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Dr. Robert H. Goddard

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Abstract

There are four main objectives regarding Dr. Robert H. Goddard in this IQP. The first objective is to develop an understanding of how important Dr. Robert H. Goddard's contribution to the field of rocketry was. The second objective is to determine the impact that Goddard has had on the Worcester community and the community of Roswell, NM. The next objective is to analyze the books written about Goddard. These will also be compared to the number of books written about other popular figures in the aerospace field. The fourth and final objective will be to determine the literacy of Goddard's scientific work among Worcester college students.

Chapter 1: Introduction

1.1 Introduction

Robert Hutchings Goddard, born in Worcester, Massachusetts, was a pioneer of the Space Age in the early twentieth century. Arguably one of Worcester Polytechnic Institute's most famous graduates, he went on to achieve recognition around the world as one of the first people who saw the value of rockets in the exploration of outer space. He overcame many hardships to successfully test the first liquid-fueled rocket in Auburn, MA. He began a journey that would eventually lead the United States to the moon and the world beyond the thin atmosphere that surrounds this planet. This IQP is going to examine some of Goddard's impact on the world, and the world's perception of Goddard's work.

1.2 Objectives

There are four main objectives regarding Dr. Robert H. Goddard in this IQP. The first objective is to develop an understanding of how important Dr. Robert H. Goddard's contribution to the field of rocketry was. The second objective is to determine the impact that Goddard has had on the Worcester community and the community of Roswell, NM. The next objective is to analyze the books written about Goddard. These will also be compared to the number of books written about other popular figures in the aerospace field. The fourth and final objective will be to determine the literacy of Goddard's scientific work among Worcester college students.

1.3 Methodology

Attempting to place a value on an individual's life work is quite a daunting task. There are an uncountable number of parameters that need to be analyzed and most are quite ambiguous. Indeed, there are so many parameters that a complete study of Goddard's life is beyond the scope of an IQP. In order to make a statement on how valuable Dr. Goddard's lifelong work was, we intend to take three different approaches to analyzing his achievements.

The first component will be an investigation into the first major publications of three scientists, including Dr. Goddard, in the field of rocketry. We chose to do this both because we were able to obtain these papers and because it provides the soundest basis for comparison between the three pioneers in rocketry. Such a comparison could be useful to other IQP groups or to groups interested in the early history of space travel. The other two scientists are Dr. Oberth and Dr. Tsiolkovsky. Oberth published a major paper on rocketry in 1924 following a communication he had with Dr. Goddard. Tsiolkovsky was one of the first to explore the theory behind using liquids as a means to propel rockets, publishing his results in 1903. We intend to do a point-by-point comparison of the major conclusions of each scientist's major publication. A chronological bias will also be investigated to see if any of the earlier publications affected the later papers. Finally, the careers of each man will be summarized and used with the previous information to determine the relative importance of each individual's work in the field.

Next, we examine how well Goddard is recognized, both in Worcester and in Roswell, NM. This is done primarily through examining references to Goddard in each of these communities. These communities were the places where Goddard was born and where he did much of his experimental work, respectively. As such, both have a special connection to Goddard and could be expected to be foci of popularity for the scientist, should any such popularity exist. References to Goddard in the names of buildings, streets, parks, and other such memorials were all considered. In addition, we searched for similar recognitions outside of the two target communities and on a nationwide scale. Lastly, we examine the Goddard Memorial Association, a Worcester group dedicated to preserving Goddard's memory, to see what can be learned from them.

The next component of the comparison will be to compare the number of books and articles that were written about the people most associated with the aerospace field. The people who were chosen are Neil Armstrong, Wernher Von Braun and the Wright brothers. This comparison was designed to tell us how Goddard stacks up against other major names in aerospace history, and thus give us another observable measure of Goddard's importance. A timeline of when the books were written will also be kept to see how long the subjects' popularity was maintained compared to when they made their contributions. The books about Goddard will be scrutinized even further by looking for the motivations of the authors and by examining when the books were written. This too shall serve to estimate how long his popularity has lasted in the media and how he is portrayed.

Another perspective in analyzing the recognition of Goddard is to examine the popularity of an exhibit dedicated to his life. Such an exhibit is in place at the Goddard Library at Clark University, and we shall examine their guestbook. The guestbook contains a listing of some of the visitors to the collection. The data gathered from the guestbook will be examined to see where the visitors come from and will be analyzed using the graphing functions of Excel.

The last major component of the IQP will be to survey local college students and assess their literacy of Goddard's work. The value of such a survey is very nearly self-evident; it can tell us both how well-known Goddard is and how far into the public's consciousness information about his work has spread. The implementation of such a survey depends upon the technology available at each school. The schools that have been included in the survey are Worcester Polytechnic Institute, Clark University and Holy Cross University. The general scientific knowledge of each group will also be determined by asking basic questions related to the aerospace field. Two surveying mechanisms have been proposed for all the colleges. One is an email-based survey and the other a mail-based survey. The email survey is the easiest to implement and produces the least amount of paper waste. The mail-based survey, on the other hand, can be done with any school or group regardless of whether all the members thereof have an email account. The surveys were analyzed using various statistical methods to determine both the public knowledge of Goddard and how well the public understands the scientific underpinnings of his work. We used the same survey for each group and it can be found in appendix B.

Chapter 2: Background

2.1 Introduction

This chapter contains background information on the life of Robert Goddard. This information includes a timeline of important dates in his life and a detailed overview. His difficulties and eccentricities will be examined, as well as the course of his rocket development. Additionally, some aspects of current rocket technology are summarized for use in conjunction with the survey discussed in Chapter 5.

2.2 Timeline of Goddard's life and work

This section of the project contains most of the important facts and dates in the life of Dr. Goddard. It is set up as a timeline highlighting important dates and events, both during his life and following his death. All the timeline data was taken from the book *This High Man*, written by Milton Lehman.

1882 – Robert H. Goddard was born on October 5 in Worcester, MA

1899 – Robert Goddard pursuits in rocketry were inspired by a vision while up in a cherry tree on October 19. In his own words, "I was a different boy when I descended the tree from when I ascended, Existence at last seemed very purposive." Robert Goddard considered this his "Anniversary Day."

1904 – Robert Goddard graduated from high school at the age of 22. This late graduation was due to Goddard's frequent absences caused by poor health. He gave a speech at his graduation, entitled *On Taking Things for Granted*, in which he stated that, "It has often proved true that the dream of yesterday is the hope of today, and the reality of tomorrow."

1904-1908 – Robert Goddard attended Worcester Polytechnic Institute and received a bachelor's degree in general sciences.

1910 – Robert Goddard attended Clark University for his master's degree in physics. His thesis was entitled "Theory of Diffraction," and actually had nothing to do with rockets. During this college period, Goddard was developing a theoretical basis for rocketry. He concluded that the most promising methods of propulsion were ion rockets, machine gun rockets, and hydrogen-oxygen fueled rockets.

1911-1912 – Robert Goddard stayed on as an honorary fellow at Clark and receives his PhD.

1912-1913 – Robert Goddard attended Princeton on a research fellowship.

1913-1914 – Robert Goddard was diagnosed with tuberculosis early in 1913 and did not recover fully until 1914. This sickness made Goddard more determined to continue his rocketry work, knowing that his time might be very limited.

1914 – Robert Goddard obtained his first 3 patents in July. Two were on the basic concept of liquid-fueled rockets and one was on multi-stage rocketry.

1915 – At Clark University, Robert Goddard tested the hypothesis that a rocket provides thrust even in vacuum, thus confirming the applicability of Newton's Third Law in space.

1917-1929 – The Smithsonian Institute supported Goddard's rocket research.

1918 – Robert Goddard started working for the Army on the development of rocket weapons, which resulted in the bazooka.

1919 – The Smithsonian Institute published Goddard's <u>On a Method of Reaching Extreme Altitudes</u>. Goddard also wrote a letter to the Smithsonian indicating ideas for uses of rocketry as propulsion to travel to the moon and beyond.

1920's – Robert Goddard tried and continually failed to obtain greater funding for his rockets from his university, private investors, and the military.

1920-1923 – Robert Goddard acted as a part time consultant for the US Army at Indian Head, Maryland regarding the development of solid-fuel propellant rocket-style weapons.

1920-1925 – Robert Goddard developed the concept and motor for a liquid-fuel rocket that runs on liquid oxygen and gasoline.

1920-1943 – Robert Goddard was given professorship at Clark University.

1926 – Robert Goddard tested the first liquid-fueled rocket on March 16, at Auburn, MA.

1929 – Robert Goddard tested the first rocket containing instrumentation and met Charles Lindbergh, who recommended him for a Guggenheim grant. The test flight on July 17 was loud enough to alert neighbors and get Goddard's rocket tests banned in Massachusetts.

1930-1932 – With the grant, Goddard moved to Roswell, NM, which seemed to contain an ideal climate and isolation needed for continued larger-scale rocket testing.

1932-1934 – Robert Goddard went back to teaching at Clark University. There, he developed a gyroscopic stabilization apparatus, deflector vanes to control flight, curtain cooling of the rocket engine, and the forerunner of the jet engine for airplanes.

1934-1941 – The Guggenheim Foundation resumed sponsorship of Goddard's work in Roswell.

1935 – Robert Goddard both broke Mach 1 and attained a record altitude of 7500 feet in the same month.

1936 – The Smithsonian Institute published Goddard's paper, "Liquid Propellant Rocket Development".

1937 – On a windy morning of March 26, Robert Goddard succeeded in his highest altitude, between 8000 to 9000 feet, with a new rocket that was 16 feet 5 inches long and weighed only 100 pounds when empty.

1938 – The National Aeronautics Association officially recorded one of Goddard's rocket flights on August 9. The flight reached an altitude of 6565 feet.
1941 – Goddard made his final rocket tests, using 22-foot long, 500-pound rockets equipped with turbine-powered fuel pumps.
1941-1945 – Robert Goddard worked with US Navy on variable thrust rockets and jet-assisted takeoffs.
1943-1945 – Robert Goddard was a consultant for Curtis-Wright Corporation.
1944-1945 – Robert Goddard was appointed director of the American Rocket Society.
1945 – Robert Goddard died on August 10, in Baltimore, MD
1959 – Robert Goddard won a Congressional Medal, which was accepted by his widow, Esther.
1959 – NASA opened their first space flight center and named it after Goddard.
1960 – NASA paid the Goddard estate a million dollars for the use of his patents.

2.3 Detailed overview

The timeline states all the basic facts relating to Goddard's life and scientific work, but certain aspects deserve to be treated in more detail. First of all, Goddard's work needs to be considered in the context of the other rocket pioneers of his time and in relation to the long history of rocketry. An important aspect of Goddard's life that the timeline does not explain is the difficulty he had in getting the recognition and funding required to progress with his research. The most important aspect of his life, his rocket research, also needs to be considered as a coherent whole and not just a list of disconnected facts. All the biographical information in this section was obtained from *This High Man* (Lehman, 1963).

2.3.1 Rocketry before Goddard

Goddard was the first American to consider liquid-fueled rockets in depth, and he was also the first person to experiment with them. For all practical purposes, he was the founder of a modern rocketry that would eventually lead man into space. He did not invent the rocket, which is a several thousand-year-old invention. However, these ancient rockets were all based on solid fuels and were inadequate for the large-scale rocketry needed to reach high altitudes. This is mainly because the solid fuel available in Goddard's time did not have enough chemical energy. Nor was he the first to envision the liquid-fueled rocket. That honor goes to Konstantin E. Tsiolkovsky (1857 – 1935), a Russian high school teacher who published an article in 1903 entitled, "A Rocket into Cosmic Space." Goddard did, however, develop the theories of Tsiolkovsky independently and in greater detail. Goddard's greatest achievement was that he was the first to bridge the gap between theory and application.

2.3.2 Goddard's difficulties and eccentricities

In 1914, Goddard received his first 3 patents. The first was on his machine gun system of propulsion, a system he later abandoned. The second was a detailed description of a liquid-fueled rocket; so detailed, in fact, that he was advised to make 2 patents out of it. The third was a description of multiple stage rocketry. These last two are extremely important even today. The second patent was broad enough to be the basis of all of Goddard's later research and experiments. This practice of patenting ideas was actually uncommon for a professor of physics, and other scientists felt that he was too possessive and too fixated on legality. In all, Goddard has 214 patents to his name, 131 of which were filed posthumously. Comparatively, he only wrote 32 actual scientific papers in his life, out of which only 20 have to do with space travel or rocketry.

Goddard had some problems that went far beyond the issue of patents; neither his colleagues nor the public respected him for a variety of reasons. His biggest problem was his secrecy, which alienated him from his fellow researchers. This mania for secrecy developed from several bad experiences. The problems started when Goddard released his seminal paper, On a Method of Reaching Extreme Altitudes, in 1919. When the media got its hands on the paper, they immediately fixed upon Goddard's very brief mentions of travel to the moon, which they used to make him seem like a madman. The New York Times went so far as to incorrectly state that Goddard's rockets would not work in space because they had nothing to push against. This statement was obviously untrue to anyone familiar with Newton's Laws. In fact, Goddard had explicitly tested this conjecture and found it to be without value in 1915.

The next blow came from the Germans. A young German scientist named Oberth asked Goddard for a copy of his paper. Upon receiving it, Oberth proceeded to write his own book on rocketry, which he published in 1924. This book was heavily based on Goddard's paper and patents. Oberth was hailed in Germany as a great rocket pioneer. Oberth did recognize Goddard's contributions, but claimed he was not visionary enough, because he did not elaborate enough on space travel. In fact, Goddard's life-long dream was space travel, but years of past ridicule taught him to keep this dream to himself. Theft of ideas, ridicule, and general lack of positive results from collaboration and exposure all shaped his desire to keep his work secret.

Not only did Goddard have problems with reputation, he had associated problems with funding. Big dreams, especially big rockets, need big budgets. Goddard had a research budget at Clark, but it was insufficient for more than the most rudimentary of his experiments. He knew that he would need funding and invested a large amount of time trying to obtain it.

His earliest success was with the Smithsonian Institute, who granted him a small amount of money that would later be used for his first liquid-fueled rockets. This money could not keep up with his experiments, however, and he tried both private investors and the military. The military did grant funding to Goddard three times. The first of these was in 1917, when Goddard developed the bazooka. The second time was to further test his rocket weaponry in the early 1920's, and the third from 1942 until his death in 1945 was to develop jet assisted takeoff technology. Only just prior to Goddard's death was the military interested in liquid-fueled rockets.

Goddard's one great success required the help of Charles Lindbergh, who was by then famous for his Atlantic crossing flight. After crossing the Atlantic, Lindbergh began looking for new frontiers, and he decided one of these would be space. He knew airplanes and propellers had reached their limits, and he found promise in Goddard's rockets. Together, Goddard and Lindbergh managed to obtain funding from the Guggenheim Foundation. The Daniel and Florence Guggenheim Foundation was a philanthropic organization set up to encourage research in the field of aeronautics. Goddard's research was a little out of the ordinary, but Guggenheim and Lindbergh were old friends. Lindbergh managed to convince Guggenheim that rocketry would someday be an important aspect of aeronautics, and Goddard got his grant money. With this, he was ready to work on the next major step, the actual development of his rockets.

2.3.3 Rocket Development

The most important aspect of Robert Goddard's life was his liquid rocket development. This period in his life was marked at its beginning by the world's first liquid-fueled rocket launch. This launch occurred on March 17, 1926 in Auburn, MA. This would eventually be followed, over a decade later, by Goddard's highest rocket flight, approximately 9000 feet on March 26, 1937 at Eden Valley in Roswell, NM.

These early rockets were very modest contraptions, the first being only a few feet high and weighing only 5 pounds without its fuel. The rocket contained storage for its two fuel components, liquid oxygen (rare and expensive in Goddard's time) for oxidation and gasoline for combustion. Also included were an engine where the two fluids would mix and be ignited, and a gas pump to force the fluids into the engine at the necessary rate. The launch frame was a small mess of pipes and the ignition was handled with fuses and hand-turned valves. The rocket amazingly cleared the frame and flew 41 feet into the air until turning and crashing into the ground.

Goddard's second successful flight would be his last in Massachusetts. It was a vast improvement over the first test, flying twice as high, but it was also twice as loud. Neighbors thought it was a plane crash, alerted the police and fire departments, and caused Goddard publicity that he did not want or need. The state fire marshal then outlawed future rocket tests. Goddard tried to relocate to a section of an abandoned airbase, but the military was not hospitable and the conditions that Goddard had to work under made successful flights impossible.

With the coming of Lindbergh and the Guggenheim funding, it became feasible for Goddard to expand his experiments to rockets that would dwarf his current designs. This would require a more hospitable and remote location; Roswell, New Mexico was an ideal choice. Goddard's first test in Roswell was of a much greater scale, with a 12-foot rocket and a 60-foot launch platform. This rocket was very similar to the Auburn rockets, except for the larger scale, and it managed to attain a height of 2000 feet before turning and smashing into the ground. This test clarified the two major problems of stability and cooling.

All of the successful rocket flights up until this point had simply turned and flew into the ground after flying straight up for a very short amount of time. Something was needed to stabilize the flight, however, if rockets were ever to be usable. The solution to this was gyroscopically controlled steering fins. The gyroscope detects a tilting, and the fins then correct the flight direction to keep the rocket going straight up. The other problem Goddard had was that the combustion chamber would always end up melting in the extreme heat of the fuel combustion. An obvious solution to this problem was to use heat-absorbing materials on the sides, but in Goddard's time there were no insulators that were sufficiently light for this purpose.

The only feasible solution Goddard found was his method of curtain cooling, which consisted of uniformly coating the edge of the combustion chamber with fuel. With such a configuration, the edge of the chamber only comes in contact with a relatively cool layer of the fuel that has not been ignited. This is because the fuel combustion starts at the surface contacting the heated oxygen. If this combustion surface and the cooler edge surface never intersect, and the fuel is pumped fast enough, then the combustion will never spread to the edge of the chamber. If the fuel coating is uniform, then there are no combustion chamber surfaces directly adjacent to the burning fuel.

This method worked, but it was not 100 percent reliable. The combustion chamber melting was always a potential cause of flight-test failures, one Goddard never remedied through all of his experiments. Goddard treated this rocket development as an evolutionary process, an endless string of tests, where even failures were important data. The rockets themselves were also physically evolving and constantly being rebuilt with those parts that had survived the previous flight. With a working stabilizer, Goddard hit 7500 feet on May 31, 1935. In the final tests of his perfected small motors, he reached his highest altitude ever of 9000 feet on March 26, 1937. An observer placed a certain distance away measured these approximate altitudes. This observer used a telescope and marked the angle of telescope inclination as he viewed the ascending rocket. Goddard continued to perfect new aspects of the rocket, such as high-pressure pumps and variable thrust, but he would never again see a rocket reach such heights.

From this point on, Goddard began to look back almost as much as he looked forward. This was largely because he was simply left behind by progress. The Germans had supported their rocket scientists, at first with public recognition, and as the Second World War raged on, with money. In all, Germany spent 6 years, the equivalent of 3 billion dollars in marks, and employed thousands of scientists and engineers within its rocket program. All of this work was based on Goddard's patents, which Germany had bought copies of. The end results were the V1 and V2 rockets, which Germany used to terrorize Britain.

When the US captured one of the V2 rockets and Goddard got a chance to examine it, he found it an experience that was at once frightening and satisfying. Goddard had clearly been outdone, as these rockets were engineered to perfection. Each weighed 12 tons, and was capable of reaching an altitude of 68 miles. However, the design was very similar to Goddard's smaller rockets, matching them almost part for part.

