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An Accuracy Prediction of OBC System Reset LAPAN-A3/LAPAN-IPB Satellite

Desti Ika Suryanti
Satellite Technology Center
National Institute of Aeronautics and Space (LAPAN)
Bogor, Indonesia

Muhammad Taufik
Satellite Technology Center
National Institute of Aeronautics and Space (LAPAN)
Bogor, Indonesia

Ade Putri Septi Jayani
Satellite Technology Center
National Institute of Aeronautics and Space (LAPAN)
Bogor, Indonesia

***Abstract*—Currently LAPAN has launched three A-series satellites which are still in orbit. One of them is LAPAN-A3/LAPAN-IPB satellite that has various missions, such as earth observation using multispectral camera and digital space camera, global maritime awareness support using AIS receiver, and scientific mission using magnetometer. With these various kinds of complex missions, reliability are needed for all satellite subsystems and operation. OBC is one of the subsystems that has a role as satellites brain. On LAPAN-A3/LAPAN-IPB satellite, it equipped with fault tolerant system in form of external reset system to keep it reliability. When the reset occurs, all subsystems will be restored to the initial setup, therefore all operators must know when it will happen in order to anticipate that condition to keep all satellites mission operations continues. The accuracy of LAPAN-A3/LAPAN-IPB satellite OBC's reset system time prediction will be analyzed using LAPAN-A3/LAPAN-IPB satellite log files in this paper. Based on the analysis of log files data, it is known that the OBC's reset system time prediction is 37 seconds slower than the actual reset system time.**

Keywords: On-Board Computer, system reset, LAPAN-A3/LAPAN-IPB satellite

I. INTRODUCTION

The rapid development of microsatellites that bring out more complex payloads and missions affects the demands of higher spesification On-Board Computer usage too, to make sure the satellites work properly and can carry out their missions [1].On-Board Computer (OBC) is an important part which act as the brain of satellite system and in charge of monitoring and controlling all subsystems in satellite system. When the satellite is out of ground station coverage, all necessary actions and important decissions about satellite operation will be taken by OBC [2]. OBC will collect and analyze all information from each satellite subsystem such as payload subsystem, communication subsystem, attitude determination and control subsystem, and electrical power supply subsystem to get the subsystem health monitoring data[3].

Considering the importance role of OBC on satellit system, Fault tolerant strategies are needed to maintain OBC device reliability because that device will be on space environment that usually tends to extremes and affected by radiation effect. Satellites OBC can fail as a result of electrical failure, mechanical failure, thermal failure, space debris, etc. If the satellite OBC fails, the satellite either goes into a safe mode or totally fails, which causes a loss of the mission [4]. Fault tolerant strategy is a technique that enables a system or application to continue working even if some fault / error occurs in a system [5]. One of the fault tolerant strategies that can be used is monitor the operating systems by using a watchdog timer, which is a computer hardware that acts as a timer that can trigger the system to restart the program when an error is, occur on the system. Watchdog timer can be stand-alone hardware component (external) or build-in processor (internal). The application must be reset periodically before a certain interval ends to avoid reset when the application still works normally [6].

On LAPAN-A3/LAPAN-IPB satellite, OBC is located at PCDH block along with Power Control Unit (PCU) and equipped with hammer circuit (reset counter logic) that implemented on PCDH circuit as a satellite fault tolerant strategy that refer to external watchdog timer strategy. This circuit using RC oscillator is to trigger the system to do PCDH hardware reset with time range between 13-15 days [7]. Figure 1 below showing PCDH block diagram on LAPAN-A3/LAPAN-IPB satellite.

