THE SOCIETAL IMPACT OF MARS EXPLORATION

An Interactive Qualifying Project Report

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by

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In Memory of

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Abstract

This eight-week project completed at NASA’s Johnson Space Center addresses the societal impact of Mars exploration. The focus of this project is communicating the potential discoveries, scientific knowledge, and the valuable public insights that have been and can be developed as a result of exploring Mars. The final product, a magazine article, seeks to capture the excitement of scientific discovery that is waiting on Mars in a way that the majority of citizens can fully understand and appreciate.
# Table of Contents

Acknowledgements ............................................................................................................. iii  
Abstract ................................................................................................................................ iv  
Table of Contents ................................................................................................................ v  
Table of Figures ................................................................................................................ vii  
Chapter 1: Introduction ...................................................................................................... 1  
  1.1 Goals ................................................................................................................................. 2  
  1.2 Purpose and Audience of Project .............................................................................. 3  
  1.3 General Method and Procedure ................................................................................ 3  
  1.4 Presentation and Utilization of Results ..................................................................... 5  
  1.5 Report Overview ....................................................................................................... 6  
Chapter 2: Background ...................................................................................................... 8  
  2.1 Specifics about Mars ................................................................................................. 9  
  2.2 Current State of Affairs ........................................................................................... 10  
      2.2.1 Mariner 3 .......................................................................................................... 11  
      2.2.2 Mariner 4 .......................................................................................................... 11  
      2.2.3 Mariner 6 & 7 ................................................................................................... 12  
      2.2.4 Mariner 8 .......................................................................................................... 13  
      2.2.5 Mariner 9 .......................................................................................................... 14  
      2.2.6 Viking 1 & 2 .................................................................................................... 15  
      2.2.7 Mars Observer ................................................................................................. 16  
      2.2.8 Mars Pathfinder ............................................................................................... 17  
      2.2.9 Mars Climate Orbiter ....................................................................................... 18  
      2.2.10 Mars Polar Lander/Deep Space 2 .................................................................. 19  
      2.2.11 Mars Global Surveyor .................................................................................... 19  
      2.2.12 Mars Odyssey................................................................................................. 20  
      2.2.13 Mars Exploration Rovers ............................................................................... 21  
      2.2.14 Mars 96 .......................................................................................................... 23  
      2.2.15 Nozomi ........................................................................................................... 24  
      2.2.16 Mars Express .................................................................................................. 24  
      2.3 Literature Review.................................................................................................... 26  
      2.3.1 Mars: Past, Present and Future ....................................................................... 26  
      2.3.2 Mars: The Next Step ....................................................................................... 28  
      2.3.3 The Case for Mars ............................................................................................ 29  
      2.3.4 Viking 1: Early Results .................................................................................... 30  
      2.3.5 Review of NASA’s Planned Mars Program ..................................................... 31  
      2.3.6 The Search for Life on Mars .......................................................................... 32  
      2.3.7 Proceedings of the Founding Convention of the Mars Society: Part I......... 32  
      2.3.8 Writing the Modern Magazine Article ............................................................. 33  
      2.3.9 Various Websites ............................................................................................. 34  
Chapter 3: Project Procedure ........................................................................................... 36  
  3.1 Resources Used ....................................................................................................... 36  
  3.2 Project Method ......................................................................................................... 38
Chapter 4: Presentation of Results ................................................................................... 41
  4.1 Presentation of Data and Research Findings .......................................................... 42
   4.1.1 Searching for Life on Mars .............................................................................. 43
   4.1.2 The Search for Water on Mars ......................................................................... 46
   4.1.3 Comparing the Planetary Evolution of Earth and Mars ................................... 47
   4.1.4 International Collaboration and Relating to the Missions ............................... 49
  4.2 Choosing a Demographic and Selecting a Publication ........................................... 50
  4.3 Writing the Query Letters and Article .................................................................... 51
Chapter 5: Analysis of Results.......................................................................................... 54
  5.1 Comparison of Data from Different Sources .......................................................... 54
  5.2 Benefits of Mars Exploration .................................................................................. 55
   5.2.1 Human Desire to Explore and Ability to Accept Challenge ............................ 56
   5.2.2 Evolutionary Questions and Obtaining Answers ............................................. 58
   5.2.3 Engaging International Partners ..................................................................... 60
  5.3 Detriments of Mars Exploration ............................................................................. 61
   5.3.1 Contamination, Back and Forward .................................................................. 61
   5.3.2 Radiation .......................................................................................................... 63
   5.3.3 Financial Cost .................................................................................................. 66
  5.4 Linking Science and Technology to Society .......................................................... 68
Chapter 6: Conclusions and Recommendations .............................................................. 70
  6.1 Implications of Findings ......................................................................................... 70
  6.2 Procedural and Analytical Limitations ................................................................... 73
  6.3 Recommendations for Future Study ....................................................................... 76
Bibliography ..................................................................................................................... 78
Glossary ............................................................................................................................ 84
  Acronyms ...................................................................................................................... 84
  Technical Terminology ................................................................................................. 85
Appendices ......................................................................................................................... 89
  Appendix A: Summary Table of Mars Missions ......................................................... 89
  Appendix B: Proposed Magazine Article for Publication ........................................... 91
  Appendix C: Earthrise and Blue Marble Photographs ................................................. 96
Endnotes............................................................................................................................ 98
## Table of Figures

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 1</td>
<td>Mariner 4 image of craters on Mars</td>
<td>12</td>
</tr>
<tr>
<td>Figure 2</td>
<td>Viking Orbiter image of a global mosaic of Mars</td>
<td>15</td>
</tr>
<tr>
<td>Figure 3</td>
<td>Mars Pathfinder image of Martian twin peaks</td>
<td>17</td>
</tr>
<tr>
<td>Figure 4</td>
<td>Mars Global Surveyor image of gullies in a crater</td>
<td>20</td>
</tr>
<tr>
<td>Figure 5</td>
<td>Artist rendition of Mars Odyssey</td>
<td>21</td>
</tr>
<tr>
<td>Figure 6</td>
<td>Mars Exploration Rover</td>
<td>22</td>
</tr>
<tr>
<td>Figure 7</td>
<td>Nozomi image of Earth and the Moon</td>
<td>24</td>
</tr>
<tr>
<td>Figure 8</td>
<td>Possible landing sites of the Beagle 2 lander</td>
<td>25</td>
</tr>
<tr>
<td>Figure 9</td>
<td>Image of ALH84001 before processing</td>
<td>45</td>
</tr>
<tr>
<td>Figure 10</td>
<td>Summary Table of missions to Mars</td>
<td>89</td>
</tr>
<tr>
<td>Figure 11</td>
<td><em>Earthrise</em></td>
<td>96</td>
</tr>
<tr>
<td>Figure 12</td>
<td><em>Blue marble</em></td>
<td>97</td>
</tr>
</tbody>
</table>
Chapter 1: Introduction

There is a vast amount of information that is unknown about the Earth, including its history, its future and whether or not it is the only planet that houses life. “The exciting thing about comparative planetology is that it will permit us to unfold the lost part of the Earth’s history, now largely obliterated by erosion, mountain building, and other processes”.¹ Studying other planetary bodies can bring about a deeper understanding of our own planet and what lies ahead. The subject of this project is communicating the potential discoveries and scientific knowledge, as well as the valuable public outlook and insight, which have and can be developed as a result of exploratory space missions to Mars. Ultimately, this is done to gain public support for further exploration. As Arnold Aldrich of the National Aeronautics and Space Administration (NASA) Headquarters states:

“The challenge I see is not in defining a science plan for Mars. That is something we know how to do…. The challenge is to capture the excitement of scientific discovery that is awaiting us on Mars in such a way that a majority of our citizens can fully understand and appreciate it. For NASA and the science community at large, that is a real and important challenge.”²

Certain assumptions must be kept in mind when examining this project. The entire project was conducted while on location for eight weeks at the Johnson Space Center in Houston, Texas. Therefore, it may be assumed that there is an inherent bias in support of the efforts of NASA. Information regarding the detriments of Mars exploration and failed missions to Mars is included. Despite the presentation of this
balanced argument, this project puts forth the opinion that the exploration of Mars is still worth the risks involved.

1.1 Goals

The main goal of this Interactive Qualifying Project (IQP) is to convey the importance of the exploration of Mars to the portion of the general population that, for the most part, is not informed or knowledgeable of technical information or events. There are two focus questions expected to be answered by this project. How do the potential discoveries and scientific knowledge generated by NASA when planning and executing the Mars missions benefit the general, non-technical public? Furthermore, why are the scientific and societal benefits resulting from Mars exploration worth the risks involved?

One intention is to communicate that although the hardware, spin offs, scientific innovations, or eventual samples returned have value, they are not the most important products of Mars exploration. An essential objective of the project is expressing the human experience and insight as the most important outcome of Mars exploration. The project aims to articulate the valuable public attitudes, perceptions, and understanding generated by past and future Mars missions. For the general public to appreciate the information presented, connections between the perceptions and knowledge gained from exploratory missions and the benefits that they add to the average daily life and experience need to be clearly drawn.

Another element of the project is taking into account the risks involved in Mars exploration. A goal is to explain why such exploration is still worth the investment, in
terms of money, time, safety, and effort. This creates a balanced argument that will receive more positive consideration as well as offer better public understanding.

1.2 Purpose and Audience of Project

The purpose of the project follows from its goals. Currently, a majority of the public not directly involved in science, engineering, or technology knows little about the efforts of NASA to explore Mars. This section of the public is even less aware of the reasons and benefits behind endeavors of that nature. As a governmentally funded organization, NASA is reliant upon the approval and financial allocations of Congress. In order for the representatives of the public to see a necessity for the continuation of these efforts surrounding Mars, they need to sense greater support for Mars exploration from their constituency. It seems logical that engineers, scientists, and the portion of the public with a technical background are far more inclined to support present and future missions to Mars. Therefore, the audience this project is directed towards is those who of their own accord, are not apt to research the endeavors NASA is undertaking or visit the websites NASA has created. The purpose of the project is to foster support from this stratum of the public by educating its individuals about the benefits and advantages of Mars exploration.

1.3 General Method and Procedure

The following is the general methodology that was carried out through the entirety of the project. The first task that required attention was defining the focus and
scope of the project. There was a discrepancy between what was envisioned by
Worcester Polytechnic Institute (WPI) for a project and what NASA was hoping to
accomplish with the completion of the project. This was clarified, and the important
focus questions were drafted. These questions served as the ruler to measure what should
and should not be included in the analysis of the project. Continuous revisions were
made to define the project and its scope as specifically as possible for the first three
weeks.

In addition, meetings were held with various NASA personnel. The method
behind the interviews was to direct questions at the individual about how his/her specific
area of expertise correlated to the focus of the project. The interviewees also provided
various reference materials, including Johnson Space Center (JSC) internal publications.
The meeting participants ranged from scientists and engineers to public affairs personnel
and employees of a government research laboratory, the Jet Propulsion Laboratory (JPL)
of Pasadena, California. Some printed materials were received from JPL, also.

The next stage of the procedure of this project was researching three categories of
information; factual data, implications and perceptions, and marketing and public
outreach writing. This required much time and attention, for it was the primary method
to obtain information from which the societal impact of Mars exploration was extracted.
Following this research, the report was drafted, and continuous meetings were held with
the advisor for updates on the progress of the project. The manner in which the magazine
article was written was to finish the formal report first and have the information for the
article flow from it. This was planned in order to facilitate the filtering process necessary
to limit the information included in the article. It was important to not make the article too long in order to retain the attention of the reader.

The final portion of research that needed to be performed was selecting the proper venue for communicating with the target audience. This occurred simultaneous to the report being written. Once it was decided that the magazine would be the venue, it was necessary to agree on a particular demographic of the general public. The mission statements and intended audiences of various news magazines and periodicals were investigated. This process led to query letters sent to the editors of the magazines of interest.

1.4 Presentation and Utilization of Results

The culmination of these efforts will be presented publicly in the form of a published magazine article (Appendix B). The article must define the value of exploring Mars in a way that captivates the audience and interests people to search for supplementary information on the subject. The success of the project will rest in the ability of the article to present a sound, compelling, and thought provoking argument for Mars exploration. The optimum use of the article, the product of the project, is increasing public support for Mars exploration missions.

Photography resulting from exploratory missions can be very powerful. An example of this is pictures from the Mars Pathfinder mission which returned pictures containing either the lander or the rover. Appealing pictures of Mars have complemented the magazine article of this project in order to intrigue and capture the attention of the reader. It was also important to choose pictures to which the audience can easily
associate. For example, pictures of the Martian landscape with parts of the spacecraft allow for the public to easily relate and be interested. They convey the aspect of a human presence on Mars. This has a grand effect on the societal perception of Mars exploration.

1.5 Report Overview

The following project report is divided into several chapters of distinct subjects. Chapter two will cover the background information necessary to understand the importance of the project. It also discusses the current state of affairs of NASA and a review of each source of literature used. The theme behind chapter two is presenting a brief description of past missions to Mars executed by NASA, any significant Mars missions carried out by foreign agencies, the present projects of NASA that target Mars, and the future plans NASA has for exploring Mars. The literature review briefly describes each literary material used. It presents the judgments and conclusions of each source followed by critiques of this information.

There are two sections to chapter three. One section gives a detailed description of the resources used, while the other outlines in detail the methodology employed throughout the project. More importantly, this section of the report convinces the reader that the authors have a clear understanding of the problem on hand and have logically gone about reaching the objectives of the project.

Chapters four and five are closely coupled. The former contains the results, findings, and data, in their entirety, utilized to address the focus questions of the project. In chapter four, it is also noted how the target demographic was chosen and how the magazines of interest were chosen. The last section in chapter four discusses the process
of writing the query letters to the editors and the article, for they are both important results of this project. Chapter five is an analysis of the results in the preceding chapter. It contains an examination of the comparisons and contrasts of the information gathered from different sources. The division of this section is by the criteria for such analysis. In addition, an investigation of how the benefits of Mars exploration weigh against the downfalls is included in chapter five. The heart of the Interactive Qualifying Project, linking science and technology to society, is also conferred in chapter five.

The final segments of the report are a description of the conclusions drawn from the project, implications of the findings, statements of the procedural and analytical limitations, and recommendations for future study. Following chapter six, which houses these items, is a bibliography, a glossary for detailed definitions of technical terms contained in this report, and several appendices for information and text too lengthy for addition into the body of the report. Among the appendices are two historical photographs that had an impact similar to that which is desired from the photographs for the article, a summary table of Mars mission information, and the actual article generated.
Chapter 2: Background

“The Sun”s planets…boast something…valuable: The keys to understanding our Earth…. Their different chemistries, geologies, and meteorologies derive from their different masses and varying distances from the Sun. This diversity alone makes planetary exploration worthwhile. What the planets can tell us about life is possibly even more important…. Life may be an integral, perhaps inevitable, part of the unfolding evolution of the universe. Very likely some of the precursors of life exist somewhere on our eight sister planets or their several dozen assorted moons. Somewhere in the solar system, chemical evolution may have taken that one critical additional step into the realm of life, just as it did some 3.5 or 4 billion years ago on Earth.”