Goddard had the satisfaction of knowing that his designs could indeed fly to extreme altitudes.

Goddard would never get over the fact that he could have done better than the Germans, and with less money, if he had only been given the support he required. Even during this period, with the government and military support of rocketry finally at full force, Goddard was just dismissed as an old, secretive relic.

2.4 Current technology

This section will introduce some of the technology used in modern rockets. The primary example will be the Space Shuttle, as it is the workhorse for all U.S. manned space missions. Since the Shuttle has been the only U.S. manned space vessel since the late 1970's, we have focused the technical questions of our survey on the types of rockets the Shuttle uses for propulsion. The Shuttle uses two different types of rockets to reach a low earth orbit, and the differences between these rockets will be discussed.

2.4.1 The Space Shuttle

The Space Shuttle is the only manned U.S. space vessel in service today. It uses two types of rockets to reach a low earth orbit from which its mission can be carried out. The two types of rockets are solid-fueled and liquid-fueled. They will be discussed in greater detail in section 2.4.2.

The Space Shuttle was designed to enter a low earth orbit and only carries enough fuel to meet that objective. It is not possible for the Shuttle to travel to the Moon without significant alteration due to this lack of fuel <http://louis.lmsal.com/~strous>. The Saturn

V rocket that flew the Apollo missions to the Moon, on the other hand, were designed with enough liquid fuel to make the trip. The Shuttle uses three liquid-fueled main engines to reach orbit. If one or more of these engines were to fail, then the Shuttle could not reach orbit. The fuel for the main engines is stored in a large external tank, which is jettisoned once the Shuttle reaches its desired orbit. Once that tank is discarded, the Shuttle can only maneuver using low power thrusters.

The external tank contains the liquid hydrogen fuel and liquid oxygen oxidizer, and it supplies them under pressure to the three space shuttle main engines in the orbiter during lift-off and ascent. This is a direct descendant of technology that Goddard invented. The idea to use separate fuel tanks and to control their mixture to achieve thrust was among the first things Goddard tested.

The Solid Rocket Boosters (SRB's) provide the main thrust to lift the space shuttle off the pad and up to an altitude of about 150,000 feet, or 24 nautical miles (28 statute miles). The SRB's are the largest solid-propellant motors ever flown, and they are also the first designed for reuse. Each is 149.16 feet long and 12.17 feet in diameter [http://www.ksc.nasa.gov/shuttle/technology/sts-newsref/srb.html#srb].

2.4.2 Comparisons of liquid- and solid-fueled rockets

Conventional gasoline engines require both fuel and air, as the air contains the oxygen required for their operation. A rocket, however, does not require air; the necessary oxygen supply is contained within the propellant. This is the difference between a propellant and a fuel. A propellant system can be thought of as a balanced source of potential energy, containing both the necessary ingredients for combustion and for conversion of this energy to kinetic energy. A propellant is composed of two main ingredients, a fuel and an oxidizer. When the propellants are properly used, the energy stored in the mixture is released slowly rather than all at once, as happens in an explosion.

Although the first rockets were propelled by a solid propellant, Dr. Goddard carried out the first scientific studies of jet propulsion using liquid-propelled rockets (Zucrow, 1948, p. 464). Liquid-propellant rockets differ from solid-propellant rockets in that they require a combustion chamber and a system to feed the propellant from storage tanks to the combustion chamber. Liquid propellants have found wide acceptance in the field of ballistic missiles (Warren, 1958, p. 18).

There are two main groups of liquid propellants, monopropellants and bipropellants. A monopropellant is a substance that does not require the addition of another ingredient to bring about release of its thermo-chemical energy. Some examples of these are nitromethane, diehtyleneglycol dinitrate, or a mixture of compounds such as hydrogen peroxide and alcohol. These materials are stable at ordinary atmospheric conditions but react when heated, under pressure or in the presence of a catalyst (Warren, 1958, p. 19). Since there is only one liquid, the feed system from the storage tank to the combustion chamber can be relatively simple.

In bipropellants, the fuel and the oxidizer are stored separately in the rocket, and mix only in the combustion chamber. The majority of successful liquid-propelled rockets have used this system. As in the case of all propellants, the oxidizer is the most important ingredient to the liquid propellant system. The principally used oxidizers are liquid oxygen, nitric acid, and hydrogen peroxide. The number of compounds that can serve as fuel is almost limitless (Altman, 1956).

Solid propellants were used in the earliest rockets and have always been used in ammunition. There are two main types of solid propellants, the homogeneous and the composite. A homogeneous propellant is a compound that is mixed with nitrocellulose to give it a moldable shape. A composite solid fuel, on the other hand, is a mixture of a finely ground oxidizer in a matrix of plastic, resinous or elastomeric material. The matrix provides fuel for the combustion reaction. Black powder can be classified as a composite since it uses the nitrate as oxidizer and sulfur as both binder and as a fuel. The oxidizer is the major constituent of composite propellants and it contributes the most to the burning characteristic of the fuel (Warren, 1958, p. 10).

How well a rocket performs depends mostly on how the rocket creates combustion gases. For rockets, this is a function of the contents of the propellant and the geometry of the fuel. Since the fuel is being burned, the surface area is an important factor in the performance of the rocket. In a liquid-fueled rocket, however, the performance can be controlled by mechanical means. These mechanical parts are responsible for controlling the amount of liquid that enters the combustion chamber (Warren, 1958, p. 126).

Controlling the amount of fuel entering the combustion chamber can easily control the thrust of the liquid propellant rockets. The direction of the thrust can be changed at will through the use of a gimbaled thruster. The thrust can also be terminated by simply cutting off the valve controlling the propellant supply. The solid propellants have a harder time controlling the thrust. The thrust is a function of the burning of the fuel, and is hard to regulate after the ignition phase (Warren, 1958, p. 142).

Chapter 3: Three Space Pioneers

3.1 Introduction

The three acknowledged pioneers of rocketry are Konstantin Tsiolkovsky, Hermann Oberth, and Robert Goddard. At one time or another each has been called the “Inventor of Liquid-Fueled Rocketry,” and to understand Goddard’s historical value we should determine who truly deserves the title. "Inventor" can mean either the first to build something, or the first to envision it. If we consider the inventor to be the builder, then the title would indisputably go to Goddard. If we consider the visionary to be the inventor, however, then the title should to go to Tsiolkovsky, because he theorized the liquid-fueled rocket a decade before Goddard considered it. Yet Oberth, although not first in anything, is still credited by many as the "inventor.” To compare the three men on an equal footing, their three initial papers on rocketry will each be considered in turn. In general, the first paper in a field has significance over subsequent work in that field, as it represents the moment in which the author was finally sure enough of his work to prove its feasibility to the world. Goddard is an exception to this rule, as he had already patented various ideas critical to rocketry 5 years before he published his first official paper on the subject. In this comparison, time acts as a critical factor. On any ideas that are stated by all three pioneers, Tsiolkovsky should be given the most credit, as he was chronologically the first of the three.

3.2 *A Rocket into Cosmic Space*, Tsiolkovsky, 1903

In 1903, Konstantin Tsiolkovsky published “A Rocket into Cosmic Space.” This was the first paper to discuss rocketry as a means for space travel, and it was also the first to propose a liquid-fueled rocket. The paper was short, only 32 pages in length, and clearly stated. It also was written with a well-defined purpose, that of showing that the rocket to be the optimal means for space travels. The tone was both optimistic and primarily theoretical, meaning that the details of the feasibility of construction and of real-life losses in ideal equations were not discussed. The author was aware of the problems with this tone, which he justified by stating that the paper was only intended to arouse interest, and that considerably more work was required.

The paper began with a discussion of the highest-flying device available during Tsiolkovsky's age, the balloon. Tsiolkovsky pointed out the limitations on altitude and the problems of scalability. He then went on to discuss the most popular (perhaps due to Jules Verne) alternative for reaching high altitudes, the cannon. Here, the limiting factor is not altitude, but gun length versus acceleration. If all the acceleration happens in the gun, then the object must be at escape velocity when it exits, so either the gun must be very long, or the acceleration very violent. Neither of these problems had feasible solutions at the time, but it is interesting to note that there remain current plans to build a space launching rail gun. In this manner, Tsiolkovsky systematically considered and rejected alternate methods of reaching space.

Tsiolkovsky's feasible alternative for high altitude travel was, of course, the rocket. He described this as consisting of a chamber for people/cargo, two containers filled with liquids designed to be mixed, and a tube in which the mixed, combustible substance is ignited. The liquid would then explode, causing a high velocity gas to exit the rocket. He immediately cited an obvious problem with the rocket; if the thrust is not applied radially outward from the center of mass very exactly, then the rocket will receive an angular acceleration. However, he just as quickly provided a solution in the form of a rudder to deflect the thrust. Another problem that Tsiolkovsky considered briefly was the effects of an atmosphere on the rocket. He did not dwell on this, but explained that it is detrimental but that it is not a large effect. This is quite different from the experiences Oberth and Goddard would later have with a related issue, the insistence of their colleagues that the rocket could not move without something against which to push. This means either that Tsiolkovsky's colleagues were more knowledgeable of basic physics, or otherwise that his work was completely ignored.

Using the basic mechanical law of action and reaction, Tsiolkovsky went on to derive the basic equation describing motion in space when a rocket's forward momentum is increased by the expulsion of high velocity gases. This equation showed that the final velocity of the rocket is related by a logarithm to the ratio of the fuel mass to ship mass. This means that great efforts must be made both to reduce the ship mass and to increase the velocity of the escaping gas, or exhaust velocity. The exhaust velocity is determined in part by the chemicals used in the fuel. Here, Tsiolkovsky advanced the use of liquid oxygen and liquid hydrogen as the two fuels to be used in a rocket. He came to this conclusion because hydrogen both burns with more energy per mass than any other volatile gas, and has the minimum of atomic mass per atom of any substance.

Tsiolkovsky spent the rest of the paper examining the behavior of his rocket under certain conditions and looking for optimal solutions. The first quantity that he examined was the ratio of rocket velocity to exhaust velocity, which he considered with respect to the ratio of rocket mass to fuel mass. He was very optimistic in his treatment of these ratios, concluding that if only half the rocket's mass is composed of fuel, the final velocity would be enough to escape Earth's gravity. The solution to this ideal equation, however, is considerably removed from reality. In fact, all modern orbital and super-orbital devices are composed of at least 80 percent fuel by mass. This is mainly because Tsiolkovsky had not yet included gravity into the calculations. His next calculation was of rocket efficiency. This efficiency rating approaches zero at the extremes of infinite fuel mass and infinite rocket mass, and reaches a plateau in the fuel/rocket mass ratio region between 2 and 10. This range brackets the actual ratios used in modern space rockets.

Tsiolkovsky lastly added the effects of gravity into his calculations, which makes the rate of acceleration a significant issue. If the rocket accelerates very slowly, then gravity will prevent the rocket from achieving a significant final velocity. Alternatively, if the rocket accelerates at a high rate, there is danger both to the rocket and to its occupants. Tsiolkovsky concluded here that rockets are too inefficient for atmospheric flight, a naïve statement that is yet understandable, as this paper was published just prior to the Wright Brothers' accomplishment of manned powered flight. The velocity and efficiency equations for a rocket in a gravitational field were then derived and proved to be similar to the zero gravity equations when the acceleration is much larger than that of gravity.

The paper ended on a strange note with an example of inclined flight and a discussion of the fuel requirements of accelerating to a stop. Tsiolkovsky understood that the necessity of both accelerating and decelerating a rocket requires considerably more fuel than just the acceleration. However, he never considered that there might be other ways of slowing down, especially in the neighborhood of a planet.

3.3 *On the Method of Reaching Extreme Altitudes*, Goddard, 1919

Goddard's paper had a radically different tone and focus from Tsiolkovsky's, primarily due to Goddard's reserved nature and experimental tendencies. He did not talk at all of space travel, and he only discussed theory where it relates to an experiment he performed.

Goddard began his paper in a manner similar to Tsiolkovsky, with balloons. Unlike Tsiolkovsky, however, Goddard did not talk of the inability of balloons to travel to the stars. Instead, he discussed how they are used to gather high altitude meteorological data, and also how they cannot explore the entire extent of the atmosphere. He listed some of the scientific benefits of the exploration of these new regions, and he then began to discuss means of reaching such heights. The only sources of power available to him were chemical combustion and momentum exchange involving jets of gas. He remarked that this type of propulsion already exists in the form of the solid-fueled rocket, but the common perception of such devices is that they are inefficient toys. The remainder of the paper was an analysis of rocket efficiency and how it can be improved. These methods included increased thermodynamic efficiency, controlled combustion of the fuel, and multiple stage rockets. His claim was that these three considerations would make rockets the most efficient heat engines yet devised.

To begin his discussion of rockets, Goddard wrote out the general, ideal theory of rocket motion. This 'ideal' theory involved both air resistance and gravity, unlike Tsiolkovsky's treatment, which completely excluded air resistance and neglected gravity until the paper's end. The resulting equation is not analytically solvable, but Goddard derived an approximate solution using the calculus of variations, which shows the extreme importance both of maximizing the exhaust speed and minimizing the mass of the rocket.

The rest of Goddard's paper was completely experimental. The first of these experiments described was a test of the efficiency of commonly available solid-fueled rockets. The results were disappointingly low, as Goddard had expected, with the largest measured efficiency being less than 3 percent. However, this still brought great hope, as these inefficient rockets were capable of considerable range, about a quarter mile on the ground and 500 feet in altitude.

The next sets of experiments were conducted with powerful smokeless powder and Goddard's hand-made steel combustion chambers. He designed the chamber in a shape he felt to be optimal for rocketry, and he varied the size of the chamber and length of the nozzle by machining multiple parts. Measurements were made of the heat of the different powders' combustions, the velocity of the gas jet upon ignition, and the efficiency of the powder/engine combinations. The measured efficiencies for the small chamber were around 45 percent, and the velocities varied from 1500 to 2000 meters per second. Goddard reasoned that a larger chamber would be more efficient, as the losses due to friction on the edge of the chamber are greatly reduced by the increase of the volume to surface area ratio. He was correct, and the results were a jet of 2400 meters per second and of 65 percent efficiency. This was encouraging, especially compared to Tsiolkovsky's ideal theoretical estimates of 5000 meters per second and 65 percent efficiency for the 'optimal' hydrogen/oxygen fuel setup.

The next set of experiments involved repeating the rocket engine tests in a vacuum chamber, to show that rockets can work in the vacuum despite the unreasonable warnings of his critics. This was the most difficult experiment in the paper, and great care was taken to keep the system as close to a vacuum as possible, including trapping expelled gases as the rocket was thrusting so that they would not interfere with the rest of the gaseous stream. The results proved to be better in the vacuum chamber, with velocities ranging from 1600 to 2400 meters per second and 30-50 percent efficiency using the small chamber. This excluded a systematic error in calculations found by Goddard, one that involved the vacuum chamber's displacement during tests, and which caused many of the results to be underestimates.

Goddard then returned to the theory. He compared the results to approximate theoretical values and obtained a good match. His next steps finally turned to the theoretical end of rocketry, as he constructed a piecewise method for considering high altitude flight, in the region where air density and the gravitational acceleration start to vary. Using this method, Goddard determined how much fuel mass was required to reach various high altitudes. He noted the extreme dependence on the efficiency, as the required fuel mass starts to approach the mass of the Earth for sufficiently high altitudes when the efficiency is low. On the subject of infinite altitudes, Goddard said that the key to a good rocket is in a high efficiency. Goddard's final note, on the subject of infinite altitudes, involved verifying such altitudes by striking the moon with flash powder. He stated this speculation as an experiment, and performed some scaled down experiments to estimate what would be required. Still, this moon remark and the infinite altitude speculations were sufficient, despite the experimental basis of the whole paper, to set off a media frenzy that would significantly impact Goddard's career.

3.4 *The Rocket to the Planets*, Oberth, 1923

Oberth's first rocket-related publication was significantly different from both Tsiolkovsky's and Goddard's work, especially in its scope. This book, in fact, exceeded 500 pages in length. While Tsiolkovsky and Goddard wrote essentially scientific papers, Oberth invested the time to write a whole book on rockets before he had even built one that worked. Also unlike Goddard and Tsiolkovsky, Oberth wrote this paper with the knowledge that others (Goddard and possibly Tsiolkovsky) were also working on rockets and had already published on the subject. Perhaps Oberth felt that by writing a very long and comprehensive book, he could overshadow the earlier works, and he indeed succeeded in doing so for several decades.

As with Tsiolkovsky, Oberth began by saying that his goal is space travel and his projected tools to accomplish this are rockets. He then proceeded to boldly map out the course of his book. The first part was on the physics of rocketry, the second was on rocket construction, and the third was on applications of the rocket, including space travel. This confidence is very unsettling when one considers the reality of rocketry, and that experimentation proved the only path towards practical rocket design. This fact alone renders the entire second part of the book speculative.

The beginning of the book is perhaps the most useful source of information, as it was simple, theoretical, and applicable towards rocketry in general. It is interesting to note, first, that Oberth claimed to be holding back certain pieces of technical information that he felt needed to be protected. Also, he said that in the case of estimates, he estimated unfavorably, so that his answers are a worse case scenario, as opposed to reality. Oberth started building the concept of the rocket with the "rearward thrust principle," which was actually just Newton's 3rd Law and stated that every action has an equal and opposite reaction. The hot gases escape downwards, and as a result, the rocket travels upwards. Oberth even directly attacked the common criticism that the gases require an atmosphere to push against. He defended himself both by explaining the situation as the interaction of individual gas atoms in a chain reaction, and also by referring to Goddard's experiments with rockets in a vacuum.

Oberth went on to describe the common fireworks rocket and in what aspects his rocket differed, most notably his choice of liquid fuels. He then described several methods of combining and combusting the oxygen and fuel, some simple and some complex. This even included a method of cooling the engine, which Oberth called "dynamic heat protection," but which turned out to be similar to Goddard's own method of "curtain cooling." Oberth fought off another critical accusation, that combustion would not occur in space. With the basic description of how rockets work complete, Oberth discussed properties of the materials that are desirable for rocket construction. These properties include first and foremost a low density, but also high tensile strength and low temperature dependence, so the material will not melt at high temperatures or become brittle at low temperatures. After all these design considerations, Oberth finally had an initial theoretical prototype rocket, whose construction and operation he then went on to discuss in detail.

At this point, Oberth slowed down, and spent the next 300 pages on rocket theory. He discussed many of the concepts already introduced by Tsiolkovsky, such as the optimum velocity, the most appropriate fuel to mass ratio and the forces on a rocket's occupants. He even followed Tsiolkovsky's lead in considering the effects of gravity only as a correction factor later in the paper. Yet another area of similarity between the two is the discussion of stability and control, and both papers concluded that the answer lay in deflecting the rocket's stream with fins.

The next section of the book was a theoretical discussion of the experimental problem of the construction of rockets, which we have already noted as highly speculative. The final section on the usage of rockets was equally speculative. Oberth suggested some possible uses for rockets: the meteorological rocket (mentioned by Goddard), reconnaissance rocket, geographical rocket, mail rocket, weapon rocket, and the rocket airplane (which Tsiolkovsky dismissed). The remainder (and majority) of the section focused on the use of rockets for space travel, and was written in the form of a fictional story, as Oberth related what he thinks the experience will be like. He even discussed as individual cases the trip to different celestial bodies, and discussed the concept of space stations.

