ATTITUDE CONTROL SIMULATOR FOR THE SMALL SATELLITE AND ITS VERIFICATION BY ON-ORBIT DATA OF QSAT-EOS

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ABSTRACT

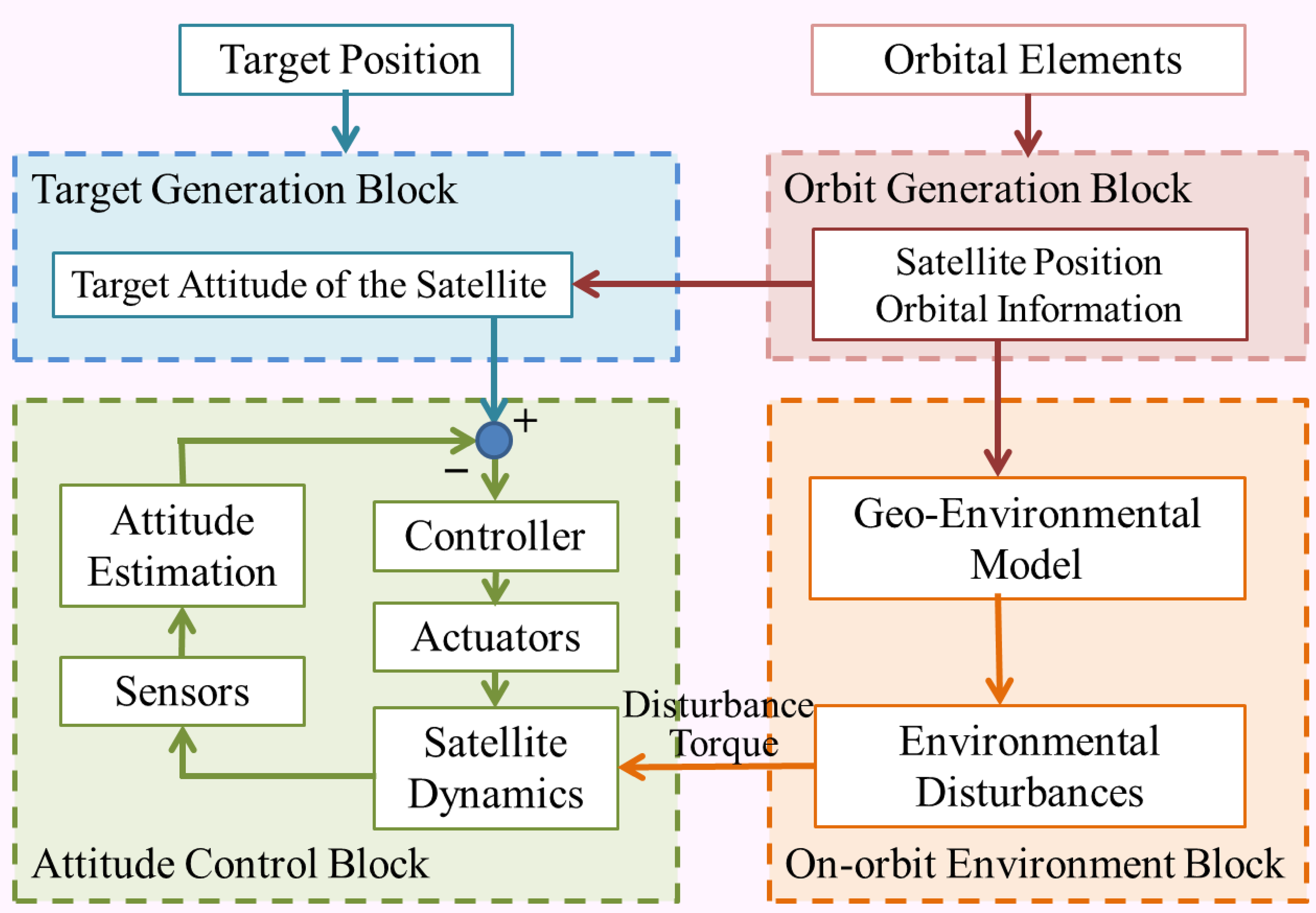
The attitude control simulator for the microsatellite for the use of design of the attitude control subsystem has developed. Quaternion feedback control is proved to be effective and stable. Then the on-orbit data of the QSAT-EOS (Kyushu Satellite for Earth Observation System Demonstration) is analyzed to confirm the effectiveness of the quaternion feedback control. QSAT-EOS was launched in 2014 and now is in the deorbit phase after two year operation. Results of the on-orbit data analysis have suggested some necessities of improvement of the simulator and control algorithm which are the future subject.

