Development of a Mars Curiosity Rover Simulator

A working model intended for modern space science education and outreach

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Terms of Reference

Title

Development of a Mars Curiosity Rover Simulator for the Cape Town Science Centre

Description

Our knowledge of the planet Mars has been greatly expanded by several rovers that have landed on the planet over the past twenty years. The most capable of these is the Curiosity Rover, which is currently exploring the surface of Mars. The Cape Town Science Centre has requested the UCT SpaceLab to design and build a model of a Mars exploration rover that will be the centrepiece of a future Mars exhibit at the Centre.

Deliverables

Skills and Requirements

Mechanical Design, Software and Electronics Interfacing and Programming.

Area

Science and Technology

Declaration

1. I know that plagiarism is wrong. Plagiarism is to use another's work and pretend that it is one's own.
2. I have used the IEEE convention for citation and referencing. Each contribution to, and quotation in, this report from the work(s) of other people has been attributed, and has been cited and referenced.
3. This report is my own work.
4. I have not allowed, and will not allow, anyone to copy my work with the intention of passing it off as their own work or part thereof.

Signature:..........................
Sean Wood

Date:..............................

Acknowledgments

Abstract

- Open the **Project Report Template.tex** file and carefully follow the comments (starting with %).
- Process the file with **pdflatex**, using other processors may need you to change some features such as graphics types.
- Note the files included in the **Project Report Template.tex** (with the .tex extension excluded). You can open these files separately and modify their contents or create new ones.
- Contact the latex namual for more features in your document such as equations, subfigures, footnotes, subscripts & superscripts, special characters etc.
- I recommend using the **kile** latex IDE or *TeXstudio*, as they are simple to use.

Contents

List of Figures

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Glossary

Abbreviations listed here are used throughout the document.

- MSL - Mars Science Laboratory
- RSVP - Rover Sequencing and Visualization Program
- RCE - Rover Compute Element
- MEP - Mars Exploration Program
- TMI - Trans-Mars Injection

Chapter 1

Introduction

1.1 Background to the study

A very brief background to your area of research. Start off with a general introduction to the area and then narrow it down to your focus area. Used to set the scene [?]. The section should highlight challenges in the study area to put your work in context [2].

1.2 Objectives of this study

1.2.1 Problems to be investigated

Description of the main problem(s) to be solved and/or hypothesis of your work. Questions to be answered in order to confirm the hypothesis or solve the problems are also articulated here.

1.2.2 Purpose of the study

Give the significance of investigating these problems. It must be obvious why you are doing this study and why it is relevant. Contributions of your work should also be given here.

1.3 Scope and Limitations

Scope indicates to the reader what has been and not been included in the study. Limitations tell the reader what factors influenced the study such as sample size, time etc. It is not a section for excuses as to why your project may or may not have worked.

1.4 Plan of development

This section summarizes the methods, tools, techniques and the order of doing things followed in order to accomplish your work. It also includes such planning tools as project Gantt chart, Critical path analysis and mind mapping.

1.5 Report Outline

Here you tell the reader how your report has been organised and what is included in each chapter. You should give a synopsis for each of your chapters here.

I recommend that you write this section last. You can then tailor it to your report.

Chapter 2

Literature Review

2.1 Space Exploration and NASA's Journey to Mars

2.1.1 A Brief History

The human race possesses a trait that proposedly sets us apart from the majority of life forms around us; the powerful will to explore what is unknown. It is the curiosity and the thrill to push past the boundaries of what is thought to be possible, perhaps felt stronger by some, that forms the basis of many scientific endeavours relating to facts of life and existence around and outside of the immediate environment in which we live.

A prime example of such a drive to explore is in the research and exploration of outer space, which, from a technological perspective, transitioned from astronomer's dream to scientist's and engineer's reality during the Cold War. Although space exploration as we know it today is motivated by human curiosity, it was during this period of political tension that significant breakthroughs in spacecraft and rocket propulsion technology were brought about. This period is referred to as the "Space Race" and stemmed from research and development of nuclear weaponry during World War II [3, p. 147]. The race began with the attempted launches of artificially made satellites [4, pp. 3-5] and within the 40 years following the success of the USSR's *Sputnik I* in 1957, the first object to be put into orbit by man, space technology progressed from early manned flights beginning in 1961[1] through the *Apollo 11* lunar flight to having flown by of the majority of the planets in our solar system.

By 1981, the launch of *Columbia* [5], a space shuttle designed to be used for more than one flight, marked the beginning of reusable space technologies answering to the problem of cost and with the forethought of future increase in space flight frequency and demand. Today, the efforts to lower the cost of space travel and the attempt to bring space exploration into the private sectors to make these opportunities more realisable by the public are evident in Elon Musk's SpaceX development of the Falcon 9, a reusable rocket that returns and lands safely back on the surface of Earth [6].

[1]First human in space, Soviet launched

The National Aeronautics and Space Administration (NASA) of the United States has been and still is responsible for a large chunk of mankind's search among the stars and, with respect to research and exploration, has made great efforts to better understand the planet that we live on in conjunction with the immediate spacial environment around Earth, the solar system and the planets within, and that which lies in deep space. After the Apollo lunar missions, efforts by NASA to explore involved one of the first space stations, the *Skylab*, which suffered technical difficulties originating from launch but proved the ability to conduct research in space as well as allow astronauts to perform repairs and maintenance to artificial bodies in that environment [7]. *Skylab* was followed by the International Space Station (ISS), intended to be a more sustainable microgravity environment in which to conduct research that might require such conditions. Research of this type include a very broad range of investigations from the effects of near-weightlessness on plants and animals through to growth of human-like tissues and protein crystallisation [8]. An area of research that specifically relates to this project is in the development of technology to allow for longer, cheaper and faster flights in space, both in spacecraft materials and systems and in astronaut health and performance. This is closely coupled with the search by entities around the world for other forms of life outside of Earth's atmosphere fuelled by the prospect of finding environmental architectures similar to ours. One of NASA's goals outlined in [9] is to send humans to Mars and this has lead to enormous amounts of research, promising engineering and technological successes that will ultimately allow humankind to extend civilisation across more than one planet.

