

VASTS 2026 Final Project

Prithvi Chakraborty

Virginia Aerospace Science and Technology Scholars

Master Teacher: Dr. Tyiesha Gainey

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Scope Summary

- **Need:** The mission needs to confirm if subsurface polar brines exist on Mars and understand their properties. It also needs to build a human surface base that can support long-term science, hazard testing, and early use of local resources.
- **Goal:** The goal is to establish a Phase III Mars base that studies habitability and supports future human exploration. The base will also show that long-term operations on Mars are possible with some use of local resources.
- **Objective:** The mission will drill into polar deposits and analyze samples to study possible brines. It will also study how the Martian environment affects materials over time, support continuous human habitation, and produce oxygen using ISRU systems.
- **Mission Case:** The mission will deploy an international Phase III base at Planum Australe before 2046. It will support 18 astronauts and return all crew safely to Earth before 2055.
- **Operational Concept:** Cargo will be sent first to prepare the site. The crew will then arrive, operate the base, and return during the next transfer window.
- **Assumptions:** The mission assumes that life support, power, and communication systems will work as planned.
- **Constraints:** The mission must launch before 2046, support 10-40 crew members, and return to Earth by 2055.

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Human missions to Mars are more complex than robotic missions because they must support both science and human survival. A surface base must provide air, power, and protection while also allowing astronauts to carry out research. Aurora Base builds on earlier robotic work that identified the south polar region as a key site for possible brines beneath the Martian surface (Lalich et al., 2022). This mission uses that research as a starting point and connects it to the design of the base. This proposal outlines the base design, mission, and system requirements, timeline, site selection, constraints, risks and dangers, and crew structure.

Surface Base Name

The proposed surface base is named Aurora Base. This name reflects both the polar location of the mission and its scientific purpose. The design of the base is meant to study processes that occur underneath the Martian south polar surface. This includes possible brine layers, ice behavior, and environmental conditions that cannot be measured or observed from orbit. The name “Aurora” represents the idea of revealing hidden activity, which aligns with the goal of studying subsurface features (Thomas, 2025).

The name also reflects the mission’s role in moving from robotic exploration to long-term human presence. Earlier robotic missions focused on identifying possible brines at Planum Australe and understanding their importance. Aurora Base builds directly on that work instead of starting a new objective, and it clearly appears as a clear demarcation from initial discovery to a potential sustained human presence and operations on Mars.

Mission Statement

Aurora Base is a Phase III Mars surface base that is designed to support permanent human occupation at a scientifically important site in the south polar region of Mars. Its mission

is to investigate subsurface brines, study the environmental hazards that affect people and equipment, and develop systems that make long-duration human exploration of Mars more realistic. The base combines scientific operations with engineering and survival systems so that each part of the mission supports the others.

This mission is guided by three connected goals. The first goal is to determine whether brines beneath the surface exist and to study their chemical and thermal properties. The second goal is to understand the hazards that affect long-term missions. This includes dust, radiation, extreme heat, the degradation of material, and delayed communication (Casas, 2026). The third goal is to prepare for future exploration by developing systems that can use local resources, reduce resupply needs, and support long stays on the surface. These goals connect directly to MEPAG priorities that involve habitability, climate history, and preparation for human exploration.

Mission Requirements

Mission requirements describe what Aurora Base must accomplish for the mission to succeed. Aurora Base shall establish a Phase III surface base on Mars with a continuous population of 18 crew members. The mission shall launch before 2046 and return all crew safely back to Earth before 2055. The mission shall also confirm and study possible subsurface brine zones at Planum Australe by drilling to depths that go up to five meters and analyzing samples. The mission shall also complete a long-term surface experiment that studies how dust, radiation, temperature changes, and possible microbial exposure affect the materials that are involved with engineering.

Furthermore, the mission shall also produce oxygen by utilizing in-situ sources and test the usage of water-bearing materials that are local (Lalich et al., 2022). These requirements are

representative of and fit the SMART characterization. They are specific because each one states a clear task and is measurable because they include values like crew size, mission timeline, drilling depth, and experiment duration. They are achievable because they build on earlier robotic missions and existing systems. Lastly, they are relevant because they support science and human survival and are traceable due to each requirement being connected to the mission need, goal, and objective.

