Introduction of Small Solar Power Sail Demonstrator "IKAROS"

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Overview of IKAROS

IKAROS is a space yacht that gathers energy for propulsion from sunlight pressure by means of a membrane (or a solar sail.) The mission aims at verifying navigation technology using a solar sail for first time in the world. A solar sail can move forward without consuming propellant as long as it can generate enough energy from sunlight. This idea of a solar sail was born some 100 years ago, as we often find it in science fiction novels, but it has not been realized to date. In that sense, if we can verify this navigation technology through the IKAROS it will mark the first spectacular achievement of its kind in the world.

In addition to the solar sail technology, the IKAROS will also verify power generation from thin film solar cells attached on the membrane in addition to acceleration by solar radiation. Therefore, the demonstrator is named "Solar Power Sail" and is not just a solar sail mission.

A solar sail is technology that can generate propulsion in space without propellant as long as sunlight exists. In the case of a solar power sail, it can gain the necessary electric power using a vast area of thin film solar cells on the membrane even when the demonstrator is away from the sun. The IKAROS is, therefore, an ambitious mission to verify the above two technologies together which are essential for us to explore deep space.

The IKAROS is a spin-type explorer, thus it will deploy its square membrane 14 meters to the side (or 20 meters across) using the centrifugal force in space. After its deployment, we will evaluate the performance of the power generation by the thin film solar cell on the membrane, then perform experiments by navigating deep space through sunlight pressure power. The solar sail used for the IKAROS is made of polyimide resin deposited with aluminum. It is very thin, only 7.5μm (about 1/10 of a human hair.) On top of this thin sail, various devices are equipped, including the thin film solar cells, a liquid crystal device that controls attitude by changing light reflection characteristics, a temperature sensor, and a dust counter.

Through the technologies verified by the IKAROS, we can transport larger volumes to deep space and generate more power there. We would like to realize an explorer that can travel to the sphere of Jupiter by combining solar sail technology and a high-performance ion engine to become a pioneer in the age of solar system voyages of discovery.

IKAROS = **I**nterplanetary **K**ite-craft **A**ccelerated by **R**adiation **O**f the **S**un

What is a Solar Power Sail?

A **Solar Sail** is a space yacht that gathers sunlight for propulsion by means of a deployed large membrane (sail) in space. It is like a yacht that sails by gathering wind. This idea was born some 100 years ago, but it has not been realized as it requires a thin film mirror that is extremely light and strong enough to hold a vast area.

A **Solar Power Sail** is a Japanese original concept that combines solar sail propulsion and electricity generation from thin film solar cells attached on the membrane. IKAROS will verify the concept. In the future, we aim to further elaborate this technology to a hybrid propulsion system with a solar sail by activating the high-performance ion engines with the power generated by the solar power sail.

