

The Role of Dr. Robert Goddard in Moving the World of Space Travel From Science Fiction to Science Fact

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Introduction

As Artemis prepares to return humans to the Moon, it is hard to believe that 100 years ago, a liquid propellant rocket had never flown before and the world altitude record was set at 35,000 feet, by passengers in the gondola of a balloon.

The development of the technologies and capabilities to support space missions from Explorer 1 to Artemis 1 can be thought of as having evolved through a number of phases in the past 100 years. As we celebrate the 100th anniversary of the launch of the first liquid rocket engine, this paper reflects on the critical role that Dr. Robert Hutchings Goddard played in the earliest phases of space exploration as he led the way in moving spaceflight from science fiction to science fact. This story is less focused on the details of Dr. Goddard's technical accomplishments and more on the overall impact that his research and writings had on the global community as researchers and average citizens came to understand that the world was on the verge of a "space age".

Before Dr. Goddard

The evolution from imaginary travelogues to the applications of science and technology to the challenges of spaceflight, began in the late 1800s. The first serious technical discussions of space travel came from Russia and France. In France, a contemporary of Jules Verne, Achille Eyraud, proposed the use of a "rocket" for space travel in 1865.¹ During the same period, a Russian teacher, Konstantin Tsiolkovsky, was theorizing on the prospects of rocket-powered space travel. In 1903, Tsiolkovsky compiled the results of 20 years of research into a paper titled "Exploration of Cosmic Space by Reaction Devices"². Although technology limitations of the 1800s prohibited Tsiolkovsky's theoretical research from turning into practical experiments, he foresaw many of the developments of the 1900s. Tsiolkovsky's writing provided invaluable detailed descriptions in areas such as liquid propellants, staged rockets, space weightlessness and the heating problems associated with atmospheric re-entry.

At the dawn of the 20th century, a third space travel pioneer, Robert Esnault-Pelterie, joined the discussion. A French designer of high-speed aircraft and aircraft engines, Esnault-Pelterie, began, in 1907, to research the issues of space travel using rocketry. On March 8, 1913, Esnault-Pelterie stood before the French Physical Society at a meeting in Paris, and described a human flight from the Earth to the Moon. He announced that the trip would take approximately two days in a "closed vessel of extreme lightness (total vehicle weight of approximately one ton), combined with a motor of great power (414,000 horsepower)."³ Esnault-Pelterie noted that the passengers would have the sensation of weighing one-tenth more than usual during the early phases of flight but they would cease to weigh at all during the remainder of the flight. "Special appliances" would be developed to counteract any detrimental effects that this lack of weight would have on the passengers. Most importantly, he noted that his ideas were, "practical, based on scientific calculations and not reminiscent of Jules Verne's romance."³ This was a reference to books written by Jules Verne, H.G. Wells and others, where space

travelers began their journey by being shot from a giant cannon which propelled them to their destination (for science fiction authors, long-range artillery, which was a rapidly advancing technology at this time, seemed like a practical way of sending things into space).

The foresight of early pioneers such as Esnault-Pelterie, Eyraud and Tsiolkovsky, would greatly influence the future of space travel. Their theories and conjectures were “ahead of their time”, but by being ahead-of-their-time, they were limited to theoretical research – but – experimentation was just around the corner.

Only a year after Esnault-Pelterie’s speech, France, Russia and other nations, became involved in the first World War. During the War (1914-1918), investigations into rocketry and space travel gave way to more practical war-focused scientific efforts. For example, the United States realized that they needed to invest significantly in aircraft research, as they saw the value of aircraft for military and other purposes. The formation of the National Advisory Committee on Aeronautics (NACA) in 1915 along with its first research laboratory at Langley Field, VA, spearheaded the federal government’s investment in ensuring the US played a leading role in future cutting-edge aviation technology and aircraft design. The same realization didn’t occur for rocketry, and it wouldn’t be until the U.S. military became aware of the development of rocketry in Germany in the 1930s, that put them far ahead of the U.S., that the government stepped in to play a larger role. Until then, there were numerous philanthropic groups, including the Rockefeller and Guggenheim Foundations and the Smithsonian Institution, as well as corporate labs, that provided critical seed money to marry the space exploration dreams of the past with the rapidly evolving technologies of the early 20th century.

The Turning Point: Robert Hutchings Goddard

As a youngster growing up in Massachusetts, Robert Hutchings Goddard, read the works of authors such as Jules Verne. In addition, his scientific curiosity led him at an early age to begin experimenting with rocketry. After receiving his Ph.D. from Clark University in Worcester, MA, Dr. Goddard attended Princeton University on a research fellowship. While at Princeton (1912-1913) he spent evenings working on his theory of rocket propulsion, focusing on ways to increase propulsion efficiency through the use of various powder and gas propellants. In 1919, under a grant from the Smithsonian Institution’s Hodgkins Fund for Atmospheric Research, Dr. Goddard published a paper describing his work at Clark and Princeton to develop a rocket which could carry payloads up to 200 miles above the Earth’s surface. This paper, titled: “*A Method of Reaching Extreme Altitudes*”⁴, would provide a foundation for those looking to move space travel toward reality.

