

Mission Design Technical Report: Polar Night Ice Behavior Explorer

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The first part of a space mission starts with identifying a scientific problem and then reasonable methods of studying it with engineering constraints in mind. Within the realm of Earth system science, there are many instances where important environmental processes and changes occur but are difficult to observe due to external reasons. The result of this is the presence of gaps in the available data that may lead to uncertainty in scientific conclusions and future projections. A specific area where this situation is present is in the study of polar ice sheets that are difficult to study during polar night because months of darkness prevent many traditional observation methods from being effective (Bamber et al., 2022). The Polar Night Ice Behavior Explorer (PNIBE) mission is developed and designed to address this gap by using space-based sensing technologies that don't need sunlight, so scientists can keep studying polar ice sheets all winter instead of losing months of data.

Mission Subject

The Polar Night Ice Behavior Explorer (PNIBE) is a space-based mission for Earth observation that focuses on studying polar ice sheets during polar night. During this time, regions like the Arctic and Greenland experience months of complete darkness, which makes it very hard for many satellites that rely on optical sensors to collect data (Poseidon Expeditions, 2024). PNIBE specifically looks into collecting data for subsurface ice structure, how ice deforms internally, and how gases that are trapped within ice layers move over time. These processes are important for data collection because they affect how stable ice sheets are and how much they influence sea level rise over time. However, scientists do not have much data on them because most Earth observation missions collect information only when there is sunlight, mainly during

the summer. Even so, ice sheets continue to change during the winter due to temperatures dropping, pressure within the ice shifting, and the ice slowly moving (Bamber et al., 2022). By studying ice sheets during polar night, PNIBE fills this missing gap in data instead of collecting information that satellites already gather in other seasons.

Mission Objective

The main objective of PNIBE is to better understand how polar ice sheets behave during long periods of darkness and extreme cold. By collecting data continuously throughout the winter, the mission helps reduce uncertainty in climate models that track how ice changes shape and loses mass. This information is important because it lets scientists make more accurate predictions about future sea level rise. A secondary objective of PNIBE is to provide reliable data that can be used in climate forecasting systems. Many current models rely a lot on data collected during the summer, which does not accurately reflect how ice behaves throughout the entire year. PNIBE helps to fix this problem by focusing specifically on data collected during the winter.

Mission Type

In regard to the type of mission, PNIBE is categorized as a space-based Earth observation mission. This is the most appropriate mission type for achieving the outlined objectives. Polar regions are extremely hard to access during the winter because of the harsh weather and continuous darkness (Poseidon Expeditions, 2024). Because of this, any ground-based and airborne observations become both very difficult to conduct and inconsistent. On the other hand, a satellite-based platform allows for regular and repeatable coverage without facing the detrimental constraints that cause difficulty for ground-based and other airborne methods.

Furthermore, optical imaging systems are not very effective during polar night, so an Earth observation mission using active sensing technologies is significant for conscious data collection (National Institute of Biomedical Imaging and Bioengineering, 2020).

Mission Users

The primary mission user is the National Oceanographic and Atmospheric Administration (NOAA). The NOAA would use the data collected by PNIBE to improve climate models, seasonal weather forecasts, and predictions of long-term sea level rise (National Oceanic and Atmospheric Administration, 2025). Because the NOAA connects scientific research with actual weather-forecasting and decision-making, it is well-suited to use this information in practical ways. Other users include climate scientists, polar researchers, and international environmental monitoring organizations (Nuwer, 2023). These groups would also benefit from better access to winter polar data, which is currently limited but would be better accessed by this mission to better project and understand long-term climate trends.

Mission Duration

The PNIBE mission is planned to operate for 18 months. This length is ideal because it allows the spacecraft to observe at least one full polar night cycle in both the Northern and Southern Hemispheres. It also allows for observation of the transition periods before and after months of darkness, which is important for comparing how ice behaves across different seasons. An 18-month mission also balances the perceived scientific value of this mission while keeping engineering limits in consideration. A mission that is either shorter or longer than 18 months would have other problems arise. For example, a shorter mission might miss key seasonal

changes, while a longer mission would increase the risk of radiation exposure, extreme temperature effects, and battery wear (Moldwin, 2025).

Mission Elements

To begin, PNIBE involves a single satellite placed in a near-polar low Earth orbit at an altitude of about 600 kilometers. The payload includes a synthetic aperture radar system, which is used to image surface ice structure because it can operate reliably without sunlight. A passive microwave radiometer is also included to measure ice temperature and composition, as well as a low-frequency radar sounder to analyze internal ice layering and detect trapped gases to analyze ice behavior under the surface (National Aeronautics and Space Administration, 2025). The satellite is launched aboard a commercially available medium-lift launch vehicle during a planned winter period. Power is also provided by deployable solar panels alongside high-capacity batteries, so operation can be sustained during a long period of eclipse (National Aeronautics and Space Administration, 2023). Optical instruments are not included because they are limited in terms of working efficiency during polar night and involve power and mass demands that are unnecessary (National Institute of Biomedical Imaging and Bioengineering, 2020).

Mission Operational Concepts

Putting everything together, PNIBE mainly operates in pre-programmed autonomous mode rather than heavy manual control. During each orbit, the spacecraft automatically activates its instruments when passing over selected polar target regions. The collected data is then stored onboard and transmitted to ground stations during scheduled communication windows. Ground operations are managed through NOAA facilities, where engineers monitor spacecraft health,

and scientists review and validate the incoming data (Labrador, 2025). This operational approach is effective because it reduces staffing demands, lowers operational risk through predictable scheduling, and makes sure that all spacecraft systems work together efficiently.

Mission Constraints

The most significant constraint on the PNIBE mission is the availability of power. During long periods without sunlight, the spacecraft cannot generate much solar energy, so instruments must be carefully scheduled to avoid draining the batteries. This power limitation also influenced which instruments were chosen and how the mission operates as a whole. Extreme cold during polar night also creates another constraint, as it could reduce battery performance and affect how well instruments work. Other limitations include how much data can be sent back to Earth, how much mass the launch vehicle can carry, and overall budget limits (Barclay, 2024). Together, these constraints required design tradeoffs, but the mission is still designed to meet its main scientific goals.

Conclusion

The Polar Night Ice Behavior Explorer is an Earth observation mission designed to fill an important gap in climate data by studying how polar ice sheets behave during long periods of darkness. By collecting data when transitional observational methods are limited and don't work, the mission would help improve climate models, make sea level rise predictions more accurate, and support climate forecasting. In the future, the PNIBE mission concept could help shape new polar missions, such as larger satellite systems or constellations that monitor ice sheets year-round. Overall, this shows how carefully planned missions can lead to better and more reliable climate observations.

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