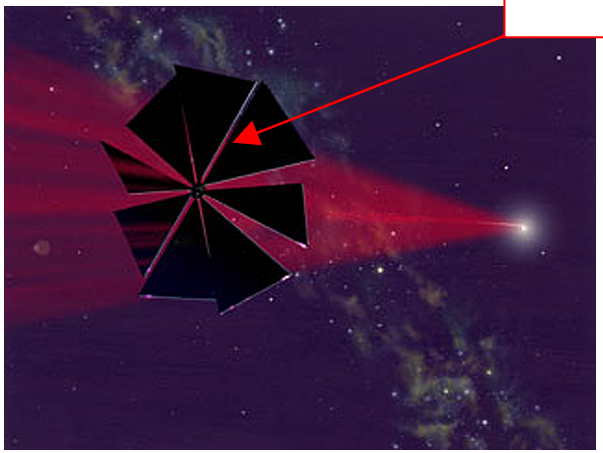
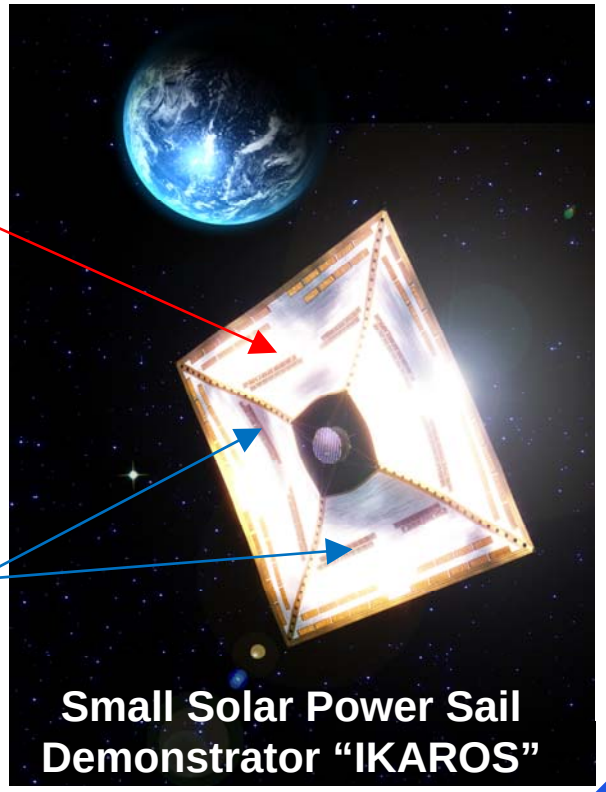


Image of solar sail (The Planetary Society)



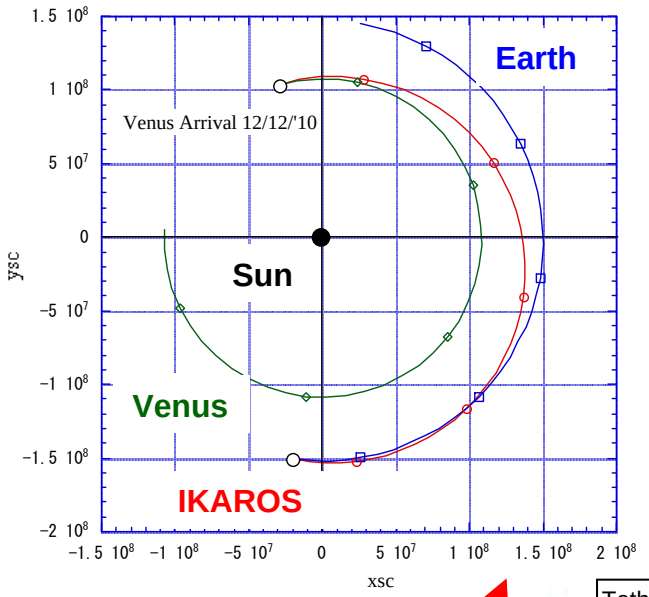
Small Solar Power Sail Demonstrator “IKAROS”