3.5 Comparison of the three pioneers

When comparing the three papers, it is best to start with their similarities. They all identified rockets as the only practical means of high altitude travel, and they all derived similar formulas for the motion of the rocket and the efficiency. Tsiolkovsky and Oberth both discussed liquid-fueled rockets and the optimal hydrogen/oxygen setup, a factor absent from Goddard's paper. This is because his paper was primarily experimental in nature, despite his standing patents on liquid-fueled rockets. The beginnings of the papers were also similar, as both Goddard and Tsiolkovsky discussed rockets as the successor to balloons, while both Tsiolkovsky and Oberth were very direct about the imperative to travel to the stars.

Goddard's theoretical treatment, compared with those of Tsiolkovsky and Oberth, was refreshingly concise and exact. He derived only one case for the rocket's motion, which incorporated realistic losses due to gravity and air resistance, and he even accounted for a changing gravity and air pressure as the rocket travels farther from the Earth. Tsiolkovsky began from very simple equations without losses, and added the gravity loss in later, but even then he considered only a constant gravitational force. Oberth used only ideal equations as well, but he also discussed the effects and reduction of losses that do not enter into the equations in an easily solved manner. Here, the methodology was split among the pioneers, as some considered approximate answers to exact complicated equations more insightful than exact solutions to idealized equations, while the others did not.

Another advantage to Goddard's paper was his resolution of certain problems through experiment rather than theory. Theories can more readily be dismissed and ignored than a well planned and executed experiment. Oberth himself conceded this point to Goddard by referencing his paper. This was also apparent in Tsiolkovsky's calculations of velocity and efficiency, as opposed to Goddard's measurements of these properties. Tsiolkovsky's work never left the realm of 'maybe' and 'in an ideal situation,' while Goddard first did the experiment to get 'the' answer and then went back to obtain theoretical confirmation.

One very important property of a paper is its ability to convince a reader. In this case, the goal was to convince a reader of the plausibility of space travel. There does not seem to have been any special effort on Tsiolkovsky's part to convince the reader; he was developing a new field of science and perhaps that was sufficiently convincing for him. Goddard's method of convincing the reader involved tying everything into the real world, and he did this through experiment or reasonable application. For most of his paper, he was discussing not a moon rocket, but rather a meteorological rocket whose usefulness is made clear early on. Only when the experiments and theory have been fully laid out and explained did he take the simple forward step from high-altitude flight to infinite altitude, a reasonable extension of the theory. Only then did he refer to a moon rocket, and he kept the discussion grounded scientifically, by explicitly demonstrating both that a rocket will work in a vacuum and by proposing a method of measuring the rocket's altitude. Oberth attempted to convince the reader by completely covering the entire field of rocketry as he sees it, and by an explicit discussion of the common opposition that he has encountered. By answering every question in a reader's mind and by covering every path, there was nothing left for the reader except to believe. As to which method is most successful, it is essentially a toss up between Goddard and Oberth. Oberth gained the respect of the scientific community and even government support in a small amount of time. Goddard, by way of comparison, set the press on fire instantly with space travel hysteria. The difficulty in any reasonable comparison between the two is the different audience the two authors faced. If the audiences were switched, the results might have proven very different.

Tsiolkovsky, Goddard, and Oberth are each considered pioneers because they all added something to their field. Tsiolkovsky first put space rocketry into words. Goddard experimentally showed the possibility of space flight. Oberth fleshed out a vision of space flight's future, one that was inexact but still captured the essence of what was to come. All of these are significant, but Goddard's contribution is the most practical as it is the only one backed by experiment. If someone were to read just one of these three papers, Goddard's would be the most appropriate, as it focuses on what is important without drowning out important results in ultimately useless analysis of simple, but inexact equations or in endless speculation.

Chapter 4: Social Impact

4.1 Introduction

As previously established, Robert Goddard did a great deal of early work in the fledgling science of rocketry. He designed, built and tested a great number of the early inventions that ultimately developed into the science that took man to the moon; his achievements cannot easily be overstated. But how many people even know who he is? This chapter, and the chapter following this one, will attempt to partially answer this question through several different means. This chapter will use a number of different yardsticks to determine how well his work has been promoted to the public. His recognition by public organizations, the literature available to the public about him, and the visitation of a museum showcasing his work all tell us something about this topic, and each shall be examined in turn. In addition, the books written about him shall be compared and contrasted with books about other important personages in the history of aerospace science. In the next chapter we shall use a more direct measure of his recognition, a survey of Worcester post-secondary students to determine both who knows the most about him and what they know about the science, which he worked so hard bringing to fruition.

4.2 Recognition of Robert Hutchings Goddard

Robert Goddard is an important pioneer in the history of rocketry. But how well do people in power know this fact? Have they done anything to bring his achievements to light, or have they simply left them to linger on the shelf of history? This section is concerned with how well Goddard is recognized by various social bodies. The first subsection concerns itself with Worcester, Massachusetts, birthplace of Dr. Goddard, and the surrounding areas. Following this, the same things are examined in Roswell, New Mexico, where Goddard did much of his experimental work. Other bodies, affiliated with neither of these regions, have also recognized Goddard. Our third subsection deals with these recognitions, in the United States in general. Lastly, the Goddard Memorial Association (GMA) is an organization dedicated to promoting both Goddard and Worcester as the foundation of the space age. Our fourth subsection will talk about this group, and some of what they have accomplished.

4.2.1 Recognition of Dr. Goddard in Worcester, MA

In this section we look at how Dr. Goddard has been recognized within Worcester, MA. This was his hometown, where he grew up and, ultimately, where he was based during his working years as a professor at Clark University, so it is a good place from which to start.

Searching for public recognition of Goddard, we find first the Goddard Memorial Drive, located near the airport. It intersects with Airport Drive and runs along the eastern boundary of the airport. The airport itself also has a connection with Goddard; the terminal building is named after him. Tied in with this, there is a large monument on the terminal floor, a circle with a dedication to his memory, near the security checkpoint in front of the gates. In addition, the airport hosts the Goddard Composite Wing of the Civil Air Patrol, a governmental group who acts as a civilian auxiliary to the Air Force [http://www.goddard.mawg.cap.gov/].

Worcester, with the support of the Goddard Memorial Association, is building a memorial park on the corner of Apricot and Goddard Memorial Drive. More information about this project can be found in the subsection about the GMA later in this report. There is another memorial park to Goddard's work in the Worcester area as well. Located in Auburn, near the site of Goddard's first rocket launches, this park is fairly simple. It includes a solid fuel ICBM and a plaque in Goddard's memory. The Auburn High School sports teams are also named the 'Rockets', putatively in commemoration of Goddard's first launch from an Auburn field [http://www.i-t-a-inc.com/cdblair/air_space/space/Goddard/goddard.html].

Goddard's life is also memorialized by his birth house, which is owned by a member of the Goddard Memorial Association. It is located at One Tallawanda Drive, and is the mailing address of the GMA. There is also a pair of signs on I-290, one on the Worcester-Shrewsbury town line, the other on that between Worcester and Auburn. These signs proclaim Worcester as the birthplace of Robert Goddard and Goddard as the father of the modern Space Age.

Educational institutions in Worcester have also recognized Goddard by naming buildings after him. Indeed, one even goes further. There is a school named after Goddard in Worcester, the Goddard School of Science and Math. This is a magnet school within Worcester's South District, established in 1992. They host students in grades K-6 [http://www.wpsweb.com/goddard/home.htm].

Goddard worked as a professor at Clark University for many years, and was attached to this school when he did his major experimental work. For this reason, Clark has named its library for the scientist. The Goddard Library at Clark also includes a special collection devoted to Goddard's life and work. This collection includes pictures, books about Goddard, and his archives, which include notebooks, correspondences, and other artifacts, donated to the school after his death by Goddard's widow [http://libref.clarku.edu/archives/archivesintro.htm].

Worcester Polytechnic Institute, where Goddard spent his undergraduate years, also has named a building for its esteemed graduate. Goddard Hall houses the Chemistry and Chemical Engineering Departments. This building has several pictures of Goddard, including a painting by Margaret Mansley Kranich, a charcoal sketch by Carol Lebenick, as well as some historical information about Dr. Goddard. Goddard Hall, near the charcoal sketch, also has some historical memorabilia about Goddard, including a lab coat, tools, commemorative stamps, and a copy of the declaration of Goddard Day (section 4.2.3).

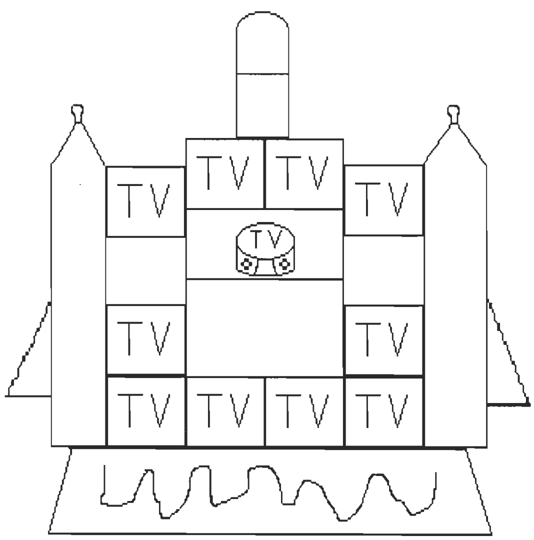

Figure 4.2.1: A sketch of the sculpture named after Goddard located at the Worcester Art Museum

The Worcester Art Museum, located on Lancaster and Salisbury Streets, is also home to a tribute to Goddard. There resides a sculpture named after him, which is designed to look like a rocket. Built by Nam June Paik in 1995, it consists of a number of television sets within a framework that also includes blinking lights, a neon base designed to look like flames exiting a rocket nozzle, and other fixtures to enhance the rocket resemblance. Figure 4.2.1 depicts a schematic sketch, based on one made when Lewis Kotredes visited the museum and saw the sculpture firsthand. The light bulbs at the rocket tops blink, the television screen displays a psychedelic program, and the base of the sculpture is an orange neon flame.

There is also a celebration of Anniversary Day (October 19) in Worcester. Initiated with the support of the GMA, this day was first proclaimed by the Mayor of Worcester in 1999, on the 100th anniversary of the first Anniversary Day in Goddard's life. Lastly, there is a business in Worcester named after Goddard as well. Goddard Valve is a cryogenics firm. They make pumps for NASA, and for other companies as well [http://www.goddardvalve.com].

On the whole, Worcester has done fairly well for Dr. Goddard. Although a single, unifying monument to his work has yet to be completed, the number of minor tributes is rather touching. The work of the GMA, especially, has done a great deal to promote Dr. Goddard here, and the ongoing work that they are doing suggests that more monuments to Dr. Goddard are likely to come in the future.

4.2.2 Recognition of Dr. Goddard in Roswell, NM

Goddard also worked in Roswell, New Mexico. In honor of his work there, several local landmarks are named in his honor. The first of these is the Goddard Planetarium. This is a wing of the Roswell Museum, and they host both educational and public shows. The museum itself also hosts a replica of Goddard's workshop in Roswell. This is as accurate a recreation as possible, and includes many of the tools used by Goddard in the building of his rockets. This workshop also houses a Goddard-style rocket [http://www.roswellmuseum.org].

Roswell also has a high school named after Goddard. The Robert H. Goddard High School has as their mascot the Rockets, an obvious reference to Goddard's work in Roswell. This is one of two public high schools in a town of Roswell, whose population according to current estimates exceeds 50,000 people. Roswell also holds the Robert Goddard Days, an event in October, which is a component of their Science and Technology month [http://roswell-usa.com].

On the whole, Roswell does not contain as many sites dedicated to Dr. Goddard as one might have hoped. This may well be due largely due to the popularity of the site among those who are interested in UFOs and aliens. Compared with these fantasies, the real science done by Goddard at the site begins to lose its luster. What it lacks in quantity, though, it makes up in quantity; the Roswell Museum collection of Goddard memorabilia is one of the largest in the world, if not the largest.

4.2.3 Goddard outside of Worcester and Roswell

Outside of Worcester and Roswell, as well, there are also many things that commemorate Goddard's life. The following is a partial listing of the most important or best-known tributes. We obtained this list by searching on the World Wide Web for references to Goddard, and also using a list of tributes found in the back of the book of Goddard's writings.

Arguably, the best-known and largest tribute to Goddard's work is the Goddard Space Flight Center. Located in Greenbelt, Maryland, this is one of NASA's premier facilities. They do a great deal of satellite instrumentation, including space telescopes and satellites to study earth's climate. They were the first space flight center, built in 1959, and they are responsible largely for Earth Science endeavors under NASA.

There is also a national Goddard Day. It is March 16, the date of Goddard's first liquid-fuel rocket launch in Auburn. The first such day was celebrated in 1965, and was commemorated by a ceremony and a plaque, a copy of which resides at Skull Tomb on the campus of WPI. This is not an unusual honor, but it is still significant. For comparison, March 16 is also Docking Day, Black Press day, and a number of others.

In addition to the Goddard Space Flight Center, there is also a Goddard Power Plant at Indian Head, Maryland, named after Dr. Goddard (who worked there for a short time on military projects). Air Force Association Chapter #266 at Vandenberg Air Force Base in California is also named after Goddard. There is a display, including an early rocket, at the Smithsonian National Air and Space Museum in Washington, D.C. There is a memorial tower at Fort Devens, MA, where Goddard worked for a short time before moving his work to New Mexico. There are also a number of streets named after him, primarily at Air Force bases and similar institutions, and there are also some schools named in his honor beyond those we have already mentioned (Goddard, 1970, p 1671-1674).

4.2.4 The Goddard Memorial Association

The Goddard Memorial Association, or the GMA, is a grass-roots organization dedicated to preserving and promoting Goddard's memory in the Worcester area. Although they were formed about twenty years ago, it is finally in the last several years that they have begun to achieve some of their major goals. At the time of the writing they have approximately a dozen truly active members and approximately sixty to seventy due-paying members who receive the GMA newsletter.

The GMA works in coordination with several other groups in the city. These include the Parks department and a mother organization called Park Spirit. Park Spirit is a collection of neighborhood and GMA style groups, which work with the city to build parks where there is a need or desire for them. The GMA also works with area businesses and the Chamber of Commerce to further its mission. The GMA was instrumental in getting October 19 declared as Goddard Anniversary Day here in Worcester. Further, they obtained the support of Representative James McGovern in getting this day put into the Congressional Record on October 19, 1999. They have worked with Congressman McGovern on several occasions. He was among the notables who attended the dedication of the airport terminal to Goddard in 1998, along with Daniel Goldin, the administrator of NASA.

The primary project of the GMA at the time of this writing is the development of a memorial park for Goddard in Worcester. This will be located at the corner of Apricot and Goddard Memorial Drive. The memorial will consist of a sixty-foot circle, with a perimeter of cherry trees around cobblestone and a granite monument, with a well-known quote from Goddard's graduation speech. The monument itself is still being designed at the present time, however, and the cost of the park is estimated to be quite high, approximately one hundred thousand dollars. WPI and Clark have pledged to provide informational kiosks at the park site, valued at seven thousand dollars apiece. The GMA is currently engaged in considerable fundraising activities to raise the necessary funds for the park's completion, including scheduling a celebrity pool tournament in May of 2001.

Goddard's birth house, located at One Tallawanda Drive, is owned by Kathryn McNamee, a founder and current president of the GMA, and friend to the late Esther Goddard. Mrs. Goddard originally bequeathed this house to WPI and Clark Universities, but they then proceeded to sell it and Mrs. McNamee eventually purchased it. The GMA has applied to have this house added to the Register of Historical Places; the background research has been completed but the actual registry has not been finalized at the time of this writing.

The Goddard Memorial Association has done a great deal to promote Goddard throughout the Worcester area. In addition to that which has already been mentioned in this section, it was largely through their efforts that the signs on I-290 were erected, as well as several other signs in Worcester, including one on James Street. They also supported the rededication of the Worcester Airport terminal and the declaration of Anniversary Day in Worcester (although they were not responsible for the declaration of Goddard's first launch as a holiday). They have done considerable work to get Goddard recognition in the Worcester area, and in all likelihood will continue to do so for some time yet to come.

4.3 Books about Goddard

Since Robert Goddard's original papers are not widely available, the public's opinion of Goddard is formulated primarily from secondary sources; articles, books written about him and even some television shows. However, old television programs and magazines are difficult to trace and are generally not available to a person unless he is searching for them. As such, our discussion of sources about Goddard shall be confined to books about Goddard. As our basic measure of society's recognition of Goddard's contributions, we looked at the quality and quantity of material written about him. In a later section of this paper, we shall also compare this available material to that written about other historical figures. This section, however, deals primarily with an analysis of the sources. The date of publication, background of the author, target audience, and subject matter are discussed in our examination of these books.

The list of books on Goddard that has been compiled is complete according to the Library of Congress and the C/W Mars library system. The subset of books that are readily available to buy are important in the analysis, and the Amazon online bookstore was the source for this information. We also listed articles about Goddard in the appropriate section of the appendix, which we obtained from the Clark University Goddard reference website [http://www.amazon.com], [http://www.cwmars.org], [http://www.loc.gov], [http://libref.clarku.edu/archives/GoddardSources.htm].

4.3.1 Descriptions of books about Goddard

There are 18 books written primarily about Goddard, a total that includes 2 Senate transcripts of Congressional recognitions of Goddard's work. Of all these books, 4 were not obtainable through standard channels, these being inter-library loans and trips to the Clark special collection, and one book was written in Russian. The missing books include 2 juvenile biographies, one having been recently published in 2000, one of the Senate transcripts, and a book by a NASA historian, Eugene Emme. Of the 13 that were located and read, 11 were classified as juvenile literature. A summary of important information about each of these 13 books is presented below:

Robert Goddard: Space Pioneer, 1962

This book was the first and, based upon a Library of Congress search, only book ever written by Anne Dewey. Her motivation for writing the book was a personal interest in rocketry. This book was kept as accurate as possible through contact with Mrs. Goddard and several scientists.

This book is of a moderate length, 148 pages, and does a good job covering all the aspects of Goddard's life. The first third of the book is written about Goddard's childhood and pre-college years, the second third about his scientific work in Worcester, and the final third about his work in Roswell. This book is clearly intended for a younger audience, as demonstrated by two observations. The first of these is that the book is written as a story, with dialogue between people told from a third person perspective, which is not how a 'proper' biography is supposed to be written. More importantly, this book is written to a child's perspective.

In the first part of the book, where Goddard is still a child, the book has a very personal tone and is focused on social events and presenting certain events in a social manner. For example, the book expounds upon activities with friends in school, and tells the story of Goddard's first trip to buy fireworks as a demonstration of his interest in rocketry as a child. As Goddard grows older in the book, however, the focus becomes less personal and the book takes a more objective, factual tone. This book is a perfectly adequate biography for Goddard, but it is only meant for a younger audience.

Robert Goddard: Father of the Space Age, 1963

The author, Charles Verral, wrote children's books, most of which were fiction. This was his last book, and although he does not give a reason for writing it, the book contains a letter of approval written by Mrs. Goddard, indicating interaction with her while writing the book. This is another short book, only 80 pages, which manages however to cover the important aspects of Goddard's life, with a particular emphasis on his childhood. Five of the book's twelve chapters discuss Goddard's pre-college years.

