EARLY STAGE DEVELOPMENT OF DYNAMIC SIMULATION PLATFORM FOR REACTION WHEELS CONTROLLED CUBESAT MODEL

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Background

Satellite Communication
TV Satellite
Internet
Military
Research
Disaster Management

Number of Cubesat

Launch Cost per kg

Design Process is necessary
Research Purposes

1. To develop a Cubesat Dynamic **Design Tool** to support the design process of the simulation platform.

2. To design, manufacture, test, and evaluate a simple **Cubesat model** and an **inertia platform** to support it. (*hardware simulation platform*)

3. To develop a **simulation system** to run the simulation process, including the interface between embedded system and station, user interface, and functions needed. (*software simulation platform*)
1. The platform is designed for Cubesat, sized 10 x 10 x 10 cm and weigh less than 1 kg.

2. The embedded system is replaced by microcontroller.

3. The actuators that are used are modified motors to mimic the function of reaction wheels.
Methodology

Introduction

Simulation
  → Configuration
    ↓
  Dynamic Performance Analysis
    ↓ meet the requirements
  System Architecture Design
    ↓
  Component Sizing & Selection
    ↓ items are available
  Component Procurement
    ↓
  HILS Interface Design
    ↓

Performance Test
  → Functional Test
    ↓
  Platform Integration
    ↓ materials are available
  Hardware Manufacture
    ↓
  Hardware Design
    ↓ well interfaced
  Software Interface
    ↓
  Partial Software Development
    ↓

Integration failure
  ↓
Software failure
  ↓

Inadequate performance
  ↓
Unavailable parts
  ↓
Limited resources
  ↓
Missing functions
  ↓
Config Tool

Configuration Tool Interface

- Density of the components
- Dimension of the Cube
- Dimension and Configuration of the Reaction Wheels
- Dimension and Configuration of Ballast
- Inertia Matrix of specific group of Components
- Position of Center of Gravity
- Total Mass of specific group of Components

Design Tools
Open Loop Tool

Initial condition of Cubesat
Constant External Torque
Temporary External Torque
Simulation Period

State condition of Cubesat at given time
Simulation time
Plot of state condition of Cubesat at given time

Graphic: Open Loop Simulation Tool Interface

- Initial Angular Velocity: [0, 2, -3] deg/s
- Initial Angle: [0, 0, 0] deg
- Constant External Torque: Use Constant External Torque
- Step External Torque: Use Step External Torque 1, Use Step External Torque 2
- Simulation Time: 100 s

Graphic: State Angular Velocity

Graphic: State Angle

Graphic: State External Torque Applied

Graphic: State Time

Design Tools
Closed Loop Tool

Closed Loop Simulation Tool Interface

- Initial condition of Cubesat
- Constant External Torque
- Desired Condition
- Feedback Gain
- Simulation Period
- State condition of Cubesat at given time
- Simulation time
- Plot of state condition of Cubesat at given time
Simulation Platform

Whole System Architecture

Hardware Platform
- Cubesat Model
- Inertia Platform
- HILS
  - GUI
  - Simulink
  - Arduino

Software Platform
- Design Tools
- Design Aids

Simulation System Workflow

Software
- Dynamic Reaction (Attitude Changes)
- Brushless Motor (Reaction Wheel)
- Inside Cube
- 10 DOF
- Current State

Hardware
- Torque
- Cotton
- ESC
- MCU
- RPM Sensor
- User
- Ground Station
- Command
- Data
1. Simulink to GUI (Real Time Object)
2. GUI to Simulink (Assignin/ Set_Param)
3. Arduino to Simulink (Serial Receive)
4. Simulink to Arduino (Serial Send)
5. Sensor to Arduino (Digital Motion Processing/ Complementary Filter)
6. Arduino to Motor (Servo PWM)
7. Sensor to GUI
8. GUI to Motor
Inertia Platform

Simulation Mechanism

a. Gyroscopic Platform
b. Air Bearing Tabletop
c. Air Bearing Dumble
d. Magnetic Levitating Platform
## Cubesat Model

### Modeled Subsystems

<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structure</td>
<td>Aluminum &amp; Acrylic</td>
</tr>
<tr>
<td>Thermal</td>
<td>-</td>
</tr>
<tr>
<td>OBC/OBDH</td>
<td>Microcontroller</td>
</tr>
<tr>
<td>ADCS</td>
<td>IMU – Reaction Wheels</td>
</tr>
<tr>
<td>EPS</td>
<td>Battery</td>
</tr>
<tr>
<td>COMM</td>
<td>Radio Telemetry</td>
</tr>
<tr>
<td>Propulsion</td>
<td>-</td>
</tr>
<tr>
<td>Payload</td>
<td>-</td>
</tr>
</tbody>
</table>

### Cubesat Configuration

![Cubesat Configuration Diagram](image-url)
Here it is...
Functional Test

Static Test: Angle Measurement
Dynamic Test: Reaction Wheels
Functional Test

Dynamic Test: Gyroscopic Phenomenon with Reaction Wheels
Evaluation

Design & Component Selection Evaluation
1. Gyroscopic Mechanism
2. Gravity Gradient
3. Bearing Lock

Encountered Problem
1. Wireless Communication → Wired Communication
2. Cubesat Model Weight Distribution
3. Friction in the bearing lock
4. Wheel Balancing
5. Motors are stuttering in High RPM
1. the simulation platform that is intended to simulate the dynamic performance of a cubesat and to observe the capability of ADCS that is being used has successfully been developed at early stage.

2. Cubesat Dynamic Design Tool that has been built to support the design process of the Cubesat.

3. The simulation platform has been tested and evaluated, to be improved for further research.
1. Hardware components have to be machined and/or processed in more proper way (balance, weight distribution, accuracy).

2. Component selection has to be reconsidered based on its performance.

3. A system to simulate perturbation in the outer space is also can be added.


Thank you