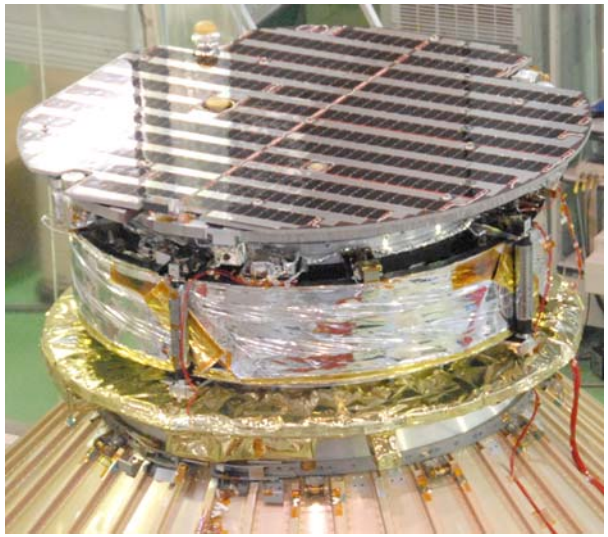
IKAROS Characteristics

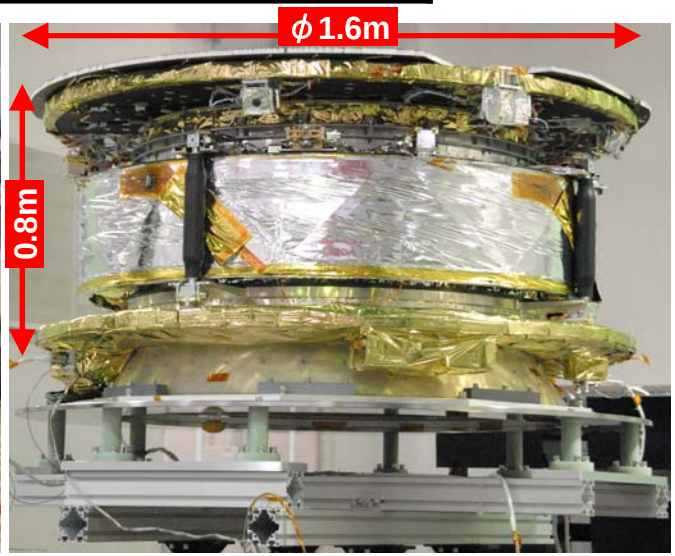
<Major Characteristics>

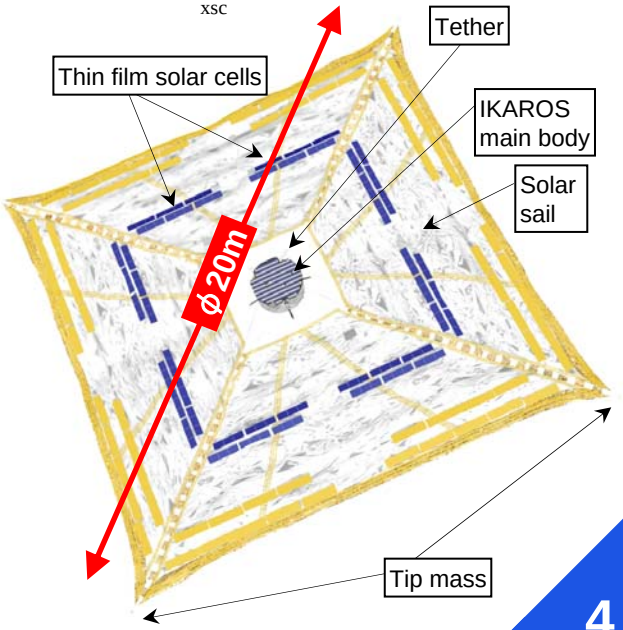
Scheduled launch day:		May 18, 2010 from the Tanegashima Space Center
Launch Vehicle:		H-IIA
Configu-ration	Body:	Diam. 1.6 m x Height 0.8 m (Cylinder shape)
	Membrane:	Square of side 14 m and cross section 20 m (after deployment)
Mass	Launch time mass:	310 kg *Including membrane mass
	Dry mass:	290 kg
	Membrane mass:	15 kg *Including 2 kg of 4 tip masses
Orbit:		Venus transfer orbit
Attitude control system:		Spin

