InnoSAT PROGRAM

1. MISSION

Mission Statement

To design, develop and implement indigenous ACS

Mission Objectives

To test advanced control algorithms for satellite attitude control

To utilize the available attitude knowledge of InnoSAT to provide the attitude control using different control algorithms

Secondary Objective

To evaluate control algorithm performance with unpredictable conditions

2. PROJECT OBJECTIVES

To develop attitude control algorithms software; ACS is the part of the ADCS payload. The ACS has Adaptive Predictive Fuzzy Logic The objective of this project is to develop attitude control algorithms that are going to be tested when the InnoSAT is in the orbit. Upon deployment in the Near Equitorial Orbit (NEqO), it will tumble and has difficulty to oriented itself. Hence the needs to control to the designated orientation. This is called Attitude Control System (ACS). On receiving the desired and actual angles, intelligent control algorithms using the Adaptive Predictive Fuzzy Logic Control (APFLC) and Adaptive Parametric Black Box (APBB) will be employed separately according to the command sequence that will be determined by the InnoSAT's main controller. Resulted data from this control algorithm experiments will be downlink to the ground control for analysis.

1. PROGRAM ORGANIZATION

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Hardware
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5. Muhajir Abdul Rahim
6. Mohd Adam Razali
7. Rosfariedzah Rusli
8. Abu Hassan Abdullah
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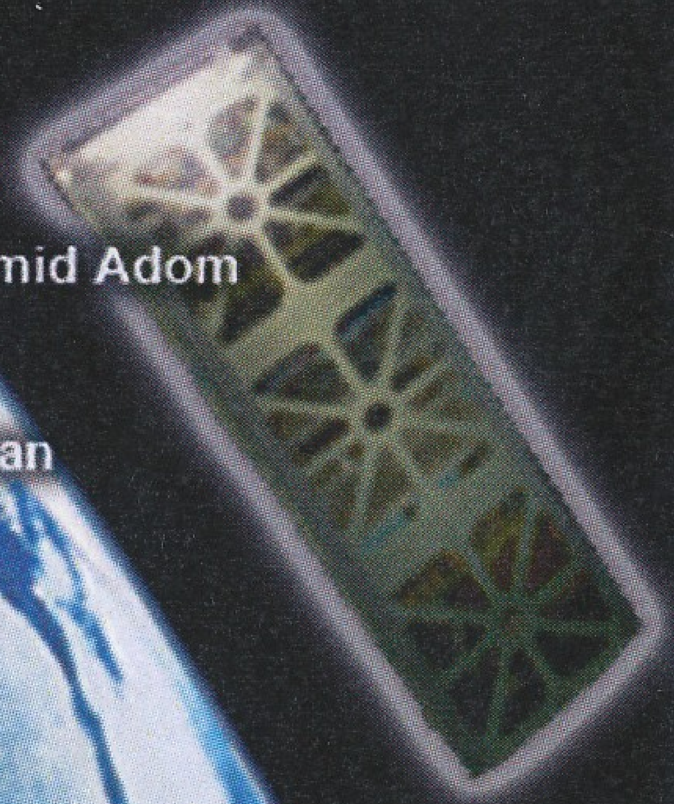
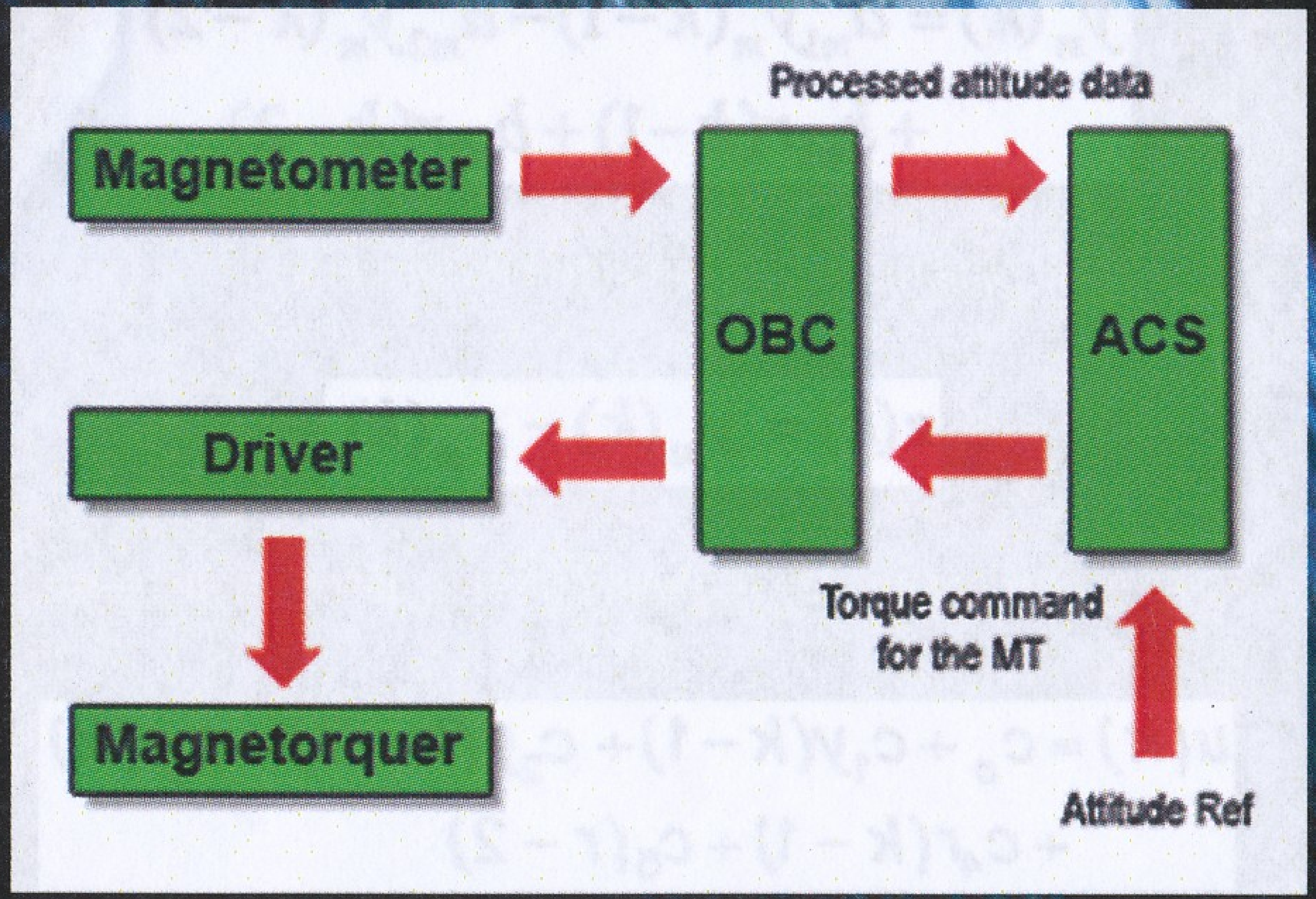




