PolarCorer Mars Robotic Mission Scope Technical Report

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Abstract

Regarding the need for geological, atmospheric, and biological investigations on Mars prior to the arrival of humans, this report discusses and sets the scope of a mission to the polar ice caps of Mars named the PolarCorer mission. This mission will primarily focus on using the technique of ice coring to make scientific discoveries about potential life, and past geological and atmospheric changes as done on Earth using a PolarCorer lander which contains two sample collectors for the sample collection and return mission. Within a 1050-day long mission, the PolarCorer will utilize two Hohmann transfers to go to and from Mars while having a main phase for drilling and collecting 100 ice cores. These cores will be collected through the use of both an aerial collector similar to the Ingenuity and a primary collector based on the lander itself. With the return of the samples, scientists and researchers from universities, labs, and national organizations will all be able to investigate and discover more about the preserved past of Mars in ice cores selected by the PolarCorer’s collectors to ideally offer insight into potential life and the history of Mars in order to predict future events for human settlers in the coming decades.

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With the age of human exploration reaching well into thousands and tens of thousands of years, it is hard to understand the true novelty of space as a frontier for exploration. Having only entered the expanse of the vacuum of space and continued residing there for a few decades, the pace of achievements has been unrivaled with any other exploration in human history. This push has relied on the incredible development of technology and scientific understanding and allowed for even more returns on human knowledge than expected, serving as one of a multitude of reasons for the current quest for Mars. The arrival of humanity on another planet will be tremendously monumental in setting an unimaginable path for human endeavors in the future. Yet, much of Mars’ history remains unknown and, in order to ensure the safety of human settlement on Mars, this gap in knowledge must be bridged as critical questions regarding the unique environmental conditions of Mars are answered. Indeed, the Mars Exploration Program (MEP) has highlighted focuses on the topics of biology, geology, and climatology for the end goal of human exploration (Bolles, n.d.). Specifically, identifying past life and analyzing the Martian atmosphere and surface are necessary for any mission to Mars. The proposed PolarCorer mission will need to be able to accomplish the criteria set by MEP as it explores Mars’ past, with a mission scope focused on discovering information that will enable scientists to answer the very questions MEP proposes.

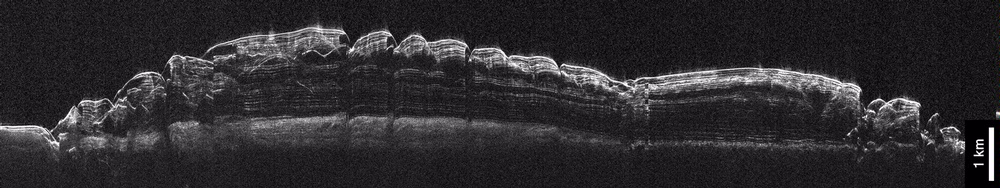
The PolarCorer mission will focus on providing the robotic means necessary to offer insight into three main categories. Specifically, the mission will focus on discovering how the composition of the polar ice and Martian atmosphere have changed over time, as well as investigating potential signatures and viability of life present in polar ice. Studying biological signs of life will be coupled with general research into polar ice since water will play a massive role in the future potential of human exploration, enabling the mission to meet both MEP goals regarding life and human exploration. The mission will also correspond to the other MEP goals of characterizing the climate and researching the geology of Mars as the mission’s research into polar ice will uncover the past climate and glacial geology of Mars. In order to best accomplish analysis of both historical geological and atmospheric data, ice coring, a technique used on Earth for this exact purpose, will be the primary method of instrumentation for the robotic explorer. Ice cores are unique in providing the information for the proposed mission due to their ability to preserve layers of past events of both solids like dust, revealing geological surface activity, and gases from the atmosphere, uncovering the atmospheric change over time (Seasonal Changes, n.d.). Furthermore, by investigating ice cores, a potential for preserved biological remains will work alongside the potential discovery of trace gases and organic molecules associated with life to bring a clearer picture of possible Martian life (First Ice Cores, 2021). These driving questions will be the focus and objective of the PolarCorer mission, enabling the pressing desires of the scientific community shown by the MEP goals to be met.