Orbit from Earth to Venus





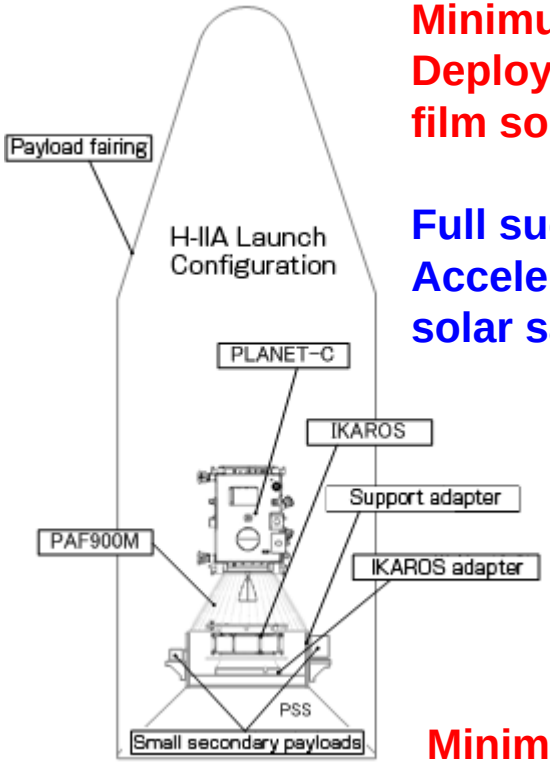




IKAROS Mission

Minimum success:
Deployment of the large membrane and power generation by the thin film solar cells. → If we succeed with the above, it will be a global first!

Full success:
Acceleration verification and navigation technology acquisition by the solar sail. →Verification of solar sail acceleration and navigation itself will be the first in the world!!

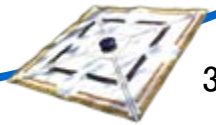


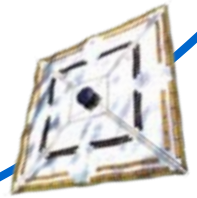
Full success

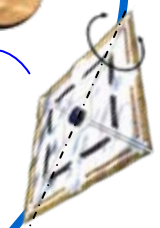
(in six months)

Minimum success

(in a few weeks)







5) Orbit control and navigation technology using solar sail

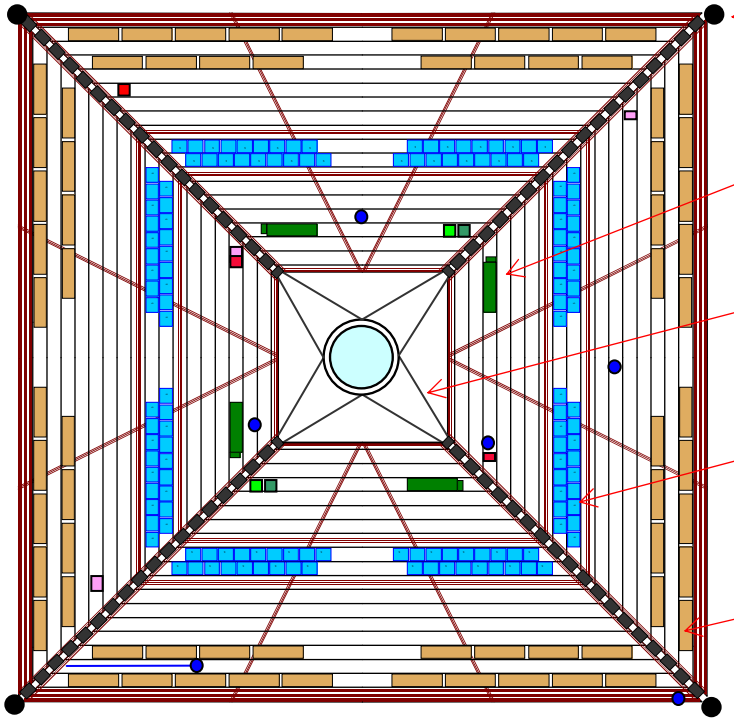
4) Acceleration experiment by solar sail

3) Membrane deployment experiment
Spinning-down (1-2 rpm)
Solar power generation by thin film solar cells

1) H-IIA Launch
Sun-pointing
Spin separation (5 rpm)

2) Radio telemetry ON
Initial operation check
Spinning-up (20 rpm) and deployment start

IKAROS Membrane



Tip mass: A 0.5 kg weight supports the deployment of the membrane.

