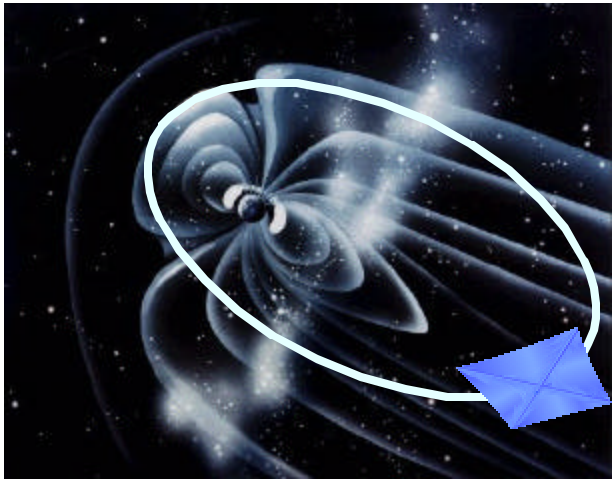
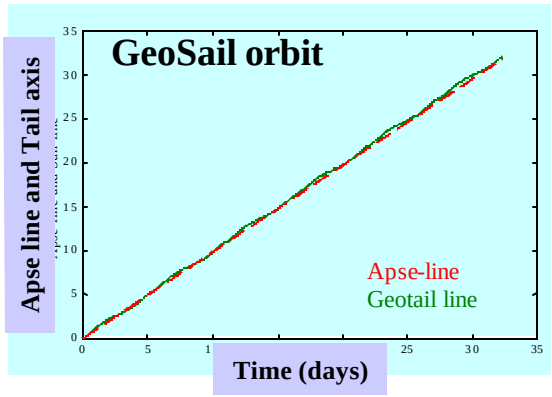
GeoSail: A Novel Mission Concept for Geospace



GeoSail will provide the next breakthrough in our understanding of the physics of the magnetosphere

Technology Requirements

- Solar sail and/or SEP propulsion
- Lightweight subsystems and instrumentation



Fundamental Question

How does reconnection occur in the Earth's magnetosphere?

Why is this important?

Reconnection in the Earth's magnetotail is an important process in the creation of substorms and energy transfer from the solar wind to the magnetosphere yet how it occurs and what form it takes is poorly understood.

Science Objectives

- Enable detailed statistical characterization of the magnetotail plasma through long residence times in key regions of interest
- Understand the mechanisms behind reconnection in the magnetotail
- Understand reconnection and particle dynamics at the dayside-dawnside low-latitude boundary layer along the magnetopause

Mission Description

- In-situ particles and field measurements in Earth's geomagnetic tail and magnetopause utilizing a single spacecraft in a precessing orbit
- Elliptical orbit in ecliptic plane with perigee of 11 Earth radii and apogee of 23 Earth radii
- Precession of orbit at ~1° per day to maintain long residence times in geomagnetic tail
- Possible element of Space Weather program

Measurement Strategy

- High time resolution particle and fields measurements
- Long residence times in region of interest

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GeoSail: Further Explanation

The key to understanding the physical processes responsible for the transfer of solar wind energy into the magnetosphere is the measurement of reconnection.

The presence of a finite magnetic field normal to the magnetospheric plasma sheet makes it (theoretically) stable. Why then does reconnection occur? Recent simulations indicate that, at least in a 2D geometry, reconnection is governed by whistler dynamics. The electron timescale, while important, has never before been investigated. *There is a clear need for particle measurements at time resolution of between the ion and the electron gyroperiods, which are 4-8 seconds and 2-4 ms respectively.*

Achieving long-residence times in the magnetotail

The sites of reconnection are initially very small (10^3-10^4 km) and last at most a few minutes every time a substorm occurs (once per three hours). The resultant probability of in situ observation of reconnection with a single spacecraft is therefore 1 in 1000. A spacecraft, therefore, needs to remain in a region $5x5R_e^2$ in the plasma sheet near midnight ~4 months before a single event is detected. In the absence of station-keeping, typical orbits have a 1 month/year residence in this limited local-time region. The novel use of solar sail technology to precess the spacecraft orbit at a rate which matches the annual rotation of the geomagnetic tail around the Sun enables GeoSail to enhance the residence time by an order of magnitude, permitting in situ observations of several reconnection events per year.

Lightweight instruments enhance the mission capability

Recent developments in high time resolution plasma detectors and lightweight electric field detectors make them ripe for exploitation in the reconnection region of the geomagnetic tail. GeoSail incorporates a number of highly-integrated, lightweight particles and fields experiments capable of temporally resolving the dynamical behavior of particles and fields in the reconnection region.

Breakthrough science with near-term solar sails

The GeoSail mission employs a low-performance solar sail, attainable with the current state-of-the-art technologies, to carry out breakthrough scientific measurements in the Earth's magnetotail. A solar sail ~40-50m across can achieve the 0.1 mm/s^2 acceleration required to provide the necessary precession rate. Such a mission provides a scientific milestone on the road to significantly more advanced solar sail missions.

GeoSail without the sail

While solar sails are the preferable propulsion option, solar electric propulsion with a propellant mass fraction of only 14% could achieve the same precession rate, thereby enabling the science objectives of GeoSail.