Marsrad - Radiation Analysis Satellite Mission Design Technical Report

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Abstract

Regarding the future of humanity on Mars and the obstacle deep space radiation is to astronauts on Mars, this report examines the design of a proposed mission to Mars known as the Marsrad mission. Defining the challenges facing humans and the demand for more knowledge on the effects of deep space radiation, the Marsrad mission proposal discusses the design of a satellite that uses biosensors, ultraviolet sensors, and particle detectors to accumulate knowledge in a retrievable way. Backed by proven technology, the Marsrad mission will give humans an insight into the way cells respond to radiation outside of the protection of a magnetic sphere, examine the magnetic sphere of Mars and its capabilities in shielding future astronauts, and give an early warning to future astronauts during volatile events from solar storms. Positioned at a Mars-Sun Lagrange point, the Marsrad mission will be an observation mission of Mars while being primed for a future sample return mission as humanity enters deep space with the knowledge provided by Marsrad on radiation’s effects and presence.

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The coming decades will become the first to see humanity’s exit of the gravitational confines of Earth as humans become a spacefaring species. The Artemis missions, while offering a historical first step, are only the beginnings of a journey past the Moon and onto Mars. Offering boundless scientific opportunities to contextualize the Earth in our cosmos, these journeys to Mars will also be met with monumental engineering challenges that have never been faced before, including those of deep space radiation. NASA’s determination of the radiation’s role as a primary obstacle in deep space flight underscores the demand for scientists to have for relevant data (Mars, 2018). The proposed Marsrad satellite mission will offer a uniquely cost-effective way to provide the necessary supply of varied and pertinent information in deep space radiation by building on the backbone of tested technologies, all while offering a modular structure for future radiation warning systems to the early explorers of Mars. Accumulating radiation information during its journey and eventual orbit, the Marsrad satellite and overall Marsrad mission will setup NASA and humanity for a safer and more knowledgeable experience on Mars.

The Marsrad mission’s main objective of recouping the most information about deep space radiation will be carried out through a series of steps in order to efficiently combat the collective lack of knowledge on radiation in space. A human mission to Mars will likely take years, far longer than weeklong missions to the Moon. With this will come the currently unknown risk of long term radiation beyond low Earth orbit, which itself provides relatively high doses of radiation within the safety of the Earth’s magnetic shield (Perez, 2017). Arriving on Mars will also do little to shield astronauts from radiation, as Mars had a weak magnetic field that is battered by periodic, yet unpredictable, solar storms that release significant amounts of dangerous particles (Gawlowicz, 2010). With these facts, the imperative need for a space-based planetary exploration mission is evinced as Mars-based astronauts shall need the knowledge and warning that a scientific observation satellite would provide. However, a mission to a planet in deep space, such as Mars, will be both costly and heavily affected by time as launch windows that provide efficient trajectories to Mars do not occur continuously. With rapid progress of space exploration in the coming decade, the need for data to provide for analysis also means that the mission will have fairly short notice and will not be able to fail due to the infeasibility of fixing a mistake so far in space prior to the likely Mars missions of the next decade. These factors dictate that the mission’s foundation should rely on proven technologies in the field of radiation research, while also being relatively small in order to save on power. Furthermore, with the distance communication would have to travel and the strength any telecommunication device would need, any communication would be impracticable, necessitating technologies that operate without human intervention and simply collect data for future retrieval missions. The Marsrad mission will thus operate within these constraints in its endeavor to collect the data the mission is designed to collect.