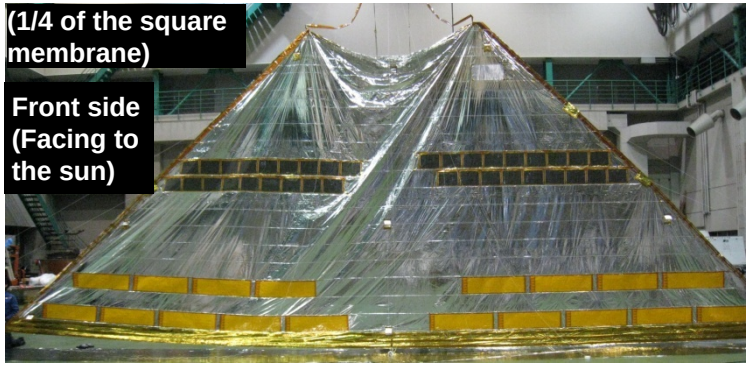
Dust counter: Space dust counter using piezoelectric elements.

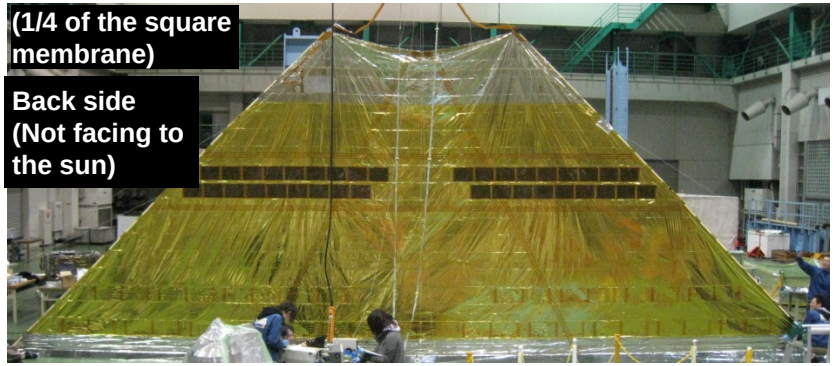
Tether: Connecting the main body and the membrane.

Thin film solar cells: Amorphous silicon cell of 25 μ m in thickness.

Liquid crystal device: Controlling attitude by changing reflection ratio. (In addition to the above, an electric charge-measuring patch and a thermometer are equipped.)

Membrane:7.5 μ m in thickness made of polyimide resin deposited with aluminum and specially processed with reinforcement to prevent cracks.

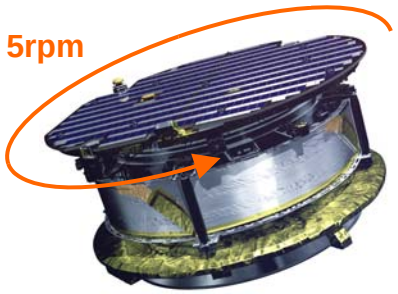




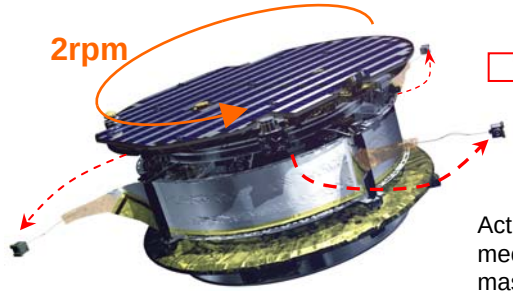
Membrane Deployment Sequence and Mechanism

Tip mass separation

Separation from launch vehicle

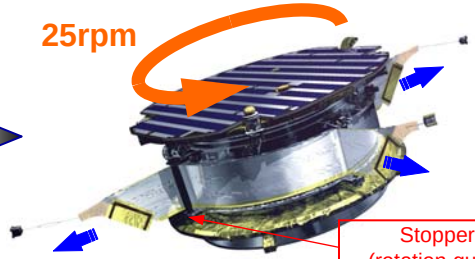


Spin down



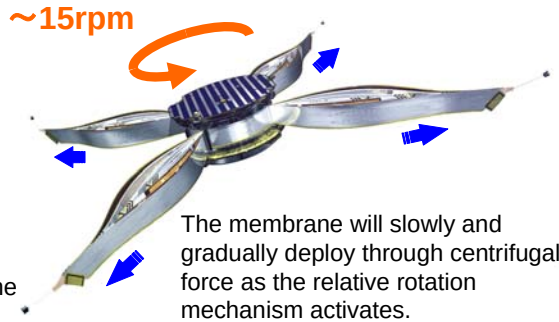
Activate the tip mass separation mechanism to separate all four tip masses at the same time.

