Robots on Mars

Wilson Hibbs

Junior Division

Historical Paper

Paper Length: 2,492 Words
Robots on Mars

Without robotic space exploration, humans wouldn’t know anything about the solar system surrounding them beyond what can be seen through telescopes. Robots break the literal barrier of the Earth’s atmosphere and the metaphorical barrier of knowledge.

If Earth became uninhabitable, knowledge of other planets, particularly ones as close as Mars, would be of utmost importance. Robots can explore dangerous planets without risking human casualties, and they can incorporate multiple scientific instruments that humans can’t.

The people who design these robots “are optimistic, can-do, hopeful, bright, and sometimes quite lucky.”\(^1\) Scientists such as Robert Manning and Roger Wiens are constantly upgrading these robots to do more jobs and break more barriers.

Robots have been used on Mars since 1960, when the Soviet Union attempted to launch Marsnik 1. However, this paper is going to focus on robots from the time of the Mars Sojourner rover’s launch in 1996 to the Mars Curiosity rover’s most recent findings in 2018. In this period of 24 years, so many robots have been sent to Mars that this paper can only cover a fraction of them.

\(^1\) Manning, Robert *Foreword: Destination Mars* 11
Sojourner

“Faster, better, cheaper”\(^2\) was the slogan that led scientists to send the first rover to Mars. The idea was to build a cheap, yet functioning, robot that could be sent onto another planet. For this particular project, it worked beautifully.

Today, the Sojourner rover is considered to be a “miniscule technology demonstration vehicle.”\(^3\) However, when it was first launched in 1996, it was important because it was “the first-ever robotic rover to the surface of the red planet.”\(^4\) After it landed in 1997, it found rounded pebbles, possible riverbeds, and metallic dust. Additionally, it discovered that the weather on Mars included dust storms and dust devils.

Sojourner included five instruments. They were an *Alpha Proton X-Ray Spectrometer*, an *Atmospheric Structure Instrument/Meteorology Package*, and three cameras. The Alpha Proton X-Ray Spectrometer’s job was to determine what various rocks and soils were composed of. The Atmospheric Structure Instrument measured temperature conditions and conditions of Mars’ atmosphere. The cameras took pictures of the martian terrain and transmitted them back to Earth.

Each of these instruments were revolutionary in their own way. Not being able to build instruments that could survive on another planet and transmit their findings back to Earth had been a barrier for scientists for years. Now, it had been broken.

\(^2\) NASA FBC Task Final Report [mars.nasa.gov/msp98/misc/fbctask.pdf](http://mars.nasa.gov/msp98/misc/fbctask.pdf)
\(^3\) Wiens, Roger Inside the Story of Robotic Space Exploration, from Genesis to the Curiosity Rover 98
\(^4\) Pathfinder [mars.nasa.gov/programmissions/missions/past/pathfinder/](http://mars.nasa.gov/programmissions/missions/past/pathfinder/)
Robert Manning led the entry, descent and landing-- or EDL-- of Sojourner. He worked on several other missions to Mars as well, and eventually became the chief engineer of the Curiosity rover in 2011.\(^5\)

The Sojourner rover was part of the Discovery mission cycle, which was launched in 1994. It allowed smaller companies to build robots to be sent to space. NASA would speak with the people who submitted the project and provide feedback. When all the submitted robots were completed, NASA would choose one to be sent to space. The Discovery mission cycle launched multiple robots into space.

**Mars Polar Lander**

On December 3, 1999, the Mars Polar Lander team sat in a room, staring at a screen which would determine the fate of the entire mission. The entire team was on their toes in anticipation as they watched. If there was a spike in the radio frequency, it meant that the lander had made it. If not, all of their hard work would be destroyed.

"Mars Polar Lander was an ambitious mission to set a spacecraft down on the frigid terrain near the edge of Mars' south polar cap and dig for water ice with a robotic arm. Piggybacking on the lander were two small probes called Deep Space 2 designed to impact the Martian surface to test new technologies."\(^6\)

After several minutes of waiting, the time arrived.

The frequency didn’t spike.\(^7\)

---

\(^5\) Manning *Mars Rover Curiosity* 11

\(^6\) *Mars Polar Lander* mars.nasa.gov/programmissions/missions/past/polarlander/

\(^7\) Manning *Mars Rover Curiosity* 16
The mission had failed.