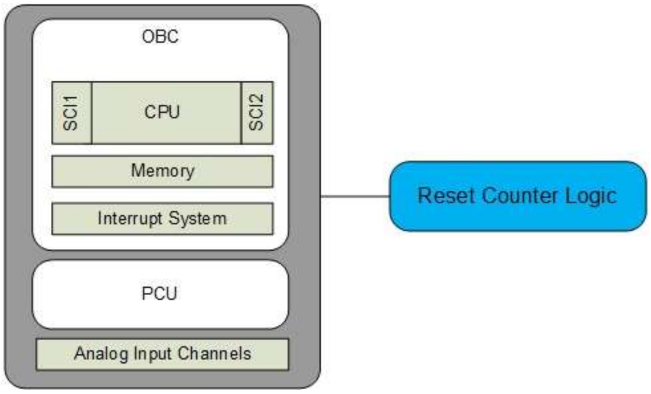

Figure 1. PCDH Block Diagram on LAPAN-A3/LAPAN-IPB Satellite

There are two types of mechanism usually adopted to recover a system from faults, those are backward recovery and forward recovery. In backward recovery, the present state of a system is replaced with a previously correct state by means of check pointing [8]. The backward recovery scheme is implemented by using recovery blocks (RcBs). Recovery block has an executive, acceptance test, primary and alternate mechanisms/ algorithms [9] [10]. In forward recovery, instead of moving the system to a previous check pointed state, an attempt is made to bring the system to a correct new state from which it can continue to execute. LAPAN-A3/LAPAN-IPB satellite is using backward recovery mechanism for fault recovery procedure. When the system reset occurs, satellite will be restored to the initial set up so it needs to be set back again such as battery setting and attitude setting before the satellite can works normally. Therefore, it's really important to know when the system reset will be occur to anticipating the effect so the satellite can work normally and do the missions.

LAPAN-A3/LAPAN-IPB satellite system reset time can be predicted from the reset counter that displayed on data telemetry log along with other satellite subsystems healthy data as shown in the figure below. Figure 2 show the telemetry log before system reset time where the satellite still on standard operation mode and the reset counter value almost reach the maximum counter value. Figure 3 show the telemetry log when the reset system occurs and the recovery setting have not been done where the satellite mode is change into hibernation mode and the reset counter is start counting from beginning. Hibernation mode is a mode where the satellite is on the free tumbling condition and all subsystems except OBDH and TTC are turned off [11]. Figure 4 show the telemetry log after system reset and some recovery setting are done such as set the operation mode, and turn on satellite subsystems for standard mode operation.

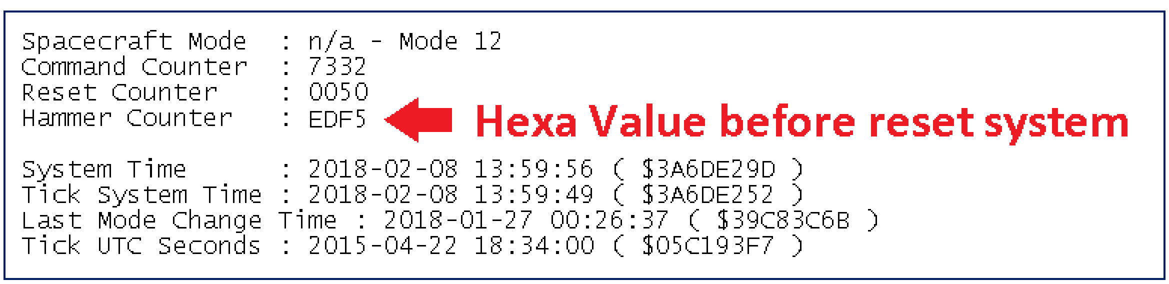

Figure 2. Telemetry Log Data before Reset System

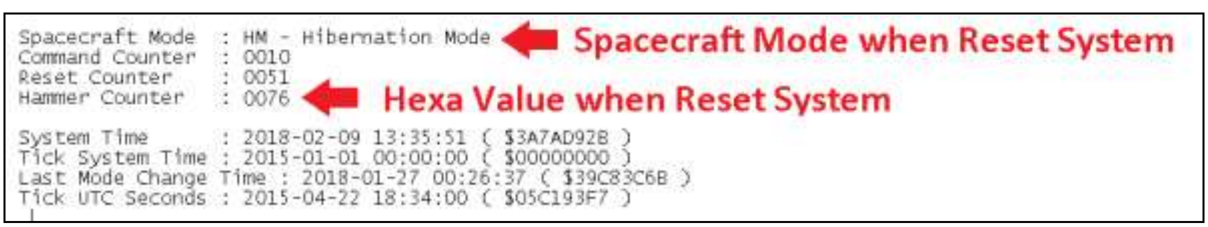

Figure 3. Telemetry Log Data Reset System

Figure 4. Telemetry Log Data after Reset System

Some research to find out the accuracy of the LAPAN-A3/LAPAN-IPB satellite counter reset production will be done in this paper by observing the degradation of reset counter value every second. The method will be explained in the second section. While the third section will discuss and analyze the data. And section four will conclude the result of this study.