INTRODUCTION

The purpose of this simulator is to design the attitude control subsystem to fulfill the requirements of the microsatellites and to define the specifications for the equipment of the subsystem. This simulator is used in the preliminary design phase to confirm the realizability of the attitude control requirements derived from the system study. Also this simulator is used in the detailed subsystem design phase to derive the requirements for the components such as sensors and actuators. After selection of the components to be used, the actual characteristics and performance of the components are to be modeled and installed in the simulator to study under more realistic and precise conditions.

OVERVIE OF THE SIMULATOR

This simulator is composed of the four major blocks, the Orbit Generation Block, Target Generation Block, On-orbit Environment Block, and Attitude Control Block.

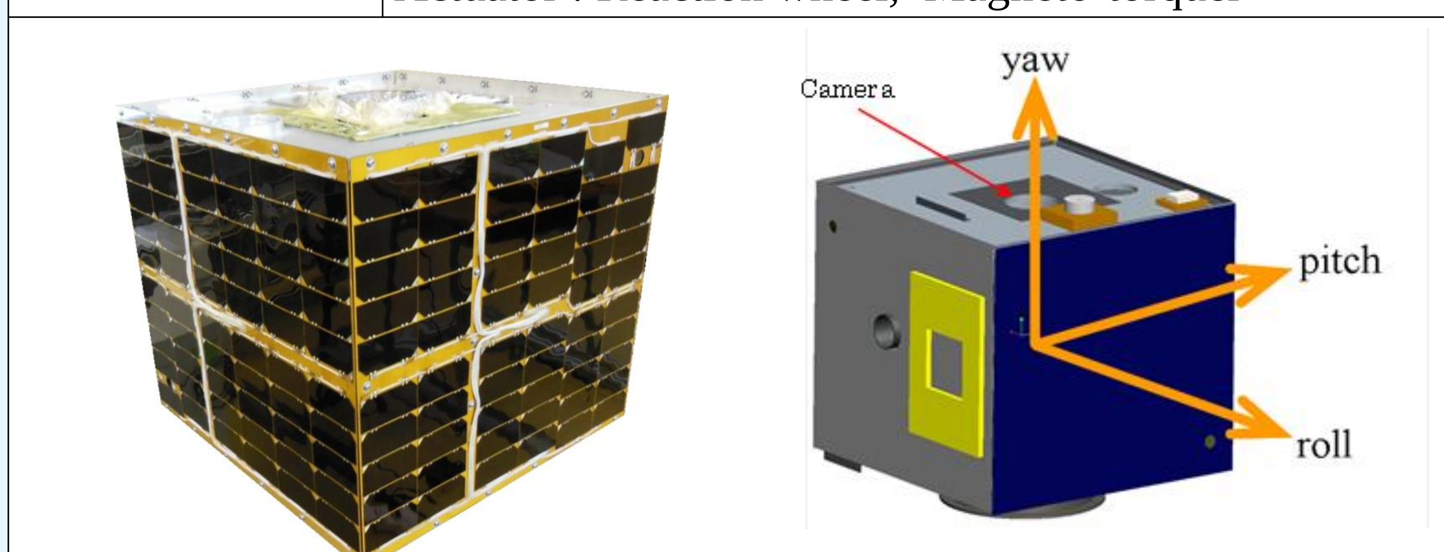


QSAT-EOS ON-ORBIT DATA ANALYSIS

QSAT-EOS was developed by the Department of Aeronautics and Astronautics, Kyushu University and Institute for Q-shu pioneer of Space, Inc. (i-QPS). QSAT-EOS was launched on 6th November, 2014 from the Yasny Launch Base of Russia by Dnepr Launch Vehicle. It had been operated for about two years on orbit and now is in the de-orbit phase using expandable deorbit sail to accelerate the descent. Major characteristics and feature is shown below.