Over the next six years, “searches by various Mars orbiters [didn’t] find any sign of the lander. No wreckage, no artificial crater.” It wasn’t until 2005, when NASA scientist Mike Malin reexamined photos from previous years and found what appeared to be the wreckage of the lander, that the lander was found.⁸

“Faster, better, cheaper.” It had worked so well in 1996. This was now far from true.

**Spirit and Opportunity**

Mars Polar Lander had been a failure, but after a few successful missions that weren’t to Mars, NASA was doing well again. It was time to try again with the red planet.

In 2004, NASA and its Jet Propulsion Laboratory (JPL) decided to launch a pair of exploration rovers called Spirit and Opportunity. "With far greater mobility than the 1997 Mars [Sojourner] rover, they... trekked for miles across the Martian surface, conducting field geology and making atmospheric observations. Carrying identical, sophisticated sets of science instruments, both rovers... found evidence of ancient Martian environments where intermittently wet and habitable conditions existed."⁹

Both Spirit and Opportunity exceeded their planned 90 day lifetimes by a lot. Opportunity lasted until 2018, and Spirit sent its last message to Earth in 2010.¹⁰

---

⁸ Manning *Curiosity* 16
⁹ *Mars Polar Lander Found at Last?* skyanettelescope.org/astronomy-news/mars-polar-lander-found-at-last/
¹⁰ *Mars Exploration Rovers* mars.nasa.gov/mars-exploration/missions/mars-exploration-rovers/
¹¹ *Mars Exploration Rovers* mars.nasa.gov/mars-exploration/missions/mars-exploration-rovers/
broke the record for farthest distance traveled by a Mars rover in 2015 when it rolled farther than 26 miles.\textsuperscript{12}

\section*{Phoenix}

In 2007, the Discovery program launched Phoenix, a Mars lander that was designed to do what Mars Polar Lander did, but better. "Phoenix used a lander that was intended for use by 2001's Mars Surveyor lander prior to its cancellation. It also carried a complex suite of instruments that were improved variations of those that flew on the lost Mars Polar Lander."\textsuperscript{13} Phoenix, unlike Mars Polar Lander, actually succeeded.

“Phoenix landed farther north than any previous mission, at a latitude equivalent to that of northern Alaska. During the course of its three-month mission, Phoenix dug into an ice-rich layer near the surface. It checked samples of soil and ice for evidence about whether the site was ever hospitable to life.”\textsuperscript{14}

Phoenix collected samples using a robotic arm and analyzed them using tiny ovens as well as portable laboratories. It scanned the martian atmosphere, dust particles, fog, and ice.

Phoenix’s main job was to find out if it had ever been possible to live on Mars. It used samples of soil and ice obtained from the arctic plains of Mars to do this. In “an ice rich layer near the surface[,] it checked soil and ice,”\textsuperscript{15} finding that Mars may have one day been hospitable to life. This led scientists to begin work on their most ambitious project yet: a massive rover that would come to be called Curiosity.

\begin{thebibliography}{9}
\bibitem{12} Mars Exploration Rovers \url{mars.nasa.gov/mars-exploration/missions/mars-exploration-rovers/}
\bibitem{13} Mars Phoenix \url{mars.nasa.gov/mars-exploration/missions/phoenix/}
\bibitem{14} Mars Phoenix \url{mars.nasa.gov/mars-exploration/missions/phoenix/}
\bibitem{15} Mars Phoenix \url{mars.nasa.gov/mars-exploration/missions/phoenix/}
\end{thebibliography}
Curiosity

Right after Spirit and Opportunity were launched, scientists at NASA and JPL began work on what would become the most advanced Mars rover yet. It was decided that Robert Manning, who had worked on Sojourner, Mars Polar Lander, Spirit, and Opportunity, would be the leader of the project.

Curiosity was gigantic compared to any other rover that had been sent to Mars. Its 899 pound frame positively dwarfed Sojourner’s 23 pound one\(^\text{16}\), and it was almost twice as large as the exploration rovers.\(^\text{17}\)

Similar to the Discovery program, this project would allow people from smaller companies and universities to design instruments and send them in. The best of these instruments would go on the Curiosity rover and be sent to Mars.

Roger Wiens, a geochemist who had played a key role in building the Genesis probe, a mission to the sun, teamed up with several other scientists to design ChemCam. ChemCam was an instrument that would use lasers to study rocks, minerals, and the general Martian terrain.