System Requirements

On the other hand, system requirements describe how the base must perform in order to meet the mission requirements. Aurora Base shall maintain a pressurized habitat that supports continuous human life using a redundant Environmental Control and Life Support System (Ridgeway, 2025). The system shall be in control of regulating oxygen levels, removing carbon dioxide, and controlling temperature and humidity. The base shall provide continuous power using a nuclear power system that is supported by solar energy and storage. The habitat shall additionally have radiation protection that uses shielding with regolith and be able to support communication by using Mars relay satellites (Llamas et al., 2022). There shall also be mobility systems, laboratories, medical capability, and EVA support systems.

The system shall include backup oxygen systems, multiple carbon dioxide scrubbers, and continuous atmospheric monitoring in order to reduce the risk of air failure. The base shall include pressurized and unpressurized rovers for the surface work to be supported alongside cargo movement as well. It shall also include greenhouse space for supplemental food. These requirements are SMART and follow its guidelines because they define clear functions for the system, while also including measurable performance and being based on known technologies. They support long-term operation and connect directly to the requirements of the mission. In

comparing the two types of requirements, mission requirements describe what Aurora Base must achieve, while system requirements describe how the systems must perform to make that possible.

Timeline

In order to reduce risk before humans arrive, Aurora Base follows a phased timeline. The first phase starts with robotic precursor missions in the late 2030s. These missions deliver cargo, communications equipment, power systems, construction machines, habitat parts, drilling hardware, and environmental monitoring instruments. This phase allows final site checks and confirms that Planum Australe remains the best choice for a permanent base. Robotic preparation is important because it lowers the burden on the first crew and makes the outpost safer from the start.

The second phase starts when the first crew launches before 2046 during a favorable Earth-Mars transfer window. After about seven months of cruise, the crew lands at Planum Australe and starts a commissioning period. During this time, the astronauts activate the habitat, test life support and thermal systems, establish communications, inspect the landing area, and prepare for field operations. The third phase expands the outpost into a full Phase III base with additional crew and cargo. The fourth phase is the long-term operational period, when Aurora Base performs drilling, analysis of the brines, materials testing, ISRU work, EVA-supported field science, and routine habitat operations. The final phase is departure and return. The crew leaves Mars early enough to guarantee safe return to Earth by 2055, and the base is left in a stable automated state if systems continue running after human departure (Carney, 2024).

Table 1

Timeline for Aurora Base Mission

Date	Event
January 2038 - December 2041	<ul style="list-style-type: none"> • Deliver cargo and base equipment • Set up communication systems • Install power systems • Deploy construction tools
January 2042 to December 2044	<ul style="list-style-type: none"> • Prepare landing site • Place habitat modules • Add radiation shielding • Set up surface systems
August 2045	<ul style="list-style-type: none"> • First human crew launches from Earth
March 2046	<ul style="list-style-type: none"> • Crew lands at Planum Australe • Begins base setup and system checks
March 2046 to December 2048	<ul style="list-style-type: none"> • Activate habitat • Start science work • Test ISRU systems • Expand base to Phase III
January 2048 to December 2052	<ul style="list-style-type: none"> • Maintain full operations • Support an 18-person crew • Continue research and maintenance
June 2053	<ul style="list-style-type: none"> • Final crew departs Mars
By December 2055	<ul style="list-style-type: none"> • All crews safely to Earth

Major Phases

Phase 1 - Precursor Exploration and Site Preparation

Robotic missions prepare the site before the crew arrives. For example, they deliver power systems, communication equipment, habitat components, and tools. They also confirm and secure the landing zone at Planum Australe. This phase reduces risk and makes sure that the base is ready for the arrival of humans.

Phase 2 - Crew Launch, Cruise, and Surface Landing

The first crew launches in 2045 and travels to Mars over about seven months. During the cruise, the crew monitors systems and health. The spacecraft lands using entry, descent, and landing systems. There is high importance for accurate targeting and site preparation from Phase 1 in order to ensure a safe landing.

Phase 3 - Base Establishment and Commissioning

After landing, the crew activates the habitat and checks all systems. They confirm life support, power, thermal control, and communication. They also prepare airlocks and begin early surface work. By the end of this phase, the base supports regular operations.

Phase 4 - Operational Expansion and Surface Operations

The base expands to a full Phase III outpost with 18 crew members. The crew conducts drilling, sample analysis, and long-duration experiments. They also manage ISRU systems, maintenance, and EVA tasks. This phase completes the main science and engineering work.