This paper and the associated research were originally intended to assist scientists in exploring the upper regions of the Earth’s atmosphere. Up to 1919, scientific instruments had been carried by balloons to heights of no greater than 20 miles. Through the use of rockets, Dr. Goddard believed that instruments could be flown in the upper reaches of the atmosphere to investigate the density, chemical constituents and temperature of this region as well as determining the height to which the atmosphere extends. He believed that experiments on ozone in the upper atmosphere, the composition of the aurora, the nature of alpha, beta and gamma-rays from the Sun as well as a determination of the ultraviolet spectrum of the Sun could all be accomplished using the rocket as a research tool. Within his discussion of the rocket and its capabilities, Goddard may have reached back to his childhood readings when he mentioned that a rocket might someday be designed which could travel to the Moon and

impact it, causing a flash which could be observed on Earth. When the *New York Times* reported on Dr. Goddard's efforts in their January 12, 1920 edition, the headline read "*Believes Rocket Can Reach Moon*" in large print, followed by "*Smithsonian Institution Tells of Prof. Goddard's Invention to Explore Upper Air*" in smaller print.⁵ That was all it took to stir the imagination of headstrong Americans who were going through a renaissance of discover and technological advances. Only twenty year earlier, in 1903, the Wright brothers had flown the world's first heavier-than-air flying machine. This period would also see the distribution of electricity and electrical appliances throughout the United States, the introduction, in 1908, of Henry Ford's affordable motorcar, the development and widespread use of radio and telephone service, and in 1914, the completion of the Panama Canal. Although many history books describe Americans in the 1920s as "post-war disillusioned" there were also many fervent believers in the concepts of progress, science and opportunity. They wanted heroes and heroines who represented these values and they wanted to participate in the excitement and pride associated with risk, accomplishment and progress. For many, Goddard and his "Moon voyage" embraced these values.

As a scientist with Smithsonian backing, Goddard's work was taken seriously by many Americans. As a result of the publicity that Goddard's research received, a number of scientists, engineers, mechanics, pilots and entrepreneurs went to work preparing for trips to the Moon and Mars. One month after the *New York Times* released information regarding Goddard's research, 23-year old Captain Claude Collins of Philadelphia volunteered to be the first person to be sent to Mars (February 5, 1920).⁶ Captain Collins made this offer, "in order to aid science and to arouse the people of the nation to act to make America the peer of the other nations in the air". Captain Collins provided the following conditions for his flight: "1) he should be permitted to assist in planning the mission and constructing the rocket, 2) communications with Mars must be established prior to his launch and a test rocket must be sent to Mars first, 3) a board of ten preeminent scientists must agree that the flight is practical, 4) a \$10,000 insurance policy must be taken by the government for his heirs, 5) he must be given an airplane and funds to tour the U.S. to promote his flight". Collins said he was serious about his intentions and had great faith in Dr. Goddard and his rocket design. The importance of Captain Collins' story is that it was published on the front page of the *New York Times*. Many Americans now believed that flights to the Moon and Mars would be practical in the near future and they wanted the United States to lead the way in exploring this new frontier. Within a few weeks after Collins' letter was received, four other Mars flight candidates had volunteered to fly Dr. Goddard's "super-rocket". One candidate, Peter P. Devlin of Brooklyn, NY, felt that his experience testing parachutes in the war made him a prime candidate for the flight.⁷

An additional effect of the publicity that Goddard's Moon rocket received was the refocusing of astronomers on searching for the presence of atmospheres and life on the Moon and Mars. While the focus on Martian life speculation continued to follow Percivell Lowell's earlier efforts to map canals that were supposedly bringing water from the poles to Mars' vegetation growing in the equatorial regions⁸, Harvard astronomer William Henry Pickering led the lunar-life search effort. In 1921, Pickering completed a series of telescopic observations of the Moon at the Harvard station in Mandeville, Jamaica, which he asserted proved, beyond a shadow of a doubt, that life existed on the Moon. Pickering stated that "vast fields of foliage spring up with almost unbelievable rapidity when day begins to dawn on the Moon, that these wide sweeps of flora come to full blossom and then as rapidly wane and disappear, vanishing completely in a maximum period of eleven days and in some places a less number of days."⁹ In addition, Pickering's analysis of the Moon revealed that "great blizzards sweep

across portions of the Moon, that volcanic eruptions are frequent there, that fields of moisture, of mist and fog, appear and disappear and that clouds abound”.

Overall, Goddard’s technical developments, Pickering and Lowell’s astronomical observations and the conclusions they drew regarding extraterrestrial environments, added to the general excitement which now surrounded the notion of space travel, with this momentum propelling researchers forward.

Between the Wars – The Romantic Age

The period between World Wars can be considered the “romantic age” of interplanetary travel research, with research continuing even through the Depression years, when Americans were in search of escapes from their troubles. Movies, sports and even the fantasy of space travel, provided this escape. In addition, the development of rocket power continued through the 1920s for a variety of reasons. Rocket power offered the potential for mail and passenger delivery across the Atlantic Ocean in 20 minutes, high speed automobile travel, and a variety of military applications. Throughout this period, the promise and sense of adventure of space travel combined with the practicality of rocket research, created a stimulating and progressive research environment where many people believed that space travel was “right around the corner”.