Work on ChemCam had begun with Dave Blake. When he invited Wiens to work on the project, he explained that "Zapping a rock of another composition [with a laser] produced a spectrum with a different mix of colors."\(^\text{18}\) This would help to identify items on Mars by means other than just looking at them from Earth.

\(^\text{16}\) Mars Pathfinder mars.nasa.gov/mars-exploration/missions/pathfinder/
\(^\text{17}\) Mars Exploration Rovers mars.nasa.gov/mars-exploration/missions/mars-exploration-rovers/
\(^\text{18}\) Red Rover Wiens 70
Wiens joined the project, along with many other scientists. NASA even teamed up with the French space agency to maximize the outcome.\(^\text{19}\)

Of course, ChemCam was not the only instrument on the rover. Mike Malin, who had discovered the wreckage of MSL, worked with Ken Edgett to design the mast camera, called MastCam, and another camera, called *Mars Hand Lens Imager*, or MAHLI. Paul Mahaffy was in charge of an instrument called *Sample Analysis at Mars* (SAM). Ralf Gellert, from the Max-Planck-Institute for Chemistry in Mainz, Germany, was in charge of the *Alpha- Particle-X-ray- Spectrometer*, (APXS)\(^\text{19}\)” Donald Hassler from Southwest Research Institute, led the *Radiation Assessment Detector*, (RAD) Dave Blake, who had started Roger Wiens on ChemCam, led his own laser instrument, called *CheMin*. Igor Mitranov from the Space Research Institute in Russia, led the *Dynamic Albedo of Neutrons*, or *DAN*. The rover team, led by Robert Manning, designed the rover itself and placed the instruments.

There was definitely a lot of tension between the people building the instruments, such as Roger Wiens, and the people designing the rover, such as Robert Manning. One of the biggest issues was when Wiens’ team wanted the cable connecting their instrument to the rover as short as possible, and they wanted it close to the mast.

Transmissions sent through the cable could be lost, and connectors would lose even more. However, “In spite of [Wiens’] attempted explanations, the rover team wanted at least four connectors along the fiber and... they still had not moved the spectrometers any closer to the mast.”\(^\text{20}\)

\(^{19}\) *Red Rover* Wiens 98

\(^{20}\) *Red Rover* Wiens 114
JPL’s reasoning was that “otherwise it would be extremely difficult to remove and reinstall, which has to be done often during the process of assembling, testing, rearranging, and so forth that goes on throughout the later stages of getting a spacecraft ready.”\textsuperscript{21} JPL believed that the connectors were necessary.

The issue was resolved when Roger Wiens and other ChemCam workers presented the issue to an audience. The audience agreed with Wiens and ended up arguing with JPL for a week “As the project progressed…[they] started seeing [their] common goals.”\textsuperscript{22} By the end of the week, JPL no longer required ChemCam to include any connectors.

After that, things got a lot easier. The different projects met most of their deadlines. There were still plenty of issues, but nothing big enough to truly worry about. However, there was still one massive obstacle to come.

In 2007, when ChemCam was just $1.5 million dollars over budget, it was canceled. When Wiens first got the news, his initial response was “You’ve got to be kidding!”\textsuperscript{23} While they had gone over budget, canceling the project would waste $10 million for the United States government, and even more for France. It seemed insane.

Everyone at JPL, including Manning, “knew how important the project was [and] had a hard time pulling the plug.”\textsuperscript{24} However, they simply did not have enough money to fund the project.

Despite being canceled, Wiens still had some money left in the bank, and continued building ChemCam, just in case another opportunity came up.\textsuperscript{25}

\textsuperscript{21} Mars Rover Curiosity Manning 83-84
\textsuperscript{22} Red Rover Wiens 116
\textsuperscript{23} Red Rover Wiens 130
\textsuperscript{24} Mars Rover Curiosity Manning 84
\textsuperscript{25} Red Rover Wiens 133
Meanwhile, Ken Edgett and his team were still designing MAHLI, the main camera that would be used on the rover. Ken Edgett had worked on the Viking probes, which had been sent to Mars in 1978, well before Sojourner. He had also worked on the Mars Global Surveyor, a Mars orbiter. These missions had provided him with information on what types of rocks, minerals, and geological formations his camera needed to be able to capture on Mars. He designed MAHLI to photograph evidence of possible martian life.

CheMin, SAM, DAN, MastCam, and all the other instruments were being built, slowly but surely. It seemed that the so far unnamed rover would be nearly perfect. The only thing that was missing was ChemCam.

