CubeSat Station Keeping Maneuver Analysis Planning Document

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1. Scope

This paper will examine the orbital dynamics of station-keeping for up to a 12U Cube Satellite deployed in two distinct orbits. The primary objective is to assess how different orbital parameters and propellant options influence the satellite's longevity and maneuvering capabilities. There will be three different types of propellants tested and the ability of each to maintain the orbits will be evaluated. The testing outputs will provide insight into fuel efficiency, maneuverability, and long-term mission planning for small satellites.

The report will be formatted as shown below:

1. Introduction
    i. Problem Statement
2. Background
    i. Orbit Information
    ii. Propellant Information
    iii. Python Information
3. Methodology
    i. Description of simulation
        1. Assumptions
        2. Pseudocode (full program in appendix)
    ii. Description of cases
4. Analysis
    i. Display results of case matrix
    ii. Discussion on results
5. Conclusion
    i. Select 1 optimal propellant per orbit
    ii. Future research & development opportunities

2. Assumptions

The design of the spacecraft will be a symmetrical cubesat body up to 12U. The spacecraft will start the simulation directly after detachment from the transport vehicle in the specified orbit. Several environmental factors will be accounted for, including atmospheric drag, Earth's oblateness (J2 perturbation), and solar radiation pressure. Mass will be constant for each initial condition with no external forces considered, such as third-body gravitational effects from the Moon or Sun, and all propulsion maneuvers will assume instantaneous burns. Orbital lifetime will be analyzed using the SGP4 propagator. A constant thrust vector will be assumed for all propulsion maneuvers with no variation in direction or magnitude during burns. Idealized ISP values will be used for fuel efficiency calculations. Legacy propulsion systems will be used as a reference allowing for a better evaluation of the effectiveness of the selected propellants.

3. Case Load

Three propellants will be evaluated for two distinct orbits as shown below in Table 1. The first orbit will be circular, and the second orbit will be highly elliptical. The propellants utilized in the study will be a monopropellant hydrogen peroxide, a bipropellant monomethylhydrazine, and a cold gas propellant isobutane. All of these are common propellants amongst small spacecraft depending on the propulsion technology utilized and space available on the vehicle[1].

Table 1: Caseload Matrix for Trade Study

Case	Orbit	Propellant
1	Circular	Hydrogen Peroxide
2	Circular	Monomethylhydrazine
3	Circular	Isobutane
4	Elliptical	Hydrogen Peroxide
5	Elliptical	Monomethylhydrazine
6	Elliptical	Isobutane

4. Path

The primary driver of analysis will be a computer simulation utilizing the SPG4 module in Python 3. For each time step, the program will use the previous state to determine the spacecraft's new state and the next timestep's "ideal" state. If the error is above a specified tolerance, the program will calculate a maneuver and Delta V required to reach the "ideal" state from the current state. The spacecraft will have a Delta V limit corresponding to the amount of initial fuel. Once the spacecraft reaches the Delta V limit the simulation will end and the program will output how long the spacecraft stayed in the desired orbit and provide statistics on how it conformed to the desired orbit. Each of the three propellants utilized will have their own function to determine how the Delta V differs for each timestep.

References

1. https://s3vi.ndc.nasa.gov/ssri-kb/static/resources/KrejciLozano_PropSamllSat_ProcIEEE2018presub.pdf