2.1.2 Mars

NASA has identified that Mars is a planet with greater similarity in formation and conditions in its history and as a result has been a target of exploration for more than 40 years. This has involved multiple flybys and orbits starting from 1962 through to the first lander, the *Viking 1*, to touch down on the surface of the planet in 1975 [10]. NASA's Jet Propulsion Laboratory (JPL) landed the spacecraft, named *Pathfinder*, that contained the first successful rover vehicle, the *Sojourner*, in 1997 [11]. The purpose of this mission was to prove the possibility of cheaper spacecraft development and the transport of scientific equipment to the planet as well as taking photographs of the red surface, from the surface.

2.2 The Mars Science Laboratory and Curiosity

2.2.1 Overview

The Mars Science Laboratory (MSL) is a mission that was launched by NASA to further explore the surface of Mars, one of many orbiter, lander and rover type missions as part of the Jet Propulsion Laboratory's (JPL[2]) Mars Exploration Program (MEP). The program is structured to work towards a set of goals to ultimately understand and determine the potential for life on Mars [12] by observation of the current climate and geology. The MSL is the latest mission in operation as part of MEP and was intended to span roughly

[2] Jet Propulsion Laboratory of California Institute of Technology

one Martian year after touchdown on Mars. However, it has continued to operate for more than double that amount of time.

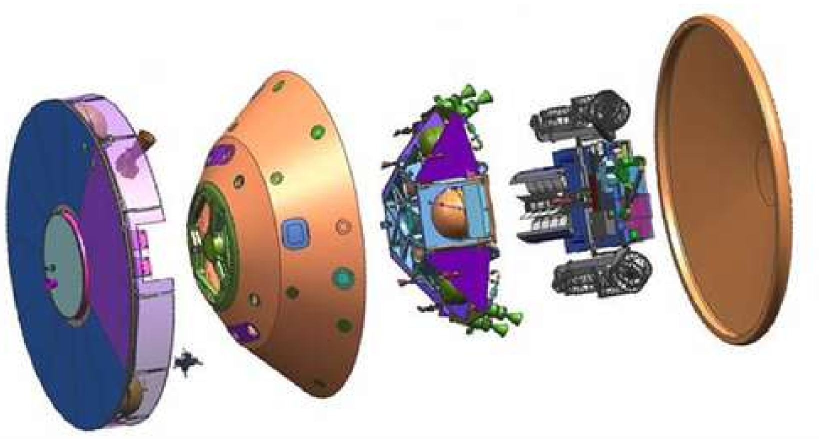

Figure 2.1: An exploded 3D model of the Mars Science Laboratory spacecraft including the cruise stage (far left) and heat shield (far right) [1]

MSL was launched from Cape Canaveral Space Station, Launch Complex 41, atop an Atlas V vehicle, a two stage rocket [13]. The mission required the launch vehicle to insert the five-piece MSL spacecraft into a transfer orbit in a process known as a Trans-Mars Injection (TMI) allowing the spacecraft to arrive at Mars after a 566 million kilometre trip that lasted 256 days. Figure 2.2.1 shows a 3D render of the components of the spacecraft that made the trip. Four trajectory correction manoeuvres were made during the flight to result in a landing near "Mount Sharp" in Gale Crater, deemed the most accurate landing on Mars of any other spacecraft [14].

2.2.2 Primary Mission Goals and Objectives

Touching down on the surface of Mars, the MSL had primary objectives tailored to contribute to the four goals as outlined in the MEP. The objectives were carried out by the MSL's flagship component, the Curiosity rover, and consisted of a wide range of biological and geological observations such as to determine the chemical building blocks that exist on the surface including organic carbon compounds, prospective historical biological activity, atmospheric processes of evolution, surface radiation and state and distribution of water [15].

Apart from the primary objectives, the MSL mission pushes further the boundaries of space exploration in that it proved the ability to land heavier vehicles at incredibly precise landing accuracy as well as the achievement of wider surface coverage to collect and observe more diverse samples of the surface of Mars.

2.2.3 Technical Breakdown of the Curiosity Rover

23% of the MSL spacecraft's total mass of 3.893 metric tonnes was thanks to the missions vehicle, *Curiosity* . The six wheeled, instrument bearing rover features much improved hardware over previous vehicles along with a multiple systems of instruments to enable the carrying out of the mission objectives. The mechanical and technological specifications are broken down in the sections to follow.

Mechanical Structure

Rover Compute Element

Manoeuvrability

Instrumentation

Communication

2.3 Space Education and Outreach

2.4 Web Technologies for Modern Outreach

2.5 Additive Prototyping and Manufacturing Techniques

Chapter 3

Discussion

Here is what the results mean and how they tie to existing literature...

Discuss the relevance of your results and how they fit into the theoretical work you described in your literature review.

Chapter 4

Conclusions

These are the conclusions from the investivation and how the investigation changes things in this field or contributes to current knowledge...

Draw suitable and intelligent conclusions from your results and subsequent discussion.

Chapter 5

Recommendations

Make sensible recommendations for further work.

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Appendix A

Additional Files and Schematics

Add any information here that you would like to have in your project but is not necessary in the main text. Remember to refer to it in the main text. Separate your appendices based on what they are for example. Equation derivations in Appendix A and code in Appendix B etc.

Appendix B

Addenda

B.1 Ethics Forms