First stage deployment (quasi static): About one hour

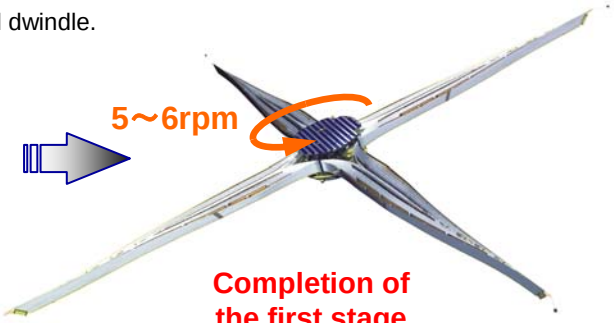


To spin up to 25 rpm, and start the first stage deployment by activating the stopper (rotation guide) that holds the membrane through the relative rotation mechanism (motor drive).

As it deploys, the spin rate will dwindle.

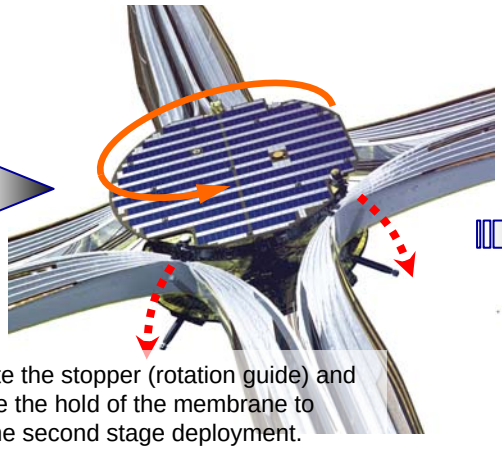


The membrane will slowly and gradually deploy through centrifugal force as the relative rotation mechanism activates.



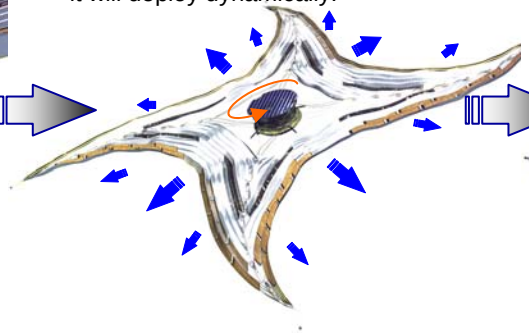
Completion of the first stage deployment.

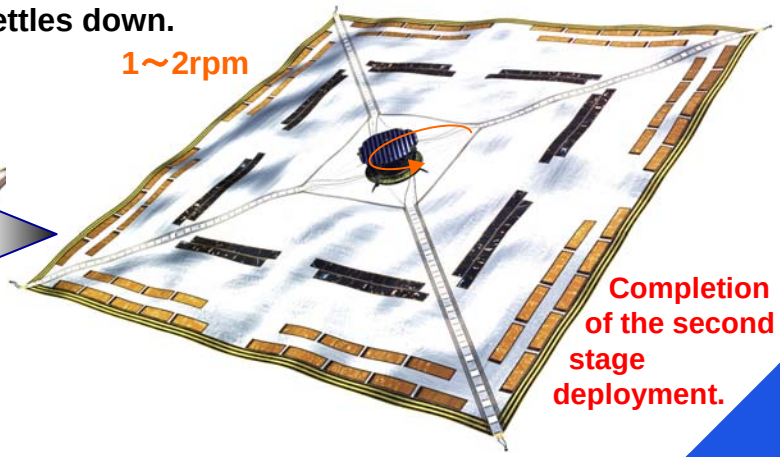
Second stage deployment (dynamic): About five seconds, or about 100 seconds until vibration settles down.