In the section about Goddard's early life, the book takes its time discussing single events in order to build up Goddard's character, especially his inquisitiveness and dedication. Some of these events include his abortive attempts to jump to the moon using static electricity and his aluminum-shelled, helium-filled balloon that never quite rose. The rest of the chapters cover a much larger scope and as such do not have quite as much depth. They read like a standard biography, and discuss from Goddard's college years to his death and post-mortem recognition. Overall, this is another good biography targeted at children.

Robert Goddard: Father of Rocketry, 1963

The author of this book, Gertrude Winders, claims to specialize in "biographies for children in exciting fictional style of men who have pioneered in America's past." For this book specifically, she cites Goddard's childhood diaries, which were provided by Mrs. Goddard. This book is 189 pages and 24 chapters long, out of which the first 17 chapters are about Goddard's childhood.

This childhood discussion is elaborate, as the author creates a detailed narrative around events in Goddard's early years, including minor ones such as a trip to his uncle's house. Furthermore, there is a completely fictional, though minor, character inserted into Goddard's life, and even events that take up whole chapters are not factually verified. One such event from this story involves Goddard watching a recreation of a rocket battle between the Chinese and Japanese. The author is apparently trying to reach a young audience by focusing on Goddard as a child. The end result, however, is thus lessened, as Goddard's adult life was more eventful and historic than his youth.

This High Man, 1963 (Robert H. Goddard: Pioneer of Space Research, 1988)

This book, written by Milton Lehman, was the only book he ever wrote. The fact that it was reprinted testifies to its quality. It is the longest biography written about Goddard, at 430 pages, and the only one strictly targeted towards an adult audience. As reflected by its length, this book is the most complete of all the biographies written about Goddard as well. All the improvements made by other biographies over this one seem fairly superfluous, such as questionably fictional elaborations on childhood events and discussions on the life of Charles Lindbergh.

Robert Goddard: Trail Blazer to the Stars, 1964

This is an extremely short picture book about Robert Goddard. The author, Charles Daugherty, has written and illustrated several other children's books as well. The book is only 42 pages in length, and it is divided evenly between pictures and text. For all of its short length, this book actually does a good job of summarizing Goddard's life, only spending about a third of the book on his childhood. There is even an interesting aside on the legend of a Chinese "rocket pioneer" named Wan Hoo, who attempted to fly into the heavens using a large collection of solid-fueled rockets and ended up blowing himself up. This book doesn't seem very scientifically informed, however, as it makes such mistakes as calling both gasoline and liquid oxygen "fuels" for the rocket, when there is a definite distinction between fuel and oxidizer. This is a distinction, however, that would likely be lost on the target audience.

Rocket Pioneer, 1965

The author, Charles Coombs, writes juvenile literature, primarily about aviation. This book is immediately interesting in that it is filed under the subject "juvenile fiction" as opposed to non-fiction. This book is definitely not fictional, but it does seem not to have been thoroughly researched. The first questionable piece is right at the beginning, with young Goddard playing baseball, which was a fairly out of character activity for the sickly child. The first actual error, however, is when Goddard gets patent advice from a "friend." In fact it was his father's influence and actions that led to Goddard's decision to patent his work. The next discrepancy is with Goddard's research during WWI. Coombs states that Goddard left Worcester because he was causing commotion with the noise of his experiments. In all the other biographies written, the reason that Goddard left is cited as a fear of being spied upon by the Germans. The final oddity is an omission of an important near-accident during the jet-assisted take off testing, even though this topic is given 10 pages. Overall, this book is filled with too many mistakes to be credible, even though all the essentials of Goddard's life are presented accurately.

Robert Goddard: Pioneer Rocket Boy, 1966

Clyde Moore, who writes children's books on varied topics, wrote this book. His dedication at the beginning is "to the boys and girls who will be the space travelers of the future" and this is part of a "Childhood of Famous Americans" series. It is not surprising then, that this book is focused on Goddard's childhood. Of the book's 200 pages and 15 chapters, 9 chapters are written about Goddard's childhood. As with other books that focus mainly on Goddard's childhood, it is questionable whether some of the events portrayed actually happened, such as Goddard visiting Boston Harbor and discussing the evolution of boats with his father. Still, this book might be more accurate than other children's books, as Mrs. Goddard is directly cited as a reference through interviews.

This book heavily emphasizes Goddard as an example of positive traits for young children to have, such as inquisitiveness, enthusiasm, and creativity. Goddard here is primarily a role model for young children, and the biographical portions of the book are secondary. The perspective also shifts dramatically; as Goddard grows older, he goes from being a narrative character to an object of discussion. Goddard gets much more distant as the book progresses, and the author goes so far as to focus one chapter on a pair of nameless children in the midst of a discussion on rockets. Goddard intervenes on their conversation at the end, in order to provide the readers with a list of innovations that he was working on at the time. As a biography, both the content and perspective are of questionable validity.

Congressional Recognition of Goddard Rocket and Space Museum, Roswell, New Mexico with Tributes to Dr. Robert H. Goddard, Space Pioneer, 1882-1945, 1970

This is not a real book on Goddard; rather, it is a transcript of a Congressional hearing. Many of Goddard's friends and admirers spoke at the hearing, including Mrs. Goddard, von Braun, Dr. Abbot (Goddard's contact at the Smithsonian Institution), and Lindbergh. They each basically gave a condensed biography of Goddard, detailing their own personal interactions with Goddard. After the end of the transcript, there is an additional section of tributes written to Goddard. This gets a shade repetitive, but the book gives good insight into how Goddard was viewed by those who worked with him, and tells of their opinions in their own words.

The Boy Who Dreamed of Rockets: How Robert H. Goddard Became the Father of the Space Age, 1978

The author, Robert Quackenbush, is a writer and illustrator of children's books. He has written several dozen biographies of famous people, including Jules Verne, the Wright brothers, and, of course, Robert Goddard. This book is geared towards very young children in its size and simplicity. It is only 30 pages long and every other page is an illustration. The font is large, and on the bottom of each page is a little cartoon that summarizes a key fact or question presented on the page.

The focus of the book is almost entirely on Goddard's childhood and his early mishaps, experiments, and dreams. Only in the last few pages does Goddard grow up, and it notes his first liquid rocket flight and a few of his later achievements on the final page. At the end of the book, there is a short discussion of Newton's 3rd Law, explaining the action/reaction principle upon which rockets work. The goal of the book seems to be the promotion of Goddard's favorable childhood traits, inquisitiveness and creativity, to the young reader. The book uses Goddard primarily as a role model, more than it informs the reader about his important achievements.

Robert H. Goddard, 1991

Karin Farley, the author of this book, writes biographies for children, which is justification enough for this particular biography. As far as Goddard biographies go, this is just about standard in length, 138 pages, and content. All the important events in Goddard's life are mentioned and given appropriate attention. Of course, there are a few deviations from this standard. The life of Goddard's parents is described in some detail at the beginning. Goddard's childhood is very brief, only 2 chapters, compared to most of the juvenile literature on Goddard. Finally, there is a whole chapter on Goddard's World War I work with the bazooka, which includes the suspicion of spies and the resulting secrecy. The over-emphasis of this particular event is unique to this book. As a whole, this is another adequate children's biography of Robert Goddard.

Robert Hutchings Goddard - Pioneer of Rocketry and Space Flight, 1992

Suzanne Coil has written 10 books, all aimed towards a young audience, and she does not give any indication as to why she wrote about Goddard. She begins the book on an interesting note, the first recorded story of space travel, written by a Greek, Lucian of Samosata, in the 2nd century AD. From there, the book quickly regresses into a very standard, very complete biography of Goddard, neatly summarized into 134 pages and 11 chapters.

Rocket Man - The Story of Robert Goddard, 1995

Tom Streissguth, the author of this book, is a writer of children's books on a variety of subjects. Among these books, biographies of John Glenn and Jules Verne are the only ones related to the subject of Goddard. This book is a short 88 pages, and it quickly summarizes Goddard's childhood in the first 2 of the 13 chapters. The content of Goddard's life is properly summarized and emphasized, with a few interesting deviations from other books.

The first of these deviations is an emphasis on the division in Goddard's early space flight work, marked by Goddard burning all his notes. This was caused by his frustration with physics, as he tried to find loopholes in laws, but only found a lack of understanding. After reinitiating thoughts on space travel, Goddard takes a much more careful scientific approach. The second deviation is in an emphasis on Goddard's secrecy. Here, a very appropriate comparison is made to Lindbergh's acceptance of media attention and the bad fortune and suffering it caused him all his life, whereas Goddard learned from his two painful encounters and shied away. The final deviation is in the discussion about Germany stealing Goddard's work, which is actually two-sided, unlike the Goddard-sided discussions in other books. The conclusion here is that many of the engineering problems related to the rocket had only one optimal solution and that both Goddard and the Germans reached that optimum independently.

Rocket! : How a Toy Launched the Space Age, 1995

The author of this book, Richard Maurer, is a general science writer and a rocket enthusiast. Besides this book, he has written several other books, mostly about space and flight. As references for this book, Maurer sites Clark University, the Smithsonian Institute, and WPI as helpful sources.

Based on the title, this book might not seem like it focuses on Goddard, but rather the history of rockets in general. It is indeed a history of rockets, but it is constructed around the scientific achievements of Goddard. It starts off with some talk about solid fuel rocketry before Goddard, its Chinese origins and its ineffective use as weaponry during the war of 1812. The book then turns to the second prerequisite to space rockets, the desire to go to space. This dream was popularized by the science fiction writers of the 19th century, including Jules Verne and H. G. Wells, and this book emphasizes that all three of the main rocket pioneers, Goddard, Oberth, and Tsiolkovsky, were inspired by these stories.

Goddard's early attempts at space travel are then discussed, from naïve creations such as his "centrifugal force" machine, to more mature ideas such as a "reverse gun," and finally the rocket. Goddard is only discussed as a rocket scientist here; this is by no means a complete biography. The book doesn't begin with Goddard nor does it end with him; it instead goes on to discuss the Cold War space race that followed him. Goddard's achievements are kept in perspective, quite literally, as his biggest, most successful rocket is compared, side-by-side, with future landmark rockets, such as the V-2, the R-7, the Titan V, and the NASA Space Shuttle.

This book is short (65 pages), very colorfully illustrated, and simple enough for children, making it more a children's book than anything. Goddard's life isn't discussed adequately for a true biography, but his achievements are put in an interesting perspective with the rest of rocket history.

4.3.2 Analysis of the books on Goddard

The most obvious point of analysis is that the majority of the books on Goddard, 13 of the 18, are children's books. Of the non-juvenile books, 2 are Congressional transcripts, one is written in Russian, and only the final two are actual biographies in English. Out of these two adult biographies, only the one authored by Lehman was widely available. It was one of the first books written about Goddard, and it was even republished. This is in sharp contrast with the juvenile literature, which has produced a steady stream of biographies.

There is a definite trend in the content of the juvenile literature that would suggest a changing attitude towards Goddard over time. All the early biographies on Goddard spend a significant portion of the book on Goddard's childhood. They dwell on particular 'key' events in his childhood and build up fictional narratives around them. They also try to embody certain key traits in his actions, in an attempt to make him as positive a role model as possible. Newer books on Goddard, especially the ones from the 1990's, stress Goddard's work and achievements and summarize his childhood in a very prompt manner. This shift could have one of many possible causes. One obvious reason is that Goddard's childhood was just too different from a modern childhood for today's children to identify with, and as such he is no longer quite as appropriate as a role model.

There may also have been a shift from respect of his personal genius to a respect for his work, now that the world has seen all of its end results. Knowing that he led us into space is probably far more engrossing to a young adult than reading about a young boy trying to jump to the stars. Whatever the cause, there seems to have been a slow refinement in the way Goddard is presented to children, and thus in the way he is seen by children. There is also no sign of Goddard being forgotten, as the stream of juvenile literature doesn't seem to be letting up.

4.4 Books about Goddard and 3 other well-known figures

To assist in measuring Goddard's social impact, we compared the works written about him with works written about other people. We chose as our other subjects Neil Armstrong, Wernher von Braun, and the Wright Brothers (considered as a unit). Our goal was to make some comparisons among these people, based both upon the volume and the nature of books written about them. We found 15 books in English written about von Braun, 11 written about Armstrong, and 77 written about the Wright Brothers. These books are listed within Appendix A.

We looked into several aspects of the books, with criteria that were designed to examine various aspects of society's view of these pioneers in avionics. The first of these criteria was a bias towards children's literature. As a society, we tend to try and give our children role models to look up to, and in order to teach them we give them books about these men. We anticipated this effect, and so we attempted to account for it in our analysis. As we compiled our lists of books, we specified those that were clearly intended for younger readers. After the fact, we tabulated these results and compared them. Indeed, as we had expected, a significant proportion of the books written about our subjects was written for a juvenile audience. As a matter of fact, both Goddard and Armstrong proved to be the subject of considerably more children's books than adult material. The Wright Brothers, as well, had a large number of juvenile books written about them, although this number was not quite a full half of the total literature about them and their flights. The exception to the rule, however, was von Braun; of the fifteen books written about him, only 2 were primarily intended for a juvenile audience. This effect, although not important as such to our paper, does have some consequences of interest. The most significant of these is the reason that he is not the subject of more children's literature. In all likelihood, this was largely due to his collaboration with the Nazi regime during the Second World War, and the fact that his rocketry studies were then aimed at developing the V-2 rocket. Such a blemish does not exist on Goddard's reputation, and therefore he is capable of being a respectable role model for youth.

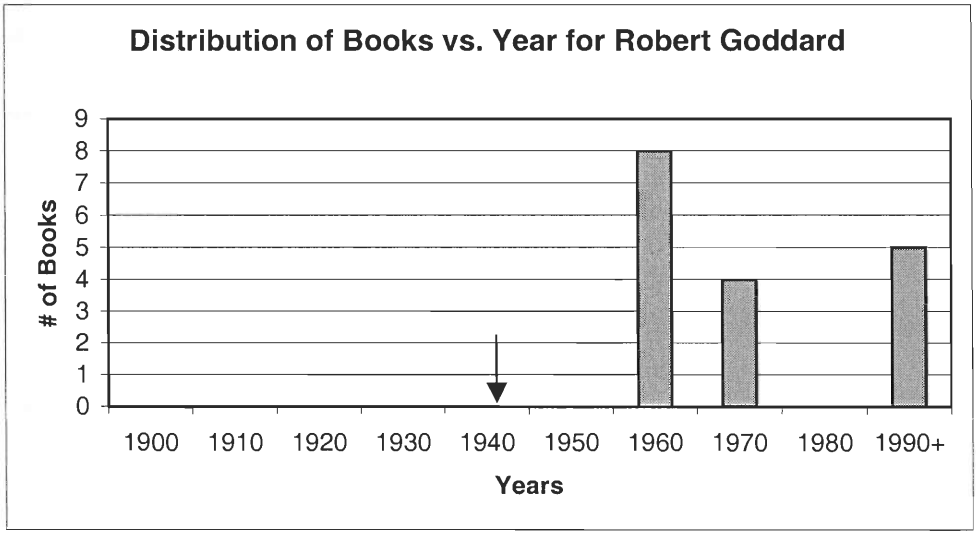

Figure 4.4.1 Distribution of Publishing Dates for Robert Goddard

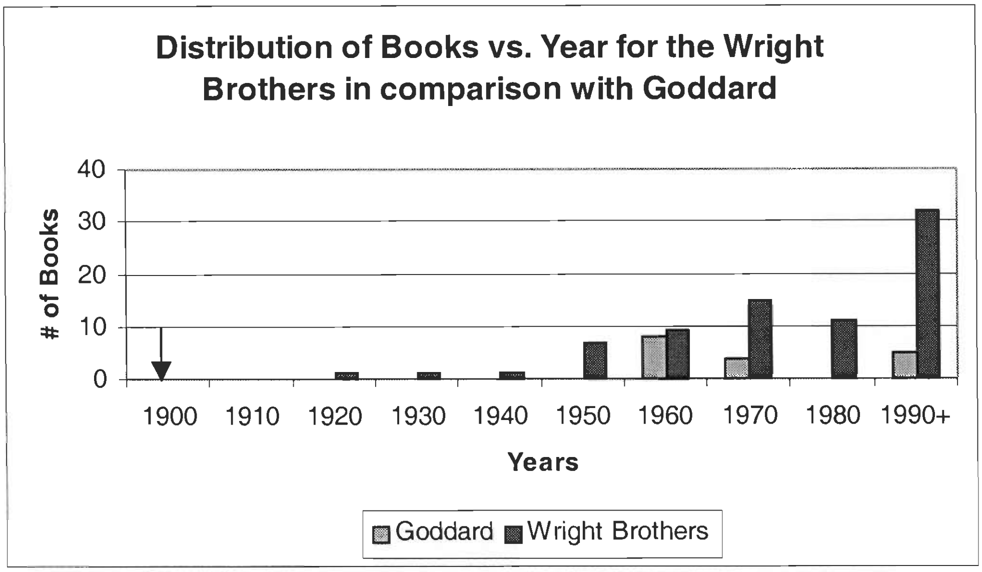

Figure 4.4.2 Distribution of Publishing Dates for the Wright Brothers

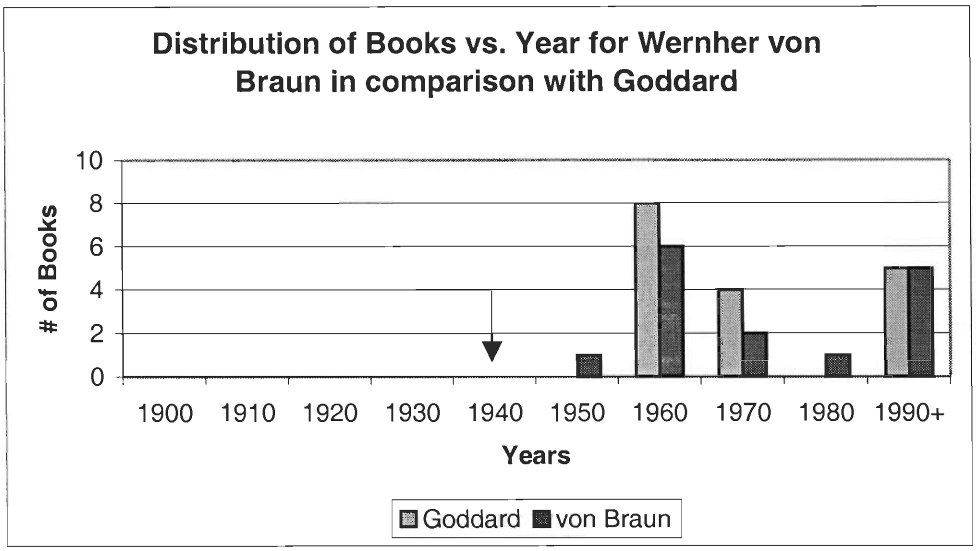

Figure 4.4.3 Distribution of Publishing Dates for Wernher von Braun

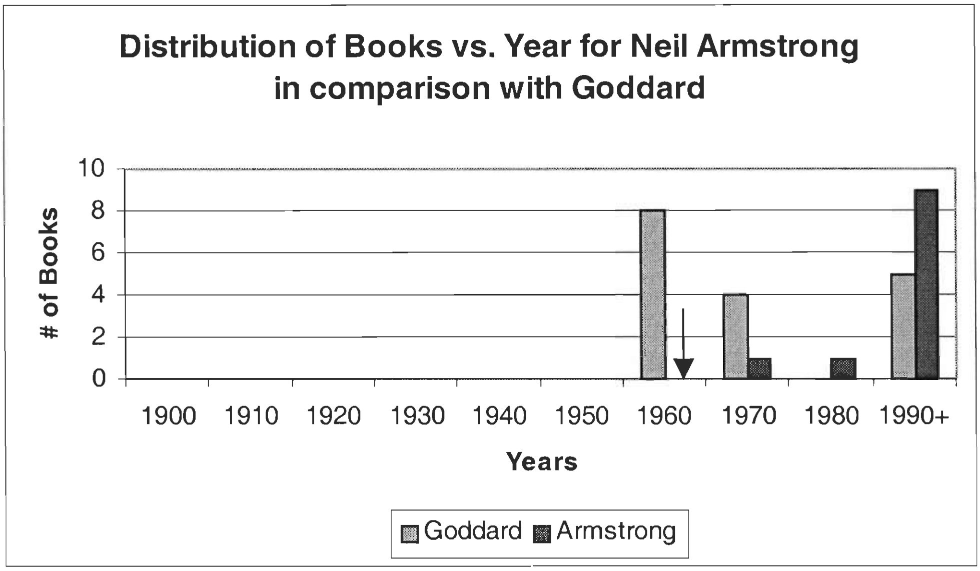

Figure 4.4.3 Distribution of Publishing Dates for Neil Armstrong

Another aspect of the literature of which we took special note of was the publishing date. By noting the publishing dates, we hoped to establish some links between how each scientist was recognized and the historical circumstances surrounding the time of publication. The various distributions are shown in histograms, which show some interesting characteristics. Each distribution (except for Goddard's) compares the publication dates with the books about Goddard, and also includes an arrow specifying the year we chose as that of their primary achievements. For Goddard, this was the 1940's, when he died; for Von Braun, it was the 1940's, when he was working on the V-2 project, for the Wright Brothers, it was the 1900's, when they first flew, and for Armstrong it was the 1960's, the date of the first manned lunar landing. As a general rule, our subjects did not immediately get a great deal of recognition right when they were doing their work. Another factor, one that tended to disrupt the trends, was a surge in biography publication during the 1990 into the present day for all four subjects.