Throughout the 1920s and early 1930s, Dr. Goddard, funded by the Guggenheim Foundation starting in the late 1920s, continued to play a leading role in rocket research. He also became actively involved in analyzing the use of rocket propulsion for space travel. In an interview held in May of 1924, Goddard described a rocket test he was planning for the summer or fall of that year. During this interview, Goddard spoke in support of a rocket for carrying humans to the Moon. He stated that his early emphasis would be on perfecting the rocket and its propulsion system. When the rocket had been tested to his satisfaction, “all of the other things needed to attempt to reach the lunar body will come in for consideration.¹⁰” The reporter stated that this human mission to the Moon would probably take place “in a year or two”.

One interesting factor revealed in this interview is Goddard’s decision to move from research using common powder rockets to his work with gas fuels. During this discussion, Goddard described his life-long interest in the Moon and the current knowledge of its environment. Then he described the action of a “fire rocket” such as is used on the fourth of July. Goddard stated:

“What does the rocket prove? Simply stated, the amount of power and other ingredients will give off certain gases which kick-back against the atmosphere and supply driving power... Now, linking the idea of the rocket and the Moon together, I have tried to connect the two. Plainly, it was not possible to pack enough explosives in any rocket to traverse the distance between the Moon and the Earth. Then I considered the possibility of successive explosions, such as we have heard so much about in the big German shells. But that theory has been critically examined and found doubtful. So, I worked around to the thought of regular propulsion, supplied by gases released in a steady flow, just as we drive an automobile. That is the basis of my plans. I am working with well-known gases, but have found new ways of applying their use. The experimental rocket will also have considerable mechanisms. I need to say that it has required many years to study the many details involved.... But I have proved experimentally that the rocket will rise practically any desired distance. This being true,

there is nothing to prevent the construction of a greater rocket which would go up to the Moon”.

Based on this interview, it appears that Goddard’s interest in interplanetary space travel played a significant role in his decision to experiment with gas powered rockets.

During the 1920's, Goddard designed a number of high-powered propulsion systems for space travel. One of Goddard's most interesting propulsion systems that he would propose late in the decade was the "Sun Motor" which was described in the *New York Times* in October, 1929, as, "undoubtedly workable on a large scale if mechanical details which seem not overly difficult can be solved. There is still no method of turning captured solar energy efficiently into propulsive energy, for rocket propulsion requires that some mass of the flying craft be left behind in space as well as some of the energy, this discarded mass providing the 'action' to which the 'reaction' of the rocket is the twin. But probably that difficulty, when it needs to be faced, will prove surmountable."¹¹

In his writings, Goddard described a number of other potential problems of human flight to the Moon. He reported that the Heavyside layer of the atmosphere as described by radio engineers would prohibit lunar crews from sending messages to Earth once they had passed 60 miles above the Earth. In addition, he described the density of the lunar atmosphere as one-hundredth that of the Earth's, which would necessitate lunar passengers bringing their own supply of air; he described the 1/6th gravity of the Moon and how it would effect a traverse of the surface; and he mentioned the need for an additional rocket to propel the travelers back to the Earth at the end of their stay.¹⁰

Another Inflection Point: The First Liquid Fueled Rocket Launch!

The publicity associated with Goddard's 1919 publication had greatly increased interest in space travel. In 1926, Goddard's activities were to provide a second stimulus. On March 16, 1926, near Auburn, Massachusetts, Goddard launched the world's first liquid propellant rocket. The rocket climbed at 60 miles per hour, to an altitude of 41 feet, in 2 ½ seconds, while being filmed by Mrs. Goddard. After this initial success, Goddard would continue to experiment with rocketry until his death in 1945. Although his highest flights would not reach 10,000 feet, he would continue to dream of an age of interplanetary travel and he would continue to influence research in this field. Goddard's influence on young rocket pioneers in the United States and throughout the world can be seen during the 1920's and 1930's. In the United States, many of these rocket pioneers lacked funding and technology but made up for these shortcomings with imagination and spirit. As an example, in September of 1929, in Kent, Ohio, citizens were watching a "little man, with a slight stoop, who says he is going to make a journey to the Moon."¹² This man, Jim Sorgi, announced that his rocket would be approximately 90 feet long, it would carry ten tons of powder and two passengers, it would be capable of going to either the Moon or Mars, and he would be ready to go before the first snow fell. Sorgi was unsuccessful in his effort but projects such as his spread the scientific theories and emotional excitement of space travel throughout the country.

Many Americans were captivated by the thought of interplanetary travel as can be seen in a letter to the editor published in the *New York Times* on July 4, 1926. Mr. Harold Danne of New York wrote that he was very excited about the articles he had been reading on polar explorers of the 1920's. He felt that

these polar heroes should be regarded as "planetary precursors"¹³. Mr Danne stated that polar heroes were a good analogy for the exploring and colonizing of the planets that would occur in the near future.

More practical applications were being considered for Dr. Goddard's rockets as well. The International Meteorological Organization (IMO) was planning a second International Polar Year (IPY) for 1932. The first IPY, held in the 1880s, had brought together scientists from throughout the world to perform coordinated investigations of the polar regions. New technologies, including aircraft and high-altitude radiosonde balloons that could achieve heights in excess of 50,000 feet, would enable the second IPY to include more advanced research of the atmosphere as well. As U.S. plans for the second IPY were coming together, John A. Fleming, head of the Carnegie Institution's Department of Terrestrial Magnetism and a member of the Advisory Committee established by the Carnegie Institution to oversee the grant they had provided for Dr. Goddard's research at his new facility in New Mexico, made a proposal to use Goddard's rockets to support IPY upper atmosphere/ionosphere research. On January 27, 1932, Fleming testified before the House Foreign Affairs Committee that thought was being given to using Dr. Goddard's rocket for IPY research. Unfortunately, with limited Federal funding available during the Depression, funds were not available for such an expensive proposals, and much of the U.S. participation in the IPY was curtailed.