Among all of the other planets in our solar system, Mars is most like Earth. Due to the similarities between these two planets, exploring Mars has the most potential to explain the evolution and future of Earth. Many missions have been planned for Mars, and from the ones that have succeeded, scientists of all different fields have learned massive amounts of information about the climate, geology, and history of Mars. The failures have also contributed to the opportunities yielding knowledge. It is only with further exploration that more useful information can be learned to explain some of the most intense questions and emotions of life.

This project serves as a conduit for this message to reach the public. The final product, the magazine article, is conveniently accessible and very informative. The importance of this project rests in the fact that there was a lack of such a source for the
general non-technical public before this article. This project produces a bridge between the secluded scientific realm and the realm of the average individual who plays a role in funding the ventures of NASA.

### 2.1 Specifics about Mars

It is important to understand the basic properties and facts surrounding Mars. This understanding allows for one to realize how similar in certain ways and how different in others Mars is to Earth. It also conveys the value of researching the planetary evolution of Mars in comparison to Earth. As the fourth planet from the Sun, Mars has an elliptical orbit ranging from 207 to 249 million kilometers. This orbit results in a Martian year lasting 687 Earth days. The diameter of the planet is 6780 kilometers, about half that of Earth, with a rotation creating a Martian day of twenty-four hours and thirty-seven minutes. Mars has similar seasons to Earth due to the fact that its axis is approximately at the same angle as that of Earth. However, the temperatures greatly differ on Mars from Earth; the highest temperature is 30°C and the lowest temperature is -126°C.

The atmosphere is also a characteristic very different from Earth. It is composed 95% of carbon dioxide, 2.7% of nitrogen, 1.6% of argon, and 0.13% of oxygen with minute traces of other gases. It is a very thin atmosphere, and the pressure at the surface is less than one-hundredth of the pressure at the surface of Earth. Without a sufficient ozone layer or magnetosphere, the surface of Mars is also left highly oxidizing, capable of destroying organic compounds on contact.4
Mars also has many unique surface qualities. Mars has no oceans; therefore, despite its smaller size, it still has approximately the same land surface area as Earth. Furthermore, the planet boasts a canyon, named Vallis Marinaris, equivalent to the width of the United States, and a volcano, Olympus Mons, over twice the height of Mt. Everest.\textsuperscript{5}

\subsection*{2.2 Current State of Affairs}

For centuries, astronomers and scientists have been discovering and studying the heavenly bodies. Tycho Brahe was the first to map the movement of Mars across the sky and, Johannes Kepler worked out its orbit in the 16\textsuperscript{th} century. This was not long before Galileo Galilei observed Mars for the first time through a telescope. G. Domenico Cassini observed the poles of Mars in the 17\textsuperscript{th} century, followed by William Herschel measuring the diameter of the planet in the 18\textsuperscript{th} century. Succeeding these feats were Giovanni Schiaparelli describing the “canali,” or channels, on Mars in the 19\textsuperscript{th} century and Eugene Antoniadi producing the most accurate map of Mars before the space age at the beginning of the 20\textsuperscript{th} century.\textsuperscript{6} So many of the reasons for the missions that have been completed, are planned, and are being currently worked on to explore Mars lie with these great minds and their discoveries from the past.

The missions NASA has performed that target Mars have dated back to the 1960s. The Russian Space Agency, the National Space Development Agency of Japan (NASDA), and the European Space Agency (ESA) have or will be contributing to Mars exploration as well. There are three classifications of missions, and they are fly-bys, orbits, and landings. The following descriptions of Mars missions outline the rapidly
advancing technology and capabilities of the world, primarily NASA. They also serve as testament to the potential resting in future Mars exploration.

### 2.2.1 Mariner 3

Mariner 3 was launched in early November 1964 as part of a twin flight of payloads paired with Mariner 4. Both spacecraft were modeled after the Ranger spacecraft that was used in lunar research, except Mariner 3 and 4 were much more complex, boasting 130,000 parts each. Mariner 3 was designed to run on 260 kg of solar cells, producing 700 W of electrical power, which was to be converted to recharge the battery of the spacecraft. The spacecraft also carried instrumentation to study solar wind and dust, measure protons in three different energy ranges, and measure the ionization caused by charged particles.\(^7\) The launch went well; the Atlas rocket burned properly, but the shroud encasing the payload failed to separate. The Agena fired and thrust Mariner 3 toward Mars, but the mission failed because the antennas and solar panels could not work due to the shroud and the extra weight prevented the spacecraft from attaining its trajectory. The shroud for Mariner 4 was redesigned for its launch three weeks later.\(^8\)

### 2.2.2 Mariner 4

Mars exploration continued in July of 1965 when Mariner 4 made the first fly-by, collecting the very first close-up photographs of another planet. In fact, it captured twenty-two photographs.\(^9\) They showed approximately seventy lunar-type impact craters
scattered across 1% of the surface area of Mars. The information provided by Mariner 4 also described the magnetic field and atmosphere:

“Mariner 4 was also able to put an upper limit on the Martian magnetic field of not more than one thousandth of the terrestrial field. There was therefore no surprise in the discovery that there is no radiation belt around Mars because a much stronger magnetic field is needed to trap the energetic particles which make up a belt such as surrounds the Earth.”

It also determined that the atmosphere of Mars is approximately 1% of the atmosphere of Earth.

2.2.3 Mariner 6 & 7

Mars exploration continued through 1969 when Mariner 6 and 7 completed the first dual mission to Mars, flying over the equator and the South Pole region. The respective launch dates were February 1969 and March 1969. The scan platform of Mariner 6 carried an infrared radiometer and ultraviolet and infrared spectrometers which could produce data regarding the make up of the Martian atmosphere. It revealed, as suspected, that the Martian atmosphere was mostly comprised of carbon dioxide. In addition, Mariner 6 found ionized carbon monoxide and atomic oxygen and hydrogen, but no nitrogen was detected. Mariner 7 studied the climatology of Mars, taking photographs of what seemed to be clouds. It was later proved that there were many clouds on Mars.
By chance, neither Mariner 6 nor 7 captured pictures of a large volcanic region or a grand canyon that were later seen by Mariner 9. On their approach, however, they did reveal that the long dark features were not, in fact, canals, as was the previous assumption. This historic assumption was a result of a misinterpretation of the Italian word “canali.” Following Mariner 6 and 7, the features were believed to be channels. This was the original intention of Schiaparelli in his description because canals imply an artificial creation.

“After Mariner 6 and 7, we had what we thought was a pretty good idea of what the surface of Mars was like. We believed it to be largely cratered terrain, apparently inactive geologically, and not too dissimilar from our Moon.”14 Successive Mars missions, eventually achieving an orbit around Mars, demonstrated how wrong these beliefs were.15

2.2.4 Mariner 8

Mariner 8, also known as Mariner-H, was launched in May 1971. Intended to go into Mars orbit and return images and data, Mariner 8 failed on launch due to the upper stage oscillating and tumbling out of control. The Centaur engine ignited 265 seconds after launch but shut down 100 seconds later due to starvation caused by the tumbling. The payload separated and the spacecraft re-entered Earth’s atmosphere 1500 km downrange and landed in the Atlantic Ocean north of Puerto Rico. Mariner 8 was part of a dual mission in which both spacecraft were to be inserted into orbit around Mars. A minimum of ninety days were to have been taken for the spacecrafts to orbit, collecting
data on the composition, density, pressure and temperature of the atmosphere, and the composition, temperature, and topography of the Martian surface.\textsuperscript{16}

Mariner 9, Mariner 8”s twin, was reprogrammed before its launch because the two spacecraft were complementary and had different mission roles. Mariner 8 was to have been put into polar orbit, covering a majority of the surface of Mars and sending back 5400 images. Mariner 9”s original plan was to have been at 50° inclination to be synchronized with Mar”s rotation in such a way that its ground track would repeat and any changes in surface features would be observable. Mariner 9 was changed so that it was at a 65° inclination, and the ground tracking would repeat itself every 17 days. Because of this, NASA was able to maximize the data and images returned since the loss of Mariner 8 meant the full mission was impossible to complete.\textsuperscript{17}

\textbf{2.2.5 Mariner 9}

Mariner 9 became the first artificial satellite of Mars. Upon its arrival to orbit in November of 1971, it observed an enormous dust storm that engulfed the entire globe. After a month, the dust cleared and incredible images of giant volcanoes the size of Arizona were discovered, the largest towering seventy kilometers above the surface of Mars. This particular volcano was named Olympus Mons.\textsuperscript{18} Arthur Smith, author of \textit{Mars: The Next Step}, describes how the images of Mariner 9 disproved popular theories regarding the state of Mars:

\begin{quote}
“Previous Mariner flights had led to the erroneous conclusion that Mars was a dead planet, devoid of geological, or more correctly areological, activity. Mariner 9 disproved this theory and it now seems that the
planet”s entire surface may have been affected and even formed by such activity. Certainly, the extensive plains, pock-marked as they are by impact craters of all sizes down to the limits of resolution, were formed by lava flows and ash falls.”

More than 7000 images were captured by Mariner 9 showing grand canyons and ancient riverbed relics. Mariner 9 photomapped 100% of the Martian surface and also took the first close-up pictures of Phobos and Deimos, the moons of Mars. “Mariner 9 revealed the unexpected, a world of remarkable and diverse features, a world of canyons, volcanoes, channels, and fault lines. Mariner 9 revealed a world we had not seen. It brought us the unexpected, as exploration always does.”

2.2.6 Viking 1 & 2

On June 19, 1976, the Viking 1 spacecraft became the first to reach Mars and land safely on its surface. Viking 1 was soon followed by the landing of Viking 2 in August of 1976. The Viking 1 mission was designed to carry out three biological experiments to search for signs of life on Mars. One of the experiments was a pair of cameras mounted on the lander to take black and white, color, and stereo pictures. The gas chromatograph/mass spectrometer (GCMS) that searched for organic molecules in the soil of Mars was the second of the three experiments. Scientists searched for carbon, hydrogen, nitrogen and oxygen in the soil samples on Mars because they are all present in the organic compounds in all living matter on Earth. The GCMS
searched for all of these compounds either as evidence of life, its precursors or its remains. The third experiment was a biology experiment that looked for metabolic processes similar to those used by green plants and animals. The results of the biological experiments were determined to be inconclusive, since the processes observed could be explained in terms of chemical reactions. The landers, however, did detect that the atmosphere contains 2.7% nitrogen, an element essential to life on Earth. Scientists identify Mars as self-sterilizing because of the combination of ultraviolet radiation that saturates the surface, the extreme dryness of the soil and the oxidizing nature of the soil chemistry, all of which prevent the formation of living organisms in Martian soil.

2.2.7 Mars Observer

Seventeen years after the Viking missions to Mars, the Mars Observer was launched in September 1992. Observer was to study structure and aspects of circulation of the atmosphere. Studies were also done on the volatile material and dust of Mars on a seasonal cycle. These studies included determining the time and space distribution, the abundance, and the sources. The mission was to also serve as a way in which to measure global characteristics such as topography and elemental and mineralogical composition of the surface. Achieving such goals were hoped to help scientists understand the geological and climatological history of Mars and the evolution of its interior and exterior. The Mars Observer mission ended about one year later when contact was lost with the spacecraft shortly before it was to enter Mars orbit.
2.2.8 Mars Pathfinder

After a long hiatus in exploratory missions to Mars, the Pathfinder lander and rover were designed under NASA’s new “faster, better, cheaper” idea, called the Discovery program, for less than $150 million. The spacecraft was launched in December of 1996 and landed on the surface in July of 1997. The Pathfinder mission was designed to demonstrate that an instrumented lander and free-ranging rover could be delivered to Mars, that a scientific payload could be put on the surface of Mars for one fifteenth of the cost of the Viking missions, and demonstrate the mobility and usefulness of a micro-rover on the surface of Mars.27

Scientifically, Pathfinder and Sojourner, the rover, were to study the geology of Mars, including soil properties and petrology, orbital dynamics, and atmospheric structure. All together, the Mars Pathfinder mission returned approximately 17,000 images from the red planet, fifteen chemical analyses of rocks and soil as well as extensive data on wind and weather conditions. Of the images, some were of the impressive surface features of Mars, including the large mountains and deep canyons. Perhaps some of the most important images and pictures were those in which either the rover or lander could be seen. The pictures also attracted much media attention by the nation. All of the studies done by Pathfinder suggest, but do not prove, that Mars, at one time, may have had a warm, wet climate, a thicker atmosphere, and water existing in its liquid state.28
2.2.9 Mars Climate Orbiter

Mars Climate Orbiter was the preliminary portion of a dual spacecraft mission launched in December of 1998. The secondary spacecraft was Mars Polar Lander. Climate Orbiter had numerous scientific objectives all to be carried out by one of two instruments. These two instruments were the Mars Climate Orbiter Color Imager (MARCI) and the Pressure Modulated Infrared Radiometer (PMIRR). The former acquired daily atmospheric weather images and high resolution surface images. The purpose of the latter was to allow measurement of the water vapor abundance, atmospheric temperature, and dust concentration. The major reasoning behind such examinations was to understand the past of Mars in regard to its climate and ecosystem. Ulterior roles of Mars Climate Orbiter were to serve as a data relay satellite for Polar Lander and future missions, performed by NASA and otherwise, aimed at investigating Mars. The first phase of the mission to support Polar Lander was planned by navigating a beneficial Martian orbit. The orbit was to pass over the lander ten times per sol, or Martian day, elapsing five to six minutes each pass.

