A screenshot of a computer

AI-generated content may be incorrect.Fully realised Satellite Attitude Control system in MATLAB/Simulink for a repair satellite with an operational arm performing in orbit repairs on damaged non-legacy satellites.

Figure 1: Realised SACS

The SACS has is made of four Reaction wheels in a pyramidal configuration allowing for omnidirectional torque development along all axis of movement.

It implements quaternion and Euler mathematics to model the satellites dynamics and kinematics in free space.

References can be set for both the quaternion and angular velocity and depending on initial spin rate and orientation, torque is developed to both achieve and maintain the attitude of the satellite.

Four Reaction wheels were used to allow for redundancy and faster reaction times. The amount of torque generated by each reaction wheel when responding to a disturbance is fast in response and controlled by a fine-tuned PID controller (torque mode controller block).

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Figure 2: Quaternion error

Figure 2 shows the quaternion error of the SACS when responding to minimal external torque disturbance (near ideal conditions) within 30 seconds the control system aligns the quaternion with the reference and maintains the stability of the repair satellite.

A graph showing a graph of a wheel torque

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Figure 3 shows the torque generation within the same mission constraints on the four reaction wheels. The wheels generate a maximum torque of 0.02Nm until stability is reached then relevant torque is generated throughout the disturbances. In this mission all four reaction wheels are functioning thus resulting in the fast response time.

Figure 3: Torque Generation

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Figure 4 shows the MATLAB function to generate relevant torque for a repair mission.

Figure 4: MATLAB Function for disturbances during mission

A graph of a function

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Figure 5: Graph of disturbances

Figure 5 details the graph of environmental and external torque disturbances for a relevant repair mission.

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Figure 6 details the response of the SACS during the mission. The combination of quaternion mathematics and the choice of a fine-tuned PID controller allows for fast response to the disturbances and correct torque generation.

Figure 6: Torque generated by SACS during mission

A graph of a graph

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Figure 7 shows how the SACS can control torque generation along all three axes of movement, even in the presence of a (albeit rare) reaction wheel failure the control system responds in a similar manner to maintain stability just with a slightly slower reaction time (due to the lower amount of torque generation).

Figure 7: Reaction of SACS in presence of a Reaction wheel failure

A diagram of a block diagram

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Figure 8: Torque mode PD controller

Figure 8 details the torque mode controller that inputs quaternion error, angular velocity error and outputs control torque commands. In addition, figure 9 details the environmental disturbances modelled into the satellite that depend upon altitude, strength of gravity and other factors.

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Figure 9: Environmental disturbances

Desaturation is also a key factor of the control system and when the reaction wheels reach their maximum speed, micro-thrusters need to engage in order to desaturate the wheel. The thrusters are controlled using a Pulse-Width Pulse-Frequency Modulation controller (PWPF) as seen in figure 10. This minimises fuel usage while maximising effectiveness. (Simulink model detailed in figure 11).

A diagram of a computer program

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Figure : Simulink model of PWPF

Figure 10: Block diagram of desaturation thrusters