3. CONTROLLER

The **UniMAP ACS** contains the functional advanced adaptive control methodologies; **APFLC**. It is proposed that initially, the **InnoSAT ADCS** takes charge from the time the satellite is being launched until it has come into or near its orbit. Then the controller of the **UniMAP ACS** takes the control over from the **InnoSAT ADCS (via OBC)**

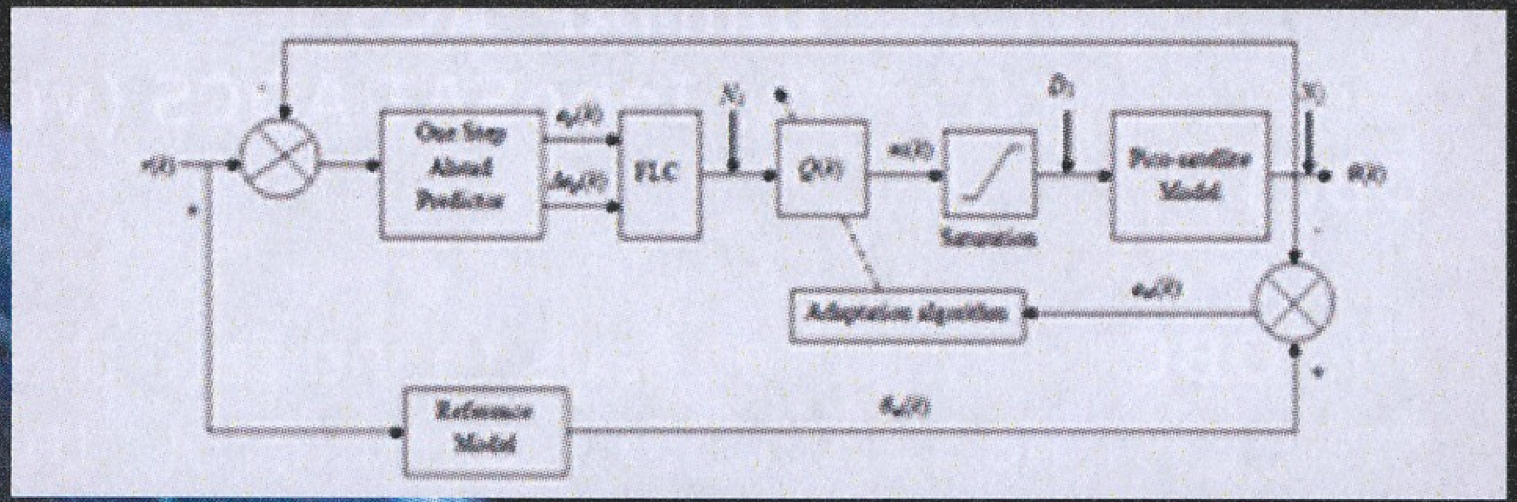
The **OBC** will wait for flags to indicate that there is no error in running of the controller programs. If after a specified delay no flag is received by the **OBC**, then the controller will go into recovery mode. If recovery mode is successful, then the controller will start again. Otherwise, **OBC** shall return satellite attitude control to **ADCS**

If the satellite attitude control of the **UniMAP ACS** is successful, it will remain in control for a specified time and then the control will be returned to the **OBC**. Then the second controller of the **UniMAP ACS** will take over the attitude control and so on

However, if any of the controllers in the **UniMAP ACS** fail to keep the satellite within a certain limit of error or deviation from its orbit, the control will automatically be handed back to the **OBC**

4. ADAPTIVE PREDICTIVE FUZZY LOGIC CONTROL

A discrete satellite model which is basically unstable is selected.
A preliminary FLC is derived and the response is studied.
A time delay of 1 sampling time is introduced and a predictive form of FLC (PFLC) is derived.
A stable reference second model without time delay is assumed for computing APFLC response.
The performance of all of them is monitored and studied with and without noise and external disturbance.