The 1920's and 1930's also saw the creation of a number of "Rocket Societies" throughout the United States. One of the most significant of these was the American Interplanetary Society (AIS). In 1934, the AIS was renamed the American Rocket Society (ARS) (In 1963, the ARS merged with the Institute of Aerospace Sciences to become the American Institute of Aeronautics and Astronautics (AIAA)), and a program of rocket construction and testing was pursued. These tests were performed in preparation for the construction of a rocket which could carry humans through interplanetary space. For example, on June 10, 1934, the ARS attempted to launch their fourth "interplanetary" rocket. The *New York Times* reported the story under the heading: "Planetary Rocket Remains on Earth; Mars and All Other Possible Goals Unmolested When it Proves to Be a Dud."¹⁴ The *Times* stated: "Shortly before 7:00 a.m. John Schesta of Brooklyn, a civil engineer and builder of Rocket No. 4; Laurence E. Manning, president of the American Interplanetary Society, and G. Edward Pendray, science editor of the *Literary Digest*, reached a platform that had been erected on the beach at Great Kills. ... instead of zooming into the air, the projectile never left the ground." Somehow, enthusiasm among these early rocket scientists and engineers remained strong even though they were having great difficulty in accomplishing successful launches.

Another group that stands out during this period is the Guggenheim Aeronautical Laboratory of the California Institute of Technology (GALCIT). Although "aeronautical" is in the name, this group, under the leadership of Dr. Theodore von Karman, was already thinking about developing scientific research "sounding rockets" with "sounding" referring to the rocket's suborbital trajectory, focused on collecting scientific data at various altitudes in the near-space environment. In 1939, with war again on the horizon, the U.S. Army became interested in funding some of the GALCIT rocket research. In 1944, the GALCIT team signed a contract with the Army Air Corps that established them as the "Jet Propulsion Laboratory".

In contrast to the enthusiasm of the rocket societies and among the public, the U.S. scientific community was divided in its support for Goddard and his theories. This division among scientists is readily visible in the following three examples extracted from one of America's most prestigious scientific periodicals, *Scientific American*. In August 1928, *Scientific American* published an article written by Mr. James Randolph titled "Can We Go To Mars?: A Physicist's Approach to a Fascinating Problem, the Solution of Which is, However, Far Away"¹⁵. As a respected publication among the scientific community, the editor of *Scientific American* felt that it was necessary to add a note placed in an outlined box at the head of the article to explain that this plan was theoretically sound and merited publishing. The editor said that he, "Makes no apology for publishing the accompanying article. It is not a Jules Verne story ... It is a physicist's conception of getting close enough to Mars to see what Mars is really like". The article was first submitted to laymen for opinion. They voted against it. It was then sent to several physicists. These favored publication ... The manuscript was submitted to Professor R. H. Goddard ... Goddard replied as follows:

"According to recent press notices, interplanetary transportation must remain impossible until atomic energy can be obtained and controlled. This attitude is, however, much like that of the scientists of thirty years ago, who declared that an airplane could not operate unless the forces of gravity could be neutralized. If atomic energy were available, it would be a very convenient means of propelling an interplanetary rocket. Atomic energy is not, however, necessary, as an interplanetary flight is possible in a rocket which is neither tremendously bulky nor unwieldy ... In light of the conclusions that I have reached, I can say that although Mr. James R. Randolph's article may read like romance, it is nevertheless thoroughly scientific, and, while not telling the whole story, it gives a good picture of what an interplanetary rocket must be like.¹⁵"

In this introductory paragraph that was included with the article, Dr. Goddard mentions a new element of interplanetary travel, atomic propulsion. Although it would be many years before achievable methods for harnessing atomic energy for spacecraft propulsion would be defined, atomic propulsion was considered beneficial to interplanetary travel since the 1920's.

The article itself (*Can We Go To Mars?*), describes the application of Professor Goddard's rocket to the problem of interplanetary travel. Mr. Randolph states that if properly scaled-up, a difficult task in Mr. Randolph's opinion, Goddard's rocket could be made large enough to reach Mars. Randolph introduced Goddard's concept of staging in his article to describe one of the design challenges involved in scaling-up the basic rocket. In staging, stacked rockets would be fired off in series. When a rocket had used up its propellants it would fall from the bottom of the stack and the next rocket would be fired. By using staging, the weight of the used propellant tanks could be jettisoned and the reduction in mass would allow the rocket to accelerate faster and travel further.

