1 Introduction

The main purpose of this work was to find a way of placing a meaningful scientific payload within the upper atmosphere of Mars such that certain scientific measurements become possible. So the altitude range covered and the possible dwell time are relevant design drivers and will be explored in greater detail within this thesis.

Either concept of flying on Mars, however, be it heavier or lighter than air (read: heavier or lighter than carbon dioxide) is restricted to altitudes well below 10 km. Since any sustained flight at that altitude or higher in such a thin atmosphere is technically impractical, so is ascending to that altitude with a sounding rocket. Therefore a team of scientists from several research institutes around Europe formed a scientific committee. Together with engineers and scientists from the Mars Society Germany and the University of the Federal Armed Forces of Germany in Munich (UBW) the committee drafted a reference scientific mission scenario [1] to find ways to do exactly that: providing an instrument suite with access to a large altitude range and a meaningful dwell time (see 10.3.1 starting on page 208).

The most practical approach was found in an inflatable entry vehicle that can provide the largest and lightest possible configuration. Since no such attempts have yet been made, the work described herein focuses mostly on the mathematical theory and the technical peculiarities of such a system, but also treats mission design and testing aspects.

1.1 Scientific Background

Until the inception of interplanetary space flight, the science of atmosphere physics and climatology was forced to restrict its research more or less to only one specimen: the atmosphere of planet Earth. More because attempts at investigating planetary atmospheres using spectroscopy with ground based observations have been made and less because some regions of the Earth's atmosphere remained beyond reach before the advent of rockets.

Because Mars is the planet which resembles our own most closely, it is of special interest to planetary science [2]. It is the only body of which we can say, with sufficient confidence, that it has once had a climate similar to Earth's and may even have harboured primitive forms of life. Today, however, Mars is a barren, cold and dry desert planet with only a ghost of an atmosphere left. The question is thus why Mars underwent such a vastly different development, when conditions at the outset were so similar.

This is why until today the Martian atmosphere has been a subject of intense study, most notably by radio sounding from satellites such as presented by references [3] and [4]. This method has contributed most of the data and our present understanding of the Martian atmosphere.

In addition to atmospheric research, high altitudes (or the traversing of a great altitude range during a meaningful period of time) has distinct benefits for other research areas as well, as the field of geomagnetism so tellingly demonstrates [1]. Placing a suite of scientific instruments on a trajectory travelling through an atmosphere across extended geographic and altitude ranges is therefore an important method of research.

1.2 Engineering Background

Ascending from the surface of Mars with a balloon is difficult at best, because relatively high wind speeds thwart the deployment of large gossamer balloon hulls or aeroplane wings without considerable mechanical effort [5]. Besides, the altitudes which such a system can ascend to are not very high. A high altitude sounding rocket commonly used on Earth in contrast might reach all regions of the Martian atmosphere, however, is quite unavailable. The large mass and complexity of such a system renders it unsuitable for a launch from the surface of a remote planet.

Instead of ascending from the surface, however, a high altitude mission might also descent from space, provided it can be built to decelerate at a sufficiently high altitude to make scientific gains desirable. No conventional hypersonic aeroshell and parachute system will slow down sufficiently to allow deployment far enough above the surface, because its mass to drag ratio (expressed in the so-called “ballistic coefficient”, see chapter 3.4) is much too high.

In summary, one can state that the effect of a lower ballistic coefficient raises the entire deceleration profile to a regime where the atmosphere is less dense (a higher altitude), prolongs descent time and lowers the aerothermodynamic heating load that the vehicle will have to absorb. This translates into the following capabilities:

- Increasing payload dwell time in the atmosphere during descent.
- Increasing the accessible altitude range for direct measurements.
- Landing at a site with such a high altitude that heavier and speedier probes cannot land on them because they cannot decelerate in time for a safe landing (such as Tharsis on Mars).
- Allowing a spacecraft to obtain an almost fuel-free delta v through aerobreaking.

In order to achieve the highest possible altitude profile, the ballistic coefficient has to be as low as technically practical. This is achieved by using a large and light inflatable sphere, which in itself offers some benefits as well. Since it can be densely packed and deployed with a small number of moving parts, it offers an attractive alternative to rigid structures. So the same technology might also be considered for the following applications:

- Providing a large aerodynamic heat shield for a heavy payload when a rigid heat shield is too big for the biggest rocket payload fairing.
- Providing an inflatable solar sail structure

While the main focus of this work is a specific task on Mars, chapters 10.4.1 and 10.4.2 give two more detailed examples for possible other applications.