of secondary rockets, the use of hydrogen and oxygen, the probability of a collision with meteors, and a few other matters.

I received the reprints early in January 1920, and sent copies to a few friends. I though it odd that no notice of the work was taken by the press, as it seemed that the method was one that they might desire to feature. Several weeks passed, and I had nearly forgotten the press question, when one morning, I was startled to learn that the Institution itself (or, as I learned afterward, its press representative) had made of the paper the first real suggestion for contact between the planets.

From that day, the whole thing was summed up in the public mind in the word "moon-rocket," and thus it happened that, in trying to minimize the sensational side, I had really made more of a stir than I would if I had discussed transportation to Mars, which would probably have been considered ridiculous by the press representative, and doubtless never would have been mentioned.