P01

ライトカーブインバージョン技術実証衛星 Q-Li

Q-Li the 3U Cubesat for Light Curve Inversion

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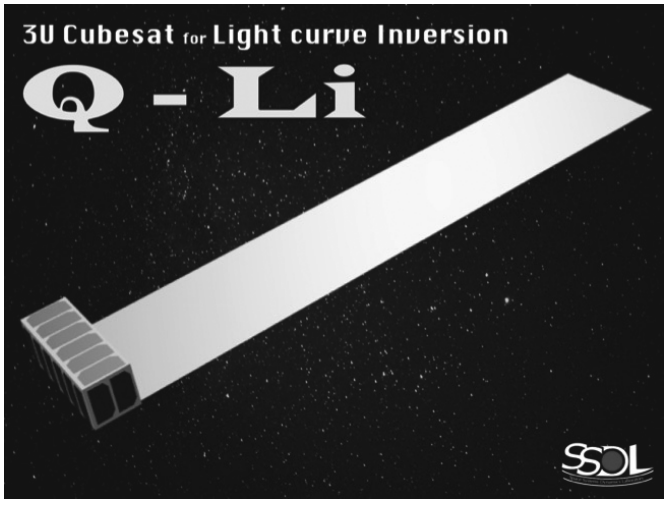
九州大学では, 天体の明るさを時間の関数として表した光度曲線（ライトカーブ）から天体の動きや変化のありさま（動態）を逆推定する技術である, ライトカーブインバージョンの確立を目指している. この技術を実証するために, 九州大学では「ライトカーブインバージョン技術実証衛星 Q-Li」を開発している.
本衛星は主ミッションとして, 実際の動態とライトカーブインバージョンで逆推定された動態とを比較・検証する. その際, 軌道上で自身の動態を計測し, 地上へ送信するとともに, 地上からの測光観測のターゲットとなる. 測光観測においてライトカーブを得やすくするため, 太陽光をより多く反射するための膜面を展開する. また, サブミッションとして膜面に微小デブリセンサを配置し, 軌道上の微小デブリの観測を行う. 本ワークショップでは, 本衛星のシステム全体に加え, 特に, 膜面展開機構およびライトカーブインバージョンについて詳しく述べる.

Kyushu University aims to establish a state estimation technique, called light curve inversion, which extracts dynamic states such as attitude motion and configuration from light curves. Light curves are brightness of space objects as a function of time and are obtained by ground-based observations. In order to demonstrate this technique, “Q-Li” the 3U Cubesat for Light Curve Inversion is being developed in Kyushu University.
The primary mission of Q-Li is the on-orbit verification of the light curve inversion by comparing actual state and estimated one by light curve measurements. To this end, Q-Li deploys a membrane to reflect sunlight so that one can be observed from the ground. Q-Li measures her own attitude angles and angular rates in orbit and transmits them to the ground. As the secondary mission, Q-Li detects tiny debris collisions with the membrane by sensors located on its surface. In this workshop, not only the whole systems of Q-Li but also the deployment mechanism of the membrane and light curve inversion technique are presented.



2018 The 8th Space Debris Workshop

ライトカーブインバージョン技術実証衛星 Q-Li
Q-Li the 3U Cubesat for Light Curve Inversion

九州大学 KYUSHU UNIVERSITY
SSOL Space Systems Dynamics Laboratory
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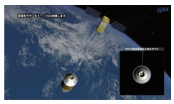
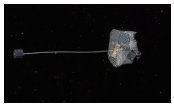
Background of Q-Li

ADR (Active Debris Removal)

- Reasonable way to remove massive debris
- A debris removal satellite approaches and puts device on a target
- **Attitude motion and shape of a target** are required in advance





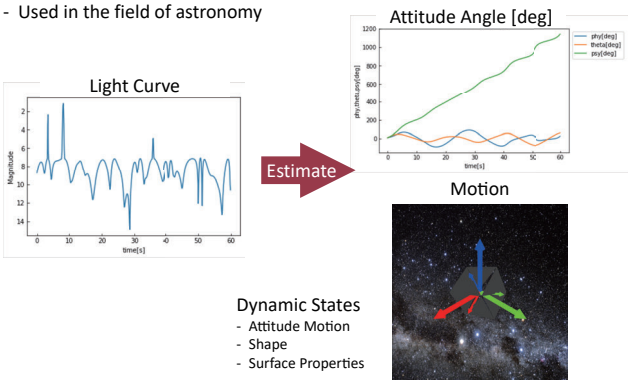
ADR

Light Curve

- **Brightness of space objects as a function of time**
- Obtained by ground-based observations
- Includes information about attitude motion and shape

