



# POLE-SITTER SPACECRAFT FOR EARTH OBSERVATION

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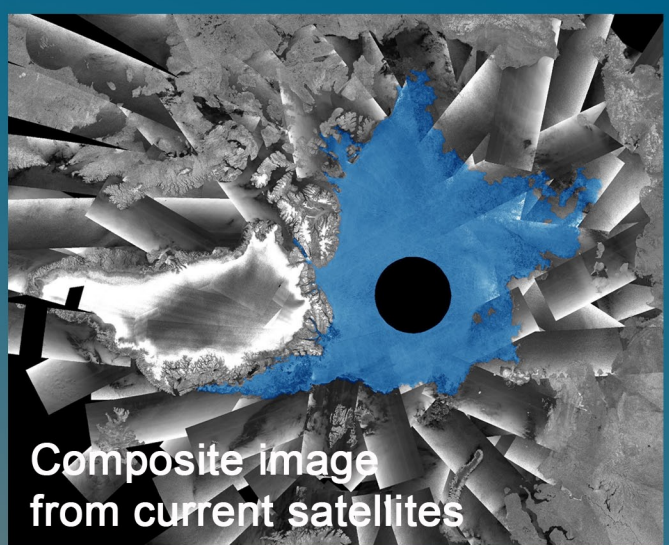
## POLAR OBSERVATION

### Need for polar observation

Space exploration has provided us with essential technologies, including the possibility to observe the Poles of the Earth. With recent changes to the polar ice packs these observations have become increasingly important as they can provide insights into global climate change and contribute to political and environmental decision making. Beyond that, observation of the Poles can also contribute to high latitude weather forecasting, communications (e.g. for Antarctic research activities) and ship tracking (especially with the opening of the Northern Sea Route).

### Lack in current polar observations

Currently, polar observation is performed from satellites that orbit the Earth in natural, circular or elliptic orbits. However, these satellites can only observe the Poles during part of the orbit and often the satellite can only see a narrow swath of the polar regions. This means that a full view of the Poles can only be constructed after multiple passages over the Poles and by patching together images taken at different times. Clearly, this is not beneficial for the availability or accuracy of the observations.



Composite image from current satellites



Instantaneous view from pole-sitter

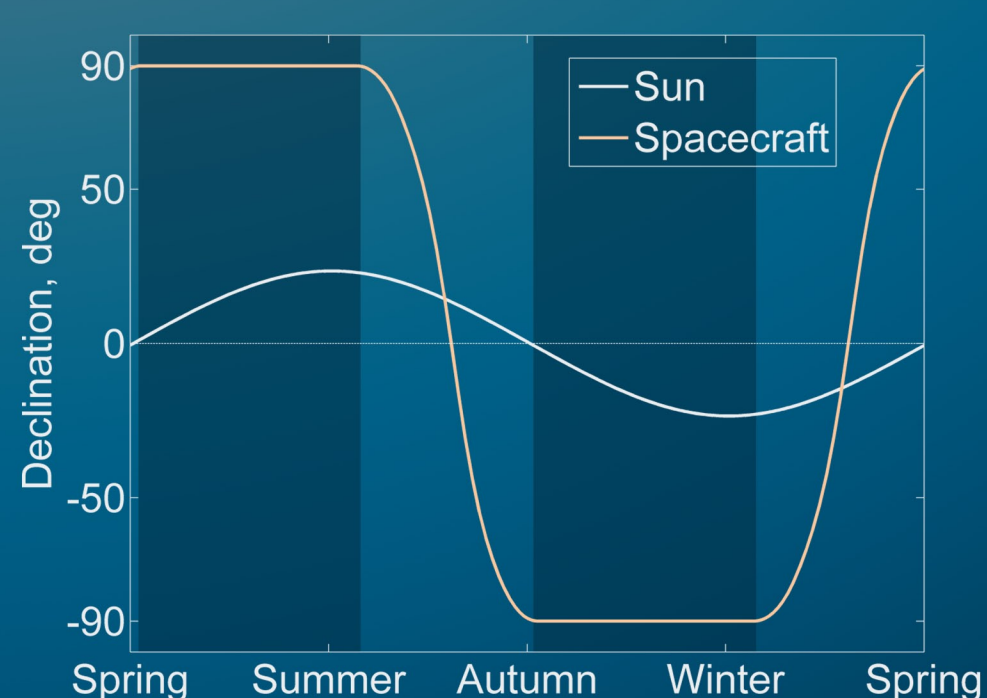
### Solution: "pole-sitter"

To overcome these limitations, this research proposes the groundbreaking concept of "pole-sitter", where the satellite does not orbit the Earth, but is stationary above one of the Poles: the only way to provide continuous, hemispherical coverage.

## POLAR WINTER

### Tilt polar axis

Due to the tilt of the polar axis, the North and South Poles are alternately situated in darkness for 6 months. Clearly, this constrains observations. Therefore, transfers have been designed between pole-sitters above the North and South Poles such that the satellite can switch every half year to perform observations of the Poles only when illuminated.