The Mars mission described in Randolph's article is a conjunction class mission with a two-year total trip time and a seven-month outbound journey. Artificial gravity is created by rotating the ship so that the passengers do not become sick, attitude control rockets are added to maintain the optimal interplanetary trajectory, and additional rockets for slowing down at Mars and for returning to Earth are

described. In addition, a small airtight glider would be jettisoned from the craft upon approaching Earth so that the crew could glide to a landing.¹⁵

March 1931, *Scientific American* published a second article on interplanetary travel. This article, "*The Future of the Rocket*", was written by David Lasser, President of the American Interplanetary Society.¹⁶ Again, the editor added a preamble: "The accompanying discussion of interplanetary rocket travel may please some, displease others. The proponents of the space rockets have not yet demonstrated its practicability but its opponents can not demonstrate its impracticability. Lasser's article discussed the use of a "station in space" which would allow crews to gain experience working in low-Earth-orbit prior to going on interplanetary voyages. His lunar rocket used staging (spent stages parachuted to Earth), and small logistics rockets which would carry propellant to the Moon prior to the launching of the larger human-carrying spacecraft. Once it had arrived at the Moon, the manned craft would collect this propellant for use on its return voyage. The lunar voyagers would use 14.7 psi diving suits for working outside the spacecraft. While on the surface, their tasks would include breaking down lunar rocks to produce oxygen and water. Lasser states that, "The first trips made to the Moon will be merely journeys to provide a quick inspection of lunar conditions, with a rapid return to Earth. Only after these conditions have been determined in full can a more extended stay, to reap some of the advantages of interplanetary travel, be made."

A few years after Lasser's article was published, *Scientific American* ran a third interplanetary travel article, "Could a Manned Rocket Reach Mars" (December 1934). Written by Dr. Henry Norris Russell, Chairman of Princeton's Department of Astronomy¹⁷. This article was not accompanied by a forward from the editor. Russell's article provided a critical analysis of the proposition that long-range artillery techniques could shoot humans to the Moon and Mars. After showing through mathematics that this concept was not feasible, Russell completed his article with criticism of interplanetary travel in general: "... But there is really no hope at all that living things could be shot through interplanetary space. Rocket ships might imaginably do better, though their success seems very remote. There is no hope, either, that such creatures as we are could survive at all on any of the planets."

Dr. Russell's more pessimistic attitude regarding interplanetary travel was shared by a number of prominent scientists of this era. For example, in 1930, another American scientist, John Q. Stewart, Associate Professor of Astronomical Physics at Princeton University, discussed the possibility of travel to the Moon¹⁸. Although Stewart considered interplanetary travel feasible, he believed that the capability to send humans to the Moon would not be available until the year 2050, at a cost of \$2 billion. Stewart stated that to develop the energy necessary to propel a rocket to the Moon, "Sufficient energy to create these speeds may be forthcoming from several sources. At present in the laboratory minute quantities of very concentrated energy stores have been obtained, such as ionized hydrogen, which contains a hundred times the energy of coal and oxygen." Stewart claimed that a lunar spacecraft which could hold 60 passengers (including a dozen scientists) on a seventy hour trip to the Moon would need to be perhaps 110 feet in diameter and weigh 70,000 tons of which 28,000 tons would be propellant. While on the lunar surface, the passengers would leave the spacecraft, "clad in diving suits. Gravity being only one sixth that of Earth, a man could carry several hundred pounds of apparatus for providing fresh air and regulating temperature." To return to Earth, the rocket would coast for most of the trip because of the Earth's gravitational attraction but, "care would need to be taken upon landing, for if the ship came

down too fast over a city and the rockets were fired to check the fall it would be disastrous to the people below."

In contrast to Dr. Stewart's \$2 billion estimate, W. A. Conrad, Assistant Professor of Mathematics at the U. S. Naval Academy, was more optimistic in 1933 when he stated that a round trip to the Moon would cost an affordable \$100 million (the price of two battleships in 1933).¹⁹

The International Environment

A discussion of space travel research during this period would be incomplete without a discussion of international research. Specifically, research in Germany, Russia, and France would expand on American research as well as breaking new ground.

Germany

In Germany, 30 year old Herman Oberth published, *"The Rocket Into Space"* in 1923. This book describes interplanetary travel by rocket to the Moon and Mars. Four years earlier, Oberth had written to Dr. Goddard requesting copies of his Smithsonian publication on rocketry²⁰. By the late 1920's, Oberth was beginning to move from experiments with powder rockets to the use of liquid oxygen mixed with benzine or alcohol. Oberth felt that a liquid powered "space rocket ship" about 136 feet long would someday travel to the Moon. Oberth stated that: "Its load of burned-out rockets would be discharged in flight, so that the 'space-ship' would be considerably smaller when and if it landed on the Moon²¹." The staged rocket and liquid propellants, both ideas examined early on by Dr. Goddard, had found their way across the Atlantic. Oberth's ideas were incorporated in German writer Thea von Harbon's story, *"The Girl in the Moon"*. The husband of the authoress happened to be Fritz Lang, production manager of UFA, the leading German film concern which in 1930 decided to convert this story into a movie. Professor Oberth was asked to support production of this movie by conducting his rocket experiments in Germany at UFA's expense. It turned out that UFA was unable to fund construction of a full size "Moon" rocket for use in the movie and Oberth was forced to construct scale-models for the film. Nevertheless, the release of this movie generated a great deal of excitement among the rocket pioneers of the period. For example, after seeing this film, David Lasser, President of the American Interplanetary Society, formed a world-wide society to fund the construction of Oberth's Moon rocket (Robert Esnault-Pelterie would become involved in this organization in 1932, after introducing them to his plan for reaching the Moon in 15 years)²². Another German scientist motivated by Dr. Goddard's work was a young Munich astronomer, Max Valier. *The New York Times* in June, 1928, stated that:

" ... Max Valier who seems to have the enthusiasm, the energy, and the skill of a first-class press agent. Valier's books are best sellers. His articles are snapped up by German newspapers and magazines. When he lectures the 'standing room only' sign is sure to be displayed. Three years of writing and lecturing have so accustomed educated Germans to the possibility of travelling to Venus or Mars a few centuries hence that it no longer seems mad.²³"

Individuals such as Max Valier and Frenchman Robert Esnault-Pelterie played a critical role in garnering public support for the dream of exploring space. Their methods were much more flamboyant than the efforts of other scientists, including Robert Goddard, who worked privately and without much

publicity. Both types of individuals were required to sustain the public support and technological momentum characteristic of space travel research during this period.