Activate the stopper (rotation guide) and release the hold of the membrane to start the second stage deployment.

As the membrane is released, it will deploy dynamically.





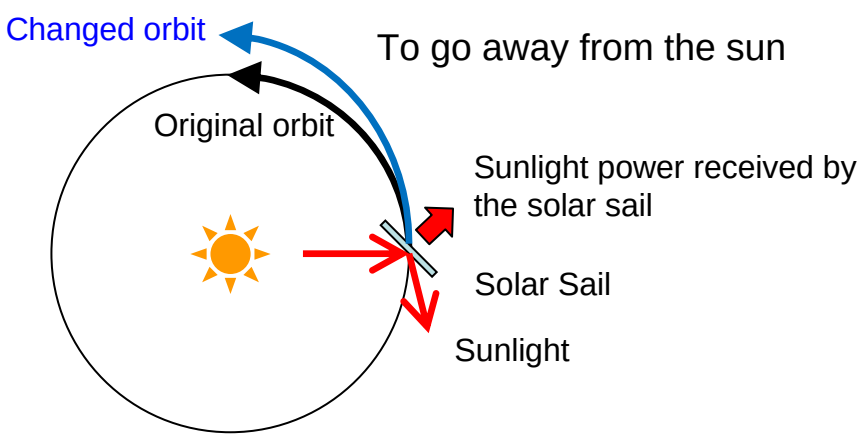
Completion of the second stage deployment.

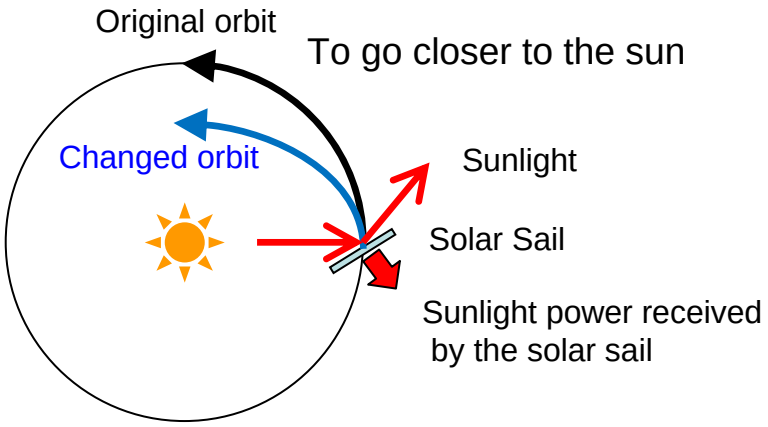
Orbit and Attitude Control by Sunlight

With a solar sail, orbit control is possible without using propellant. Orbit control requires to change the angle (facing direction) of the membrane to the sun. By shifting the attitude of the orbiter's main body through thruster jets, we will change the attitude of the membrane.

*IKAROS uses a gas-liquid equilibrium thruster.

Theory of orbit control





Other engineering and science missions

The following engineering and scientific missions are also scheduled to be conducted by the IKAROS mission in addition to the solar power sail deployment, thin film solar cell power generation, and solar sail acceleration and navigation verification.

Engineering mission

◆**Attitude control device (Liquid crystal device experiment) :** Attitude control test using a liquid crystal device whose reflection characteristics change by turning on electric power.

◆**VLBI experiment :** High accuracy orbit determination test by the Very Long Baseline Interferometer

Liquid device ON

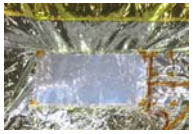
Liquid device OFF

VLBI-Tx and LGA

Science Mission

◆**ALDN (Dust counter):**
Dust distribution will be observed by a dust counter using PVDF (PolyVinylidene DiFluoride)

◆**GAP:**
Gamma-ray burst observation experiment by a polarized light detector



ALDN sensor

GAP detector