Despite much preparation and investment, it was the finer details that were overlooked which caused this mission to fail. The route of Climate Orbiter included a brief pass behind Mars lasting about twenty minutes. While behind Mars, there was no radio communication with the spacecraft. However, it was expected to emerge and make radio contact with Earth once more. Unfortunately, this never happened. The spacecraft was only fifty-seven kilometers above Mars while obtaining orbit when it was designed to be 140 to 150 kilometers in altitude. The overlooked finer detail that caused this was a failure to convert certain figures from English units to metric units. The result was Mars
Climate Orbiter entering the Martian atmosphere too low and breaking up from friction and the atmospheric stresses.\textsuperscript{29}

\subsection*{2.2.10 Mars Polar Lander/Deep Space 2}

Launched on January 3, 1999, the Deep Space 2 (DS2) project consisted of two probes that were to penetrate the surface of Mars near the South Pole. The objective was to send back data on the sub-surface properties of Mars. The probes were to test for the presence of water ice below the surface, and, if found, test for the mineral composition and phase at which the water exists as well as determine the thermal and physical properties and temperature gradient of the sub-surface materials. The machinery has alternative duties of measuring the atmospheric pressure and temperature and measuring the atmospheric density profile and near-surface soil stratification using deceleration instruments during atmospheric entry and landing. Communication between the probes and Earth was to have been via Mars Global Surveyor (MGS). The probes, as dictated by their planned course, came near Mars on a trajectory to enter the atmosphere and went to the intended landing site. Unfortunately, contact was never made with either probe, and the mission was presumed lost as of December 3, 1999. The two probes were named Amundsen and Scott in honor of the famous polar explorers, Roald Amundsen and Robert Falcon Scott.\textsuperscript{30}

\subsection*{2.2.11 Mars Global Surveyor}

Mars Global Surveyor achieved orbit about Mars in September of 1997. It observed Mars from low orbit for nearly two Earth years, studying the entire Martian
surface, its atmosphere, and interior, returning more data than all of the other Mars missions combined. Findings from Global Surveyor, once again, suggest the existence of water as a liquid at one time. It also showed that the magnetic field of Mars is not generated at the core of the planet, as it is on Earth, but at particular areas on the crust. In addition to studying Mars, Phobos was also observed. Temperature data of Phobos showed that it is blanketed in a one-meter thick coat of cosmic dust caused by millions of years of meteoroid impact. Global Surveyor completed its primary mission in January 2001 and was in extended mission phase until January 2003.

Although the Global Surveyor mission was very successful, it provided evidence there exists a necessity to curb the zeal of a mission before it is entirely lost. While in the latter stages of achieving a circular orbit with decreasing altitude, a solar panel of the spacecraft malfunctioned. The malfunction was only an unexpected amount of movement in an unplanned orientation; however, this slight movement forced engineers to employ an alternative thruster and aerobraking pattern. Through this period of correcting the orbit, only intermittent scientific observations were made.\textsuperscript{31} The event proved the need for those planning future missions to consider as many possible complications as possible.

2.2.12 Mars Odyssey

NASA launched another mission targeting Mars in April of 2001. This spacecraft was named Mars Odyssey and arrived at Mars in just six months. Mars Odyssey was designed as an orbiter to determine the composition of the Martian surface using a
gamma ray spectrometer (GRS) to detect twenty different elements, as well as study the radiation environment of Mars. It also persisted in the elusive search for water in a liquid state and any signs of such existing in the past. Mars Odyssey was designed to measure the amount of hydrogen in the top meter of Martian soil in order to determine the accessibility of water on the planet. Collecting data that will help determine the radiation environment will assist in assessing potential hazards for future manned exploration. The GRS of Odyssey did in fact return data that suggested large deposits of hydrogen near the poles of Mars.³² Lastly, Odyssey studied the radiation environment of Mars with the GRS as well to help determine the impact that this would have on human explorers in the future. Similar instrumentation has flown on the Space Shuttles and the ISS. However, prior to Mars Odyssey, such a study has never been conducted outside of the protective magnetosphere of Earth, which blocks much of the radiation from the sun that reaches the planet.³³

2.2.13 Mars Exploration Rovers

NASA has scheduled a highly anticipated mission to Mars to be launched in the middle of 2003. The mission is the Mars Exploration Rovers, or MER-1 and MER-2, launching sequentially in May and July. There are monumental goals planned for MER-1 and MER-2. The goals include further investigating the geology and climate of Mars and
continuing the endless search for evidence of past or present life. All of these aspirations combine to prepare for future human exploration.

MER-1 and MER-2 will give a collective effort to achieve an abundance of scientific objectives. The majority of the science to be performed focuses on geology, but these data will provide valuable info on the past and present climate and environment of Mars. The experiments include characterizing various rocks and soil possessing clues about water activity in the past, determining the composition and distribution of rocks surrounding the landing site, researching what geological processes have developed the terrain, and searching for geological data indicative of the Martian conditions when liquid water existed.

The instrumentation on each rover is quite extraordinary. It possesses a warm electronics box (WEB), a panoramic camera as well as a navigational camera and a hazard camera, an equipment deck including various antennae and capture/filter magnets, and solar arrays to supply power. This is all mounted on a rocker-bogie mobility system of six individually motored wheels, of which the rear and front wheels can be independently controlled. The WEB is designed to protect and thermally control its contents, the computer and other electronics. Thermal protection is provided by gold paint, heaters, radiators, thermostats, and state-of-the-art aerogel insulation.
Although previous missions have surpassed expectations of longevity and capability, numerous factors have been considered to possibly lead to the termination of the rover after the anticipated ninety day lifespan. The solar panels will collect dust, the Sun will become more distant and migrate to the northern sky (the rover will land near the equator), and the distance from Earth to Mars will grow. All of these factors will limit power and communication capabilities of the rover, leading to the completion of the mission.²⁴

2.2.14 Mars 96

In 1996, the Soviet Space Agency (now the Russian Space Agency) attempted to launch a mission to Mars known as Mars 96. The mission was slated to search for liquid water on Mars in part of a continuous quest to determine if life exists on that planet, but it was also “designed to study the red planet”s surface, inner structure, atmosphere and reactions to the solar wind.”³⁵ It featured two rovers and an orbiter to communicate its findings with control stations in Moscow. It carried twelve instruments to study the surface and atmosphere, seven to study plasma, fields, and particles, and three for astrophysical studies.³⁶ Among the twenty-two instruments on board the orbiter and rovers was “a penetrator to probe the planet”s subsurface.”³⁷ This instrument, attached to each rover, was in search of clues for the possibility of life. The instrumentation for the Mars 96 mission was a collaborative effort of different space agencies, including the ESA and NASA. Unfortunately on the day of its launch, the mission failed during its launch procedures despite the inclusion of a traditionally reliable Proton booster.³⁸ The rocket
lifted off successfully but the fourth stage ignited prematurely and sent it plummeting. It crashed into the Atlantic Ocean, carrying 270 grams of plutonium-238.\textsuperscript{39}

\textbf{2.2.15 Nozomi}

The Japanese space agency, NASDA, is currently working with an $850 million spacecraft en route to Mars, called Nozomi, meaning “Hope.” The mission, originally known as “Planet-B,” launched in the summer of 1998. Nozomi, an orbiter, is expected to enter Mars orbit and send images of the Martian surface back to Earth in early 2004.\textsuperscript{40} Nozomi boasts fourteen instruments to produce the latest images of the red planet and both of its moons. In addition, the instruments have further studied structure, composition and dynamics of the ionosphere, aeronomic affects of the solar wind, the escape of atmospheric constituents, the intrinsic magnetic field, the penetration of the solar-wind magnetic field, the structure of the magnetosphere and the dust in the upper atmosphere while in orbit around Mars. This valuable endeavor will help to develop technologies for future missions to Mars.\textsuperscript{41}

\textbf{2.2.16 Mars Express}

The European Space Agency is preparing to send its first spacecraft, the Mars Express orbiter and Beagle 2 lander, to Mars in the spring of 2003. ESA named the orbiting portion of the craft as such because it has been built faster than any other comparable planetary mission. The landing portion was named after a ship that “took
Charles Darwin on his voyage around the world in the 1830’s and led to a quantum leap in our understanding about evolution of life on Earth. We hope that Beagle 2 will establish whether life began on Mars.”

This endeavor to Mars is a collaborative effort of research institutes throughout Europe and has also implemented the assistance of NASA scientists. The Beagle 2 lander is the first lander being sent to Mars since the Viking landers, and it is also the first since the Viking missions to look specifically for evidence of past or present life on the red planet. The orbiter, Mars Express, is equipped to take images of the entire surface at a high resolution of ten meters per pixel and some areas at a super resolution of two meters per pixel. It is also capable of yielding a map of the mineral composition of the surface at 100 meter resolution, mapping the composition of the atmosphere and determining the global circulation. Other tasks hoped to be accomplished by Mars Express are determining the structure of the subsurface to a depth of several kilometers, determining the effect of the atmosphere on the surface, and determining the interaction of the atmosphere with the solar wind. The Beagle 2 lander is outfitted to determine the geological, mineral, and chemical composition of the landing site, search for life signatures, and study the weather and climate.
In 2001, the scientists building instruments for the Mars Express mission traveled to Japan to meet with fellow scientists and engineers working on the Nozomi mission. Nozomi will go into near equatorial orbit around Mars shortly after Mars Express enters polar orbit in December 2003. This fortunate scheduling resulted in the two space agencies, the ESA and NASDA, agreeing that supporting one another on planetary investigations, particularly those dealing with atmospheric analysis, would be highly beneficial. The two orbiters will be able to do simultaneous weather observations from two vantage points.

2.3 Literature Review

Reviewing and critiquing the literature utilized for research was very important. It clarified the judgments and arguments presented by each source. Focusing on the conclusions of each resource made it easier to extrapolate what the theories were regarding the beneficial societal impact of Mars exploration. This was especially necessary when it became time to filter through the report for specific information to be included in the magazine article. Arguments were made for and against the various conclusions in the research materials in order to decide what would be omitted and included in the final product of the project. A sketch of the judgments and conclusions of each literary work that was used follows in this section.

2.3.1 Mars: Past, Present and Future

This publication edited by E. Brian Prichard is a collection of speeches and papers presented at a symposium on Mars missions that was held in 1991. The symposium was
in conjunction with the 15th anniversary of the first unmanned Viking landing on Mars. The concept of this convention was to examine past, present and future missions to Mars. Past missions were to be examined with respect to the science returned and the systems, operations and management lessons learned. The present missions were examined on a very brief basis. The main focus of the convention was the future missions with respect to the Space Exploration Initiative.

Many of the articles in this collection support Mars from a technical stance, but the two articles in particular that were most applicable to the research of this paper were supportive through the use of a more poignant tone. Both articles, “Mars: Destination and Challenge” and “Mars Mission Benefits: A Layman’s Perspective,” are motivating towards the continuation of Mars exploration for two primary reasons. They address the human condition and human experience, as well as the benefits to all of society that often result more than the technicalities of exploring Mars.

Professionals passionate about the exploration of space, and particularly the exploration of Mars, author the articles taken from the conference. Therefore, the pieces tend to have very personal perspective. However, the authors are logical and sensible in their arguments and predictions, knowing all too well that space exploration is not routine and that problems often arise during all portions of a mission, from design to transit to operation. Bearing this in mind, the effect of the articles is not lost; they propose that challenges be met and overcome and that stretching and striving to learn and gain experience through Mars exploration should be on the vanguard of thought. As an excellent source of insight and wisdom, Mars: Past, Present, and Future does support the meaning of this IQP in a sensitive and refined manner.
2.3.2 Mars: The Next Step

*Mars: The Next Step*, written by Arthur E. Smith, did an excellent job of providing technical background information and pushing the goals for exploration of Mars. It recognizes that the largest hurdle to be overcome in Mars mission planning is finances because of the need for fiscal responsibility in many other areas on Earth. This holds true for both leaders of the world in space exploration, the United States and Russia. It also recognizes the impact that a manned Mars mission could have on a human being. Pathfinder and other missions have studied the radiation environment on Mars. This research allows for the potential radioactive distress to explorers to be accurately predicted and prevented. Also taken into consideration are the affect of zero gravity and the ample time spent in space. The length of time leaves the possibility of the astronauts suffering a grave illness with little or no chance of reaching medical help other than the equipment onboard the spacecraft.

The author maintains that Mars exploration is the modern day Manifest Destiny – an inexorable human movement, as inevitable as the sunrise. He urges that exploring Mars can answer some of the inescapable questions of life. By conducting experiments, making observations, and collecting data, scientists can learn incalculable amounts of information that may lead to unfolding the secrets of planetary evolution. By the same means, biologists and chemists possess the ability to analyze images, data, and samples to determine the presence and abundance of organic elements, liquid water, and life forms. The content from this book was useful for background information and for interpreting other materials that were more of a personal analysis type.
2.3.3 The Case for Mars

Much of The Case for Mars presents confident and optimistic views of the future of Mars exploration. The arguments made by the author appeal to different varieties of emotions and feelings on the subject. Most of the information dealt with in this book is out of the scope of the particular topic for this paper because it continues far beyond merely exploring Mars; it continues on to discuss the colonization and terraformation of the planet as well.

The author, Robert Zubrin, takes into account the most important factors, obstacles and distractions, in his contention for exploration by explaining the so-called “dragons” and “sirens.” The “dragons” are the obstacles that must be overcome in order to achieve success at Mars exploration. The “sirens” are the factors that draw attention away from Mars exploration. The radiation “dragon” leads the trail of fiends, followed by the affects of zero gravity, the complications of human fragility, dust storms, back contamination, and minimal settlement on the Moon. Back contamination is the pollution of Earth resulting from sample return from any other planet, but it was not a large concern for this particular project focus.

An argument not typically raised by other publications that Zubrin does introduce is the construction of bases on the Moon prior to further surveying Mars. Zubrin argues that many people think the primary focus of extra-terrestrial concentrations should be constructing lunar bases. This idea is based on an ancient Pagan belief that the Moon, or Diana, the Lunar Siren, should be appeased by the construction of substantial “temples.” He, however, follows up this archaic argument by stating “the fact of the matter is that [this belief] has no basis in reason.”44
It is important to note that the subject of forward contamination, polluting the destination planet, is not broached. This shows the bias of his writing. He has a sole desire to explore the planet with little regard for conveying to the public the consequence involved in Mars exploration. The issue of forward contamination greatly affects the views of many environmentalists and, for some, is a reason against exploring Mars at all. Reading other published works by Zubrin clarified his standpoint on Mars exploration and how passionate, yet one-sided, he is about the topic. However, many reasons supporting the exploration of Mars that follow from Zubrin’s extreme interest may not be considered by others. Therefore, his materials, although partial and sometimes misleading, were still useful.

2.3.4 Viking 1: Early Results

This technical publication served as a bookmark in the process of the Viking mission to Mars in 1976, just several weeks after it arrived. It functions as a preliminary and tentative account for early conclusions of the Viking mission, but of course, later documents contain the entirety of the mission results. The data and results, as well as the future predictions for the remainder of the Viking mission, were advantageous for comparing data before the conclusion of the mission to the outcomes at the completion of the mission.

Details of the Viking mission, such as the mission plan, program goals, strategy, and events on Mars were included. The literary source draws on a more technical insight into the orbiters and landers, how the landing sites were chosen, trajectory, instrumentation, and surface investigations, as well. It outlines the mission objectives
clearly and concisely to be observing the Martian orbit and measuring the atmosphere at surface level to obtain chemical, biological, and environmental data relevant to the existence of life. It also gives a new perspective into the technical aspects of the success of the decent and landing on the surface of Mars executed by the lander. This piece of literature was supportive of less factual literature.