Valier, besides being an important spokesperson for interplanetary travel, also performed a number of serious investigations into issues associated with space travel. For example, on the thermodynamics of space travel, Valier wrote:

"We are prepared for this. As we ascend the speed of the machine is so regulated by preliminary calculations that it will be low while the dense lower atmosphere is traversed only to increase as we emerge from it. There is more danger in descending. Unless the rocket is retarded in time it will enter the highest and thinnest stratum of air at seven miles a second and burn up. ... The peak of the torpedo-like space cruiser would contain an enormous double or triple parachute which could be folded into the nose of the vessel. This parachute would be unfolded as soon as the Earth was approached. It would spread out and draw the nose upward so that it would approach the Earth bottom first. At the same time, the powerful vents would discharge their fiery gases and serve as brakes upon the speed of the ship.²⁴"

In the area of zero-gravity countermeasures, Valier wrote, "We do not know if the lack of gravity will not bring about some new form of dizziness or even cause unconsciousness. " To counteract these potential effects Valier suggested, " various aids such as guide ropes, slings on the walls, iron-soled shoes and magnetic floors, which would help voluntary movement." Valier also discussed lunar passengers in zero-g needing to, "suck their liquids through rubber nipples like babies", he discussed the "diving suits" that they would wear on the lunar surface, the possibility of finding ice in certain craters, and the construction of a solar reflector array power station on the lunar surface. Valier also mentioned that the Moon could be used as a transfer station or "springboard" for spaceships on their way to Venus, Mars, the large outer planets, or even the Martian moons Phobos and Deimos.²⁴ Valier's research came to a tragic end when he died on May 17, 1930 when a rocket motor he was testing exploded.

As in the United States, not all German scientists believed that rockets would ever be used for interplanetary travel. For example, in Frankfurt, rocket pioneer Fritz von Opel was investigating various applications for the rocket including rocket assist takeoff for aircraft and rocket powered automobiles. Von Opel insisted that he was not proposing to fly to the Moon and was "sharply opposed to the utopian ideas which heretofore have been linked up to my work."²⁵

Russia

On May 7, 1927, Ivan Federof, a mechanic from Kiel, USSR, announced that he would fly to the Moon in September in an apparatus called a "rocket", thirty meters long, half airplane and half giant projectile²⁶. He was to be accompanied by German "Moon fan" Max Valier and the three who prove most fit of seventy-five Moscow volunteers. Gas explosions were to be used to break the vehicle as it landed on the Moon, and on a second trip, gases obtained from the bottom of lunar craters would be rendered breathable by a special plant, with a building constructed for use as the terminus of a future line of

aerobuses. Federof's Moon machine would fly like an airplane to fifteen kilometers at which time it would fold back its wings, simultaneously exploding a terrific mixture of three secret gases in lateral cylinders opening toward the tail thus acquiring a velocity of 11 kilometers/second. Federof said that his craft was half built and as proof of the seriousness of his plans he showed reporters a letter he had received from Professor Robert Goddard discussing interplanetary travel. Federof's plans add a number of new elements to the concept of interplanetary travel. His vehicle design, using airplane techniques within the atmosphere and rocket propulsion in the vacuum of space is interesting as is the concept of creating a permanent outpost on the Moon for future travelers and the use of in situ resources.

France

French scientists and engineers played a vital role in interplanetary travel research in the 1920's and 1930's. The focal point for this research in France continued to be airplane designer Robert Esnault-Pelterie. In June 1927, Esnault-Pelterie presented an elaborate mathematical study of an interplanetary man-carrying rocket. At the same time, together with his friend Andre Hirsch, he pledged himself to award through the Societe Astronomique de France an annual prize of 5,000 francs for the best technical contribution to the advancement of astronautics. In 1929, the award (which had now been raised to 10,000 francs) was given to Herman Oberth "whose work in Rumania has most contributed toward progress in research for making practical interstellar navigation." Honorable mention went to American Professor Noah Deisch for work on an artificial gravity spacecraft and a German, Herr Hartmann. The committee warned upon presenting the award that "even with Herr Oberth's discoveries the trip to the moon remains entirely impracticable."²⁷ This pessimistic announcement signaled a change from Esnault-Pelterie's earlier, more optimistic opinion regarding the feasibility of interplanetary travel. This change in Esnault-Pelterie's views is evident again a year later in a speech he made in London to the Royal United Service Institution on November 1, 1928.²⁸ In this speech, Esnault-Pelterie changed his earlier (1913) stand on the feasibility of interplanetary travel. He stated that he had never said he would venture to the Moon and he added that "travel to the Moon would not be possible until atomic energy had been harnessed" (this statement provokes Dr. Goddard's comment on J. Randolph's article in Scientific American (August 1928)). "Then", he said, "the voyage to the Moon might be accomplished, but the person so transported could hardly hope to return." Esnault-Pelterie made these predictions based on his research during the 1920's into the use of more efficient fuels for a Moon rocket. Goddard had identified early on that the efficiency and power delivered by a rocket's fuel determine its range and payload carrying ability. Even with staging, advanced propellants would be required to make the lunar trip. Esnault-Pelterie calculated that a mixture of hydrogen and oxygen provided extremely good performance (but not good enough for interplanetary travel in Esnault-Pelterie's opinion). To boost rocket performance and efficiency high enough to make interplanetary travel possible, he turned next to atomic energy. By harnessing the energy of the atom, Esnault-Pelterie calculated that travel to the Moon would take 50 hours, a trip to Venus, 48 days and 4 hours, and a trip to Mars would last approximately 3 months.²⁹ Dr. Goddard disagreed with the assumption that atomic energy was "critical" to successful interplanetary travel. Goddard's research led him to believe that a small, compact, and efficient gas-powered rocket could bring people to the Moon, although atomic power would allow for quicker trips and larger payloads for lunar and Mars missions.³⁰ Although Esnault-Pelterie was for now pessimistic regarding interplanetary travel, this change seems only temporary since in the early 1930's he once again began looking for financial backing for his proposed Moon rocket. His new proposal was