Phase 5 - Departure, Ascent, and Safe Return to Earth

The crew prepares the base for shutdown or remote use. They secure samples and data for return. The final crew leaves Mars in 2053 and returns to Earth by 2055. This phase makes sure that the mission is completed in a safe manner and that the data collected is preserved.

Location

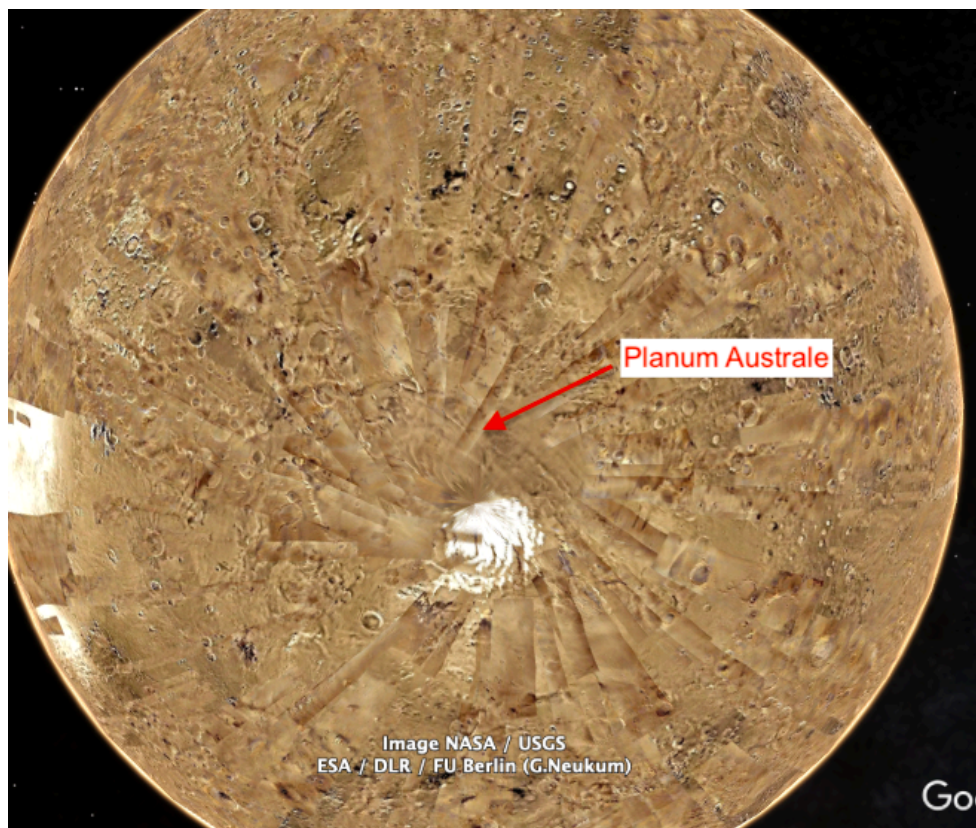
Aurora Base is located at Planum Australe, which is approximately 83°S latitude and 193°E longitude. This location was chosen because it best supports the mission's main science goals. Orbital data have shown unusual bright reflections below the south layered deposits, making this one of the strongest candidate regions for possible subsurface brines. The site also contains thick layers of water ice mixed with dust and seasonal carbon dioxide frost (Malin et al.,

2026). These features make the region important not only for questions regarding habitability, but also for climate history and resource studies.

The site also matters from an exploration viewpoint. If brines or accessible water-bearing materials are confirmed, they could help future missions with water use, oxygen production, and reduced launch mass from Earth. At the same time, Planum Australe presents real engineering challenges. For example, temperatures can fall below -120°C Celsius, sunlight is limited, frost can accumulate, and ice terrain increases landing and surface risks (Atkinson, 2024). Even so, the high science value of the region makes the difficulty worth it. A successful outpost at this site would prove that humans can live and work in one of the most demanding and scientifically valuable regions on Mars.

Figure 1

Image of Planum Australe (Eduterre, 2015)



Constraints

The design of Aurora Base is meant to meet all required mission constraints in a clear way. The mission launch occurs before 2046 by placing the first crew launch in 2045, with landing in 2046. The outpost remains a Phase III base because its permanent population is set at 18 inhabitants, which is safely within the required range of 10 to 40 people. The mission also meets the final time limit because the last crew leaves Mars in 2053, which allows for enough time to return to Earth by 2055. These constraints shape the entire proposal, including the number of crew, the size of the base, and the decision to keep the base operational rather than turning it into a settlement.