2.3.5 Review of NASA’s Planned Mars Program

This document produced in 1996 was a collaborative effort of the Committee on Planetary and Lunar Exploration (COMPLEX), the Space Studies Board, and the Commission on Physical Sciences, Mathematics, and Applications to review NASA’s future plans for the exploration of Mars. It sought to provide factual data on past and future missions and briefly explain the overall importance of each one.

Given the somewhat rocky history of the Mars exploration program, this review takes into account the failures as well as the successes to gain a better perspective on what lies ahead. The errors made and lessons learned are scrutinized and debated in order to confer a balanced review. The specific scientific goals NASA plans to accomplish via Mars exploration are mapped out and discussed in detail. Actual facts and figures for the past Mars missions and the projected data for the future missions until 2005 were provided. The discussion of international collaboration between space agencies was particularly insightful and useful toward making a connection between science and society.
2.3.6 The Search for Life on Mars

Malcolm Walter makes arguments in support of Mars exploration for the economical and industrial benefits, in addition to those that are scientific and personal. He presents a discussion of what is known about Earth, what is known about Mars, what has been discovered about Mars from completed exploration and from meteorite study, and the significance of further exploration.

An interesting aspect of the presentation of the author is an underlying religious tone felt several times during his argument discussion, raising questions such as “could Earth be the only inhabited place in the Universe, perhaps because God made it so, as many people believe?” and thoughts such as the theory of evolution challenging the thinking and the meaning of life for many Christians. He goes on to note that questions such as these only hold significance to Western tradition, going on to explain that Hindus, for example, have always believed that there is life everywhere.

Walter offers yet another very passionate and honest account of what he calls “a great story” and his “version of it.” This is not to say the information provided and used to support his opinions is faulty in any way, but rather, it is a very personal description of the dreams and desires of one scientist with the disciplines of biology and chemistry incorporated.

2.3.7 Proceedings of the Founding Convention of the Mars Society: Part I

A collection of speeches made at the Founding Convention of the Mars Society held in Boulder, Colorado, is found in this book edited by Robert Zubrin. Each and every speech is not only in favor of exploring Mars further, but each speech supports the
colonization of Mars. The speeches discuss the objectives of the Mars Society, the goals of the hope to colonize Mars in the near future, the obstacles that must be overcome to accomplish this monumental feat, and the plans to confront these obstacles. Some speeches go into great detail about the potential of privatizing Mars exploration and incorporating a business philosophy to the endeavor. Another focus is the significance Mars exploration and colonization has on the youth of the world.

The more useful information rested in the opinions backed by a multitude of facts about what the Mars missions performed by NASA had to offer. The facts covered topics of possible life and water on Mars, planetary evolution, biological experiments executed by the Viking missions, and geological experiments carried out by various orbiters. Opinions of the speakers then extrapolated what could be reaped from these facts and the undertaking of exploring Mars. However, it was not possible to manipulate the majority of the speeches and opinions for support of either side of the argument concerning Mars exploration. The views would most likely be publicly perceived as too outrageous to serve as viable reason for the exploration of the red planet.

### 2.3.8 Writing the Modern Magazine Article

Max Gunther offers a detailed description of each step to be taken when publishing an article for a contemporary magazine in his book, *Writing the Modern Magazine Article*. The literature is divided into four distinct parts; they are preparation, research, writing, and examples of articles dissected to explain their anatomy. The preparation portion describes limiting the focus of an article, classifying the desired article type, and writing a query letter to the editor that will be successful. Methods of
research were illustrated in the second portion, while the essential components to an article were explained in the third section.

Despite the publication of this book being in 1982, it still served as a very helpful guide to beginning the process of writing the article for this project. The segment of the book on doing research was not used, for there were no complications in collecting data and information about which to write. Although the literature was entirely the opinion of Gunther, it was found that the material was very logical and clarified what an editor expects from an article proposal. Complementing this source with the mission statements of the magazines of interest made it easier to apply his ideas conveyed in the text.

2.3.9 Various Websites

Three categories of information were researched through the Internet. These categories are facts about the missions to Mars, opinions about Mars exploration, and details about numerous magazines. The first category of data was by far the most researched through various websites. The websites developed by NASA, its branches, and affiliates were invaluable. The information contained in the websites was well catalogued, provided detailed technical data, and effectively expressed the objectives of each Mars mission. The two websites from which the majority of the mission information came from were the search engine available at http://nssdc.gsfc.nasa.gov/database/MasterCatalog and the catalog available at http://mars.jpl.nasa.gov/missions.

Opinions and views both for and against Mars exploration were not nearly as much a focus for research through the Internet. It was more difficult to use search
engines for finding public opinion concerning this topic rather than fact. However, the
Internet served as the most convenient source of information for several national
magazines and periodicals. Lists of magazines separated by their major target audience
were found and analyzed for the mission statements and subjects of the articles of each
magazine. This online research was crucial to limiting the periodicals of interest to three
that would receive query letters.
Chapter 3: Project Procedure

A vast array of methods was employed in performing the research required for this project. It was necessary to map out the location of the research materials, the method for extracting material relevant to the focus questions from those resources, the method of analysis to be used, and why there is a need for such an analysis. It was also essential to present a convincing argument that the problem being studied was fully understood and that the project was capable of and successful at achieving its objectives. This chapter addresses all of these topics.

3.1 Resources Used

The materials that were used for research and analysis varied in sort. They ranged from websites, to publications and periodicals from NASA and JPL personnel, as well as personal interviews. The data were grouped into three sections. The sections were factual data, the implications and perspectives of Mars exploration, and information concerning marketing and writing to enthuse the public.

All of these resources contributed to the project in a unique way. The websites offered very current, but unedited, information. The publications and periodicals were valuable for their sensitivity to the time at which they were written and edited. Moreover, some published handouts were not readily accessible to the general public, illustrating the project as a bridge between the relatively hidden technical realm of NASA and the general public upon which NASA depends for financial support. Despite the websites that were utilized being scattered in several different directions, the publications
were consolidated in only a few locations. The three sites from which published materials were taken were the library of the University of Houston Clear Lake, the Data Center in Building 31 of JSC, and the Scientific and Technical Information (STI) Center.

The other source of printed material was employees of JSC and JPL, specifically Margaret Race of JPL. The majority of research utilizing websites and printed materials supplied factual data. Some periodicals and published works, however, presented professional and public opinions and judgments of the worth of Mars exploration. Furthermore, a few printed sources provided facts regarding the criteria and formatting necessary for writing query letters and magazine articles.

The personal interviews conducted were a fascinating and priceless facet of the research done for the project. They provided a portion of the personal perspective for which the project was striving. Speaking with the astrobiologists, engineers, and scientists who base their careers on the continuation of Mars exploration supplied a point of view that needed to be presented to the public. They were passionate in their dialogue about the importance and worth of Mars exploration. The interviews contributed many ideas and facts regarding how missions to Mars would alter the attitudes and perspectives of the public if the potential discoveries and societal affects were realized. These meetings covered numerous disciplines. The disciplines included astrobiology, human exploration science, planetary protection, public affairs, and other related fields. Those interviewed were Jackie Allen, Judy Allton, John Connolly, Everett Gibson, Eileen Hawley, Karen McNamara, Wendell Mendell, Margaret Race, Nancy Robertson, Linda Singleton, Eileen Stansbery, Kay Tobola, and Kathy Watson.
Another topic that warranted attention was choosing a magazine in which the article would be published. However, the demographic that should be targeted was discussed first. Although this did not require any printed materials, many websites were researched for information regarding the mission statements and objectives of various nationally distributed magazines and publications. These statements indicated at which demographics each magazine aimed. Once the demographic was chosen, three primary magazine choices emerged.

The final resources researched were publications about writing modern magazine articles. These resources were responsible for shaping the results from the rest of the research into a magazine article, thus achieving the goal of public outreach. Topics of research included effectively limiting the focus of an article, techniques of article writing, classifications of articles, writing a query letter to a magazine editor, and what to expect in a response from the editor.

### 3.2 Project Method

Extensive research was done on past missions to Mars. Specific attention was paid towards the public attention and reactions that these particular endeavors received. The Apollo missions of the 1960’s and 1970’s were also considered. The Apollo program served as an example of positive public attention and feedback. This background information assists in substantiating Mars exploration by being proof of favorable changes to public attitudes and perceptions resulting from space exploration. The missions targeting Mars that were executed by foreign agencies were also researched to add support to a message of the project that such exploration has a global effect.
However, this research was minimal so as to focus on the primary purpose of the project, public outreach for NASA.

Present missions to Mars were researched to educate the public on the current events of NASA. Generating interest in these current events helps provide a basis for interest in future NASA projects. Additionally, future Mars missions were studied and analyzed. This was done to provide the public with an idea of what to expect and to which to look forward. This project aims to accumulate long-lasting interest in the Mars agenda of NASA, not just immediate intrigue that can fade. It will be important for NASA to continually include the non-technical portion of the public in its realm of individuals knowledgeable of the future plans for Mars.

As was previously mentioned, the potential negative affects of Mars exploration were constantly kept in mind. Information was gathered that addressed the general concerns of the public, such as concerns of forward and back contamination. Furthermore, some research and analysis focused on the beneficial aspects from Mars missions that failed. The importance of failure lies in the lessons learned, the corrections made, and the betterment of the program for future exploration. The following step after collecting information regarding the detriments of Mars exploration was to weigh it against the benefits.

In order to achieve the objectives and goals of the project, it was not enough to simply research past, present, and future Mars missions. It was necessary to delve into the societal impact of the missions. As an example, the Apollo missions provided two very moving and awe-inspiring pictures named Earthrise and Blue Marble (Appendix C). These two photographs reshaped how the world viewed its place in the universe.
Humankind recognized it shares one small planet and ecosystem, in which a change made by one country has an effect on the entire planet.$^{46}$

Mars exploration focuses on searching for conditions necessary for life and traces of life that exist now or have in the past. Such findings would forever alter the ways in which society views religious beliefs, Earth, and life elsewhere in the universe. It was an important element of the methodology of the project to stress the importance of such potential discoveries and scientific knowledge. In addition, such a stress was formatted to be easily conveyed to the non-technical public in a magazine article. Specific consideration was given to attracting the attention of the reader, keeping his/her attention, and not expecting a very long attention span. The article is to serve as a call to thought.
Chapter 4: Presentation of Results

The following two chapters are at the heart of this project. This chapter presents all of the valuable information and data responsible for the conclusions that have been drawn regarding the societal impact of Mars exploration. The first section tackles the duty of compiling all of the facts and scientific results reaped from extensive research of Mars. It also includes information concerning what has been learned from the Mars missions other than the scientific data. For example, the Mars Pathfinder mission taught NASA that the public is interested in images to which it can relate immediately, like those containing a section of the lander or rover in them. The task of analyzing these results and clarifying the connection to beneficial societal changes is left for the next chapter.

An important aspect of the research completed was determining how to present it to the target audience. The logistics of choosing this target audience and selecting the most suitable magazine for publication are contained in the second section. This was perhaps the most vital portion of the project because it served as the deciding factor of whether or not the project would make any difference at changing the public opinion of Mars exploration. It was also necessary to write an effective query letter to the editors of the chosen magazines. Some research was directed towards this new and unfamiliar assignment, and the details of what is involved are discussed in the last section of this chapter. Additionally, the findings from research about how to write this type of magazine article are provided in the final section.
4.1 Presentation of Data and Research Findings

The endeavors to Mars accomplished by NASA carried out multitudinous analytical experiments. These missions also made countless measurements and observations in the form of photographs. Despite this wide variety of data and results collected from each mission, the majority of the findings could be related to a few broader questions. An important driving force behind the experimentation conducted on Mars is the desire to search for life, whether it is extant or remnants of extinct life. A necessary component to such a search is the complementary search for water on Mars, another major mission objective. In addition, the experiments carried out in search of water and life indicate much information about the red planet and its evolution. These data are then used to conjecture about the planetary evolution of Earth. The inferences the technical community has gained from this beneficial byproduct of searching for life and water have been numerous and intriguing.

An interesting, and often overlooked, aspect to the Mars program of NASA is the cooperation it spawns between countries. The collective efforts of different countries help in sharing technology and ideas internationally. The desire of the international partners to collaborate produces a common sense of good will across the globe from space agency to space agency. However, it still remains important to involve the average individual. Therefore, NASA has begun to recognize the potential in designing missions to which the public finds it much easier to relate.
4.1.1 Searching for Life on Mars

The search for indigenous life or evidence of past life on other planets, particularly Mars, has been a steady source of interest and curiosity not only to the scientific world, but to humankind as a whole. There is increasingly compelling evidence of life on Mars and that Mars was once a water-rich planet that has undergone major climatic changes.\(^47\) This, coupled with results of indications from molecular phylogeny of the conditions under which primitive life may have existed on Earth, has led to a heightened interest in answering the question: is there, or has there ever been, life on Mars? The present likelihood of living beings surviving on Mars is considered highly improbable; much of the research being done and that which is proposed focuses on searching for evidence of past life. If some form of life did exist on Mars a considerable amount of time ago, some components may have survived in certain niches such as historic volcanic vents or deep aquifers.\(^48\)

The biological evolution of Mars is another subject pertinent to the search for life on the red planet. A better understanding of the distribution and inventory of volatiles and biogenic elements, and the locations and characteristics of potential past habitats, such as hydrothermal systems and lakes, will help to possibly explain or answer the age-old questions regarding life there. Even if life did not exist on Mars, studying how the conditions on the two planets, Earth and Mars, differ is highly significant. The “optimum strategy for biologic exploration”\(^49\) is to focus on global reconnaissance in order to assess past surface conditions and planet-wide inventories of water and the chemical elements necessary for life on Earth, including hydrogen, carbon, nitrogen, oxygen and the noble gases. This leads to the understanding of the evolution of Mars. The same “strategy”
would be able to identify promising sites where the materials previously listed are available. Following this search, emphasis would shift to surface exploration of the favorable locations to seek for more clear evidence of what the past conditions were. In addition, the presence of biogenic elements and compounds or anomalous isotopic fractionation would be sought as confirmation of past life. “Ultimately, returned samples will be needed for definitive analysis in terrestrial laboratories.”

The Viking missions were a pair of pioneering missions in which the search for life on Mars initiated. There were three biological experiments carried out by the Viking collaborative. One of the biological experiments included a search for photosynthetic microbes. The remaining experimentation investigated the possible presence of bacteria capable of consuming organic material. The results that followed from all of these experiments ultimately reached one conclusion. Further testing was necessary. These results were accepted by some, such as Zubrin, as positive because they did not completely discount the possibility of microbial life on Mars.

