47th SYMPOSIUM ON SAFETY, QUALITY AND KNOWLEDGE MANAGEMENT IN SPACE ACTIVITIES (D5)
Ensuring quality and safety in a cost constrained environment: which trade-off? (1)

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FAILURE MODE AND EFFECT ANALYSIS (FMEA) OF THE SENSORS AND ACTUATORS ONBOARD PRATHAM, THE STUDENT SATELLITE OF IIT BOMBAY

Abstract

The Attitude Determination and Controls Subsystem (ADCS) of Pratham, the student satellite of IIT Bombay, aims at controlling the orientation of the satellite within 10 degree Euler angles with respect to a reference orbit frame. The design of the student satellites is constrained by cost and expertise available, hence redundancies and back up options are less in case of any failure. So single point of failures is common and knowing possible failure beforehand can help to optimize the design. This paper deals with the various failure cases of the sensors and actuators on board Pratham and their effect on the ADCS of the satellite. In order to draw a causal relationship of a particular failure and its consequences, a single failure is introduced into system running under perfectly ideal conditions. Ideal conditions includes elimination of environmental disturbance torques, sensor noise, zero initial attitude, rate errors and non-existence of eclipse region which switches satellite to the uncontrolled mode.

Pratham uses 3 types of sensors for attitude determination. Six sunsensors are mounted on all faces of cubicle satellite to estimate Sun vector in body frame. The failure modes considered for sunsensors are based on their field of view restriction, deviation from cosine law and complete dysfunctionality of a sensor. The Magnetometer is analyzed for the sensitivity of attitude control to its bias and random errors. The consequence of these failures is analysed by studying the deviation of the estimated sun or magnetic field vectors from the real values and that of estimated Euler angles from their real values.

The two failure cases of GPS considered are that of GPS switching off after a single initial set of data and a permanent change in GPS resetting time. This work also presents results of sensitivity analysis of the attitude with GPS noise and the maximum time for which it can be afforded to keep the GPS switched off while still meeting control objectives. Analysis of performance of underactuated system resulting from the failure of one of the three magnetorquer is also conclusively presented.

Such cause and effect exposition addressed in this paper not only gives a deeper insight into the design of Pratham, but also serves as a guideline for design of similar future missions.