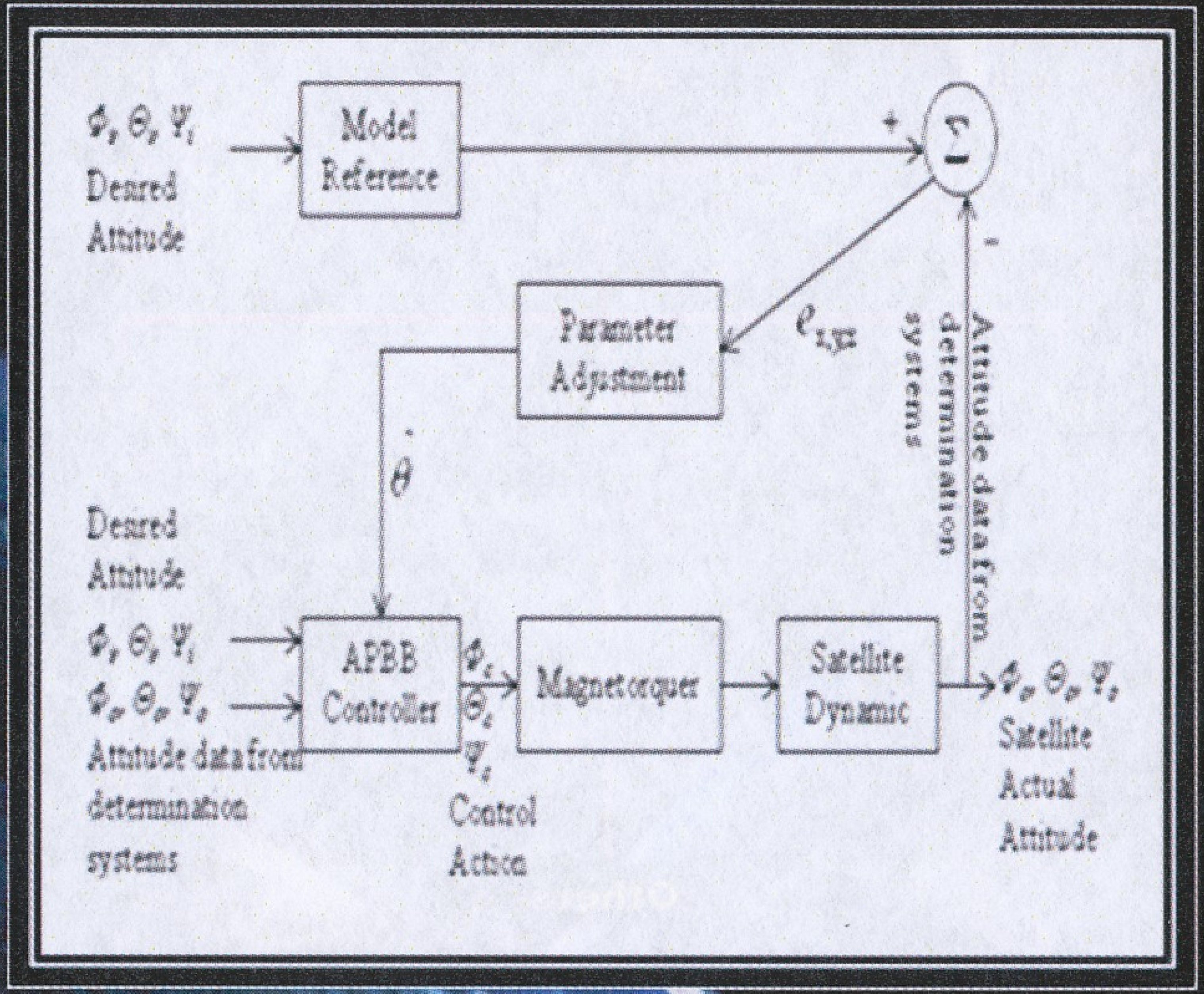


Among all Artificial Intelligence (AI) methodologies, Fuzzy Logic Controller (FLC) is very fitting to such a case of a satellite in space and accommodates a high level of human capabilities and knowledge in solving uncertainty problems. This research project proposed an attitude control of a Pico-satellite. The design schemes of modeling adaptive and predictive FLC (APFLC) is described as follow: Basic FLC, Predictive FLC (PFLC) and APFLC.

A development of an expert real time control system based on FLC is possible for the satellite in space that is exposed to non-probabilistic uncertainties such as sun flare and time dependant noises in measurement. In order to reduce the effect of unpredictable time delay and variations in unknown parameters due to various environmental conditions and inaccurate modeling of the satellite, an adaptive predictive form of a Mamdani FLC is introduced. A predictive controller is needed to compensate the effects of dead time which occurs in the Pico-satellite control system. The predictor estimates the required control at the next sampling time and applies to the system at the current sampling time. The variations of unknown parameters can be assumed to be all combined as an unknown change in the gain, k, of the satellite system. It is hence needed that the satellite is to behave with a known time response irrespective of parameter changes. The gain k has to be adjusted continuously so that the system is forced always towards a certain stable behavior. The motion of the Pico- satellite can be influenced in its attitude system by external disturbances *(D1)*. N1 and N2 are input and measurement noises. Noise in one way represents inter-attitude coupling.The simulation results are presented and the output responses indicate that this approach of FLC is acceptable even in the case of a Pico-satellite subjected to input noise, measurement noises, intermittent disturbances and also with sensor nonlinearity. It is observed that the APFLC showed convincing performance over the entire simulation of the Pico-satellite.

5. ADAPTIVE PREDICTIVE BLACK BOX CONTROLLER

Many valuable control methods have been developed over the past years since the first satellite was launched in 1957. Attitude control is control of the orientation of a spacecraft.



Control Scheme for APBB Controller

Adaptive Parametric Black Box control system using indirect adaptive control design. The system will adjust the controller parameters in such a way that the error becomes small, which is the difference between process output, y_p and model output, y_m.