Characteristics of QSAT-EOS

Size	50 x 50 x 50 (cm) 50 x 50 x 350 (cm) : de-orbit sail expanded
Mass	50.6 (kg)
Orbit	Sun-synchronous (altitude 530km)
Mission	Earth Observation (optical camera) Geomagnetic field (scientific magneto-sensor) Water in atmosphere (RF time delay) Micro-debris (thin film debris sensing device)
Attitude Control	Type : Three-axis stabilized Sensors : Sun-sensor, Magneto-sensor, Star-sensor, fiber optical Gyro (FOG), GPS Actuator : Reaction wheel, Magneto-torquer



Definition of body axis

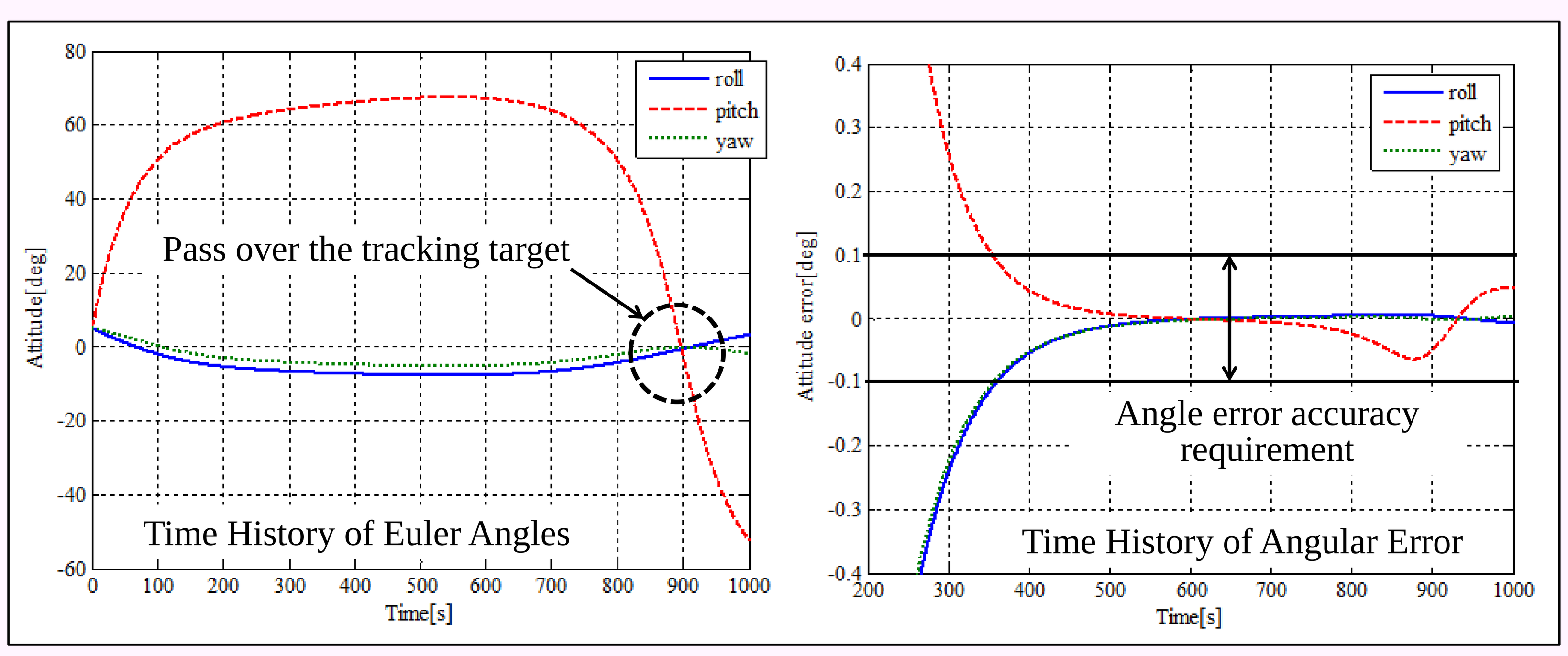
CONTROL ALGORITHMS

The earth surface tracking mode is the typical mission mode and when steering the specified axis of the satellite to the target point, the attitude of satellite can be arbitrary then the quaternion feedback control is selected to avoid the singularity problems.

Using the simple model of the satellite the effectiveness of the quaternion feedback control was demonstrated. Control torques are to be generated from quaternion position error and difference of the angular rate from the desired angular rate. Integral error is introduced when the precise tracking control is required.

$$\boldsymbol{u}_{total} = -K_p \cdot \boldsymbol{e}_p - K_d \cdot (\boldsymbol{\omega}_s - \boldsymbol{\omega}_d) - K_i \cdot \boldsymbol{e}_i$$

$\boldsymbol{u}_i$: integral error feedback control
K_i : integral error feedback gain
$\boldsymbol{e}_i$: integration of proportinal error