II. METHODE

LAPAN-A3/LAPAN-IPB has various missions that have to do every day. In order for the mission to be achieved, many factors such as enough satellite battery power, satellite attitude, reliability of OBC, etc must be considered. The OBC is equipped with integrated software (firmware) that allows PCDH to be controlled via ground station or automatic use based on time and event that triggered by the tasks that have been scheduled before. With variety complex tasks to handle, a high level reliability OBC is needed to overcome hangs that may occur when the system processing large numbers of tasks simultaneously. In addition, to refresh OBC system to make it work optimal, LAPAN-A3/LAPAN-IPB satellite is equipped by external system reset with about 14 days duration to maintain the OBC reliability. This external system reset works within 13-15 days and at temperature @20°C. because of the unprecise time range and the limitation of ground station area to control the satellite, then reset time estimation is really needed so the operator in duty can create scenarios regarding system reset in order to complete the satellite missions. Method used for this research is collect telemetry log data from 2017 December untik 2018 February. Data filtering is focus on satellite system time counter reset system values in form of hexadecimal number and then make some calculation to get system reset counter decrement values every second for about twenty for hours or one day. From the average value of system reset counter decrement values we can get system reset time prediction. The methode are summarized with flowchart shown in figure 5 below.

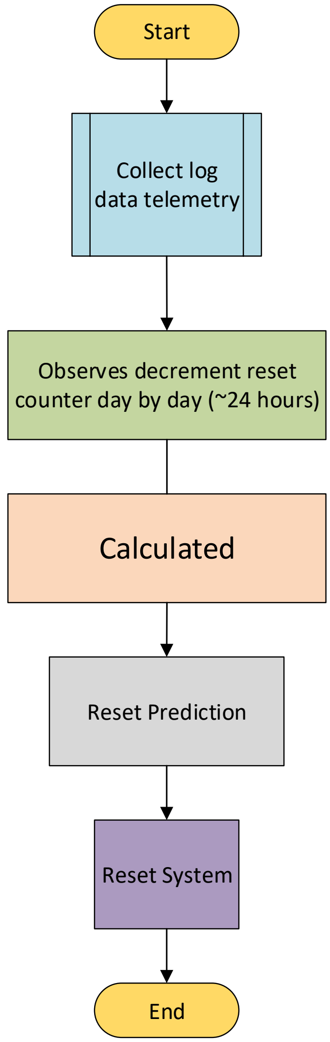

Figure 5. Methode Flowchart

III. RESULT AND DISCUSSION

LAPAN has five ground stations for LAPAN-A3/LAPAN-IPB satellite operation, there are four ground station in Indonesia consist of Kototabang ground station, Rancabungur ground station, Pare Pare ground station, Biak ground station and one ground station outside Indonesia that located in Spitsbergen. This satellite has polar orbit with 97.423^0 inclination so it will orbiting as much as 15.19 revisit/day with period 94.77 minutes. The most orbit is over the Spitsbergen ground station about 14-15 times while for Indonesia ground stations is about 1-3 pass in a day. With this condition, then standard daily operation scenarios for LAPAN-A3/LAPAN-IPB satellite arranged as in the table 1 below.

Table 1. LAPAN-A3/LAPAN-IPB Satellite Standard Daily Operation Mission

No.	Mission Mode	Ground Station			Duration (s)
		Spitsbergen	Indonesia	Other	
1	Observes	14	1		600
2	Imaging		1		600
3	Real time		1		600
4	Download	1	1		600
5	Scientific			2	3600
6	Standby				80280

The missions are divided into six parts. First mode is observation mode, that is satellite operation mode to monitoring satellite condition by get some telemetry and telecommand from satellite subsystems. The second mode is imaging mode, that is satellite operation mode to capture image of earth surface (commonly Indonesian area) by using multispectral camera. The third mode is realtime mode, that is satellite operation mode to capture Indonesian area using multispectral camera and at the same time downlink data to ground station. The fourth mode is download mode, that is satellite operation mode to downlink data from satellite to ground station. The fifth mode is scientific mode, that is satellite operation mode to get magnetic field data around the worl by using magnetometer. The last mode is standby mode, that is satellite operation mode when the satellite is in idle condition and doesnt make contact with ground stations because the satellite is outside the ground station coverrage. This mode is used to saving the satellite power so it has enough power to do the other missions.

To accommodate the missions, LAPAN-A3/LAPAN-IPB satellite provided with OBC that have spesification processor 32 bit RISC (Reduced Instruction Set Computing) architecture. To support the OBC performance, operation integrated software will be reset every 14 days. This process occurs with support from external reset circuit that counting from hexadecimal number $0 until hexadecimal number $FFFF. To find out the decrement value of the counter, then we collect the satellite log files from 2017 December until 2018 February and then calculate the difference counter values for about 24 hours or a day so we will get the counter decrement values every second. Table 2 show us the decrement values for a day in decimal numbers.The highlighted numbers are showing when the system reset occur, there are on the 2017 3rd, 17th, and 30th December, 2018 13th 26th January, and 2018 9th, 23rd February.