Light Curve Inversion

- **A state estimation technique to extract dynamic states from light curves**
- Used in the field of astronomy



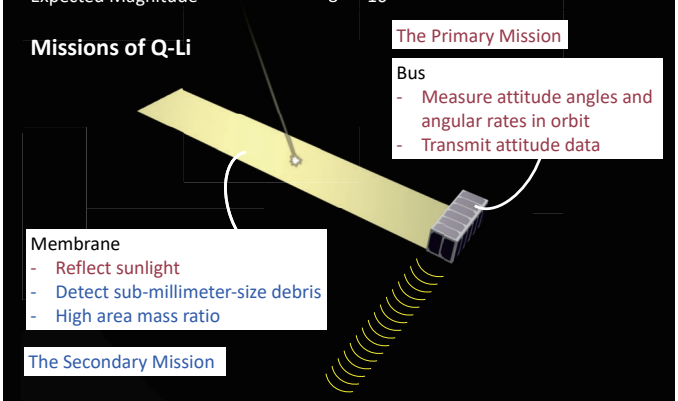
Light Curve Inversion

Q-Li the 3U Cubesat for Light Curve Inversion

About Q-Li

Orbit	Sun-synchronous Orbit (SSO)
Altitude	600 km
Mission Duration	≦ 1 year
Development Duration	≦ 2 years
Budget Including Launch	20,000,000 JPY
Attitude Determination Accuracy	≦ 1 deg , ≦ 0.2 deg/s
Expected Magnitude	8 ～ 16

Missions of Q-Li

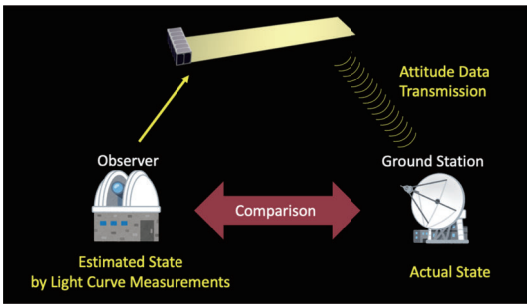


Attitude Determination and Control

- Orbit determination using optical observation and Doppler shift
- Gyro, magnetic sensor and sun sensor on board
- Only one axis controlled with magnetic torquer

The Primary Mission

The on-orbit verification of the light curve inversion by comparing actual state and estimated one by light curve measurements



The Primary Mission of Q-Li

Required Function

1. Q-Li deploys a membrane to reflect sunlight so that one can be observed from the ground
2. Q-Li measures its own attitude angles and angular rates in orbit and transmits them to the ground

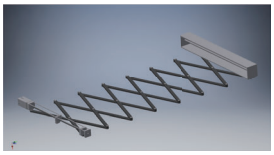
The Secondary Mission

1. **Detection of sub-millimeter-size debris** impacts with the membrane by sensors and **measurement of the time**
2. Investigation of the relationship between **attitude of a high area mass ratio object and aerodynamic torque**

The Deployment Mechanism of the Membrane

Pantograph Mechanism

- High expansion rate
- Expanded in orbit

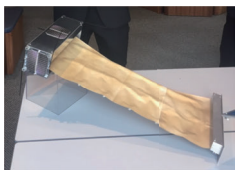


Pantograph Mechanism

Membrane

- 1650 mm in length, 289 mm in width, 70 micro meter in thickness
- Gold deposited on polyimide film
- High specular reflectance
- Very low reaction rate to atomic oxygen

Structure of Membrane

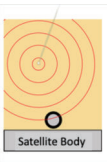


The deployment Mechanism of the Membrane

Sub-millimeter-size Debris Sensor

Piezo-electronic Device

- A sensor to detect stress wave in a material generated when sub-millimeter-size debris impact with the membrane



Piezo-electronic Device

Impact of sub-millimeter-size debris

- The number of debris expected to impact on the membrane surface a year is **56.0**
- The probability that debris larger than 1 mm impact on the arm of the deployment mechanism a year is **9.55×10^{-5}**

→ The probability that the arm is destroyed by the impact of sub-millimeter-size debris is **small enough**