Potential evidence of the possibility of microbial life having once existed on Mars may have been discovered but the research has not been exhaustive. The object offering the alleged evidence was a meteorite collected in Antarctica labeled ALH84001. The label stands for the location in Antarctica, Alan Hills, the year it was found, 1984, and the number in the series of meteorites found in that area. This particular rock was the first found in Alan Hills, hence the 001 in its label. The important characteristic contributing to the idea of ancient microbial life was the carbonates found in the rock. The carbonates formed globules from “a fluid saturation with carbon dioxide that percolated through the fracture after the silicates were formed.” Fractures commonly form in silicate
structures such as this meteorite, proved to come from Mars by its geology. Carbonates are organic materials which allude to the possibility that this portion of Mars came into contact with microbial organisms in the distant past. Moreover, “unusual structures found within the globules bear a striking resemblance to bacteria fossils found on Earth” but with properties not native to this planet. “Basically, the case for ancient microbial life on Mars is built almost entirely around the globules.”

Investigating the atmospheric conditions and climatic changes on Mars is also crucial to understanding the possibility of life forms on the planet. Measurements of pressure, wind, humidity, and opacity need to be made at a wide variety of surface stations in one Martian year. Furthermore, measurements of the abundance of dust, water vapor and aerosols, the general circulation of the atmosphere, and the systematic high-resolution soundings for atmospheric temperature must be made for the same time period. There have been modest climatic changes in the recent geological past of Mars but much larger variations in its more distant past. Information regarding its more ancient climates can be derived in various ways. Sources include the geomorphic evidence of past fluvial action and erosions rates, the composition of gases trapped in ancient rocks, the characteristics of sediments deposited in climate-sensitive environments such as lakes, the mineralogy of weathering products, as well as numerous other geological and ecological conditions. An exploration strategy should include methods for characterizing
and possibly sampling relevant deposits. Measurements of escape rates of upper-atmospheric species are also useful in constructing models of past climates.\textsuperscript{55}

\section*{4.1.2 The Search for Water on Mars}

The extensive search for water is a common goal to the majority of exploratory missions targeting Mars. Mariner 9, Viking, and Mars Global Surveyor (MGS) all provided data showing what may be fluvial features. Zubrin believes the data serve as direct evidence of liquid water flowing on the Martian surface early in its history for a period capable of carving impressive canyons and channels. However, proposals have been made that state it was not water that formed the impressive topography but liquid carbon dioxide. These results of the Mars missions act as “the fundamental motivation for the search for past life on Mars.”\textsuperscript{56} By comparing the information regarding fluvial features to that concerning the cratered terrain of Mars, it would be possible to estimate how long ago there may have been a flow of liquid water on the planet if future evidence proved the fact. The estimation also required knowledge from the Apollo program that the period of intense cratering on the Moon ended 3.8 billion years ago. Assumptions that this also holds true for Mars could lead to the possible conclusion that liquid water may have flowed on its surface 3.8 billion years ago.\textsuperscript{57} However, there is yet to have been discovered any actual evidence that liquid water does exist on Mars or ever has existed.

The search for life performed by the Viking program was previously mentioned. Following this, many more missions concentrated on searching for liquid water, an essential component to life. While doing so, the endeavors to Mars focused on
researching the physical state of their destination in terms of geology, surface chemistry, and aeronomy. In this way, the investigation into the presence of water on Mars functioned as a bridge between the search for life and the exploration of physical characteristics of the planet.

MGS was one such mission that continued the search for water long after the time of the Viking program. MGS studied the Martian surface very closely from lower orbit for quite a substantial duration, nearly two Earth years. The abundant images of Mars captured by MGS strongly suggested the past existence of liquid water. Some images advocated the presence of permafrost and possibly frozen water beneath the surface. When the mission went into extended mission status, it contributed even more to the available imagery supporting the possibility of liquid water once existing.

4.1.3 Comparing the Planetary Evolution of Earth and Mars

The Deputy Associate Administrator of NASA in 1974, John E. Naugle, expressed his thoughts about the magnitude of comparing planetary evolutions. “Only through comparative studies of other planets and their evolution will man truly begin to understand the forces which shaped his own being and the world in which he lives.”

The interpretation of the origin and evolution of Mars and its comparison with the evolution of Earth are both important goals of the efforts directed at Mars exploration.

Surface chemistry, lithology, and morphology result from a variety of internal and external processes or interactions with the atmosphere. Such events can reveal a great deal of information about the evolution of a planet when analyzed. Volcanism and tectonism are examples of internal processes, and the impacts of other celestial bodies on
the surface are examples of external processes. Interactions with the atmosphere are comprised of erosion and sedimentation. Analysis of these occurrences will require chemical, mineralogical, and morphological study from orbit and detailed surface measurements at locations on the surface of special interest identified from orbital data, such as lakes and hydrothermal deposits. Studying the interior of Mars would provide information about how the solid body accumulated, differentiated, and evolved. Orbital measurements of gravitational, topographic, and magnetic fields would provide valuable data on interior properties. However, many critical measurements required to unravel the geological history of Mars, the determination of stable isotopes and measurement of trace elements for example, seem to require sample return. A similar conclusion can be made in regard to the search for life and water.

Many spacecraft have performed experiments, made observations, and telemetried data back to Earth regarding the geology and environment of Mars. There exists a commonality in the data, also. Information from the observations and scientific tests of all spacecraft sent to Mars indicates a possibility that the planet may have been initially warm and wet but quickly became cold and dry as it is today. The characteristics possibly shared by Earth and historic Mars are numerous, and therefore, may provide a good basis for a belief that a cycle of planetary life naturally transpires. Furthermore, data that have been obtained depicting similarities between Earth and Mars has offered theories of the evolution of the solar system. The common components of the atmosphere and geology between Earth and Mars in some ways suggest a parent cosmic body from which both planets formed.
4.1.4 International Collaboration and Relating to the Missions

As was discussed in chapter two, NASA is not the only country targeting Mars for exploration. The Russian Space Agency (RSA), NASDA, and the European Space Agency (ESA) have all showed immense interest. While the ESA has not yet successfully completed a mission to Mars, the RSA and NASDA have contributed significantly to the world-wide Mars exploration program. However, NASA has remained a leader and pioneer. It is the space agency whose personnel are often requested by foreign agencies for their input on the space mission at hand elsewhere in the world. This situation has formed a peaceful setting in the technical realm of America, Europe, Russia, and Japan.

Research findings have shown that there are many facts and discoveries not known by the general public. It is often difficult to raise support from an uninformed group. One mission, however, did receive a significant amount of public attention. The Mars Pathfinder mission, with its cute little rover, Sojourner, was the subject of several newspaper headlines for weeks. This was not because it was the first mission to take pictures of Mars or because it did the most interesting experimentation. It was simply the subject of attention because the average individual was given a first-person perspective. For the first time, the images of Mars contained an entire object we, humankind, created. They were not pictures of just part of a lander; they were photographs of an entire rover, slowly but surely traversing the alien landscape. The research conducted for this IQP has shown that in order for NASA to have the public influence it wishes to have, it must personally engage the public.
4.2 Choosing a Demographic and Selecting a Publication

Many possible demographics were considered as a target for the article. To decide which to actually pursue, thoughts were first focused on what the result of reaching each demographic would be and which was ideal. A consensus was reached that ultimately, support and funding for Mars exploration was the goal. This led to a discussion about which portions of the American population tend to vote most often. Young men and women, in their twenties and early thirties for example, have a low voting percentage. This is attributed to their starting families and having young children, thus having less time to pay attention to political issues and not wanting to vote uninformed. Unfortunately, some believe that their vote is meaningless, making this a difficult audience to convince to politically support NASA. As the population becomes older, voting percentages rise. As children mature and become self-sufficient, the parents have more time to themselves. Considering this, the retired portion of the population was chosen as a target audience. The consensus of the authors that retired individuals tend to vote more often also supported the decision to target them.

Research on magazines and their intended demographics was done to gain a better perspective on which magazines to actually target and how to cater to their writing style. It was decided that to reach the retired public, magazines geared toward news would be the best route. *Newsweek*, *Time*, and *Parade* were the magazines selected for two reasons. These national periodicals have a very broad appeal, and the magazines offer many possibilities for several color pictures to complement a one or two page article. *Time* and *Newsweek* are both available nearly everywhere in the U.S. that sells magazines, and *Parade* comes standard in the Sunday edition of many major newspapers.
Including vibrant and attractive pictures from the Mars missions is hoped to capture the attention of the reader as well as capitalize on the idea of helping the public relate to the mission results.

4.3 Writing the Query Letters and Article

The query letters to the editors of the magazines of interest were the first step to publishing the product of this project. The purpose of a query letter is to gain the interest of an editor. As such, it is necessary to keep it brief, limiting it to two single-spaced typewritten pages or, ideally, one page. The limited length prevents too much detailed information being included, also. It is meant to serve as a sales pitch. If desired, the editor can always request more information. The only remaining formatting logistics of any concern are the use of formal language and the style of a letter.62

Research into the methods of writing a query letter yielded an outline of the essential components for its content. The six critical elements of a query letter follow sequentially. The first constituent of the letter is an introduction of oneself in one to three sentences. Next, a brief synopsis of the focus of the article should be provided. This should be conferred in no more than one paragraph. Following this component is a brief discussion of what other competitors have done with the topic. The authors were instructed by the advisors that there was not enough information about the topic of the project available. This was a clear enough judgment that it was not bothered to do any research investigating what other sources have produced about the societal impact of Mars exploration. It is important to clarify for the editor whether the subject of the article is overwritten or presently of very high interest to readers.
The next element in the letter can be included before or after this clarification, keeping in mind the importance of comfortable word flow. In this portion of the letter, “tell the editor why he should be interested in your idea, why his readers should be interested, why he should care.” It is crucial not to exaggerate but to convey facts concerning the focus of the article quietly in favor of the idea of the article. The fifth element of the query letter is an expansion of the second element. It develops the concise description of the topic of the article; the details include the framework of the article, a proposal of how the article will be written, and its purpose. Finally, a query letter should attend to the mechanical concerns of the editor, such as the sources of information, knowledge of any illustrations that would attract a reader, and why the present time is the proper time for the publication of the material in the article. Once the letter is completed and sent to the editor, it is important not to become discouraged with an indecisive or negative response, for no editor will promise publication without the article in its entirety in his possession. Revisions to the article can also always be made when the editor returns it with comments.

The integral portion of this project was producing the article. It was the instrument to carry out the purpose of the project and acted as a presentation of the most important data and their analyses. The goal of the article was to serve as a call to thought. When brainstorming what kinds of reactions were desired from the reader after reading the article, many results followed. The objectives of the article were found to be creating a public realization that someday descendents of the reader could be living on Mars, answering the question of how Mars exploration affects the reader in the present, conveying the importance of exploring Mars, inspiring the reader to not want the dream
of the Mars program to die, and helping the reader realize why it is worth it. It was also considered to assist the reader in concluding that with lunar success having been achieved and the International Space Station thriving, Mars is the next logical step in space exploration. Lastly, it was believed that there is not enough reflection by the public on what would be different in their lives had Mars never been explored.
Chapter 5: Analysis of Results

Rick Chappell is a research professor of Physical Science at Vanderbilt University, but he once was an employee of NASA for twenty-four years. He has expressed his belief that “critics often fail to recognize that the real benefits of the [space] program are not always tangible. „They are missing the big picture,” he said. „The biggest thing is it challenges our creative people to go out and solve problems and find new things.” This portion of the report debates the benefits and detriments of Mars exploration, providing a balanced argument and pragmatic lines of reasoning for both sides. It also contains a comparison of how data differed between sources, clarifying that the biases of some sources were recognized. Finally, the significant link between society and science and technology is investigated in order to acknowledge the goals and purpose of the Interactive Qualifying Project.

5.1 Comparison of Data from Different Sources

Most of the books that were reviewed during research presented a supportive argument for Mars exploration, some more fervently than others. In one source, The Search for Life on Mars, Walter stated directly that his book was a declaration of his opinion based on fact while other authors presented their opinion as fact. Still, other sources provided technical and factual data without interpretation which led to some complications. Difficulty also arose when having to compare the factual data to the interpretive literature in order to decipher fact from opinion. The websites used for reference, primarily NASA websites, offered the most objective description of mission
results and analysis. They were relatively void of opinion but provided little information about societal impact. Other private websites were referenced, but the majority was news articles and online publications still offering factual data.

The personnel interviewed provided an even more germane account to Mars exploration than the interpretive literature since they could cater to specific research needs on demand. The accounts of those interviewed were also helpful in clarifying the opinions of some authors. Nonetheless, a heavy bias toward the support of Mars exploration was apparent and because of this, it was more difficult to represent the opposition in order to present a balanced paper. It was important to bear in mind that, as visitors to JSC, the most readily available information was prejudicially supportive of Mars exploration and its countless benefits to society.

5.2 Benefits of Mars Exploration

Mars is a place that our previous generations could only dream of exploring by means other than a telescope. Research is favorable to all humankind, and this section seeks to prove that and much more. The major benefits of Mars exploration are discussed to encourage support of exploratory Mars missions. These major benefits range from intrinsic desires of our humanity to political collaboration. Questions of how the world, the universe, and life itself came to be may also be answered. The purpose of this portion of the report is to relay the message that the benefits and impact resulting from Mars exploration far outweigh the financial risk and public indifference.
5.2.1 Human Desire to Explore and Ability to Accept Challenge

It is much more than merely a desire that drives human beings to explore, to seek, and to search for meaning and knowledge. It is an inherent and instinctual curiosity common to all humans to hunt for and discover a means to understand the mysterious. “Why do we do this curious thing? ... An unbound curiosity seems to be a part of man”’s brain, an element of his genetic heritage. We have done this at least since a remote predecessor felt a powerful need to see what was on the far side of the mountain.” 66

Some things cannot be seen or heard, only felt. The impulse to climb a mountain to see what is on the other side is distinctly human.

“Humans are, by nature explorers, adventurers, and conquerors of frontiers. It”s in our hearts and minds and gives us purpose. In our drive to explore outside our Earthly domain, we seek who we are and where we stand in the Universe.” 67 The nature of exploration insinuates a lack of knowledge. From the beginning, there is no way of knowing what the end will be. The destination is the search itself for understanding where and how each person fits into the Universe, even if we do not know what we might be found.