Other important constraints come from the environment and the mission itself. The south polar region is extremely cold, so strong heating and thermal control are required. Limited sunlight means that solar panels are not enough solely, so the base must instead rely on a more dependable primary source of power. Communications delays also require astronauts to operate with much more independence than crews in low Earth orbit. Planetary protection is almost as important because the mission may investigate areas where liquid brines exist, so the possible risk of contamination and the control of this must be taken seriously during drilling and when handling samples (Atkinson, 2024). Mass, cost, spare parts, and reliability are also major design constraints throughout the mission.

Risks/Dangers

Microgravity

Even though Mars has more gravity than spaceflight in transit, it still has much less gravity than Earth. Over a long mission, this can lead to muscle loss, bone density loss, and changes in overall health and performance. These problems begin during the months of travel to

Mars and continue during surface operations because Mars gravity is still too low to fully protect the body (Harland, 2026). Since Aurora Base is meant to support long stays and a permanent operating crew, the effects of reduced gravity must be addressed as a continuing operational concern.

Mitigation Strategies

Aurora Base reduces this danger through daily resistance exercise, regular health monitoring, structured medical checkups, and cost-effective nutrition planning. Exercise time is protected in the daily schedule because physical health directly affects EVA performance, alongside the maintenance of the habitat and emergency responders (Garcia, 2025). Crew members are also monitored for changes in body condition so that countermeasures can be adjusted early instead of after a serious decline.

Nutrition

Another major long-duration risk is nutrition because astronauts must rely heavily on stored food during transit and surface stay. Over time, vitamins and other nutrients can break down, and a limited menu can reduce appetite. If astronauts do not eat enough or do not get the right nutrients, they might experience issues like fatigue, muscle loss, weaker immune function, and lower concentration. On the surface, the problem might become even more serious because surface work, the maintenance of the habitat, and EVA can increase needs for energy. Dust contamination during food handling is also a problem (Cranford, 2025).

Mitigation Strategies

Aurora Base uses stored food designed for long shelf life and stable nutrient content. Medical monitoring helps identify deficiencies early through health checks, body mass measurements, and other data. The base also includes a greenhouse or controlled plant-growth

area for small amounts of fresh food (Gajbhiye, 2025). This fresh food helps with nutrition and crew morale, but it is treated as a supplement instead of being the main food source, as crop systems need extra water, lighting, power, and crew time.

Communication

Because of the distance between Mars and Earth, the communication between them is delayed. Depending on planetary alignment, a signal can take between four and twenty-four minutes on the way. That makes real-time conversation impossible and means that the crew must solve many problems without waiting for instructions from Earth. This affects engineering, medicine, science operations, and even mental health. Over long periods, delayed communication can increase stress and isolation, especially during emergencies or high-pressure situations (Atkinson, 2024).

Mitigation Strategies

Aurora Base addresses this danger by training the crew heavily in independent decision-making before launch. Simulation practice includes delayed-response emergencies so that astronauts can learn to solve problems on their own. The crew is also cross-trained in different areas, including engineering, medical support, and systems management, so that the base does not depend too much on any one person or on Earth specialists. On-board software and decision-support systems can help to identify problems, but human judgment ultimately remains central to the mission (Garcia, 2026).

Crew Responsibilities and Functions

Aurora Base is an international mission with a permanent population of 18 astronauts. The crew includes 9 women and 9 men, with an age range of about 30 to 55 years old. This range supports a balance of physical ability, technical skills, and professional experience. The mission

uses an international crew because long-term Mars exploration will likely need and involve shared expertise alongside shared funding and broader scientific participation. A diverse crew also helps with improving flexibility and makes the outpost stronger from an operational point of view (Logsdon, 2026).