With the importance of these investigations, it will be critical to identify a location allowing for such versatility as demanded by the mission objectives, with the abundance of polar water ice best allowing for research. The Northern polar ice cap of Mars thus offers the most beneficial location due to the sole presence of water ice during Martian summers, which simplifies the process of differentiating from locations with dry ice like those found in the Southern polar ice cap (Seasonal Changes, n.d.). A flat location with suitable landing space for the proposed robotic collector will be found with corresponding layering and likely presence of water ice through the use of radar, which has been shown to produce cross sectional images (see Figure 1) of polar ice caps that will be used for finding the landing location (Deep Freeze, n.d). Layered water ice will be critical in providing substantial and identifiable portions of the sample with larger deposits of dust or other changes in ice composition, as these changes will be the basis of scientific determinations about the status of the Martian climate over the time span found by carbon dating the samples. Observations and data collection will be made through the use of a robotic collector and an aerial secondary robotic collector that will be deployed by the lander. The primary collector, which will be part of the lander, will drill various holes and store samples for the return launch, acting as a stationary base of operations. The secondary collector will necessarily be an airborne collector as traveling around the polar ice caps will be impossible for rovers due to the jagged terrain with thousand-foot-tall cliffs (Dunbar, 2015). Mimicking the design of the Ingenuity, the collector will be able to make small cores from more varied locations than the stationary collector to prohibit sampling bias from becoming an issue while the stationary collector uses a corer and Sample Analysis at Mars instrument derived from the Curiosity rover (Robotic Arm, 2019). The combination of an aerial collector capable of making more varied small samples and a robust primary collector based on the lander itself will allow for a wide range of samples to be both analyzed and stored for sample return. With the samples and data collected at the North polar ice caps of Mars by the PolarCorer’s robotic collectors, scientists can begin immediately discovering the potential for life, the geological state of polar ice, and the atmospheric history of Mars as information is streamed back to Earth by Martian satellites in a furtherment of human knowledge overall.