Mars is a world of breathtaking scenery with spectacular mountains twice as tall as Mount Everest, canyons three times as deep and five times as long as the Grand Canyon, and thousands of kilometers of fascinating dry riverbeds. Its unexplored surface may hold riches and resources for future humanity, wonders for the eyes to behold and our mind to embrace. “To confine our attention to terrestrial matters would be to limit the human spirit.” 68
Simply wanting to go to Mars for the resulting science and technology is not enough to fuel a mission. It takes a passionate drive to experience the unknown and unexpected. It requires an underlying need to experience the discovery rooted deeply in one’s faith and belief that Mars holds answers to so many questions. The challenge of discovery is frightening, but human beings are incredible vaults for courage to defy fear and accept challenge.

“Interplanetary travel will represent a tremendous leap forward; a costly but enormously thrilling challenge… as we learned through every great human adventure, it will bring unexpected… discoveries that will forever change our understanding of the world, in ways we cannot possibly predict.”69 Great human adventures have included the voyage of Columbus to the Americas, the expedition of Lewis and Clark over the western frontier, and the oceanographic efforts of Jacques Cousteau. Humankind is in debt to them all for their awesome contributions to shaping the world and exemplifying an inspiring portion of the human spirit. Accepting the challenge is half the battle; developing faith that exploration and discovery have a value exceeding the financial cost is essential.

In addition, the benefit of accepting challenges lends itself to opportunities for understanding and the acceptance of the unknown. Exploring Mars undoubtedly presents the prospect for remarkable discovery. Because it is the most similar planet to Earth, studying it deeply could lead to unequivocal evolutionary truth that would change lives across the globe. Both accepting a challenge and its outcomes can be difficult, but that is what makes it such a great accomplishment. Accepting this epic quest allows the future
to hold so much more. It is important to ask oneself how the world and humankind
would differ had the great challenges of the past never been accepted.

5.2.2 Evolutionary Questions and Obtaining Answers

Understanding the origins of Earth and subsequently, the origins of Earthly
beings, is a major goal of planetary exploration. However, it is taken into particular
consideration for Mars exploration because of the similarities between the two planets.

“Early explorations are driven by self-interest; their goals were trade, land,
power, and gold. Now we are impelled by motives that are almost as
cooly rational as those that govern the design of our spacecraft: we
explore other worlds that we may better understand our own. It is still
self-interest, in a more intellectual form.”

The different natures of Earth and Mars are compared with the aim of
understanding the origin, history, and future, not only of these two planets, but of the
other orbiting bodies within the solar system. Accurate conclusions and discoveries can
be made by considering certain factors. Factors such as mass, atmospheric composition
and density, temperature, and force of gravity are major aspects that are taken into
account when studying the geomorphology of planets because they are all interdependent.
As an example, the general age of Earth is believed to be known, but without continued
research to compare Earth and extraterrestrial bodies, this can never be catalogued as
fact.

The evolutionary process from the very first organisms on Earth to the current
status of Earthly life is fairly well understood and established by basic biological
principles. However, whatever came before the very first life forms remains a mystery to date. In order to understand the origins of life, the links between the fundamental processes which build sequentially upon each other to construct life and what is historically unknown must be concretely defined. The exploration of Mars presents itself as a prime option to research and analyze the most basic building blocks of life, should they exist there. Mars exists as a venue with the possibility of retaining the very elements to life about which scientists here on Earth have countless questions. Although these elements would be a part of an alien environment, the sheer chance that some of the missing answers rest in the conclusions that could possibly be drawn from further exploring Mars cannot be ignored. Furthermore, Mars may impart questions yet to be asked. Perhaps if life does exist there, the building blocks differ, causing scientists to question whether the current beliefs regarding biological evolution are the only possibility.

Several credible theories on planetary evolution exist and are accepted by scientists and nonprofessionals alike worldwide. However, unambiguous, concrete proof of any of them, from Darwinism to the Big Bang to Creationism, has yet to be found. It is believed that chemical and biological studies of Mars may one day provide the key to further understanding, particularly the studies of organics and other building blocks to Earthly life. To better recognize life on Mars, scientists are compelled to also continue learning about the only known specimen of life in the Universe – terrestrial life.

Possessing a distinct understanding of the evolutionary process of this planet and beyond is not a very simple task. It stands to change the way in which people think across the world. Evolutionary theories are a major component of the religious beliefs of
many people. While an individual religion believes that its theory is correct, no one can say for certain what is or is not. Learning clearly what the process was by which the Universe formed will change personal, cultural, and religious beliefs.

5.2.3 Engaging International Partners

“We [chose] to go to the Moon… not because [it was] easy, but because [it was] hard” and because we had political issues to resolve. As the Cold War raged overseas, John F. Kennedy called for Americans to rise to the occasion with the enthusiastic patriotism that characterized the era. Such a feat was believed to raise national morale and confront the obstacles existing in foreign relations. The current international climate is littered with strained relations between major powers. More than ever, efforts of space exploration are serving as channels of optimism and cooperation towards a common human interest. Currently, NASA is involved with foreign agencies and their Mars exploration missions, particularly in the development of instrumentation.

The cooperative efforts of foreign space agencies with NASA substantially improve the overall science return from these missions. NASA scientists have joined with the Japanese Space Agency for the Nozomi project and the European Space Agency for their Mars Express mission. Joint projects such as these promote and encourage future engagements and partnerships, both on the level of mission involvement and in the exchange of professional experiences and capabilities.

In addition, international collaborations hold possibilities to enhance political and cultural understanding. NASA, the RSA, the ESA, and NASDA are all government agencies, and as such their cooperation implies some level of agreement among the
political leaders of their respective nations. Furthermore, participation in joint missions will impact the economies involved. As new technologies are developed, the job market will also be affected. Mixing members of different cultures and backgrounds on positive terms also leads to an education and understanding of each other. International collaboration symbolizes a unity of the world for the betterment of humankind.

5.3 Detriments of Mars Exploration

Numerous risks are assessed when planning any mission. Some are controlled by technological limitations. An example is the creation of spacecraft equipment that is as little vulnerable as possible to the affects of radiation. Other detriments may not be able to be avoided, such as the concern of forward contamination. Another category of the negative impact of the Mars program is the cost. Mission costs are virtually always mentioned in an argument against Mars exploration. Therefore, to sustain a balanced argument, the topic is discussed in this section.

5.3.1 Contamination, Back and Forward

Back contamination is the term for Earth being contaminated with Martian materials. Forward contamination is the contamination of Mars with Earthly materials. Concerning back contamination, Earth organisms have never been exposed to Martian organisms, so they would have no resistance to Martian pathogens. A similar circumstance exists for forward contamination. For many, not knowing exactly what type of cross-planetary reaction could or would take place is a very large concern. The
concern does tend to be more prevalent toward back contamination than forward, although precautions for both are heavily considered. These fears are valid concerns, and as such, much time and effort has been spent to ensure that exposure is minimized.\textsuperscript{74}

The exploration of Mars is far more affected by the drawbacks of forward contamination than back contamination. Since there has yet to be a manned mission to Mars or any samples returned, the disadvantages to back contamination are limited to cosmic events out of our control, Martian meteorite impact. According to Robert Zubrin, it is estimated that 500 kilograms of Martian rocks rain down on Earth every year\textsuperscript{75} because Earth is located directly in the path of Martian projectiles (the meteorites). Thus, Zubrin believes the statistical prediction that millions of tons of Martian material have been present on Earth for billions of years may be accurate.\textsuperscript{76} However, the rocks from Mars entering the atmosphere of Earth are altered. They are exposed to cosmic rays during their journey to Earth, are significantly heated during entry, and accumulate terrestrial materials upon impact and during their stay on Earth. This may possibly mean that, though present on Earth, the Martian meteorites pose no threat while pristine samples from Mars could. The likelihood of such an occurrence may never be known until a sample is returned, which makes back contamination a legitimate consideration.

Forward contamination is a more generic concern of many types of Mars exploration. Regardless of whether or not the mission is manned or samples are returned, forward contamination can occur anytime a spacecraft enters the Martian atmosphere. It is possible that terrestrial pathogens or elements are somehow undetected when the spacecraft is inspected and analyzed for cleanliness and sterility here on Earth. In 1967, an international agreement was established to monitor both forward and backward
contamination. Such agreements have grown to be more specific, and each outlines, specifically, the amount of particles that can be carried outside of the original environment so as not to affect other planetary bodies. If these elements survive the expedition to Mars, they may contaminate the surface. This can lead to faulty experimental results concerning its geology, false positives from tests for life, or they can threaten the life that may already exist there.

Despite the possibility that forward contamination could alter if not negate any findings when exploring Mars, it still holds true that the potential of discovering water, life, or even simply more data about the red planet to assist in knowing Earth better more than compensates the risk. In circumstances such as these in which the conclusions can be immense and the certainly is beyond crucial, numerous experiments are done. This aids in limiting the interference of forward contamination. Furthermore, as time passes and science improves, the sophistication of techniques to clean and sterilize spacecraft should increase. The goals of Mars exploration and the benefits outlined in previous sections extend beyond the limiting capabilities of the simple possibility that Earth materials, resilient enough to survive the journey to Mars, may interfere with some of the experiments conducted.

5.3.2 Radiation

Radiation factors, while extremely important for consideration, should not prevent the continuation of Mars exploration. It will, however, have a significant impact on spacecraft design and the monitoring of the crew during manned missions. The reasoning behind its extreme importance for consideration in unmanned missions is its
effect on instrumentation. The materials making up the spacecraft as well as the tools in
the payload must be able to sustain an environment containing more radiation than that
experienced on Earth. Otherwise, experimental results can again be greatly affected,
altered, and even ruined.

Missions to Mars are exposed to a continuous flux of Galactic Cosmic Rays
(GCR) and Solar Energetic Particles (SEP). The atmosphere and magnetic field of Earth
protect it from much of the sun”s radiation, but when things leave these protective layers,
radiation takes its toll. Radiation presents multitudinous obstacles to overcome in
mission and spacecraft design, such as navigation and communication issues, flight
trajectories, power, mass, and cost.

Radiation comes in three forms varying in consistency and intensity due to solar
activity: galactic radiation from outside of the solar system, solar particle radiation
coming from the sun, and geomagnetically trapped radiation surrounding Earth in the
plane of the geomagnetic equator.79 Space radiation effects in any form can not only
cause degradation to instruments and systems on board spacecraft but can cause complete
failure.

It is possible under certain specifications for spacecraft design, though, to limit
radiation exposure during transition from Earth to Mars. The Apollo spacecraft had walls
thick enough that the risks of serious health problems or malfunction of instrumentation
was minimal. Spacecraft going to Mars have to travel through the Van Allen Radiation
Belts that encircle Earth. This is done at a high velocity to help minimize the effects of
radiation.80 Despite these examples of limiting the exposure to radiation, it is a
significant detriment that extends even to flight performed on Earth. Cases have been
documented in which high-altitude commercial airliners flying polar routes within the atmosphere of Earth have reported avionic malfunctions linked to radiation events.\textsuperscript{81} The exploration of Mars is certainly contested by the presence, nature, and effects of radiation.

In some cases, the process of shielding instrumentation has more to do with designing equipment that will provide maximum failure tolerance from space radiation effects than designing to completely shield the equipment. Of course, this practice provides increased chances of mission success because the failure rate due to space radiation effects will be much lower. As a result, system down time would be much lower, which conserves money and resources.\textsuperscript{82}

For semiconductor microelectronics, the electric charge induced from space radiation is comparable to the charge moving within device circuits. Because of this, the state of the device can be changed. This can result in various types of transient or permanent single event effects (SEE) such as upset, latch-up, or burnout of the device. Particle interactions can also cause atoms to be displaced from the crystalline lattice producing cumulative degradation in the characteristics of the affected component. This is a large problem because solar panels use semiconductor solar cells, and their power is significantly impacted by SEP’s. Furthermore, ionizing particles can cause background noise in sensors and optical detectors. The effects can be mitigated in several ways. One method is error correction and the implementation of redundant circuit design. Another means is spot shielding, which can reduce SEP effects but is not effective to reduce those of GCR. A third technique utilized is oversized solar panels in order to compensate for radiation degradation over the mission life.\textsuperscript{83}
Broader societal concerns about radiation are also prominent because spacecraft often use nuclear material, usually Plutonium-238. This isotope is used in radioisotope power systems (RPS) to produce heat through natural decay. The concern is that if disasters, such as the Challenger or Columbia, occur and radioactive material is onboard the spacecraft, humans within the area of destruction will be adversely affected by the fallout. However, NASA has used radioisotope thermoelectric generators (RTG’s), an example of an RPS, in many missions dating back to 1961. The radiation given off by the RPS is a minimal amount; clothing and skin are thick enough to stop alpha particle radiation, and Plutonium-238 is used both for its efficiency and its safety value.

Adequate protection for the instrumentation and systems onboard the spacecraft is less of a concern than gaining adequate protection for manned missions. However, by further studying the radiation environment not only on Mars, but en route to Mars, a better understanding for how radiation affects Earth and life on Earth stands to be fostered. Research conducted on Mars” radiation environment could be crucial in understanding the future radiation effects on Earth. Given the fact that manned missions are still only a possibility much further in the future, radiation effects on the crew of a manned mission should not be a concern limiting the opportunities inherent to Mars exploration.

5.3.3 Financial Cost

The costs of the missions that have been planned for Mars, that have been successful, and that have failed, all vary significantly. Some examples of prices are $297 million for Mars Odyssey, a $150 million budget for Mars Express, and the projected
cost of $800 million for the Mars Exploration Rovers. With price tags for missions becoming higher and higher, Zubrin conveys his opinion that Congress has proceeded to zero out nearly every Space Exploration Initiative (SEI) bill that has crossed their desks.

Currently, because space exploration is not privatized, none of the funding for such a mission could come from private venture capital. This leaves the government agencies, such as NASA, to invest the money. This puts a different light on the amount spent because it is listed in the national budget. It is funding coming from the people of the nation. Given the length of time between the initiation of a Mars mission and the first case of results, public enthusiasm declines considerably. By better communicating the vast benefits and accomplishments of exploration and the value of them in relation to the time constraints, support for exploration could increase. This could alter the perception some have of the portion of the budget space agencies possess.

It is nearly impossible to quantify much of the work that is done by NASA and other space exploration agencies. So many of the advantages reaped by society at large are intangible, and sometimes they are even invisible to the average mind. By the same token, it is difficult to measure the public support of space exploration in comparison with the benefits. Arguably, the most important aspect of exploration is the human experience, which is something not seen, only felt. Similarly, the ideas, questions, and answers raised by exploration are crucial, but not touchable. The space exploration business must operate in a world where the demand is for immediate results. Such agencies cannot necessarily deliver instantaneous gratification from its undertakings.