When ChemCam had first been cancelled, JPL had supplied the team with a cable to connect the French pieces with the American pieces. A month later, they were ready to use it.

Bruce Barraclaugh, ChemCam’s project manager, watched as the French and American pieces were connected with JPL’s cable. “Something went very wrong; the current spiked… there was a sickening smell of smoke.” JPL’s bad cable had destroyed the system.

It seemed for the third time since the ChemCam project had begun that it would never succeed. However, Wiens and his team persevered. JPL acknowledged that the bad cable was their fault, and helped to repair the system. Together, the team managed to order a new cable and fix the system.

Perhaps they felt guilty about the bad cable, or perhaps they were actually acknowledging that ChemCam would drastically improve Curiosity’s performance on Mars, but once ChemCam

---

26 Viking 1&2 [mars.nasa.gov/mars-exploration/missions/viking-1-2/]
27 Mars Rover Curiosity Manning 86
28 Red Rover Wiens 134
29 Red Rover Wiens 134
had been fixed JPL allowed it to return to the rover. It seemed that things were finally coming together.

The different teams independently completed their projects. By 2011, the rover had been assembled.

All that remained was to launch it… and somehow land it, millions of miles from Earth.

On August 6, 2012, everyone gathered in the JPL Command Center. Roger Wiens, the geochemist who had led ChemCam, was there. Ken Edgett, the man who had played a part in constructing two cameras, was there. Dave Blake, the man who had introduced Wiens to laser technology, was there. Robert Manning, the leader of the entire project, was there. It was the day that the Curiosity rover was to land on Mars.

“It takes fourteen minutes or so for the signal from the spacecraft to make it to Earth [it takes about half that time for a rover to land]… so when [they] first [got] word that [Curiosity had] touched the top of the atmosphere, [it was] either alive or dead on the surface for at least seven minutes.”

After the news that the rover had been dropped from the rocket, every person who had played even the smallest role in creating the rover bristled with anticipation. In the same room as Wiens, the scientists who were in charge of “Entry, Descent, and Landing” (EDL) started chanting “EDL! EDL!” All of the work that had gone into this rover could be destroyed, and they wouldn’t know until the alleged “seven minutes of terror” were over.

Wiens looked at the clock and announced to the room that the rover had landed. The seven minutes of terror had begun.

---

30 Seven Minutes of Terror www.jpl.nasa.gov/video/details.php?id=1090
31 Red Rover Wiens 209
The anticipation grew and grew as it got closer and closer to the end of the seven minutes. Edgett, Blake, Wiens, Manning, and everyone else were all terrified. Nearly everyone went deathly silent until the news came through to the control room. Curiosity had landed. The mission was a success.

Epilogue

Since its landing in 2012, Curiosity has made a plethora of discoveries, including that Mars was habitable for life around 3.5 billion years ago.\textsuperscript{32} Whether there actually was life in that time remains a mystery, another barrier. The robots before Curiosity paved the way for Curiosity to be built, and, in turn, Curiosity is paving the way for humans to land on Mars themselves. Thanks to robots, that barrier can soon be broken.

\textsuperscript{32} Organic Molecules Found on Mars Indicate Possible Past Life There newsela.com/read/mars-rover-makes-discovery/id/44181/?collection_id=339
Primary Sources


Robert Manning was the lead scientist on the Curiosity Mars rover. He teamed up with best selling author William L. Simon to write this book about how Curiosity was built and some of what it found. These discoveries included completely unexpected chemicals in the volcanic rocks on Mars, and incredibly detailed crystallography of some Martian minerals. Manning also worked on the Mars Pathfinder rover, and he includes information about it in this book as well. This book provides relevant, up to date information.


Robert Manning was the Mars Science Laboratory Project Chief Engineer. He worked on multiple Mars missions, and wrote the Foreword of this book.

"Seven Minutes of Terror." *Nasa.Gov*, NASA, 22 June 2012, www.jpl.nasa.gov/video/details.php?id=1090. This video was released by NASA's Jet Propulsion Laboratory and details the seven minutes of terror as Curiosity entered the Martian atmosphere. It explains all the things that could go wrong, and all the things that scientists did to ensure Curiosity's success.

*Space.Com*. 7 Aug. 2012, www.space.com/16936-mars-rover-curiosity-first-landing-photos.html. This website provided several primary source images from Curiosity's camera on Mars. It did not have much information on Curiosity itself, but it did provide primary sources that
were from Curiosity that showed the quality of the images, and labeled each image for its scientific importance.