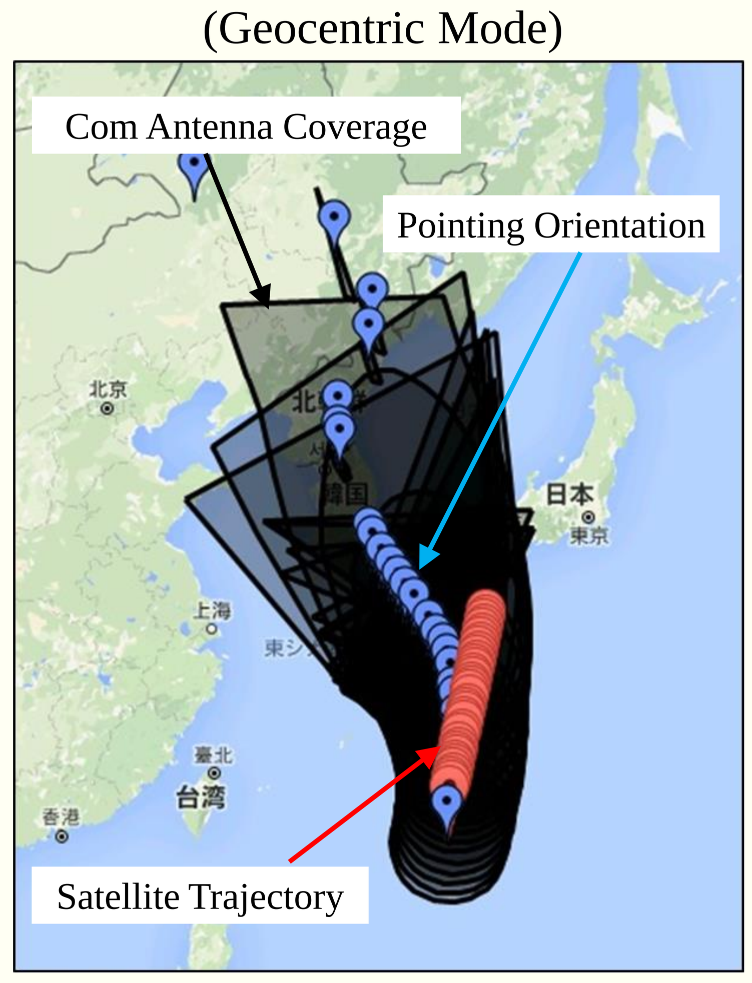


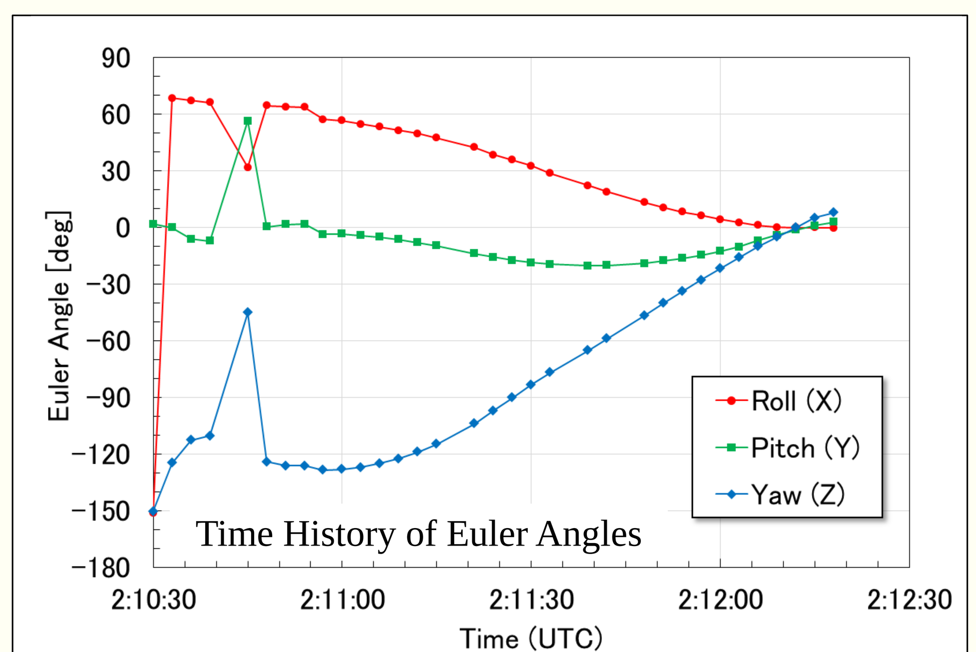
CONCLUSION

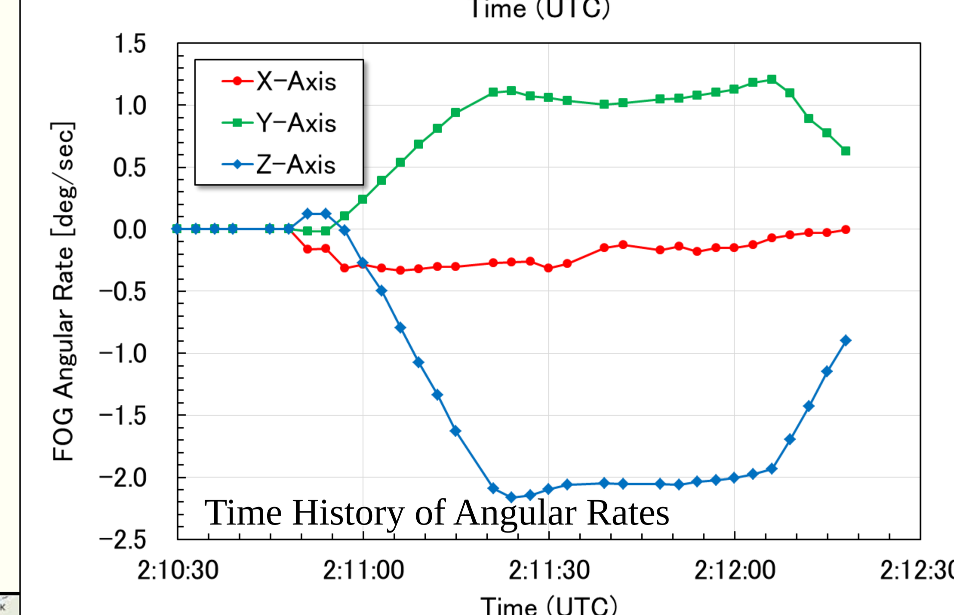
Simulator to be utilized for the attitude control subsystem design has been developed and evaluated. Simple model simulation has indicated quaternion feedback control is effective to the small satellite attitude control and provides the stable results. Through the analysis of the on-orbit data of QSAT-EOS some issues to be improved for the simulator have been found. Future work will be conducted in optimal control gain adjustment using sophisticated method such as model predicting control.