The slow progress in comparison with the high cost greatly injures the potential of the Mars program in the minds of the general public. In the eyes of many people, the
problems of poverty, inner city decay, crime, social security, Third World hunger, and environmental deterioration are much more critical issues than exploring Mars. It is their belief that these domestic issues should be dealt with before appropriating money to NASA for the steeply priced missions to Mars. However, NASA’s budget for 2003 is $15 billion, which is less than 1% of the national budget. In comparison, the federal budget for welfare for 2001 was $35.8 billion, or about 2%. The defense budget comprised approximately 16% and social security saw 23%. Societal support of Mars exploration, manned or unmanned, is imperative to its realization.

As has been previously discussed, the desire for exploration and discovery is very basic to humankind. The puzzlement spawned by Mars, outer space, and whether Earthlings are alone in the universe has lived for ages. The possibility of finding an unambiguous answer to any of these questions is real. A deep, extensive exploration of Mars presents the possibility of supplying these kinds of answers. While knowing whether life on Mars does exist or not is relevant to the lives of most people, it does not tend to be a priority or constantly on one’s mind. However, gaining knowledge that the creatures on Earth may not be the only such beings would change lives forever. A price tag cannot be placed on life or discoveries that may alter it.

5.4 Linking Science and Technology to Society

The IQP challenges students to identify, investigate, and report on a topic examining how science and technology interacts with societal structures and values. The objective of the IQP is to enable students to understand, as citizens and as professionals,
how their careers will affect the larger society of which they are a part. The preceding sections on the benefits and detriments of Mars exploration explain the understanding the authors have gained from the research conducted. The information shows how society itself is linked to the technological and scientific tasks completed thousands of miles away. It was crucial to convey the favorable changes to the public perception of life, the world, and the universe that result from Mars exploration. This cause and effect relationship is a prime example of technology interfacing with society.

The magazine article written to gain support for Mars exploration was created as a convenient yet informative bridge between the technical professionals and the larger society of which they are a part in order to fulfill the designed plan for an IQP. It assists others in learning this connection between science and society. It targets the citizens not apt to search out such information, and it does so to maximize its impact.
Chapter 6: Conclusions and Recommendations

The most important conclusions that should be drawn from the research results for this IQP are the implications of its findings. It is a summation of both the presentation and interpretation of the results. It was also crucial to include a discussion of the difficulties and obstacles encountered during the compilation and composition of this project. The procedural and analytical limitations that were a part of this project affected the progress, the results, the ways in which they were interpreted, and the general direction of the project. Suggestions for future study and recommendations on how to follow up this project are also provided. This section is indicative of the authors knowing there remain many opportunities to elaborate on this project and that eight weeks is not long enough to research and convey all that there is to be gained from Mars exploration. Lastly, a concise description of the missions to Mars in the format of a table can be found in Appendix A. This table helps to succinctly cover the current state of affairs regarding Mars exploration discussed in the second chapter of this report.

6.1 Implications of Findings

On a scientific basis, it is necessary that Mars continue to be explored; there is too much at stake for the future of Earth, Mars, and all life, known and unknown, to do otherwise. Expecting to find anything more than what has been discovered already without continuing to passionately and enthusiastically explore Mars further is unreasonable. The knowledge that stands to be gained about life and planetary evolution is substantial; moreover, it is inevitable for unexpected discoveries to be made.
The risks facing the future of Mars exploration have been outlined. As it stands today, there are three main downfalls to Mars exploration. Forward contamination can pose adverse affects to the condition of Mars itself as well as the results of the experiments conducted on the surface. Radiation has similar detrimental affects by possessing the ability to damage instrumentation. It is also the subject of societal concern when radioactive materials are utilized on spacecrafts. The third barrier is the cost of the missions. It is believed by the authors of this IQP that these risks are outnumbered by the benefits of Mars exploration. Hopefully, with the propagation of this belief, public perception will change and cause an increase in congressional support.

A counterargument can be made against forward contamination that shows Mars exploration is worth this risk. First, NASA implements the most advanced techniques that it has available to sterilize and clean its spacecraft. Secondly, orbiters pose little threat to contaminate Mars with terrestrial elements. While landers and rovers pose a greater threat, those specific spacecraft collect data of importance outweighing the limited contamination given the focus on cleanliness and sterilization before deployment. It is important to continue traveling to Mars, collecting information, and trying to piece together the puzzle that is the search for life, answers to the mysteries of Earth, and the role humankind assumes in the Universe.

The societal concern that erupts at the very news of any radioactive material on board a spacecraft is primarily rooted in misinformation. The material used is safe and efficient. It is also housed in a very sturdy and protective casing, reducing any possibility of a mishap worthy of concern.
The affects radiation has on instrumentation, however, could pose a problem when performing the science portion of a Mars mission, as well as flight navigation and communication. On the other hand, the personnel in a position to confront this problem are aware of the complication and measures are taken to design and construct spacecraft capable of withstanding the harsh nature of radiation. Experiments are performed with knowledge and awareness of what radiation can do to affect procedures and results.

The negative impact of cost arises from a unique connection between NASA, the public, and the elected officials responsible for accepting the propositions of the space agency. It was discussed earlier in this report that as a governmentally funded agency, NASA depends on the opinions and support of the politicians elected by the public. However, the desires and directions of a political campaign can change from the time of election. Essentially, more power rests with the politicians deciding on a mission proposal than the citizens that elected them. It is critical to convince these individuals of why they must grant the funding for missions targeting Mars. The most important factors to the benefits of Mars exploration outweighing the financial cost are the intangible results of the missions.

The opportunity to fulfill an intrinsic human desire to explore and answer questions regarding the origin of humankind, whether or not it is alone in the Universe, and what its role is regardless is an immense benefit to exploring Mars. There can be no price tag on such possibilities. There are also practical benefits such as international collaboration and unity. Given what is known to be on the horizon of Mars exploration and what positive outcomes may exist, the answers awaiting humankind cannot be ignored.
Although there is public support for exploring Mars, the amount of support is not
great enough or diversified enough. NASA needs to put forth a better effort to reach the
general public in order to inspire, as their mission statement dictates. Otherwise, the
other objectives of the mission statement, to understand and protect the home planet and
to explore the Universe and search for life, cannot be achieved. To paraphrase Robert
Zubrin, we must go for the knowledge of Mars, for the knowledge of Earth, for the
challenge, for the youth, for the opportunity, for our humanity, and for the future.92

6.2 Procedural and Analytical Limitations

The majority of the work done for the Pre-Qualifying Project (PQP) was not
useful toward reaching the goals for this IQP. Once on-site at JSC, it was recommended
that the focus for the IQP be directed away from that of the PQP. As it turned out, the
PQP and the IQP proposal, which were initially expected to serve jointly as a working
platform, were not reflecting the goals and aspirations of those at JSC advising this
project. Illustrating the benefits of the astrobiological curation of Mars (and curation
from a physical standpoint, as was originally assigned to another IQP group) was not
what NASA had intended. Instead, it was found that this IQP would be more useful and
fulfilling to contribute to the public outreach efforts of NASA regarding Mars exploration
through a means not typically utilized, an article in a periodical. These tasks of
redirecting the research efforts and project goals served as procedural limitations by
preventing more time from being allocated to each subsequent task involved in carrying
out the IQP.
For the first two to three weeks on-site, a great deal of time was spent speaking with the on-site advisor, other colleagues, and visiting advisors from Worcester Polytechnic Institute (WPI). This is a relatively standard portion to an on-site project; however, this team was starting off with much less preparation completed due to the necessary redirection of the project. The continual conversations and meetings were held to confine the thoughts concerning which direction to go in and learn of personal interests of JSC employees in order to draft a new proposal. However, the authors of this IQP found themselves greatly interested in similar topics and had the most investment into the topic, methods, and goals of the project. Heavy consideration of the goals that define an IQP and what NASA could gain from such a project was taken into account during the decision making process. It was eventually determined that the main topic would be Mars exploration, encompassing the entire spectrum of how it could affect society. After this topic was decided upon, the means by which to connect the topic to society, as dictated by the definition of an IQP, had to be decided. Magazines reach a broad spectrum of people, and even though a specific demographic was not immediately determined, writing a magazine article to accomplish the intended goals was found to be well suited to both NASA and the personal abilities of the authors of this report.

The time frame for the completion of the project was narrowed considerably because so much time was taken to overhaul the project focus. The compilation of materials, both technical and analytical, followed this task nearly immediately. The research began shortly thereafter. Some of the research was rather difficult to interpret because the authors were so biased with regard to the information they supplied and their personal interpretation of it. In addition, most of the sources presented the risks involved
in manned Mars missions from the attitude that the risks are acceptable. It was difficult to locate materials that logically demonstrated a case against further Mars exploration. Most material of this variety was taken from sources that generally support Mars exploration, but in the sake of presenting a balanced argument, mention in some detail the reasons that Mars exploration is not supported by others. A strong attempt was made to read the material objectively.

The main goal of this project is to convey the importance of Mars exploration to a portion of the general public that is in many ways different from those undertaking the task. The outlooks and frames of mind of the individuals targeted for the article contrast to those of the authors of the article. This posed a complication when brainstorming the subject matter of the article. It was necessary to ponder what members of the public whom, unlike those conducting the project, do not become immediately interested and intrigued by space exploration would like to read and gain from a discussion about Mars exploration.

While conducting this project, another factor limiting both the ability to proceed and focus on the project occurred. On February 1, 2003, tragedy and devastation struck the space program. Space Shuttle Columbia broke up over Texas sixteen minutes before it was expected to return home to Kennedy Space Center in Cape Canaveral, Florida. After the initial shock subsided, it was unclear to what extent this tragedy would upset the development of the project, particularly since JSC was at the heart of all of the turmoil. Emotions were running on high for the entire group of WPI students, for the citizens of Texas and the rest of the world, and for the NASA community at large. Needless to say, progress was slowed for several days. The invitation to attend the memorial service held
on-site at JSC was taken advantage of out of respect and honor for the astronauts, their families, and the dreams for which they had risked their lives.

6.3 Recommendations for Future Study

After this experience of working at a NASA facility, it has become clear that not enough has been done to inform the general public of the projects and missions that have taken place. For example, of the group of WPI students on-site at JSC for this term, half of them have studied mechanical engineering with a concentration in aerospace. Despite their major, these students did not know about many of the projects undertaken at NASA. Considering that NASA projects are primarily public domain yet still not well known by students in the field, expecting the general public to be extremely informed, and furthermore supportive, is unrealistic.

Another issue that received attention was how well matched the students of this project were to the topic of this project. An important aspect of the IQP was effectively reaching the target audience. This audience is purposely not technical, which made it slightly more difficult to devise an article catering to their perspective. As engineering students, it was found that the authors thought in a manner more similar to employees of NASA than the intended reader. Given the fact that this project interested NASA because the results assisted the organization in reaching a portion of the public that it does not typically reach well, it originally served to be detrimental that the thought processes and perspectives of the authors and advisors are very similar. A recommendation for the future is to design a similar project for a team of both engineering and public relations students in order to see how results differ. This is not to
say that engineers are narrowly focused individuals. A blend of ideas from two contrasting camps of thought would simply be beneficial.

A more in depth study, perhaps with a series of articles to complement it, into the costs of Mars exploration and proposed solutions to combat the severity that this situation presents would be an appropriate complement to the work of this project. NASA has trouble communicating with the general public about Mars exploration, but there is far more to NASA than exploring the red planet. It is believed that the public may not know about other planetary exploration or the studies of robotics used in space. Both of these topics and many more stand to be explained, understood, and showcased just as Mars does. It is suggested that the goals of such a project as this be applied to other hidden, yet exciting, programs and endeavors being undertaken by NASA.
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Glossary

Acronyms

**COMPLEX** – Committee on Planetary and Lunar Exploration

**DS2** – Deep Space 2

**ERV** – Earth Return vehicle

**ESA** – European Space Agency

**GCMS** – gas chromatograph/mass spectrometer

**GCR** – Galactic Cosmic Rays

**IQP** – Interactive Qualifying Project

**ISA** – Italian Space Agency

**ISAS** – Institute of Space and Astronautical Science

**ISS** – International Space Station

**JPL** – Jet Propulsion Laboratory

**MARCI** – Mars Climate Orbiter Color Imager

**MGS** – Mars Global Surveyor

**MSR** – Mars Sample Return

**NASA** – National Aeronautics and Space Administration

**NASDA** – National Space Development Agency of Japan

**PMIRR** – Pressure Modulated Infrared Radiometer

**PQP** – Pre-Qualifying Project

**RPS** – radioisotope power system

**RSA** – Russian Space Agency
RTG – radioisotope thermoelectric generator

SEE – Single Event Effect

SEI – Space Exploration Initiative

SEP – Solar Energetic Particles

SPE – solar particle event

STI – Scientific and Technical Information

WEB – warm electronics box

WPI – Worcester Polytechnic Institute

Technical Terminology

Aerobraking – the use of atmospheric drag rather than onboard thrusters to reduce the velocity of a satellite or spacecraft.

Aerogel – a highly porous solid formed from a gel in which the liquid is replaced with a gas; comprised 99.8% of air, one thousand times less dense than glass, thirty-nine times more insulating than the best fiberglass insulation.

Aeronomy – the study of the upper atmosphere.

Alpha ray – a stream of alpha particles.

Astrobiology – exobiology, or space biology; the branch of biology that deals with the search for extraterrestrial life.

Astrophysics – the branch of astronomy that deals with the physics of stellar phenomena.

Big Bang Theory – a cosmological theory stating that the universe originated about 20 billion years ago from a violent explosion of a very small agglomeration of matter of extremely high density and temperature.

Chromatography – a process used for separating mixtures by differences in their absorbencies.

Climatology – the meteorological study of climates, their phenomena, and their causes.
Creationism – the belief that the creation of the universe and all living things is related in the Bible.

Darwinism – a theory of biological evolution developed by Charles Darwin stating that all species of organisms arise and develop through the natural selection of small, inherited variations that increase an individual’s ability to compete, survive, and reproduce.

Extant – still in existence; not lost, destroyed, or extinct.

Gamma ray – electromagnetic radiation emitted during radioactive decay having an extremely short wavelength.

Infrared – lying outside the visible spectrum at its red end.

Interactive Qualifying Project – a project required at WPI for an undergraduate degree; the goals are to explain the connection of technology and society and ensure the student understand the societal implications of his profession.

Ionization – the formation of or separation into ions by heat, electrical discharge, radiation, or chemical reaction.

Ionosphere – the outer region of the Earth’s atmosphere, containing a high concentration of free electrons.

Isotope Fractionation – the physical phenomenon that causes changes in the relative abundance of isotopes due to their differences in mass.

Lithology – the gross physical character of a rock or rock formation; the microscopic study, description, and classification of rock.