Providing the namesake to the mission, the Marsrad satellite is the critical component of the Marsrad mission that the mission revolves around. Marsrad will be a medium sized satellite that will be robust in nature, with enough solar panels to power itself for its mission duration along with a potential indefinite period following the main mission. The Marsrad satellite will be built on the technological developments of the MAVEN, SOHO, and BioSentinel satellites in orbit today, which will allow for their proven technology to be put into action into the realm of deep space. The satellite will travel to Mars and enter orbit around the first Mars-Sun Lagrange point, which offers a spot between the Mars and Sun for observations to be made about both bodies without disruption from a blocked view in a way that mimics the SOHO satellite on Earth’s first Lagrange point (Cornish, 2020). By orbiting this point in space, the Marsrad mission will be in an optimal mission for future modifications due to the long term importance of the point and likelihood of a future structure that mimics the Gateway Module of the Moon. The Marsrad satellite will be equipped with three primary scientific instruments that will see operating at different times. The first of these elements to be used will be the biosensors implemented during the journey to Mars. Using the technology of the BioSentinel mission, a small and low cost module of the Marsrad will be utilized to rehydrate, maintain, and dehydrate a variety of cells aside from the yeast cells used on BioSentinel to offer insight into the radiation past Earth’s orbit (Ahmed, 2021). Using this technology on Marsrad will allow for the radiation gradient of deep space to be examined as cells will be rehydrated sequentially during the journey, as well as at the orbit location, in order to see directly and unequivocally see the radiation exposure that astronauts will experience through their journey. Marsrad will also be equipped with two more primary elements, which will be used primarily at the orbit. Taking technology from SOHO, a modern and more compact version of the Comprehensive Suprathermal and Energetic Particle Analyzer (COSTEP) will be built as it has shown the ability to provide an advance warning prior to a damaging radiation storm on Earth (Dunbar, 2013). By utilizing modern technology such as the Low-Power Charged Particle Detector of the Glenn Research laboratory in conjunction with the precedent provided by the COSTEP in order to detect these storms more reliably in a smaller space (Low Power, n.d.). This element will benefit from the position at the first Lagrange point by continuously pointing at the sun to gain a constant stream of data for predicting the dangerous radiating storms brought by the solar wind. The final element of the Marsrad will also benefit from the position of the Marsrad orbit by continuously pointing at Mars. Similar to the Imaging Ultraviolet Spectrograph on the MAVEN satellite orbiting Mars currently, Marsrad’s third element will utilize an ultraviolet spectrograph to visualize the effect of solar storms on the Martian atmosphere (Greicius, 2017). However, unlike MAVEN, Marsrad’s element will be able to view the entirety of Mars, due to its distance from the planet, and focus on measuring the ability of the current atmosphere to block radiation for Mars astronauts instead of predicting the historical ability of the atmosphere. Supplying an ability to gauge the necessary levels of radiation protection for future astronauts on Mars, this element, along with the entirety of the Marsrad’s elements, will work in conjunction to provide a reservoir of data for researchers to examine in preparation for NASA’s arrival on Mars.

The primary function of the Marsrad mission is to offer an insight into the role of radiation in deep space, which is dependent on the astronomical distance between Earth and Mars. However, this distance also necessarily created parameters that bind the mission. Due to the similarities between the proposed Marsrad mission and the MAVEN mission, many of these parameters can be identified. Specifically, the mission will likely require 10 months solely for travel between Earth and Mars, with an estimated cost of around a half to three-quarters of a billion dollars (Maven, 2021). However, during this time, the biosensor experiments will be taking place in order to collect important information and cost-effectively utilize the time. Following Marsrad’s arrival into orbit, an operations team, in conjunction with a team from the Space Weather Prediction Center, will analyze the basic communications of the satellite, which will include a diagnostic report as well as a small sample of the data, in order to make sure that the satellite and its experiments are working (NWS, n.d.). After two months have passed since the arrival of the satellite, a separate sample collection mission will be deployed from Earth in order to collect the biological samples from the Marsrad satellite as well as the data collected by the satellite. This mission may also include modular components that could be added to the Marsrad satellite and may have a primary goal of setting up further infrastructure at the Lagrange point of Marsrad. Following the teamwork between the Marsrad team and this future sample return mission, the operations team will be downsized in preparation for the continued analysis and predicting of Mars storms, as well as for the eventual analysis of the returned samples and data. With the initial ten months of the mission, 2 months of primary orbital data analysis, and 10 months of return time for the samples, the overall mission should take approximately two years.

The proposed Marsrad mission will tackle the challenge of radiation in space by arming the scientific community with the knowledge they need to best protection humanity’s representatives on another planet for the first time. While the constraints of deep space create many challenges and require many efficiencies to be taken on, the use of proven and functional technologies on the Marsrad mission and general small scale of the mission will be strongly outweighed by the bountiful benefits provided to not just the future visitors of Mars, but also humans on Earth, as radiation knowledge can heal the millions of afflicted individuals with cancers. The Marsrad mission’s ability to provide advances in medical research for humans on Earth, while also building steps to a bastion of humanity in another world, certifies its value as it provides humanity with knowledge that continues to better our lives into the future.

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