For Von Braun, a good number of books were written during the 1960s, the period of the space race and a time when we recognized our rocket scientists as potential heroes. For Armstrong, on the other hand, all the books written about him turn out to be relatively new; only two of the books about his life were written prior to 1990. Goddard's works are fairly evenly distributed, compared to some of the others, but they still show signs of spikes during the 1960s and 1970s, as well as the last decade. The most immediate logical conclusion one can draw from this is that, at the high point of the Apollo program and for some time after, America's homegrown rocket pioneer was a good person to respect. However, this did not last, and in the 1980s there were no books published about Dr. Goddard. Book production did begin to pick up again during the 1990s; however, how much of that can be attributed to that which has caused a spike for all the subjects cannot be determined. Indeed, the reason for the entire spike in publications for our subjects is not easily discerned.

The Wright Brothers are separate from the other groups, largely because the best data is available on them. Fully twice as many books have been written about them as have been written about the other research subjects. They were also the earliest of the pioneers, so they have had more time to build up a large number of biographies. In fact, the biographies written about the Wright Brothers have followed an interesting pattern. They seem, essentially, to be in a state of constant, almost exponential growth; each decade, more biographies are published.

We obtained some interesting and thought provoking results to our research. It is interesting and somewhat surprising as well, to note that there were more books about Goddard than about Neil Armstrong. Of course, Armstrong likely made up for it with sympathetic press coverage, but it may be interesting to note who is more significant to our culture in the long run. There is, however, the possible explanation that less has been written about Armstrong precisely because more people know who he is. Such speculation notwithstanding, it was quite an interesting surprise to see such a discrepancy in our number of biographies, and it along with our other results, especially those that run counter to expectations, justify our interest in the literature written about these famous personages.

4.5 Interest in Robert Goddard

The last section of this chapter concerns those who have visited the special collections at Clark University. As we have said, this collection contains some of the best resources available to do detailed research on Dr. Goddard. There they have all his collected works and even pieces of equipment used in his experiments. In the library, there is a section that is devoted entirely to the correspondences he made throughout his lifetime. The collection is quite extensive and contains many original works. Also stored there is a guestbook containing a partial listing of those who have visited the Goddard Collection. A separate log, used for matters internal to Clark University, contains a record of who has visited the collection and what research they were doing.

4.5.1 Goddard Collection Guestbook

The guestbook at the Goddard Collection, located within the Goddard Library at Clark University, contains the names and dates of when people visit the library. The collection is open from 9:30 AM until 4:30 PM, Monday through Friday. The listing is quite extensive and goes back to the 1970s. The listing is not perfect, however, in that not every visitor to the library signs the book, and not every member of visiting groups signs the guestbook either. These groups often include families and school field trips, so an accurate counting of the number of visitors is not possible. However, a lower bound on the number of visitors can be determined. The data analyzed are from the years 1997 to 2000. This period resulted in 491 data entries and represents a sample of the visitors.

The data gathered from the guestbook include the date of visit, the country of the visitor, and, if a US visitor, the state in which the visitor resides. These were the only data taken to protect the privacy of those who have signed the guestbook. These data were entered into an Excel spreadsheet and then analyzed using the graphing functions of Excel. One objective of this portion of the project was to determine the number of visitors to the Goddard collection. Information regarding where the visitor resides was taken to see if there were more people from out of state that were visiting the collection than local Massachusetts residents. Another objective was to see if non-Massachusetts residents visited the collection on different days than Massachusetts's residents. To accomplish this, the data were analyzed for the number of times a non-Massachusetts visitor signed the guestbook alone as opposed to when a Massachusetts resident also signed the book.

4.5.2 Analysis of Goddard Collection Guestbook

Figure 4.5.1 shows the number of visitors and where they reside. The number of Massachusetts's residents is 297, the number from other states is 120, and the number from foreign countries is 75. It was expected that the number of visitors from

Massachusetts would be the largest, since the collections are within that state. It is surprising, however, that the number of foreign visitors was so high. 15 percent of the visitors were from foreign countries while only 24 percent were from other states.

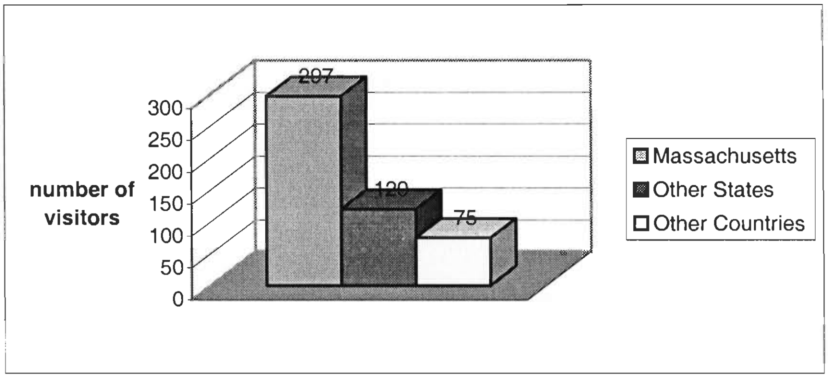

Figure 4.5.1 Number of visitors vs. place of residence.

The majority of non-Massachusetts visitors came from states like California, New York, New Jersey, Florida, and Maine. There are 26 states represented in figure 4.5.2. The New England states of Maine and Vermont along with New York and New Jersey represent 33 percent of the non-Massachusetts visitors. California and Florida represent 25 percent of the non-Massachusetts visitors.

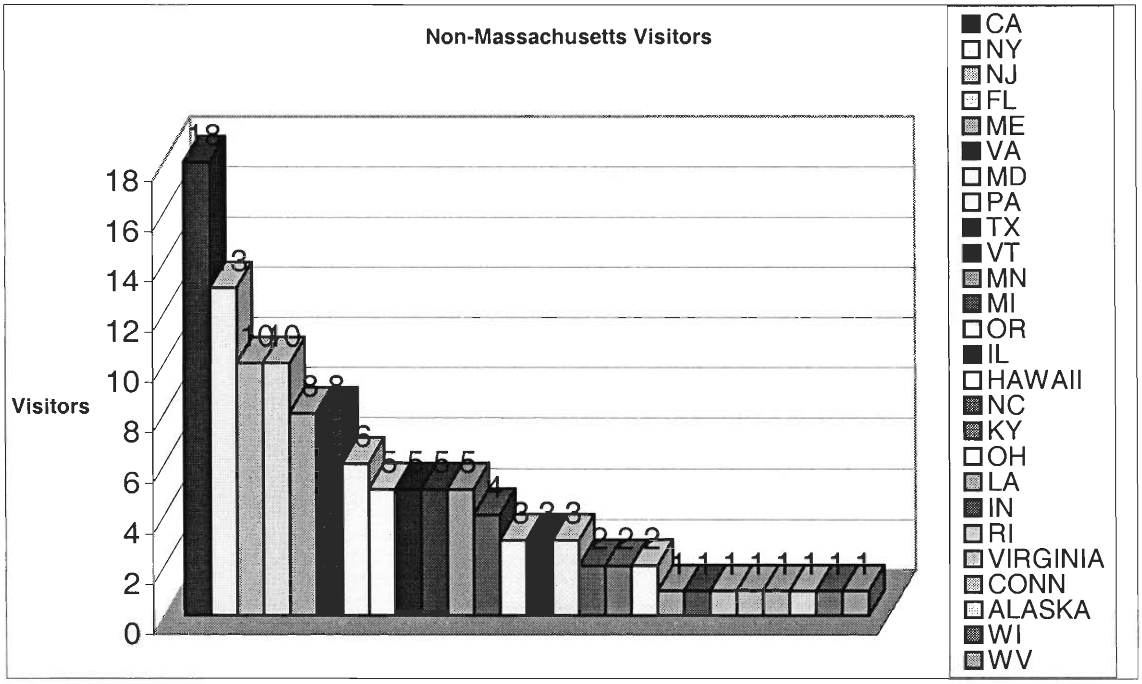

Figure 4.5.2 Non-Massachusetts Visitors

The non-US visitors mainly came from Israel and Taiwan. Together these two countries composed 30 percent of the foreign visitors to the Goddard Collection. This could have been the result of a large tour group visiting the collection. It is actually quite surprising that so many foreign countries are represented as visitors to the Goddard Collection. The number of foreign visitors that visit the Collection the same day as Massachusetts's residents is 21 percent of the 75 foreign visitors. This is a small percentage of the visitors from foreign nations.

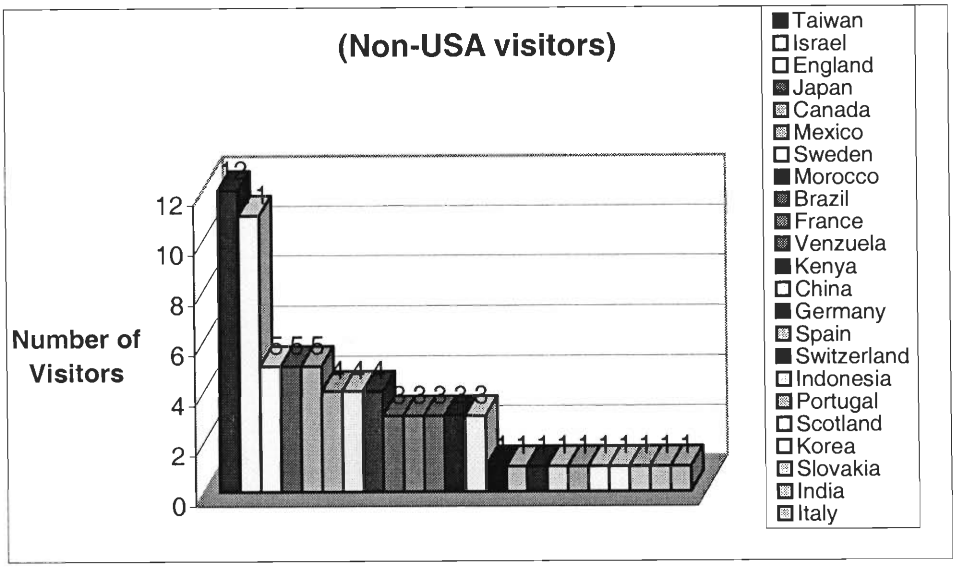

Figure 4.5.3 Non-USA visitors

It would be of interest to determine how many people visit the city of Worcester from other states and compare that number to the number who visits the Collection. The same thing could also be done for non-American visitors. This would serve to put the above data in context with the standard tourism that Worcester receives. It might also serve to explain the large number of visitors from California, Florida, Taiwan, and Israel. By itself, the guestbook is not enough data to determine the visiting habits to the collection; however, it does contain some surprising information.

Chapter 5: Scientific Literacy of Goddard's Work

5.1 Introduction

Dr. Robert H. Goddard made many advances to the field of rocketry that were highly technical in nature. Among these were the use of gyroscopes for stabilization and the use of liquid fuels. We surveyed students from 4 universities in an attempt to gauge their scientific literacy of Goddard's contributions to the field of rocketry. Although the implementation of the surveys varied across the schools, the content of the survey was the same. A copy of the survey can be found in appendix B.

5.2 Implementation of Surveys

The survey was broken up into two main sections. The first section dealt primarily with Goddard's life and his work. The second section dealt with basic scientific principles that are related to the field of rocketry. The questions asked in the first section ranged from general information about Goddard to more advanced topics about his work. The final sets of questions were based on general physical principles and on actual rockets used today.

The goal of the survey was to determine the depth of knowledge that people have about Goddard's work. Also of interest was the amount of technical knowledge the same group of people had about rocketry and basic scientific principles related to the field of rocketry. Our initial idea was to survey the Worcester populace. The information gathered from a survey of the city of Worcester would be of use to many organizations, including the GMA. However, it became apparent as the project progressed that such an endeavor was too costly and time consuming to undertake. Therefore, a second populace was chosen that was within our budget.

We decided to survey college students in the Worcester area. The final four schools chosen were WPI, Holy Cross, Clark, and Worcester State. These schools were chosen because of their sizes and their willingness to participate in the survey. WPI was considered since Goddard was a student at the school and also did some work in the magnet lab on the WPI campus. The IQP project is also familiar to the students there so the participation rate was expected to be the highest of the four schools. Also being an engineering school, the knowledge of Goddard's work and of basic rocketry was expected to be high. Clark University was chosen since Goddard was a professor at the university. There is also a library named after him on campus, so his name should be well recognized. In addition, a special collection dedicated to Goddard resides on their campus, so we expected good results from the survey; however, it is not an engineering school so recognition scores might have been higher than the rocketry scores. Holy Cross was chosen both because of their willingness to participate and because they represent a control group. The university does not have a direct Goddard connection like WPI and Clark, and is a well-rounded university with many students majoring in non-science majors. Worcester State was considered as another control group for the same reasons as Holy Cross. However, no results were obtained from the school and it was therefore dropped from the project.

5.2.1 Survey at Worcester Polytechnic Institute (WPI)

This survey took place in the days following December 8, 2000 and the responses number at 477; however, only 346 were filled out correctly with the others having mostly blank questions or answers specified as guessed in question 8. We initially considered a variety of means of distribution of our survey such as e-mail and standard mail. Choosing between the two, however, required some research. Following a meeting with our Dean of Students, we determined that a standard mail survey would be ineffective and time consuming for multiple reasons. The first of these is that the WPI mailroom dislikes sending campus-wide mailings, and has requirements in place to prevent them, including a requirement that mail to multiple persons be in numerical order by mailbox and be properly addressed. The other reason is the recognition that an extremely large proportion of such surveys are never actually filled out, but simply end up in the trash bins around the mailroom.

Therefore, we decided on an email survey of the population. Upon research, we determined that this was possible through use of a moderated mailing list maintained by the CCC helpdesk. The timing of the email may have been fortuitous, as it was sent out on a Friday afternoon as classes were ending; nearly two hundred responses were registered within the first two hours immediately after the survey was sent out. Also, this survey seems to have been the first sent within that school year. The response rate is estimated (based on student population numbers tabulated by the WPI Admissions Office) to have been about 17 percent, which considerably exceeded our expected value of 10 percent.

5.2.2 Survey at Clark University

To implement the survey at Clark University, we contacted the Dean of Students. Clark does not have a school wide email alias, so we chose to use their mail system as a means to do the survey. This required us to get a mailbox at Clark University to avoid the massive cost of postage in mailing a survey from Clark University to WPI. Because the semester at Clark ended on the 15^{th} of December, we had to implement the survey at the beginning of C term.

The number of responses received from Clark was approximately 80, twenty of which were blank. This is out of 1500 surveys that were delivered to the Clark mailroom. Thus, our response rate was approximately 4 percent, well below the desired 10 percent. This low response rate, while not disallowing response analysis, did impair some analysis methods.

5.2.3 Survey at Holy Cross

To implement the survey at Holy Cross, we contacted the Dean of Students. The survey was initially to be done through the email system, but due to concerns of divulging the student body email alias and the risk of the responses going directly to the Dean and flooding her email inbox, we eventually used the campus mail system.

We printed up 2600 copies of the survey and left them with the mailroom to distribute among the mailboxes. The surveys were then to be filled out by the students and returned using the Holy Cross campus mail system to our mailbox there, which the Dean helped us set up. The survey was implemented the third week of January and the results were collected on February 1, 2001. The responses numbered approximately 175, which indicate a response rate of approximately 7 percent, slightly lower than our desired 10 percent.

5.3 Analysis

The data from the surveys were entered into an Excel spreadsheet and the graphing functions of Excel were used to analyze the data. The data sets for each educational institution were kept isolated from each other so that the responses from the schools could be compared. The first aspect of the surveys investigated was the overall results from each school. The second aspect was a focus on only the surveys from each school that had heard of Dr. Goddard. We did this by sorting the responses by question 1, *have you ever heard of Dr. Goddard?* These surveys were then broken down into how they answered question number 8, *where did they learn this information about Goddard?* The answers to question 8 were compiled into three categories, those who learned from local media, those who learned from a personal interest, and those who learned from formal education. The third aspect of the analysis was to sort the responses by question 17, *where are you from?* The answers to question 17 were compiled into 3 categories, those from Worcester, those from Massachusetts but not Worcester and those from other US states. The fourth and final aspect of the survey analysis was to sort by question 16, *what is your major?* The responses to this question were compiled into three categories; engineering majors, science majors (non-engineering), and non-science majors. The number of majors in each category differ from school to school, however, no single major is listed in two categories. The actual majors in each category are discussed later in the chapter.

The results from the survey at WPI are represented in Figure 5.3.1 and 5.3.2. The results are stated below.

- Question 1: ***Have you heard of Dr. Goddard?*** The data show that 85 percent of those surveyed at WPI have heard of Dr. Goddard.
- Question 2: ***Who was Robert H. Goddard?*** Among the 296 people who have heard of Dr. Goddard, 98 percent knew that he was a rocket scientist, five people (2 percent) did not know his occupation, and only one person thought he was a brain surgeon.
- Question 3: ***When was Goddard active in his career?*** The data suggest that 54 percent of those who had heard of Goddard knew he was an active rocket scientist from 1900-1940. An equal number, 22 percent, answered incorrectly with either **a** or **c** while 2 percent were not sure of when he was active in his career.
- Question 4: ***Where did he do his work?*** 52 percent thought that Goddard only did the majority of his work in Worcester, MA. Only 19 percent answered correctly, that he worked at Worcester, MA and Roswell, NM. A large number, 21 percent, thought that he worked at Worcester, MA and in Germany, which is incorrect.
- Question 5: ***Where was he born?*** This question suggests that only 42 percent knew that he was born in Worcester, MA, with 11 percent who thought he was born in Germany and 46 percent who were unsure of his birthplace.
- Question 6: ***Do scientists continue to use Goddard's work today?*** 89 percent surveyed at WPI think that Goddard's work is still useful while 11 percent are unsure.