QSAT-EOS ON-ORBIT DATA ANALYSIS

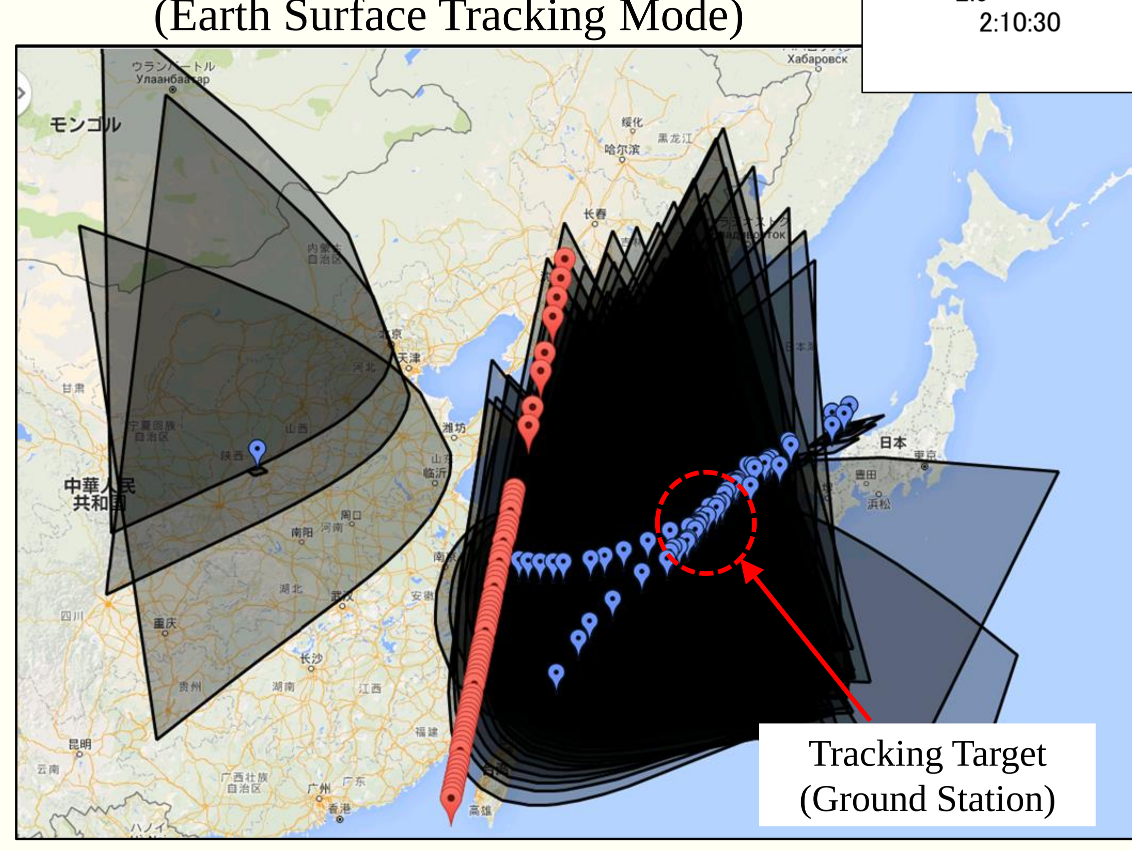
Example of on-orbit data analysis : (Geocentric Mode)







Example of on-orbit data analysis : (Earth Surface Tracking Mode)



Both of the on-orbit data analysis indicate that the quaternion control steered the satellite successfully to the target orientation. However the case of earth surface tracking mode suggests that further study be necessary to improve the tracking performance such as optimal gain adjustment to avoid overshoot behavior.

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