Each crew member has a main speciality but also receives cross-training. Aurora Base includes a base commander, deputy operations lead, flight engineers, life support engineers, geologists, astrobiologists, ISRU specialists, material scientists, robotics engineers, communications and data specialists, and one medical officer. The commander and deputy oversee planning, task flow, and emergency decisions. Engineers maintain the habitat, power systems, thermal systems, and rovers. Geologists and astrobiologists lead drilling, sampling, and analysis of the south polar deposits. ISRU specialists manage oxygen production and water-related resource systems. Material scientists supervise the long-duration corrosion experiments. The medical officer tracks individualized and overall crew health, nutrition, fatigue, and mental well-being. Robotics engineers manage the autonomous surface support systems and external construction tools (Levy, 2025). Overall, this crew structure makes sense as every major mission goal has people directly assigned to support it. Furthermore, the incorporation of cross-training allows for operation to continue even if one crew member becomes unavailable.

Daily life at Aurora Base follows a structured schedule. Crew members divide their time among system maintenance, science work, surface operations, exercise, medical checks, planning, and rest. Private living space, predictable routines, and scheduled recreation are important for long missions that can place stress on mental health and teamwork. The base must also therefore support not only scientific productivity but also stable daily living. This helps to keep the crew healthy, focused, and capable over the long term.

Conclusion

Aurora Base is a realistic Phase III Mars outpost that directly builds on earlier robotic science goals and human mission planning. It is centered on a clear mission need, the study of subsidence brines, and the long-term challenges of human exploration, and every major design choice connects back to that purpose. The selected site at Planum Australe supports the science goal, the operational timeline meets all formal constraints, and the base systems are designed around the real dangers of Mars rather than ideal conditions. The proposal shows how a permanent Mars base can serve science, engineering, and survival all at the same time.

Aurora Base also demonstrates why a Mars surface base matters beyond one mission. By combining brine investigation, resource development, environmental hazard study, and permanent human operations, the outpost moves Mars exploration from short visits toward a true long-duration presence. The mission would improve understanding of modern Mars, reduce uncertainty for future crews, and reduce the system's need for even more advanced exploration later on. In that way, Aurora Base is not only a strong final project concept but also a realistic next step in the long-term path of human exploration beyond Earth.

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Appendix A Outreach Page

Aurora Base: Human Exploration of Mars

MISSION OVERVIEW

AURORA BASE IS A PHASE III HUMAN SURFACE BASE LOCATED AT THE SOUTH POLE OF MARS IN A REGION CALLED PLANUM AUSTRALE. IN RELATION TO SCIENTIFIC GOALS, THE MISSION FOCUSES ON STUDYING UNDERGROUND WATER, TESTING LONG-TERM HUMAN SURVIVAL, AND PREPARING FOR FUTURE EXPLORATION. AS A PHASE III BASE, IT SUPPORTS PERMANENT HUMAN PRESENCE AND EXPANDED SCIENTIFIC OPERATIONS.

Phase III Base

A Phase III base is a permanently occupied Mars outpost with more than 10 crew members that supports extended research, resource use, and surface exploration.

Crew

Aurora Base supports a permanent crew of 18 astronauts from different countries. The crew lives in a pressurized habitat that provides air, power, and protection. They use rovers, laboratories, and life support systems to carry out daily work and maintain the base.

The crew will include the following:

- 2 pilots
- 2 medical specialists
- 2 engineers (systems and maintenance)
- 2 ISRU specialists (resource use and oxygen production)
- 2 geologists
- 2 biologists
- 2 physical scientists
- 2 robotics specialists
- 2 communications/data specialists

Risks and Challenges

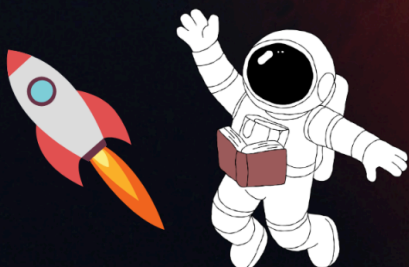
Key risks include reduced gravity, nutrition limits, and communication delay. Reduced gravity can lead to muscle and bone loss over time. Limited food supply can cause nutrient loss and affect crew health. Communication delay makes real-time support from Earth impossible and requires the crew to act independently.

Risk Mitigation

- Daily exercise reduces muscle and bone loss
- Stored food and supplements support nutrition
- Crew training supports independent decision-making

Mission Timeline

- 2038–2044: Robotic precursor missions and site preparation
- 2045: Crew launch from Earth
- 2046: Crew lands on Mars and begins base operations
- 2046–2053: Conduct research, ISRU operations, and long-term habitation
- 2053: Crew leaves Mars
- 2054 (by 2055): Crew returns safely to Earth



Appendix B Concept of Operations