- Question 7: ***Goddard was the first to successful test what?*** The data suggest that 45 percent knew that Goddard was the first to successfully test liquid-fueled rockets. 14 percent thought he was the first to test solid-fueled rockets and 12 percent thought he was the first to successfully test both solid and liquid-fueled rockets. 27 percent were unsure of what he was the first to successfully test.
- Question 8: ***Where did you learn this information about Goddard?*** 22 percent learned of Goddard through the local media, 24 percent learned of Goddard through personal interest, and 13 percent learned of Goddard through formal education.
- Question 9: ***Do airplanes work in outer space?*** This question suggests that 3 percent think that airplanes work in outer space, 13 percent are unsure and 84 percent correctly answered that airplanes do not work in outer space.
- Question 10: ***Is the Space Shuttle designed to travel to the moon?*** 27 percent think that the shuttle can go to the moon, 16 percent are unsure and 57 percent answered correctly that the shuttle is not designed for lunar travel.
- Question 11: ***The Space Shuttle uses what kind of rockets?*** The data suggest that 19 percent are unsure of the rockets used on the shuttle, 34 percent and 9 percent think that the shuttle uses only liquid-fueled or solid-fueled rockets respectively, and 34 percent correctly answered that the shuttle uses both liquid- and solid-fueled rockets.
- Question 12: ***Can rockets travel faster than the speed of light?*** 3 percent think that rockets can travel faster than light, 6 percent are unsure and 91 percent answered correctly that rockets cannot travel faster than light.

- Question 13: ***Do rockets rely on an atmosphere to push against to move upwards?*** The collected data that only 53 percent correctly answered no, while 29 percent thought they do and 18 percent were unsure.
- Question 14: ***Have you seen the sign on I-290?*** Only 43 percent have seen the sign on Interstate 290, while 57 percent have not.

According to the answers from the survey, 93 percent of those that responded from WPI were females, who make up 23 percent of the school's population. 67 percent of those that participated were ages 15-18 and 33 percent were ages 18-24. According to question 20 about race, 88 percent of the respondents were white and 4 percent were Asian. Native American, African American, and Hispanic together compiled 4 percent. The results of the WPI survey can be summarized in Figures 5.1.1 and 5.1.2, which shows the percentage of correct answers for each question. Similar results for Holy Cross and Clark can be found in Figures 5.3.3, 5.3.4, 5.3.5, and 5.3.6.

Among all three schools, nearly all of those who have heard of Dr. Goddard know he was a rocket scientist. The percentage for all three schools was in the high 90's. This can be seen in Figures 5.3.7, 5.3.8 and 5.3.9. About 50 percent of the WPI and Clark students knew that Goddard was active in 1900-1940, where Holy Cross only had 35 percent that answered correctly. All three schools had very low scores on where Goddard did his work. All were less than 19 percent correct. The majority of the responses were for Worcester, MA only and only less than 19 percent knew of Goddard's connection with Roswell, NM. Regarding the knowledge of Goddard's birthplace, only 42 and 37 percent from WPI and Clark respectively knew that Goddard was born in Worcester, while 48 percent from Holy Cross knew of his birthplace. The majority of non-

Worcester answers were for unsure and not the incorrect answers of Germany or Washington, DC. Over 90 percent of the students at all three schools believe that Goddard's work is still useful today. WPI and Holy Cross scored low on Goddard's first successful rocket test, about 45 and 40 percent respectively, while Clark had 57 percent who knew that he was the first to test liquid-fueled rockets successfully.

For the scientific knowledge portion of the survey, over 79 percent of the students at all the institutions were able to recognize the fact that airplanes will not work in outer space. Only 40 percent of the students surveyed at Clark and Holy Cross were aware that the shuttle is not designed to travel to the moon, while the number at WPI was 57 percent. However, all schools scored rather low on what type of rockets the Space Shuttle uses, less than 34 percent at WPI, less than 25 percent at Holy Cross and less than 19 percent at Clark. With regard to basic physical principles, all three schools scored high on the fact that nothing can travel faster than light, with WPI having a slightly higher percentage in this category. However, for the Newton's third law question, both Holy Cross and Clark had around 30 percent of its students answer correctly while WPI only had 53 percent answer correctly.