for a hydrogen/oxygen fueled lunar rocket that he stated could be built in 15 years at a cost of \$2 million.³¹

Overall, world-wide research efforts during the "romantic age" brought interplanetary travel closer to reality than it had ever been before. Dr. Goddard's influence on these efforts can be seen, for example, in his consultation with Scientific American regarding publication of its first article on interplanetary travel, Herman Oberth's written request to Goddard for copies of his 1919 publication, and Ivan Federof's pride in his letter from Goddard. The excitement and romance of this period is captured in Captain Collins' efforts to become the first astronaut, in the enthusiasm of Max Valier and Robert Esnault-Pelterie, and in the undying belief of Ivan Federof and Jim Sorigi. This romantic age of research which encompassed Goddard's career would draw to a close with his death and the conclusion of the Second World War in 1945.

After Goddard

The world emerged from the Second World War with a dramatically altered global political environment. Each of the four countries which pioneered the early years of research Russia, France, Germany, and the United States, had been changed by the War. Germany suffered the greatest setback. Prior to the War, through the efforts of individuals such as Herman Oberth and a young pioneer named Wernher von Braun, Germany had built an impressive capability in the field of rocketry. During the war, they and the Nazi government focused this capability on weapons and destruction. At the end of the War, these German scientists and their technologies would immigrate to the Soviet Union and the United States where they would play a critical role in the ultimate success of space travel research by both countries.

Space travel research in the United States during the 1950's built on and refined the work of the pre-WWII pioneers. Scientists such as Kurt R. Stehling, consulting editor to *Aviation Magazine*, and Anthony J. Nerad, a General Electric research scientist, now began to look at what to do once humans developed the capability to visit the Moon. Mr. Nerad visualized the establishment of a "yard" on the Moon where space ships for interplanetary voyages would be built.³² Writing in *Aviation Age*, in 1958, Mr. Stehling observed that a "Moon station" would have a number of uses including: an astronomical observatory, a high vacuum research facility, a location to store nuclear waste generated on Earth, and a refueling station for interplanetary spacecraft bound for Mars and beyond. In addition, Stehling discussed the potential use of the Moon as a military outpost from which the United States could observe the Earth and potentially as a missile base for launching an attack toward the Earth. The small size of the Moon and the hostile conditions on its surface led Stehling to the conclusion that it should not be used as a military outpost.³³ Beyond the Moon, Mars continued to be the other focal point for interplanetary travel researchers. Dr. von Braun became one of the leaders of Mars voyage research during the 1950's. In 1953, von Braun published "*The Mars Project*", which outlined a concept for sending 70 people to Mars in a flotilla of spaceships. Von Braun's spaceships used chemical propulsion (an updated version of the book released in 1962 analyzed the advantages of using nuclear propulsion) and separate cargo and crew ships.³⁴ In addition to examining methods for traveling to Mars, the possibility of life existing on the Martian surface continued to tantalize scientists during the 1950's. As an example, in 1956, a young Carl Sagan wrote that, "some organisms can exist in the Martian environment."³⁵ Other destinations for explorers included the asteroids which were considered as a potential source of resources for use on

Earth. Another use for asteroids was proposed in 1954 by W. Kaempffert and A. G. Haley. These scientists proposed colonizing an asteroid for use as a military observation base.³⁶

Throughout the 1950's, support for interplanetary travel came from a variety of sources. In April 1950, aviation pioneer Igor Sikorsky estimated that interplanetary travel would be possible by 1970. Sikorsky felt that the scientific value of these flights would support their development while passenger service to the planets was only a remote possibility.³⁷ Also in 1950, the Hayden Planetarium in New York City previewed a new planetarium show that provided the public with a view into the future of interplanetary travel.³⁸ The Hayden followed this exhibit in 1951 by hosting the "*1st Annual Symposium on Space Travel*". Attendees at this symposium discussed lunar exploration and space colonization.³⁹ A number of the attendees at this symposium were members of the editorial staff of *Collier's*, a well known magazine of the period. The success of this symposium and the excitement that it generated motivated the *Collier's* editors to sponsor a similar conference or set of roundtable discussions in March 1952. The attendees at the *Collier's* conference were: Willy Ley, Dr. Heinz Haber, Dr. Wernher von Braun, Dr. Joseph Kaplan, Oscar Schachter, Chesley Bonestell, Fred Freeman, Rolf Klep, and Dr. Fred Whipple. During these discussions, Dr. von Braun was asked if he thought that interplanetary travel was possible. He answered:

"Certainly, once we have a station in space that would enable us to take off refueled and unimpeded by the Earth's atmosphere. Although Venus is the closest planet (26,000,000 miles when it swings toward the Earth), the easiest interplanetary trip would probably be to Mars (35,000,000 miles), since either of its two moons is close enough to serve as a space station for the return voyage. To land on Venus, we would have to establish a temporary space station around it. Traveling at the most economical speed, a rocket could make the one-way trip to Mars in 258 days, or to Venus in 146 days.⁴⁰"

Not everyone in the 1950's shared Dr. von Braun's optimism on the near-term possibility of interplanetary travel. For example, in October of 1952, the Hayden Planetarium held a second space travel symposium where Dr. von Braun provided similar views as well as predicting that "within ten to fifteen years, man would fly space ships as big as light cruisers 1,000 miles out." There, he said, a floating base could be built, a tiny satellite to the Earth which would eventually become a base for expeditions to the Moon and other planets.⁴¹ An opposing view was provided by Milton W. Rosen, director of the Navy's Viking Rocket Project in his talk entitled, "A Down to Earth View of Space Flight". "Space travel may come some day", he said, "but at the present stage of rocket development the United States would be through its money away if it were to undertake any one of the fantastic projects for a space ship that have been proposed in the last few years".

This more pessimistic attitude was echoed by attendees of the Third International Congress on Astronautics in Stuttgart (1952), who concluded that a trip to the Moon or Mars, "can not even be blueprinted yet."⁴² In the Soviet Union there were questions concerning the United States' motives in discussing interplanetary travel. In 1954, the Soviet government reported that the United States was using "science fiction movies, publications, and broadcasts as forerunners of a 'New Imperialism' aimed at conquering other planets."⁴³ Later that same year the Soviets countered the publicity that U.S.

interplanetary travel research was receiving by having Moscow Radio urge the youth of the Soviet Union to be the first to reach the Moon.⁴⁴ Then in 1955, Moscow Radio announced that Soviet scientists were researching the feasibility of hydrogen fusion to propel interplanetary vehicles.⁴⁵ Finally, in 1957, there were reports that the Soviet Union was designing a lunar space station which would be used to launch interplanetary spaceships.⁴⁶ Interplanetary travel research during the 1950's served as a training period for many of the pioneers who would help the United States make interplanetary travel a reality in the 1960's. Technology limitations were not what prevented researchers of the 1950's from traveling into interplanetary space; now the limiting factors were organization and funding. Estimates during this period showed that a human voyage to the Moon would cost hundreds of millions or even possibly billions of dollars. The federal government seemed the most likely source of funds for interplanetary travel since these efforts would be performed at first for their scientific value and not as missions of commercial exploitation. The problem was that there was no federal agency responsible for establishing a civil space effort. On July 29, 1958 this changed when President Dwight Eisenhower established the National Aeronautics and Space Administration.

The Space Age: Interplanetary Travel Becomes Reality

The third phase of interplanetary travel research has included the actual development and refinement of interplanetary probes. In 1960, just two years after the formation of NASA, the U.S. Pioneer V satellite was sending back signals from interplanetary space. The contributions that Robert Goddard had made to rocketry and interplanetary travel were also recognized during 1960. It was during this year that the United States paid the Guggenheim Foundation and Mrs. Goddard \$1,000,000 for the use of Dr. Goddard's 214 patents, which cover virtually every phase of modern rocketry. The following year President Kennedy called for America to send humans to the Moon and the Robert H. Goddard Space Flight Center was dedicated in Greenbelt, Maryland.

The 1960's became the decade of accomplishment in interplanetary travel research. Never before or since have the necessary technologies, skilled professionals, and valuable resources been applied to interplanetary travel. By 1969, Americans had set foot on the Lunar surface after having become in 1968 the first country to send humans into interplanetary space. Dr. Goddard's contributions to this effort were seen, for example, in the use of liquid propellants and the multi-stage construction of the Saturn V launch vehicle which carried humans to the Moon. In the late 1960's, Dr. von Braun and other scientists urged the nation to build on the Apollo experience to establish a permanent human presence on the Moon and in Earth orbit while developing the capabilities to send humans to Mars. The issue in the 1970's became not whether the U. S. had the technology or resources to travel into interplanetary space but rather did the U. S. consider interplanetary travel a national priority.

Conclusion

The pioneering work of early 21st century researchers such as Robert Goddard, Herman Oberth, Max Valier, and Robert Esnault-Pelterie, provided the foundation for the current age of interplanetary travel. A critical period of this second phase was the "romantic age" between the World Wars, a period when Robert Goddard was most active, and a period when the dreams of the past moved to the edge of reality. Now, as we stand at the threshold of a new era in interplanetary human exploration – it is good to pause and reflect on those who initiated the path – especially Dr. Robert Hutchings Goddard!

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