Wiens, Roger. *Red Rover: Inside the Story of Robotic Space Exploration, from Genesis to the Curiosity Rover*. New York, Basic Books, 2013. Roger Wiens, the author of this book, was a geochemist who worked at NASA. One of his biggest projects was ChemCam, a laser instrument that was used on the Curiosity rover. The book was written recently enough to provide relatively up to date information. However, the Curiosity rover is still on Mars, so it has made discoveries since 2013, when this book was written.

**Secondary Sources**


newsroom.cisco.com/feature-content?type=webcontent&articleId=1804946. Laurence Cruz, a freelance writer from Los Angeles and the author of this article, has worked for multiple reliable newspapers. These include The Associated Press (Seattle, Washington) and The Statesman Journal (Salem, Oregon).


the reliable Agence France-Presse newspaper explains how the Mars Curiosity Rover discovered evidence of organic material on Mars. It was adapted by Newsela, a reliable learning website, to make it more understandable. It was only published about a year ago, making it a very reliable source.

JPL.Nasa.Gov. www.jpl.nasa.gov/missions/mars-pathfinder-sojourner-rover/. Accessed 28 Aug. 2019. This article talked about Sojourner, the first rover ever to go to Mars. It was published by JPL (the Jet Propulsion Laboratory at NASA), so it is reliable.

Nasa.gov. 10 May 2011, nssdc.gsfc.nasa.gov/planetary/discovery.html. Dr. David Richard Williams is an astrologist and scientist at NASA. He wrote this article, which provides information about the Discovery program. As he works with NASA, he is a reliable source. This article is recent enough to speak of eleven different missions sent into space by the Discovery program.

"Programs and Missions: Past." Nasa.Gov, mars.nasa.gov/programmissions/missions/past/. Accessed 29 Aug. 2019. This web page is basically NASA's database for information on robots that went to Mars. It includes links to articles about Mariner 3-4, Mariner 6-7, Mariner 8-9, Viking 1-2, Mars Observer, Mars Global Surveyor, Pathfinder, Climate Orbiter, Polar Lander/Deep Space 2, Phoenix, and the Spirit and Opportunity rovers. It is from nasa.gov, NASA's official website, so it provides accurate information from the people who sent these missions to Mars. It explained when each mission was launched, whether it succeeded, and what it found.

Spear, Tony. "NASA FBC Task Final Report." Mars.nasa.gov, mars.nasa.gov/msp98/misc/fbctask.pdf. "Faster, better, cheaper," was the slogan used by
NASA that led to the development of Sojourner (a success) and several other landers (mostly failures). This article describes this slogan and its results, both disastrous and successful.

Voosen, Paul. "NASA Curiosity Rover Hits Organic Pay Dirt on Mars." *Science*, vol. 360, no. 6393, 8 June 2018, pp. 1054-55, science.sciencemag.org/content/360/6393/1054. This clip was the summary of an article that talked about the Curiosity Rover discovering organic material on Mars. It is from a reliable magazine and was referred to on a reliable website. It was written recently and the actual article had quotes from people who worked on the rover. Unfortunately, I could not access the full article without purchasing a subscription to the magazine.

Williams, David R. "Mission Timeline." *Nasa.Gov*, NASA, nssdc.gsfc.nasa.gov/planetary/chronology_mars.html. Accessed 27 Aug. 2019. This website provided a timeline of every mission that has been sent to Mars from Russia or the United States. It provides reliable, up-to-date information from NASA's official website.
Listen to Robots on Mars | SoundCloud is an audio platform that lets you listen to what you love and share the sounds you create... 20 Tracks. 8 Followers. Stream Tracks and Playlists from Robots on Mars on your desktop or mobile device. Mars Rovers and Landers are really cool. But why do we spend millions of dollars to send these space robots? The quest for life and other challenges are waiting for them.

Why Do We Send Mars Rovers? There are many reasons for sending Mars Rovers into the wild, but do you know them? It's a good question because the budget for a Mars Lander or a rover is huge: sending the duo Spirit Opportunity cost 820 Million dollars for the original mission. 20 Jan 2017 - Explore Danlevesq's board "Robots on Mars" on Pinterest. See more ideas about Curiosity rover, Mars and The martian.

Curiosity: an ultra good-looking and cost-effective robot. Image Credit: NASA/JPL-Caltech/MSSS.