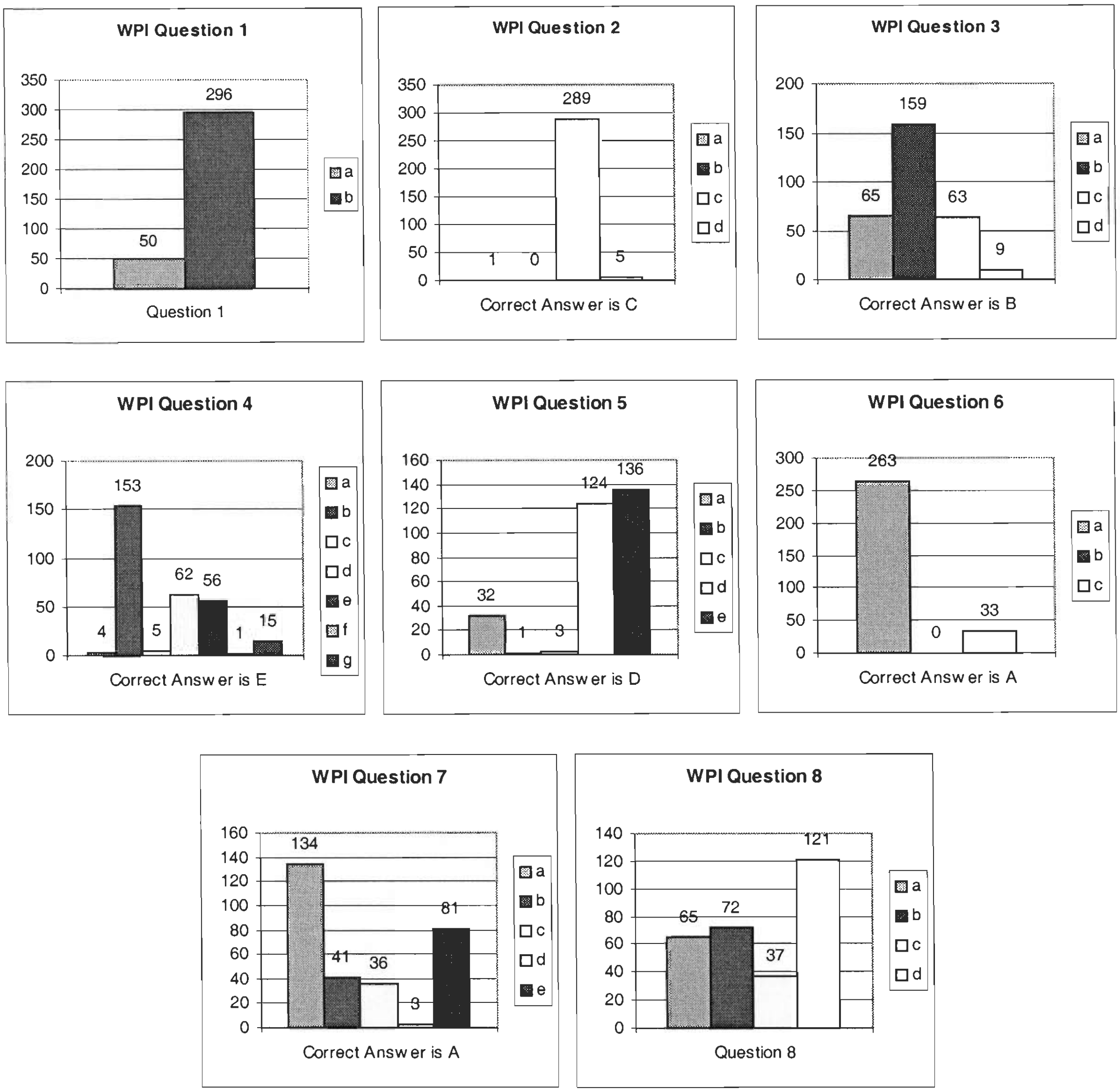

Figure 5.3.1 Goddard questions at WPI

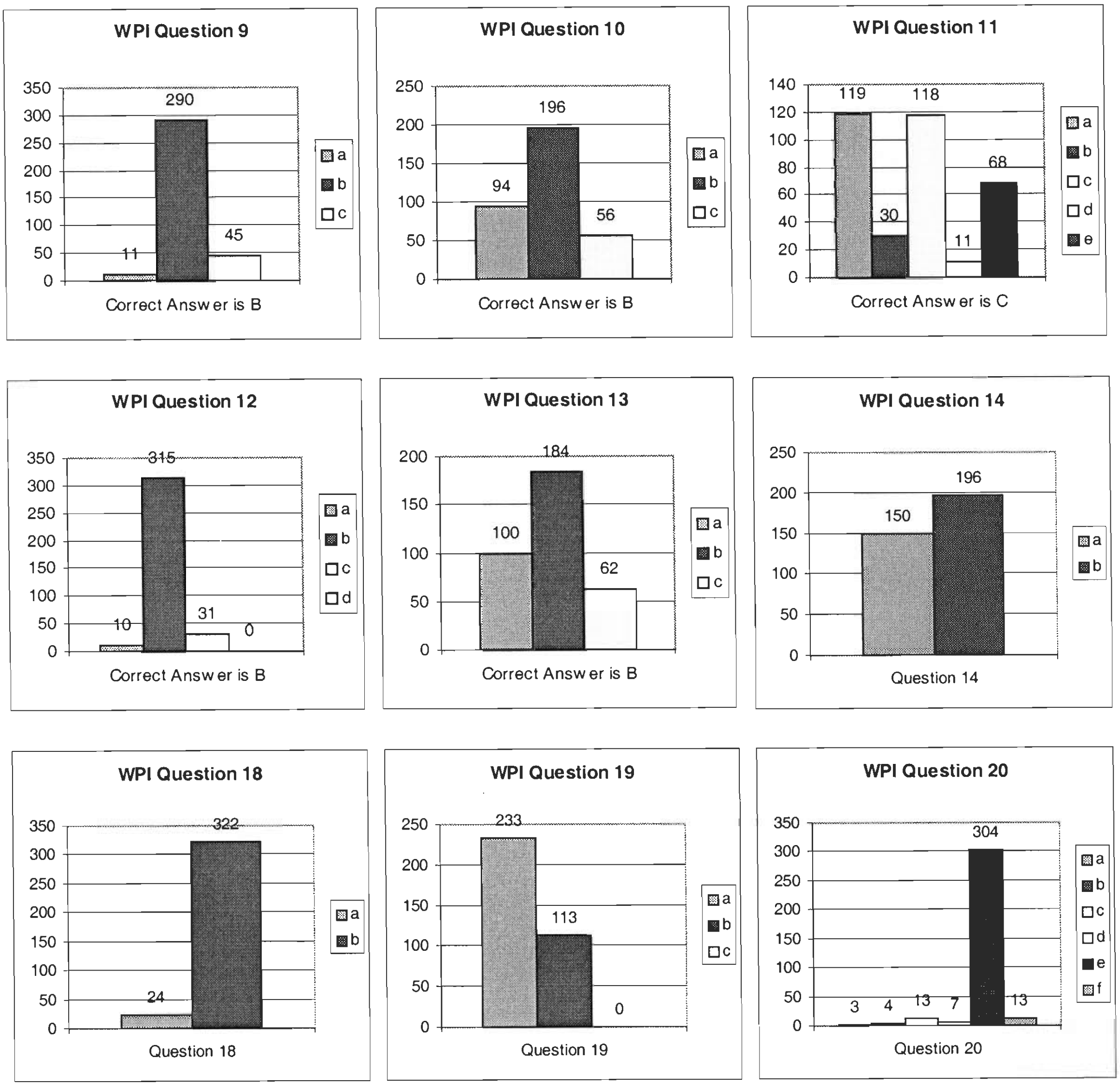

Figure 5.3.2 Science and Demographic questions at WPI

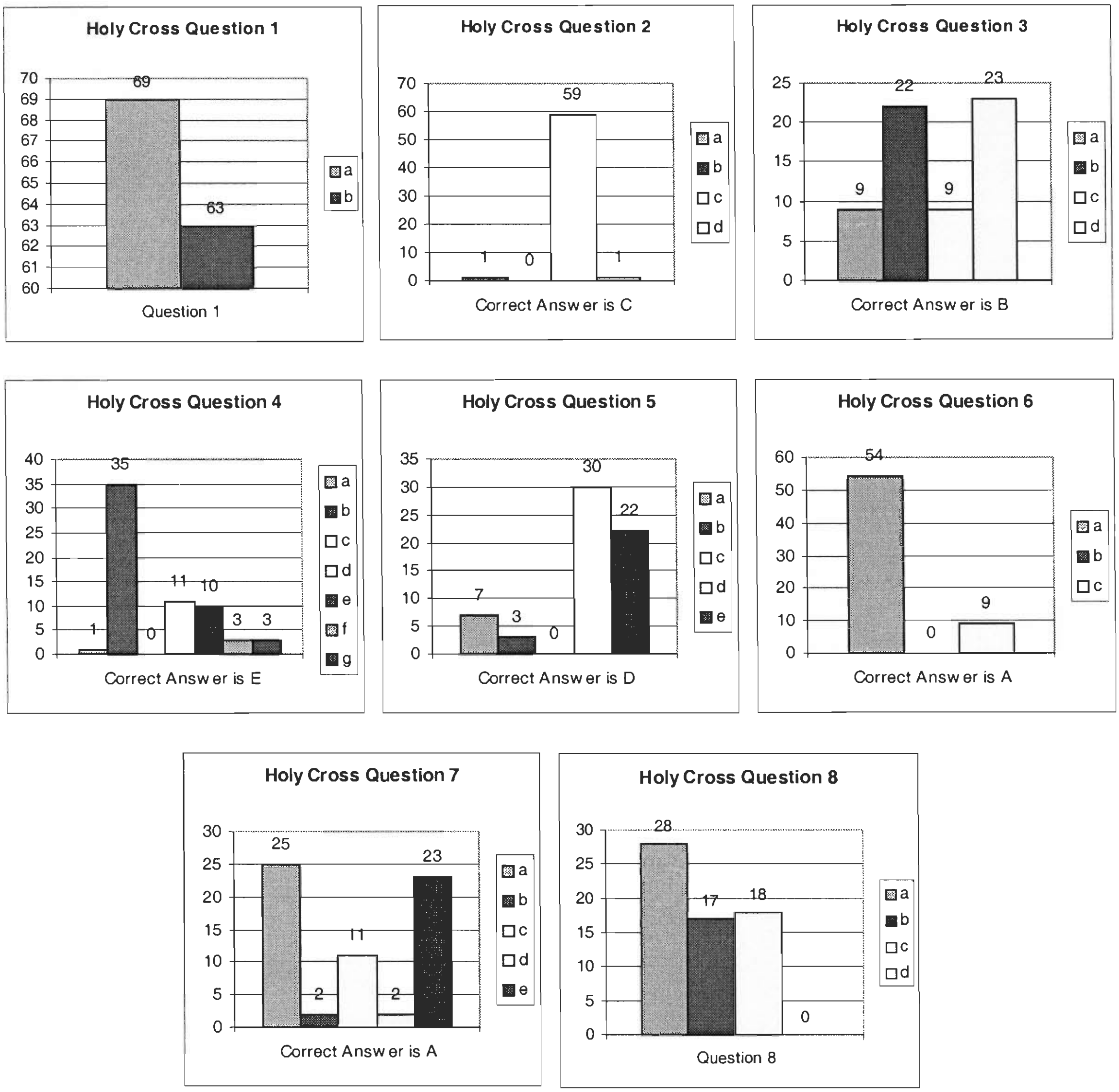

Figure 5.3.3 Goddard questions at Holy Cross

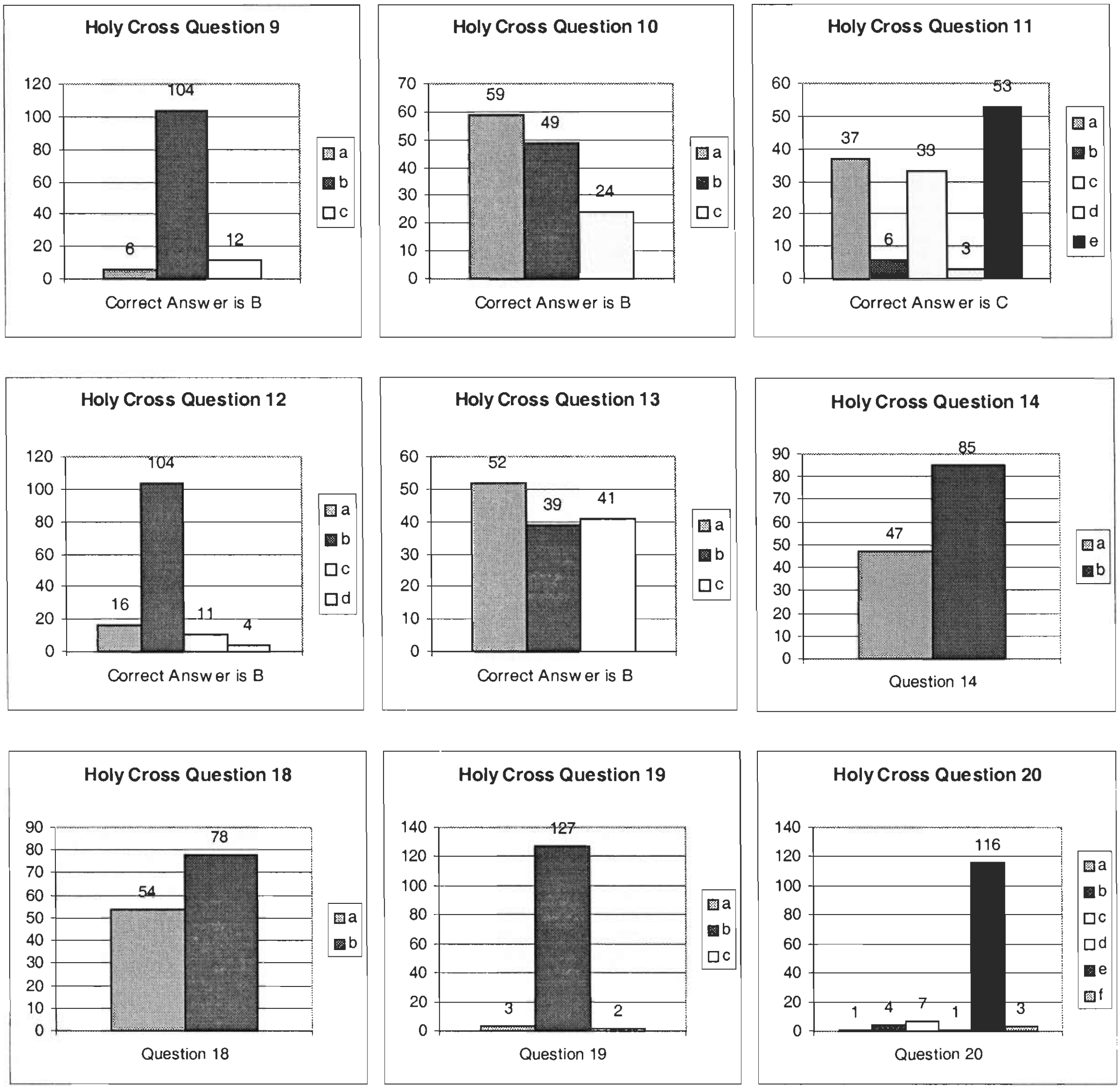

Figure 5.3.4 Science and Demographic questions at Holy Cross

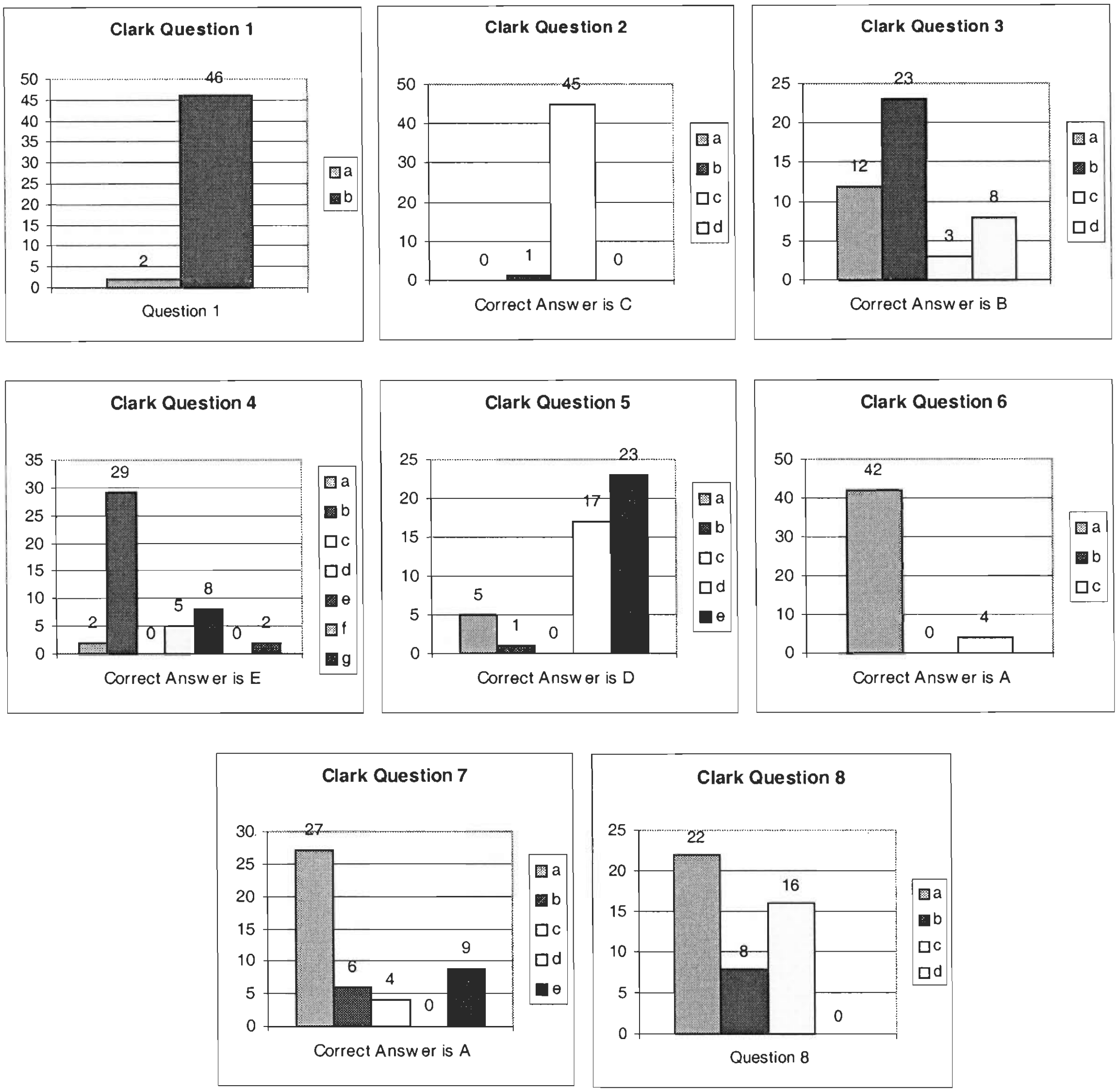

Figure 5.3.5 Goddard questions at Clark

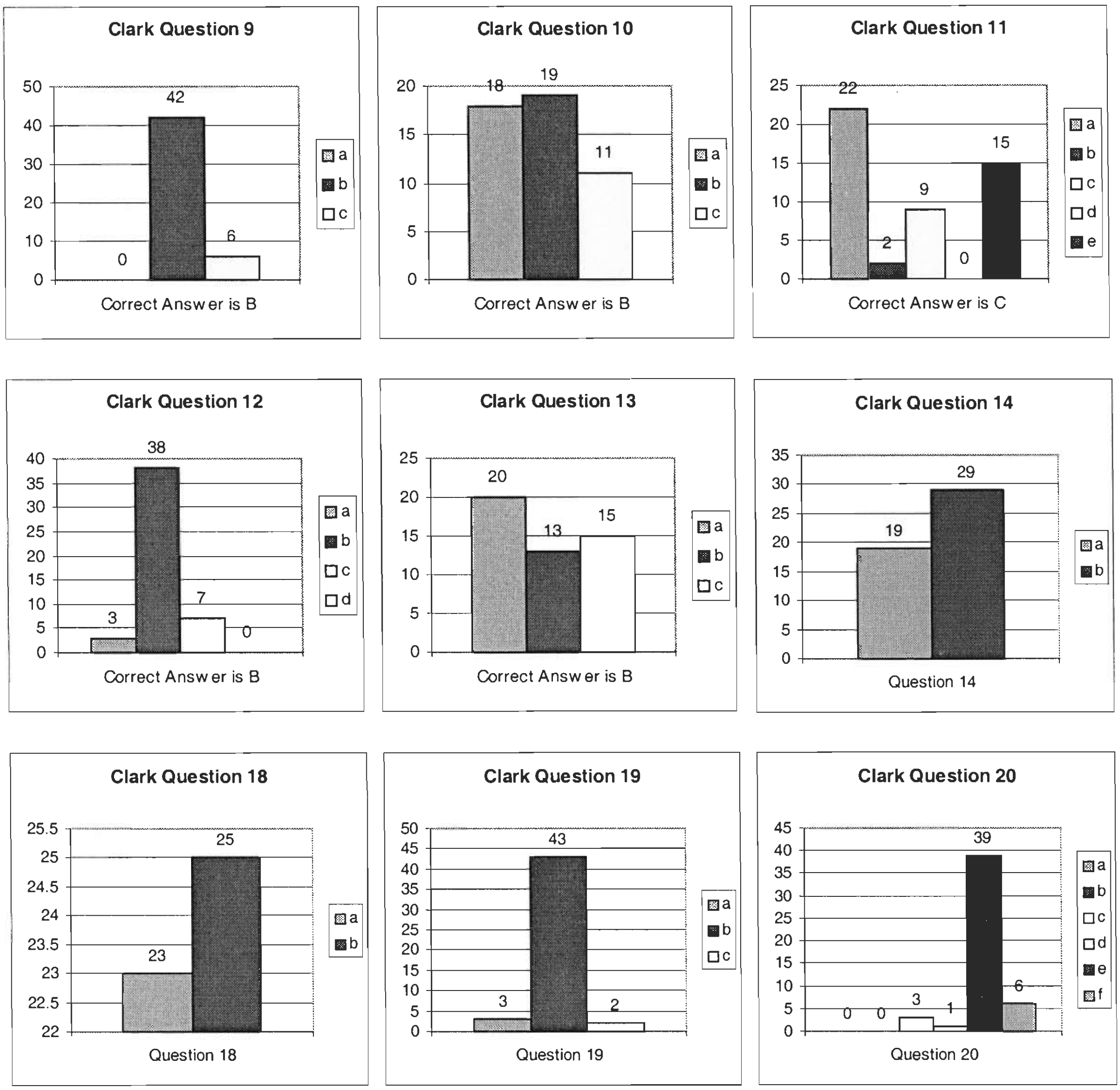

Figure 5.3.6 Science and Demographic questions at Clark

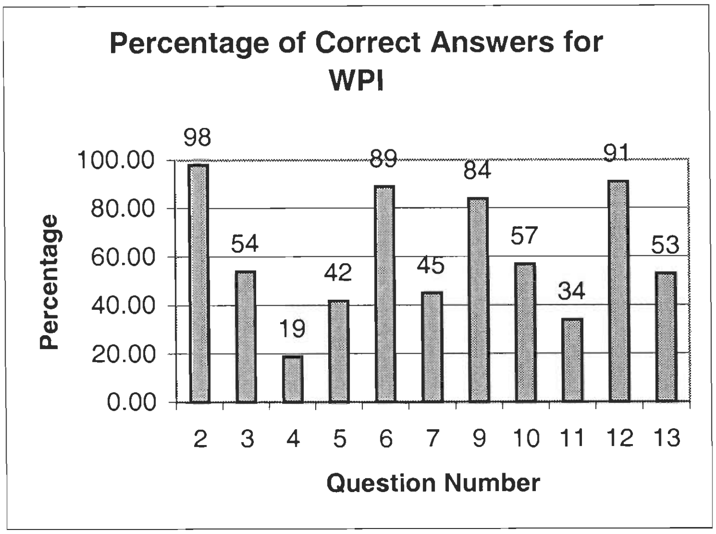

Figure 5.1.7 Correct answers from WPI

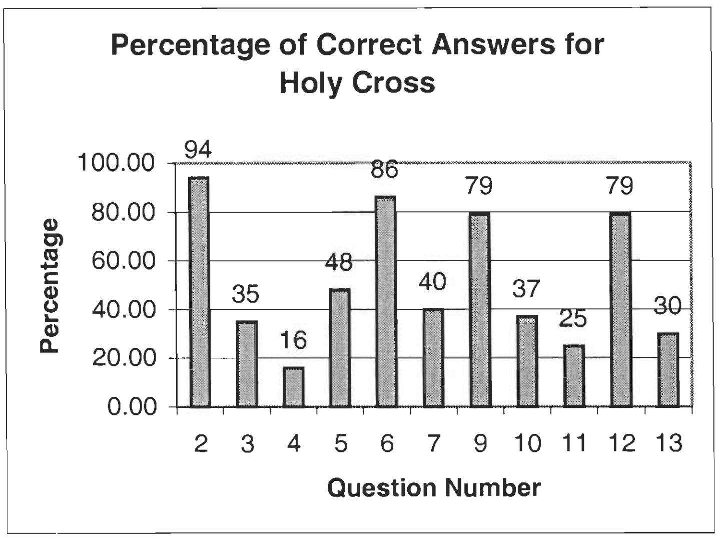

Figure 5.1.8 Correct answers from Holy Cross

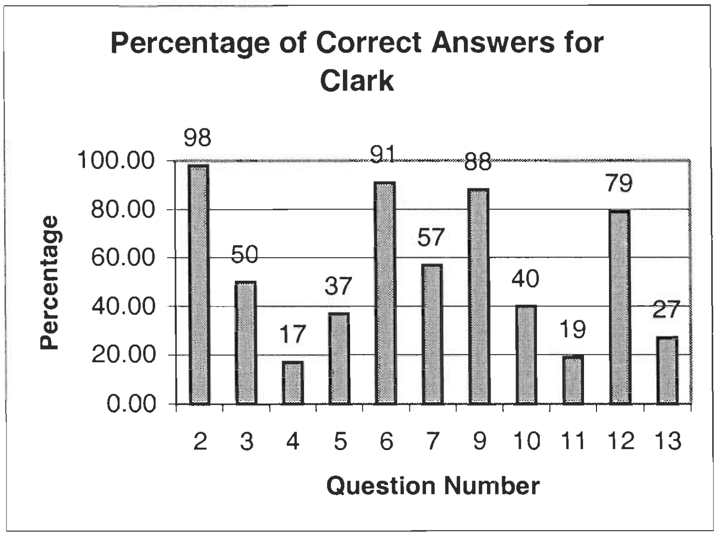

Figure 5.1.9 Correct answers from Clark

As for Goddard's overall recognition among the students, 85 percent of the students at WPI surveyed had heard of him, 96 percent surveyed at Clark had heard of him and only 52 percent surveyed at Holy Cross had heard of him. Among those who had heard of him, only around 40 percent from each school had seen the sign about him on interstate 290. The high recognition rate at WPI and Clark could be attributed to the buildings named after Goddard on the campuses and to the fact that Goddard was part of both institutions as either a student or professor or both.

When the surveys are sorted by where the information on Goddard was obtained, namely question 8, only the surveys from WPI had enough responses to use. The results are in Figures 5.3.10, 5.3.11, and 5.3.12. The number of students in the formal education category is 37, while the number for local interest and personal interest are 65 and 72. The personal interest category has a slightly higher percentage value than the other two categories, while the local media category has a lower score overall.

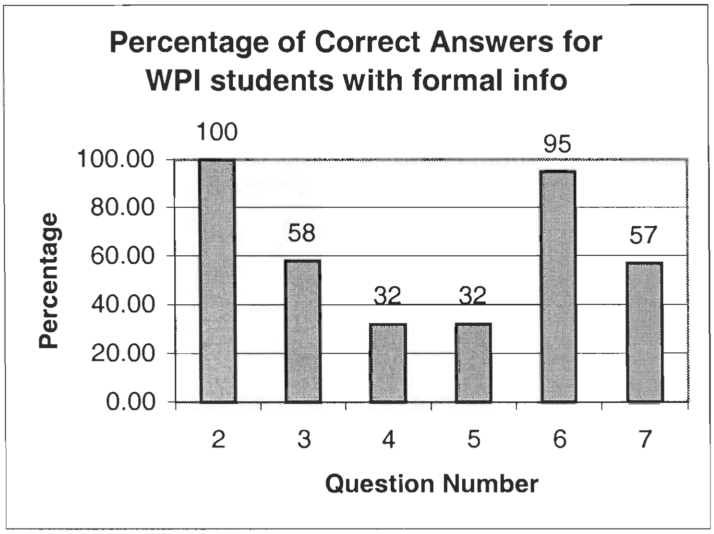

Figure 5.3.10 WPI students with Formal knowledge of Goddard

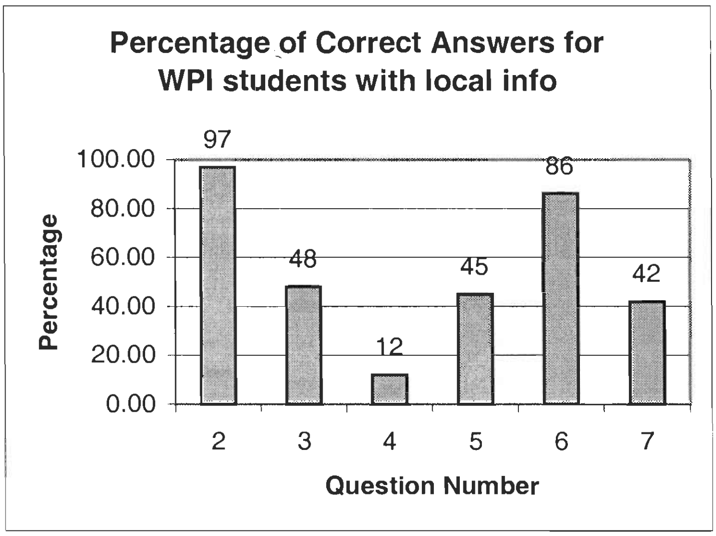

Figure 5.3.11 WPI students with Local knowledge of Goddard

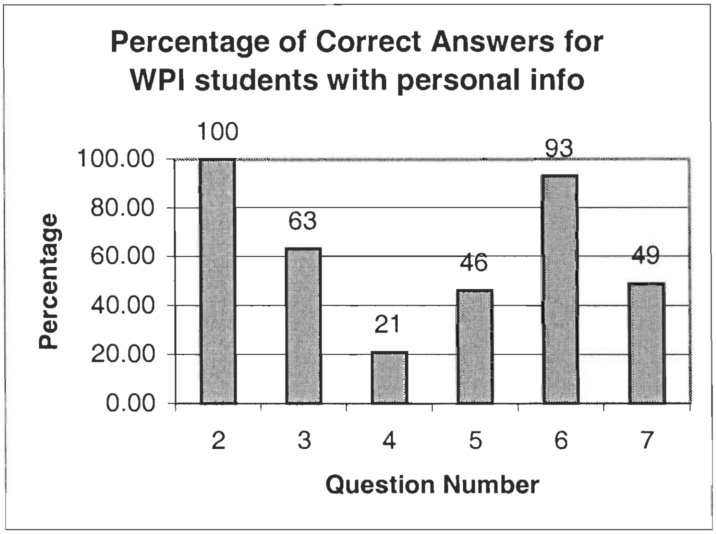

Figure 5.3.12 WPI students with Personal interest in Goddard

When the surveys are sorted by where the participants are from, only Holy Cross and WPI had enough responses to use. The results from Holy Cross are in Figures 5.3.13, 5.3.14, and 5.3.15, while the WPI results are in Figures 5.3.16, 5.3.17 and 5.3.18. For WPI, the number of out of state students is 163, the number of Massachusetts's residents is 146 and the number from Worcester is 20. For Holy Cross, the number of out of state students is 83, the number of Massachusetts's residents is 41 and the number from Worcester is 7. Both of the Worcester samples have very low numbers so the results are not representative of the population of Worcester students. From the figures, the students from out of state score slightly higher than the Massachusetts students in a majority of the categories. Although the numbers from the Worcester students are slightly higher than the Massachusetts students, no conclusion can be made because of the low number of participants from Worcester.