Magnetosphere – a region surrounding a planet, extending from several hundred to several thousand kilometers above the surface, in which charged particles are trapped, and the way they behave is dictated by the planet’s magnetic field rather than the solar magnetic field.

Mass spectrometer – an instrument for obtaining a mass spectrum by deflecting ions into a thin slit and measuring the ion current with an electrometer, an instrument for measuring voltage.

Morphology – the branch of biology that deals with the structure of plants and animals.

Occultation – the passage of a celestial body across a line between an observer and another celestial object.
**Opacity** – the quality of a body which renders it impervious to rays of light.

**Organic compound** – a compound of carbon and any other element.

**Oxidize** – to increase the positive charge of an element by removing electrons.

**Payload** – the total weight of instruments, life-support systems, equipment, and crew in a spacecraft.

**Planetology** – the branch of astrology that deals with the planets of the solar system.

**Petrology** – a branch of geology that deals with the origin, composition, structure, and alteration of rocks.

**Phylogeny** – the evolutionary development and history of a species.

**Pre-Qualifying Project** – a small project required by WPI to prepare for the IQP; background information is collected, and a proposal that includes details regarding the expected methodology and results is made.

**Radioisotope** - A naturally or artificially produced radioactive isotope of an element.

**Radiometer** – an instrument that detects electromagnetic radiation; an instrument that measures the mechanical effect of radiant energy.

**Solar array** – a large assortment of connected solar cells.

**Solar particle event** – a rapid increase in the flux of energetic particles lasting from several hours to several days; occurs in association with solar flares.

**Spectrometer** – an instrument that measures wavelengths or indices of refraction.

**Tectonism** – the structural behavior of an element of Earth’s crust; crustal instability.

**Telemetry** – the science and technology of automatic measurement and transmission of data by wire, radio, or other means from remote sources, as from space vehicles, to receiving stations for recording and analysis.

**Terraform** – to transform another planet to have the characteristics of Earth.

**Thermoelectric generator** – any machine that converts mechanical energy into electrical energy by use of electrical phenomena occurring in conjunction with a flow of heat.
**Topography** – graphic representation of a surface and its features indicating their relative places and their elevations.

**Trajectory** – the planned path of a spacecraft.

**Ultraviolet** – lying outside of the visible spectrum at its violet end.

**Van Allen Belt** – either of two zones of high-intensity particulate radiation trapped in Earth’s magnetic field and surrounding the planet, beginning at an altitude of about 800 kilometers and extending tens of thousands of kilometers into space.

**Volcanism** – volcanic force or activity.
Appendices

Appendix A: Summary Table of Mars Missions

<table>
<thead>
<tr>
<th>Mission</th>
<th>Agency</th>
<th>Launch</th>
<th>Arrival</th>
<th>Vehicle</th>
<th>Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mariner 3</td>
<td>NASA</td>
<td>11/05/64</td>
<td>Failed</td>
<td>Orbiter</td>
<td>Study solar wind and dust; measure protons in 3 different energy ranges; measure ionization by charged particles</td>
</tr>
<tr>
<td>Mariner 4</td>
<td>NASA</td>
<td>11/28/64</td>
<td>07/14/65</td>
<td>Orbiter</td>
<td>Study cosmic dust, plasma, radiation, cosmic rays, magnetic fields, celestial mechanics, radio occultation</td>
</tr>
<tr>
<td>Mariner 6</td>
<td>NASA</td>
<td>02/24/69</td>
<td>07/31/69</td>
<td>Orbiter</td>
<td>Measure atmosphere by infrared radiometry, ultraviolet and infrared spectrometry</td>
</tr>
<tr>
<td>Mariner 7</td>
<td>NASA</td>
<td>03/27/69</td>
<td>08/05/69</td>
<td>Orbiter</td>
<td>Study climatology, atmospheric conditions</td>
</tr>
<tr>
<td>Mariner 8</td>
<td>NASA</td>
<td>05/08/69</td>
<td>Failed</td>
<td>Orbiter</td>
<td>Study composition, density, pressure, and temperature of the atmosphere; study composition, temperature, and topography of surface</td>
</tr>
<tr>
<td>Mariner 9</td>
<td>NASA</td>
<td>05/30/69</td>
<td>11/13/71</td>
<td>Orbiter</td>
<td>Map surface; return close-up images of Phobos and Deimos</td>
</tr>
<tr>
<td>Viking 1</td>
<td>NASA</td>
<td>08/20/75</td>
<td>06/19/76; 07/20/76</td>
<td>Orbiter, lander</td>
<td>Search for life w/ 3 bio experiments; study atmospheric conditions; metabolic processes</td>
</tr>
<tr>
<td>Viking 2</td>
<td>NASA</td>
<td>09/09/75</td>
<td>08/07/76; 09/03/76</td>
<td>Orbiter, lander</td>
<td>Complement to Viking 1</td>
</tr>
<tr>
<td>Mars Observer</td>
<td>NASA</td>
<td>09/25/92</td>
<td>Failed</td>
<td>Orbiter</td>
<td>Study structure, aspects of atmosphere, volatile material, dust, topography; measure elemental, mineralogical composition of surface</td>
</tr>
<tr>
<td>Mars Global Surveyor</td>
<td>NASA</td>
<td>11/07/96</td>
<td>09/12/97</td>
<td>Orbiter</td>
<td>Study surface from low orbit, atmosphere, interior; observe temp. data of Phobos</td>
</tr>
<tr>
<td>Mars 96</td>
<td>RSA</td>
<td>11/11/96</td>
<td>Failed</td>
<td>Orbiter, rover</td>
<td>Search for liquid water; study surface, inner structure, atmosphere, solar wind</td>
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<tr>
<td>Mars Pathfinder</td>
<td>NASA</td>
<td>12/04/96</td>
<td>07/04/97</td>
<td>Lander, rover</td>
<td>Study geology</td>
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<tr>
<td>Mission</td>
<td>Agency</td>
<td>Launch</td>
<td>Arrival</td>
<td>Vehicle</td>
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<tr>
<td>Nozomi</td>
<td>NASDA</td>
<td>07/03/98</td>
<td>Failed</td>
<td>Orbiter</td>
<td>Study structure, composition, dynamics of ionosphere; affects of solar wind, magnetic field, dust on upper atmosphere</td>
</tr>
<tr>
<td>Mars Climate Orbiter</td>
<td>NASA</td>
<td>12/11/98</td>
<td>Failed</td>
<td>Orbiter</td>
<td>Take daily high-res atmospheric weather, surface images; measure water vapor, atmospheric temp, dust concentration</td>
</tr>
<tr>
<td>Mars Polar Lander/Deep Space 2</td>
<td>NASA</td>
<td>12/03/99</td>
<td>Failed</td>
<td>Lander</td>
<td>Study properties of subsurface at south pole, mineral composition, phase at which water exists</td>
</tr>
<tr>
<td>Mars Odyssey</td>
<td>NASA</td>
<td>04/07/01</td>
<td>10/24/01</td>
<td>Orbiter</td>
<td>Study composition of surface, radiation environment; measure hydrogen levels in 1 m of top soil</td>
</tr>
<tr>
<td>Mars Exploration Rovers</td>
<td>NASA</td>
<td>05/03 - 07/03</td>
<td>01/04</td>
<td>Rover</td>
<td>Study geology, climatology; search for evidence of life</td>
</tr>
<tr>
<td>Mars Express</td>
<td>ESA, ISA, NASA</td>
<td>06/03</td>
<td>12/03</td>
<td>Orbiter, rover</td>
<td>Search for life; high-res surface images; map mineral composition of surface; study effect of solar wind on the atmosphere</td>
</tr>
</tbody>
</table>

Figure 10. Summary Table of missions to Mars.
Appendix B: Proposed Magazine Article for Publication

*Mars, the Next Endeavor*

The desire to go to Mars simply for the science and technology that would result is not enough. Some of the most precious things in life are not tangible. Mars has the potential to answer pertinent questions that exist in society’s mind, the answers to which could change our lives. The challenge of exploration and discovery is frightening, but human beings are incredible vaults for courage to defy fear and accept challenge. We stand to challenge our intelligence, our pursuit of knowledge, and our craving for understanding by exploring Mars.

It is much more than merely a desire that drives human beings to explore, to seek, and to search for meaning and knowledge. It is an inherent and instinctual curiosity common to all humans to discover and hunt for a means to understand the mysterious. An infinite curiosity seems to govern part of man’s brain, a facet of his genetic heritage.

It started a long time ago when one of our ancestors had an intense desire to find out what was on the other side of a mountain. Exploration is an extremely personal experience that provokes a wide variety of emotions. Some things cannot be seen or heard, only felt. The impulse to climb a mountain to see what is on the other side is distinctly human.

The nature of exploration insinuates a lack of knowledge. Standing at the beginning, there is no way of knowing what the end result will be. The destination is the search itself. To understand where and how each person fits into the Universe despite having few or no theories as to what might be found is a task for the ages. Seeking to understand where and how each of us fits into the Universe, regardless of the answers,
serves as the destination itself, not the means by which we will reach an end. The only thing we know that we will find for sure is more questions.

To fully understand the benefits of exploration you have to be a student of exploration. Every great nation and power of the past has possessed a strong will and desire to explore and discover. We admire those that take the risk to do something amazing, the explorers, because it requires the audacity to do what has never been done. Even if success is not the outcome, there is a lot to be gained. Christopher Columbus failed to find a western route to the Indies, but without his mistake, the world would be a radically different place. A lack of inclination on the part of Lewis and Clark to explore the western frontier would have also greatly altered the world. Exploration leads to discovery, and discovery leads to greatness. Humans are, by nature, explorers, adventurers, and conquerors of frontiers. Mars is the next frontier.

Imagine you have just woken up in darkness after an especially bumpy landing. You slowly start to break free of your groggy state of being and remember that you are no longer on Earth. Your name is Pathfinder and you have been hibernating in space for seven months. The ride was not first-class, nor was it even on par with a coach-class seat. It was much more like traveling in the cargo bay; your forehead was pushed up against the solar panels, the rover was crammed against your left ear, the antenna was stabbing at your ribs, and the parachute canister? You were lying directly on top of it. You’ve been promised a landing in one of the most exotic places in the Universe; it is the flood delta of an ancient valley named Ares, a huge and expansive canyon. It’s very strange for you because you are all by yourself except for your friend Sojourner. The exotic place is an entire planet where, as far as you know, no one else has ever gone.
Suddenly, you open your eyes for the first time and see a landscape of bright orange and red colors; dirt, dust, and rocks continue as far as the eye can see. Next, you spot your foot out of the corner of your eye and you feel better having seen something familiar. Then, you start to work. This is the story of the Pathfinder lander and its rover, Sojourner, brought from Earth to Mars.

In many cases, passionate aspiration and hard work does pay off, and the benefits are realized. Society has gained masses of scientific and technological innovations that have come out of space exploration. Many of these developments make our daily lives much easier and better, but often the most meaningful things in life are not tangible. Pathfinder has not been the only mission that has been sent to Mars, and certainly, it will not be the last. It didn”t do very much science, but what it surely did do was captivate the world”s attention. Then why go if the amount of science being done is not great? Not all missions are of the same design as Pathfinder, but what”s more, we should go because it”s there. The challenge alone beckons us.

We explore other worlds so that we may better understand our own. Our drive to explore outside of our own world is to seek and find the place where we belong in the Universe. Given that Mars is the most similar of all the planets to Earth, it houses the most potential to allow us to understand our own planet and the Universe at large. Only by understanding the history of Earth and the Universe can the future of either possibly be accurately predicted. Exploring Mars is the most logical step toward gaining that understanding, especially since the question of life on Mars has existed in the human psyche for such a long time, and the desire to have the answer has existed for nearly as long.
Clues to the answer about life on Mars were stumbled upon in 1995. Two NASA scientists in a lab in Houston were studying a Martian meteorite that had been collected from Antarctica. The scientists were familiar with studies similar to those that they were running, but there was something different about this one. They realized that what they were looking at was possibly a fossil showing compelling signs that life might have existed at some point on Mars. These two men had made a life-altering discovery in the lab that day… and they couldn’t tell anyone about it. For nearly two years, they held this information within, all the while seeking to disprove themselves, day after day. While the information that was uncovered cannot be taken as conclusive proof that life once existed on Mars, it is quite persuasive and changed our thinking considerably. As the great astronomer, Carl Sagan, once said, “Absence of evidence is not evidence of absence.” Whether we actually believe that there is Martian life or not, the idea is more firmly planted than ever before.

The idea that there may be other beings in Universe is tremendously powerful. But what if we are all alone? The need to explore the beginnings of our lives is a natural desire encoded in the human spirit. Although we cannot be distinctly positive whether Mars can tell us about ourselves or other beings, it being the planet most like Earth leads us to believe that if ever we were to find answers, they would come from Mars. Mars’’ unexplored surface stands to hold riches and resources for future humanity - wonders for our eyes to behold and our minds to embrace. Scientists are still compelled to continue learning about the only known specimen of life in the Universe – terrestrial life – to be more capable to understand Mars. It is important that this not hinder the development of
Mars exploration because, as renowned physicist, Stephen Hawking, said, “To confine our attention to terrestrial matters would be to limit the human spirit.”

He who stands still ceases to exist. Just as naturally as we have learned to walk after we learned to crawl, we learned to fly after we learned how to pedal a bicycle. We were compelled to traverse the seas; we were driven to conquer the skies. If we stop exploring now, our past efforts will be in vain. We stand to gain so much more than we stand to lose by following our natural, intrinsic instincts for exploring the unknown. It is our destiny to discover. It is our destiny to explore Mars.
Appendix C: *Earthrise* and *Blue Marble* Photographs

The following photographs were mentioned in section 3.2 for their positive societal impact. Despite not resulting from Mars exploration, these photographs are proof that a humanistic view, not just a technical view, can have immense power. If the sight of all humankind can inspire awe, then humankind can only begin to imagine what the knowledge of extraterrestrial life could create. This knowledge can never come about without further exploring Mars.

![Earthrise Photograph](image)

**Figure 11.** The very first manned flight to leave the orbit of Earth, Apollo 8, took this photograph, *Earthrise.*
Figure 42. This photograph, *Blue marble*, was taken on December 7, 1972. It is provided by the crew of Apollo 17.
**Endnotes**


42 Judy Redfearn, “Mars Express: Europe Goes to Mars!” Eds. Bruce Battrick and Monica Talevi, 16.

43 Judy Redfearn, “Mars Express: Europe Goes to Mars!” Eds. Bruce Battrick and Monica Talevi, 16.


45 Malcolm Walter, The Search for Life on Mars, 141.

46 Karen McNamara, Personal interview, 10 Jan. 2003, Johnson Space Center, Houston, TX.