The scope of the PolarCorer mission will be designed to provide the information that has been deemed necessary by MEP in a versatile way that will, by nature of the mission, place demands on the proposed operational concepts. Specifically, the mission will be constrained by time in many of its phases as explorations to Mars inherently require great lengths of time to account for the distance between Earth and Mars. However, aside from this factor, which only increases the time required for the initiation of the mission and retrieval of samples, is the greater factor of the Martian seasonal cycle. Since Mars, like Earth, is on an approximately 25-degree tilt, Mars experiences seasons that affect the polar regions in ways similar to Earth by having a melting polar region that reveals an underlying region of ice that is more permanent and stable (Seasonal Changes, n.d.). However, with this factor comes the onset of winter, which results in a drastic increase in the size of the polar ice cap, and would thus result in the burial and likely destruction of the robotic collector and lander in dry ice and water ice. As a result, the mission will face a hard constraining deadline for both arriving and leaving the Martian poles, with a feasible date for the summer arrival of the PolarCorer available on March 3rd of 2029 and a autumn exit of September 3rd of 2029 (Mars’ Calendar). Given a 30-day buffer for maneuvering and allowing the collector to become situated, the PolarCorer will launch on May 18th of 2028 and follow a Hohmann transfer of 259 days to arrive around the start of the Martian summer (James, 2020). Following its arrival at Mars, the PolarCorer will be landed on Mars using thruster and a parachute to slow itself down and land automatically at the previously found landing spot. Throughout its primary mission phase, the PolarCorer will extract ice cores from Mars and make evidence-based decisions on storing the core or utilizing the chemical analysis instrumentation, which will deconstruct the ice core and reveal its composition layer by layer to allow for time to be recorded. (First Ice Cores, 2021). The drilling will occur in extended intervals to prevent the ice from heating up due to the potential for any chemical alterations and disturbances to manipulate scientific analysis. With drilling occurring every other day, the lander will be able to make a maximum of 92 holes while the aerial collector can make 8 every 23 days for a total of 100 cores. However, extra cores will likely be dug for chemical analysis instead of storage as only segments of 100 cores will be kept for sample return. Following the completion of the main phase, with the aerial collector left behind, the main lander will takeoff and return its chosen 100 samples to Earth, leaving Mars at the end of summer on September 3rd, 2029, before any seasonal conditions make the mission irretrievable. Prior to this launch, on July 18th of 2029, a spacecraft for sample return will be sent from Earth on a mission to Mars where it will meet the orbiting PolarCorer sample module and collect it for a Hohmann transfer back to Earth, which will last from July 18th of 2030 to April 3rd of 2031. The entire span of the mission from May 18th, 2028, to April 3rd, 2031, will take 1050 days, or almost 3 years, but will offer many scientists unique opportunities for sample analysis of Martian ice on Earth. Initially, samples will be analyzed by the National Science Foundation’s Ice Core facility, which will allow NASA scientists from Apollo sample missions and Perseverance scientists from the Perseverance sample missions to contribute to streamlining and creating a well-defined process for sample analysis with professionals in ice core analysis (About Ice Cores, n.d.). The information from analysis regarding atmospheric properties of the samples will be shared and merged with existing knowledge from the Space Weather Prediction Center of NOAA to allow for a better understanding of the data to be achieved. Finally, following an information archival process to store data for a wider audience, these samples will be made available for research to many different universities and labs across both America and the wider world in order to generate scientific understanding about Mars.

The past life of Mars has wooed many imaginations as prolific writers, young astronauts, and the wider public have all experienced and expressed a fascination for the unique geography and geology of the Martian world while wondering about its potentially lively past. With so much of Mars’ atmosphere missing compared to that of other planets, investigations into the polar ice can act to answer missing knowledge about not just the prior composition of the atmosphere, but also the geological changes and potential for past life that so captivate the human mind. With the destiny of humanity in even the short-term headed towards settling Mars, discoveries about the past will help safely predict and guide astronauts through events that the PolarCorer will help uncover as it answers questions about the changing composition of the Martian atmosphere and polar ice, as well as the potential of previous extraterrestrial life, in a mission to define the limits of human ingenuity and willpower.

Figure 1:



Scope Summary: PolarCorer

* Need: Obtain samples for polar ice analysis to investigate biological, geological, and climatological questions initiated by MEP’s scientific goals.
* Goal: Allow for an understanding of Mars’ geological and atmospheric past for prediction of future conditions and determine ice composition for life sustainment.
* Objective: Obtain 100 polar ice cores from Mars’ North polar ice cap and return for analysis.
* Mission: Land on Mars to collect samples and bring return them before loss.
* Operational Concept: Launch the rocket, Hohmann transfer to Mars, land on Mars, begin coring, deploy aerial collector, store samples, launch lander, orbit and pretransfer maneuvering, pickup from sent rocket, collection, Hohmann transfer to Earth, payload return.
* Assumptions: Creation of a team and technologies prior to launch is viable. Collection and pickup technologies made before launch of collection rocket and orbit matches pickup possibilities.
* Constraints: Land the PolarCorer lander on or before March 3rd, 2028, and launch for return before September 3rd, 2028, or before polar dry ice accumulation.
* Authority and Responsibility: PolarCorer is to be headed by NASA with a third-party pickup rocket used and interagency cooperation between NOAA Ice Core facility and NASA.

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*Figure 1* | *North Polar Region of Mars*. North Polar Region of Mars | National Air and Space Museum. (n.d.). Retrieved February 17, 2023, from https://airandspace.si.edu/explore-and-learn/multimedia/detail.cfm?id=6046

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