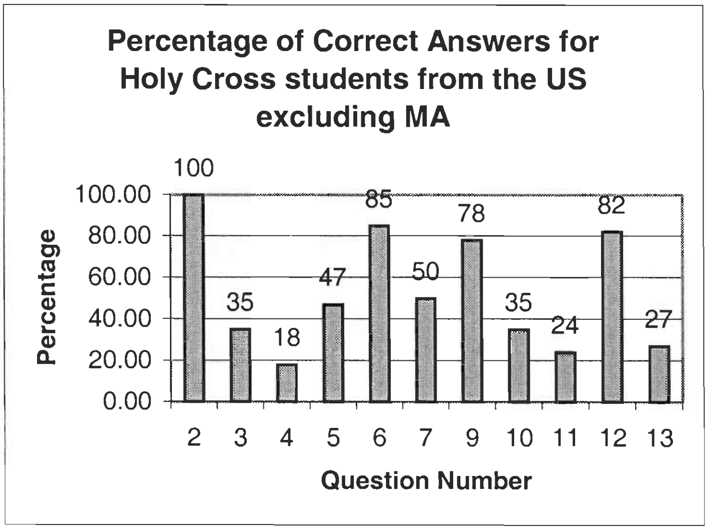

Figure 5.3.13 Holy Cross students from the US excluding MA

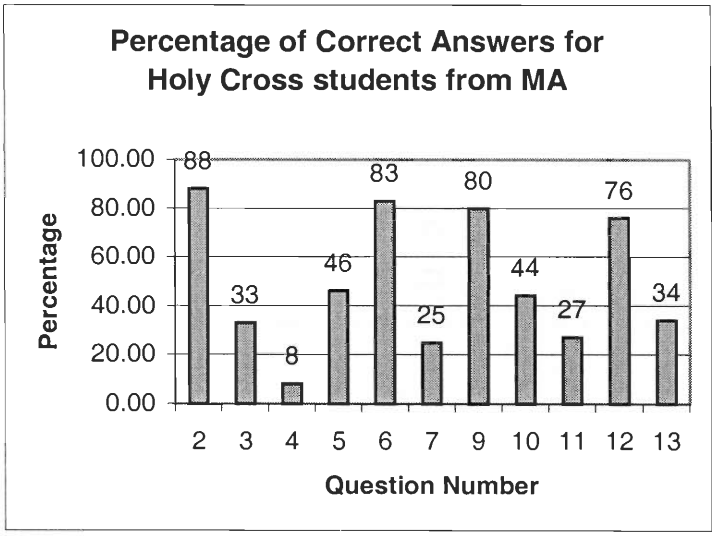

Figure 5.3.14 Holy Cross students from MA

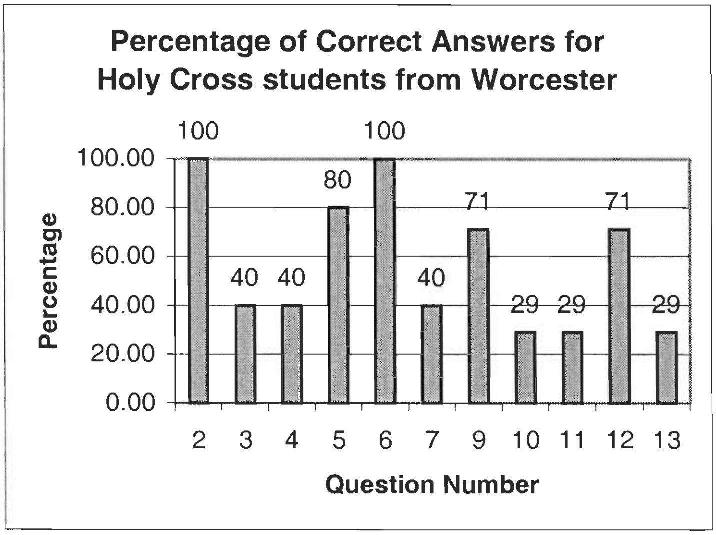

Figure 5.3.15 Holy Cross students from Worcester

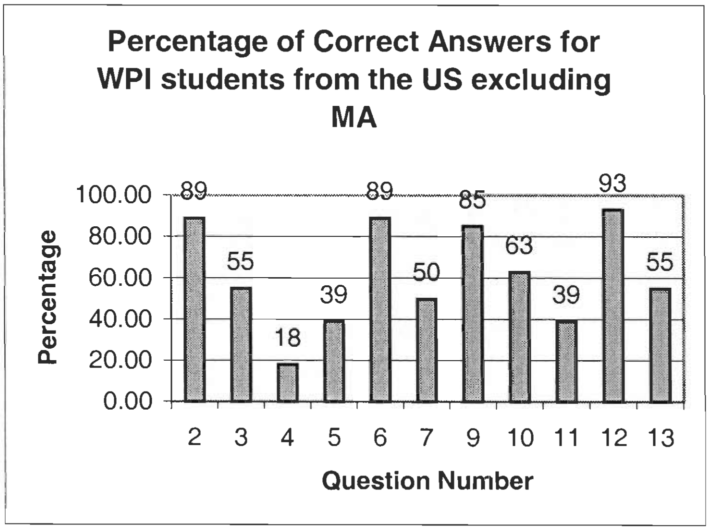

Figure 5.3.16 WPI students from the US excluding MA

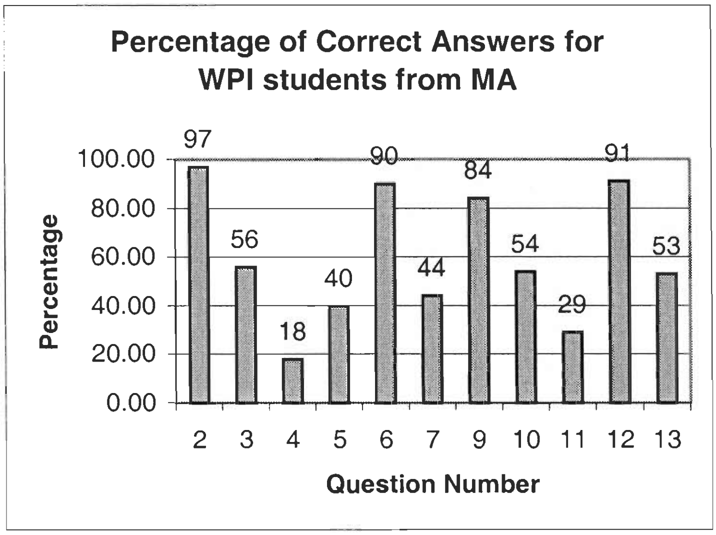

Figure 5.3.17 WPI students from MA

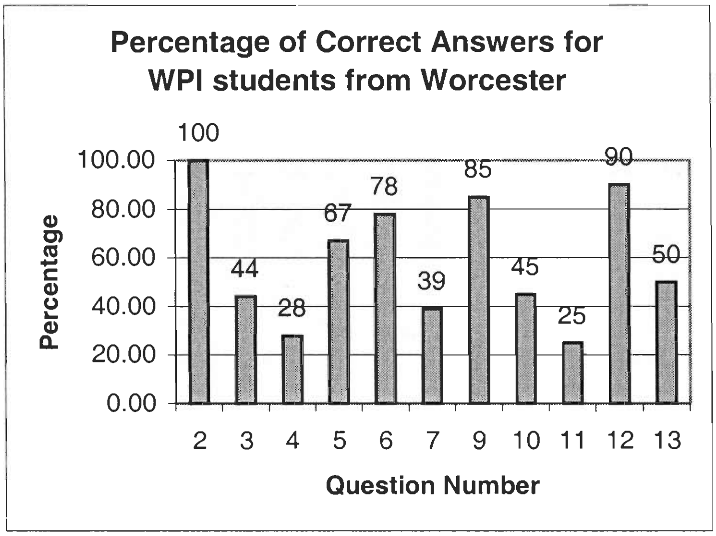

Figure 5.3.18 WPI students from Worcester

When the surveys were sorted according to the participant's major field of study, only WPI had enough responses to use. The results from WPI are in Figures 5.3.19, 5.3.20 and 5.3.21. The majors at WPI were compiled into three categories: engineering, non-engineering, and non-science. The non-science category includes humanities, management, and non-declared majors and contains 33 students. The engineering category includes chemistry, electrical engineering, fire protection engineering, mechanical engineering, and physics and contains 156 students. Those majors in the engineering category are directly related to the field of rocketry. Those majors in the non-engineering category include biology, civil engineering, computer science, and mathematics and contain 156 students. These categories were chosen so that the majors that were strongly related to rocketry would be grouped together and those that are scientific, yet not directly related to rocketry, would also form a group. The rest are lumped into the non-science or humanities categories.

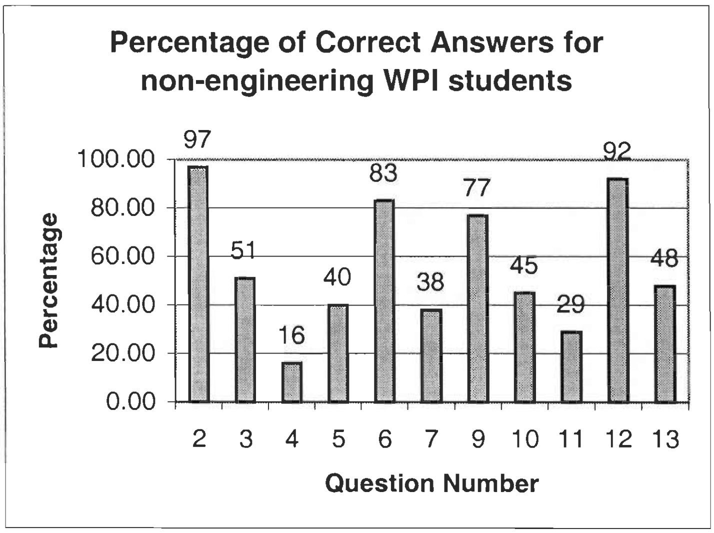

Figure 5.3.19 WPI non-engineering students

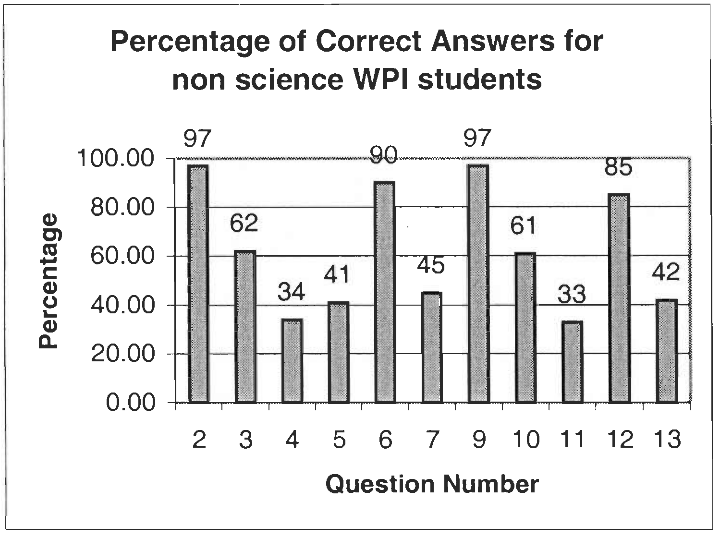

Figure 5.3.20 WPI non-science students

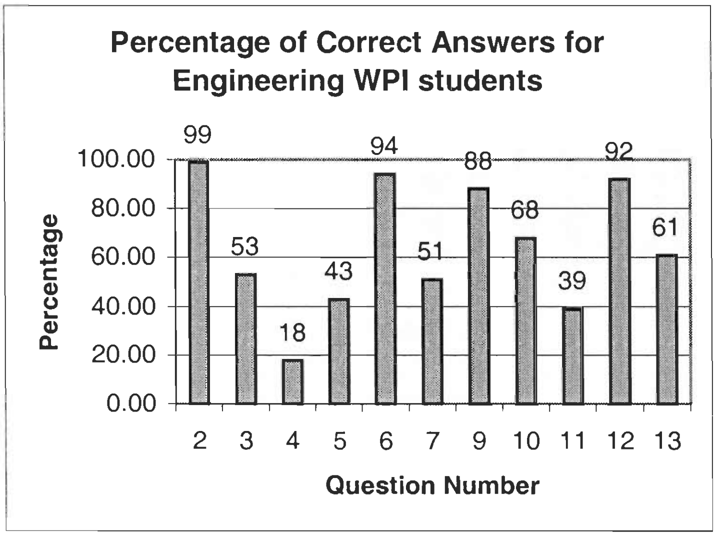

Figure 5.3.21 WPI engineering students

The non-science majors at WPI did several percentage points lower than the engineering majors on the science questions but did better by a few percentage points on the Goddard related questions. The non-engineering WPI students averaged the same technical score as the non-science majors at WPI, however, the non-engineering students scored lower with their knowledge of Goddard.

Overall, the scores were as expected with WPI, an engineering school, doing better in the rocketry questions than Holy Cross. WPI also scored higher with their knowledge of Goddard, but in most categories the difference was less than 10 percent. This can be attributed to the fact that Goddard has a building named after him on the WPI campus and was a student there as well.

Chapter 6: Conclusions

6.1 Summary

This project involved a number of main components, some of which were connected only by the common theme of Robert Goddard. However, it provided an excellent learning experience and uncovered a great deal of data about how Goddard's life is perceived by the public. In addition, we also learned a significant amount about how important Goddard's work actually was in the development of the fledgling field of rocketry. The following is a summary of some of our more important conclusions.

The analysis of the three landmark papers in rocketry corresponding to the three rocket pioneers primarily confirmed each author's place in rocket history. They each contributed to rocketry in an important way, but Goddard's contribution was the most practical. Rocketry had turned out to be a primarily experimental science, and Goddard's paper suggested this fact in a way the other papers did not. His goal was the stars, but his work recognized the necessity of working in steps, and this was also indicated in his paper.

Examination of how well the public recognizes Goddard yielded some interesting results. We found that Goddard is extremely well recognized in Worcester, or at least well lauded, but that outside of the area people are far less aware of him. In fact, Roswell, where he did most of his important research, has only a very few monuments to Goddard and his work. The biggest tribute to Goddard, by far, is that of NASA, with their dedication to his memory of the first space flight centers. What other monuments to his memory exist are mostly those undertaken by the Goddard Memorial Association, who have done a great deal of work in Worcester to increase public awareness of Goddard's past in that city.

Of all the books written about Goddard, most are intended for a juvenile audience. There has been a steady stream of these books since the 1960's, whose their focus has slowly shifted over the years, suggesting a shift in the public's perception of Goddard. When the first biographies were written, the focus was on Goddard's life, but as time has passed the focus has moved towards Goddard's work in developing the awe-inspiring field of rocketry. The sole accessible biography of Goddard written for adults is *This High Man*, which was one of the first biographies written and also the best respected. It is so well respected, in fact, that it was republished three decades after its initial release.

The comparison of Goddard books with books on other famous figures in aviation uncovered no major differences except for volume. The Wright Brothers had the most books, as we expected, but Goddard had the second largest number of books, which we found a surprise given Neil Armstrong's greater name recognition. There is also a larger lag between Goddard's famous achievements and the biographies, about 4 decades, as opposed to the 2 decades or less for the other subjects of this paper. This signifies the public's past unwillingness to accept Goddard's work, at least until they saw large scale proof of its validity.

The data from the guestbook at the Goddard Collection, located at Clark University in Worcester, were insufficient by themselves to make any strong statements about those who visit the collection. However, if they were examined in context with the tourism that Worcester receives annually, then one might be able to make some conclusions about whether there are people who travel to Worcester primarily to visit the

Goddard Collection. Without some sort of other information, the guestbook data can only yield a few interesting observations, such as the fact that so many foreign countries are represented in the guestbook.

The surveys done at the three schools showed that Goddard's recognition among the students was the highest at the universities with which Goddard was associated with, namely WPI and Clark. This is not too surprising, but it is noteworthy that approximately half of the students at Holy Cross had not heard of Goddard.

6.2 Suggestions

A natural extension of the literature survey is to read and analyze more books and papers. Instead of just the first papers of the rocket pioneers, the progression of their papers could be examined. This would indicate how their thought processes evolved as they delved deeper into the field of rocketry. A necessary aspect of the analysis of this progression is a study of the interactions of the three pioneers. Goddard was ignorant of Tsiolkovsky's work, but Goddard had a definite impact on Oberth. Oberth might even have known about Tsiolkovsky's work in rocketry prior to his first publication. Tsiolkovsky might also have become aware of Goddard and Oberth after they started publishing, years after his initial paper. The other sources of literature are third party books on rocketry and the people of rocketry. This project focused on the manageable subset of the books on Goddard, but books on Tsiolkovsky and Oberth, and books on the history of rocketry could all help towards developing a more complete picture of public perception.

The survey portion of the project would be more valuable if the Worcester populace could be surveyed. The use of college students as a sample is not representative of the city of Worcester, since they compose a small fraction of its population and typically come from cities other than Worcester. To truly gauge Goddard's recognition among the city of Worcester, the citizens of Worcester must be surveyed. This information would be of great interest to organizations like the GMA, which are trying to promote Goddard's recognition.

In short, while this project told us a great deal about Goddard and his relation to society and science, a great more remains to be learned. A follow up project could tell us much more about Goddard himself, the details of his relationship, both scientific and otherwise, with the major figures of his time including Oberth, Lindbergh, and the Guggenheims. Such a project could also implement a more general survey of the Worcester area, a survey that could be of considerable use to the GMA. Lastly, a follow up project could give the GMA data about where their expansion would be appropriate and what work remains to be done to promote Goddard as fully as he deserves to be recognized. The above are our suggestions for future work on this project, and so conclude our exploration of the life of Dr. Robert Hutchings Goddard.

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Appendix A: List of books about scientists

The listing and comparison of books about 4 different scientists, including Dr. Goddard, was an important component of this project. However, due to the length of said list, we have created a special appendix with the full listing of our sources.

Robert Goddard

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Unable to find exact author name and title of the following magazine articles.

NY Times - 01/13/1920

Reader's Digest - vol. 67, no. 403 11/1955

Boys' Life - vol. 52, 06/1962

NY Times - 07/17/1969

Smithsonian Magazine - vol. 6, no. 12, 03/1976

American Heritage - vol. 31, no. 4, June/July 1980

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Invention and Technology - vol. 12, Summer 1996

Time Magazine - 03/29/1999

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APPENDIX B. Survey

As students at Worcester Polytechnic Institute, we must complete an Interactive Qualifying Project (IQP) in order to graduate. The IQP challenges students to identify, investigate, and report on a self-selected topic examining how science or technology interacts with social structures and values. Our IQP deals with the public's knowledge of Dr. Robert H. Goddard. Your answers to the following questions are pivotal to the success of this project and will remain confidential. Participants in the survey include people from WPI, Worcester State, Clark University, and Holy Cross. Please take 3-4 minutes to fill out the following survey. Thank you for your time.

-- Brian Ball, Jonathan Moussa, Bassam Soubhi, and Lewis Kotredes

INSTRUCTIONS:
Please complete the following questions in the order provided.
Please do not go back and change your answers.
To answer a question, place an X before your answer, or fill in the blank.

1. Have you ever heard of Dr. Robert H. Goddard?
   a. No (skip to question #9)
   b. Yes (please continue)

2. Who was Robert H. Goddard?
   a. Brain Surgeon
   b. Politician
   c. Rocket Scientist
   d. Not sure

3. When was Goddard active in his career?
   a. 1870-1920
   b. 1900-1940
   c. 1930-1970

4. Where did he do his work?
   a. Germany
   b. Worcester, MA
   c. Roswell, NM
   d. BOTH a&b
   e. BOTH b&c
   f. BOTH c&a
   g. None of the above

5. Where was he Born?
   a. Germany
   b. Houston, TX
   c. Washington, DC
   d. Worcester, MA
   e. Not sure

6. Do scientists continue to use Goddard's work today?
   a. Yes
   b. No
   c. Not sure

7. Goddard was the first to successfully test what?
   a. Liquid fuel rocket
   b. Solid fuel rocket
   c. Both a&b
   d. None of the above
   e. Don't know

8. Where did you learn this information about Goddard?
  a. Local Media
  b. Personal Interest
  c. Formal Education
  d. Guessed the above answers

9. Do airplanes work in outer space?
  a. Yes
  b. No
  c. Not sure

10. Is the Space Shuttle designed to travel to the moon?
  a. Yes
  b. No
  c. Not sure

11. The Space Shuttle uses what kind of rockets?
  a. Liquid Fuel
  b. Solid Fuel
  c. Both a&b
  d. None of the above
  e. Not sure

12. Can rockets travel faster than the speed of light?
  a. Yes
  b. No
  c. Not sure
  d. What's the speed of light?

13. Do rockets rely on an atmosphere to push against to move upwards?
  a. Yes
  b. No
  c. Not sure

14. Have you seen the sign about Goddard on I-290?
  a. Yes
  b. No

15. What school are you from?

16. What is your Major?

17. What city are you from?

18. What is your age?
  a. 15-18
  b. 18-24
  c. 25+

19. What is your sex?
  a. Male
  b. Female

20. What is your race?
  a. Native American
  b. African American
  c. Asian/Pacific Islander
  d. Hispanic
  e. White
  f. Other