A reference model is used to produce the desired output :

$$y_m(k) = a_{m1}y_m(k-1) - a_{m2}y_m(k-2) + b_{m1}r(k-1) + b_{m2}r(k-2)$$

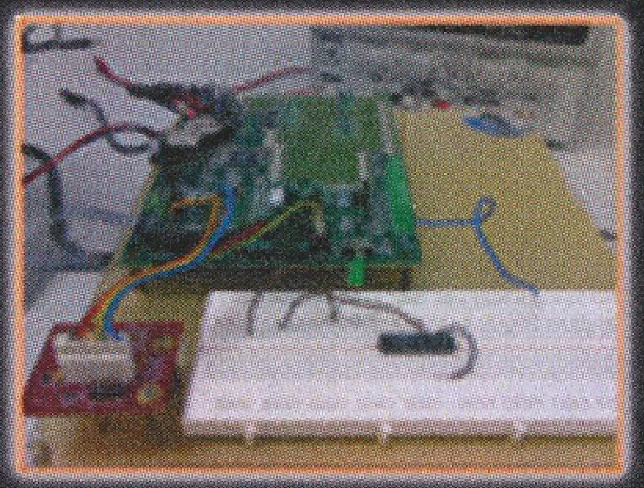
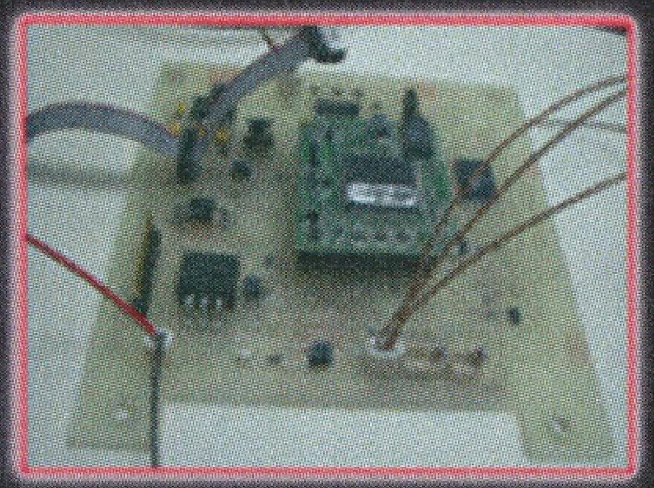
The model following error is defined by :

$$e(k) = y_m(k) - y_p(k)$$

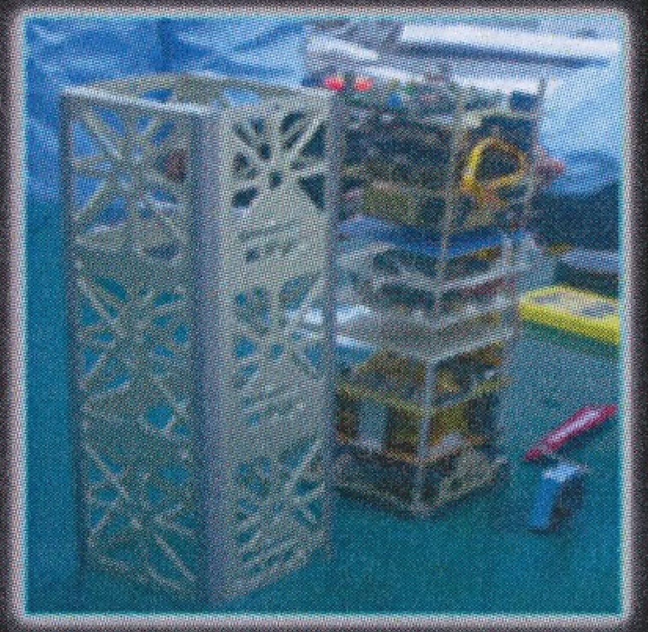
The controller structure is given for fast updating parameters :

$$u(k) = c_o + c_1y(k-1) + c_2y(k-2) + c_3r(k) + c_4r(k-1) + c_5(r-2)$$

HARDWARE PLATFORM

UniMAP ACS Hardware Development

1. Develop program interface between On Board Computer (OBC) and the Rabbit Core Module 3400 (RCM3400).
2. Personal Computer (PC) were used as OBC for the simulation.
3. Develop interface between RCM3400 and the 8MB flash memory (SF1000).
4. Simulate the functionality of the controller algorithm using Dynamic C on the RCM3400 by utilizing the SF1000 for data logging.

A Research Collaboration of:

ANGKASA ATSB MOSTI UniMAP