### Transfers

The transfers are designed such that they need a minimum amount of propellant, so they do not negatively influence the mission lifetime. Again, for the far-term mission this transfer performs better due to the use of hybrid propulsion: 65.3 kg (SEP) versus 11.6 kg (hybrid) of propellant.

## IN CONCLUSION

This work has demonstrated the feasibility of a near-term and far-term pole-sitter mission to significantly improve current polar observations for a range of applications. The proposed near-term solution is feasible in the short term through the use of existing technologies. By introducing a novel propulsion concept (far-term solution), an increased mission performance can be obtained: it allows for additional instruments to be taken onboard or for an extended mission lifetime.

## NEAR-TERM MISSION

### Pole-sitter requires continuous thrust

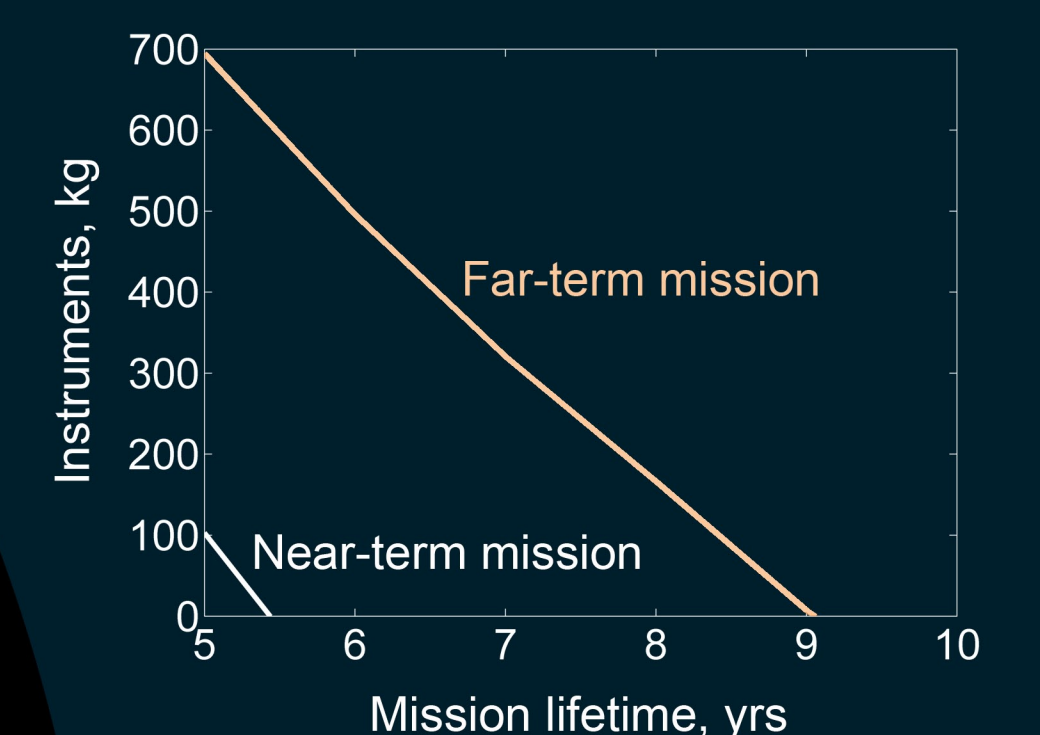
The pole-sitter position is not a natural state for the satellite to be in. Instead, it needs a continuous force to counterbalance the gravitational attraction of the Earth and Sun. Otherwise, it falls back into a natural, elliptic orbit around the Earth. A technique that could provide this force in the near-term is solar electric propulsion, SEP, that uses solar power to accelerate a propellant to very high velocities to produce a force.

### Mission design

The mission design starts from launch, which is assumed to take place using an Ariane 5 rocket (ESA). The launch is optimised to deliver the largest mass possible to the pole-sitter position. That way, either more instruments for observation or more propellant to extend the mission can be taken along.

The pole-sitter position itself is chosen at 1.5 million kilometers from the Earth. That way, it is close enough to the Earth for proper observations, but far enough such that the required force does not become too large.

This position can be maintained for a maximum of 5 years. In that case, the initial satellite mass is 4432 kg: 103 kg for instruments and the rest for propellant and supporting hardware.



## FAR-TERM MISSION

### Hybrid propulsion

To improve the performance of the mission, another novel concept is proposed: "hybrid propulsion", where a solar sail is added to the SEP satellite. Solar sailing uses the force generated by solar photons impinging on a large, highly reflecting surface. In this concept, the Sun is the propellant source and the force therefore basically comes for free.

### Improved performance

In hybrid propulsion, the sail generates part of the force required to maintain the pole-sitter position, relieving the SEP system. This means that less propellant is needed for the same mission. The created available mass can be used to take onboard either more instruments or extra propellant to extend the mission time (see figure above).

### Feasibility

Solar sailing is a relatively new concept, but was recently successfully demonstrated in space. Since a relatively high performing, large (i.e. 325 x 325 m<sup>2</sup>) sail was assumed in this study, the feasibility is considered to be 'far-term'.