Table 2. Counter Decrement for a Day

Date	Total Counter (Decimal)		
	December (2017)	January (2018)	February (2018)
1	4847.43387	4853,643	4812.53728
2	4835.63775	4814,939	4808.131737
3	-60174.075	4817,586	4817.873713
4	4844.17107	4822,36	4815.829168
5	4843.16834	4814,377	4814.721957
6	4840.08482	4813,377	4814.154292
7	4611.95064	4804,596	4817.89637
8	5055.13034	4811,576	4817.411568
9	4829.79329	4815,653	-61432.00874
10	4825.1757	4815,502	4815.967711
11	4832.83472	4812,183	4812.521676
12	4838.7795	4813,533	4820.06274
13	4832.78411	-61548,9	4818.907958
14	4835.66126	4819,719	4821.461061
15	4828.9674	4815,047	4818.255506
16	4828.99173	4814,662	4822.54483
17	-61537.8542	4815,171	4821.069054
18	4840.8773	4814,383	4818.524377
19	4834.7223	4813,02	4822.311491
20	4826.68989	4816,408	4826.795303
21	4828.43756	4814,378	4824.378735
22	4823.81898	4815,097	4821.060879
23	4832.44533	4815,968	-57378.18079
24	4833.68208	4815,544	4827.690828
25	4815.02881	4817,655	4825.471295
26	4801.50176	-61378,2	4823.579655
27	4802.90814	4821,783	4825.396226
28	4823.32087	4826,29	
29	4811.49316	4821,522	
30	-57412.3284	4806,164	

From table 2 above, we can see that the counters decrement values tend to be stable, and from the analysis we know that number of missions performed only give very small effect to counter decrement value so it can be ignored. With the counter decrement values for a day as shown in the table above, the system will be reset on around 13-15 days. From the table, we can also know the average number of counter decrement values every second for each month, as shown in table 3 below.

Table 3. Average Number of Counter Decrement Value/sec for Three Months

Date	Average no. of Counter/sec	Period/day (seconds)
Desember 2017	0.05591807	86373.378
Januari 2018	0,055768	
February 2018	0.055797079	

Data from Table 2 then plotted into chart as shown in the figure 5 for 2017 December data, figure 6 for 201 January data, and figure 7 for 2018 February data. In a day, there is about 7% counter values decrement from maximum number of the counter that is 65535.

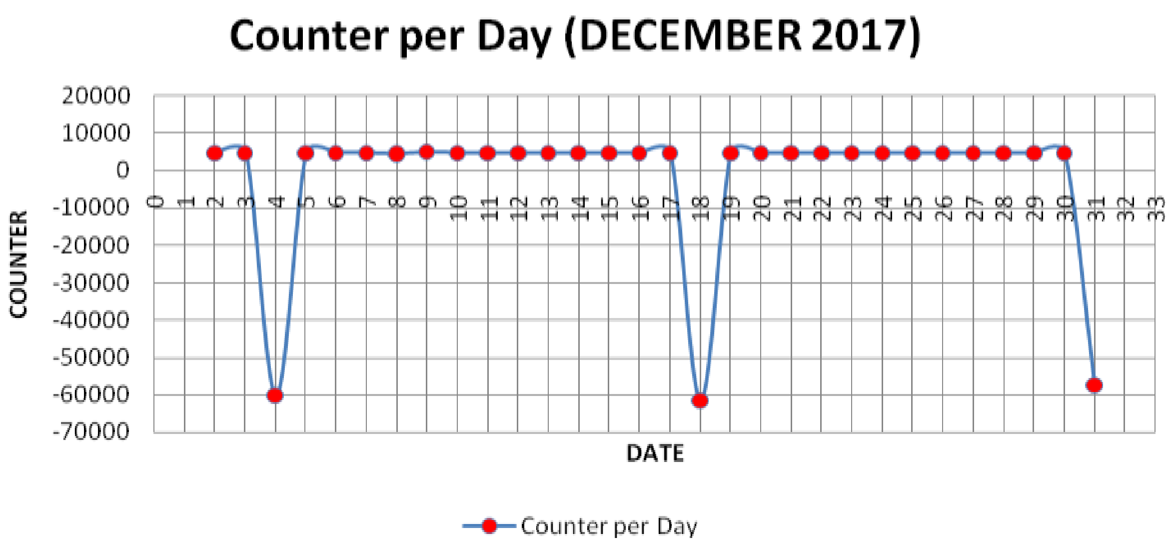

Figure 6. Counter Decrement Value/sec Chart for 2017 December

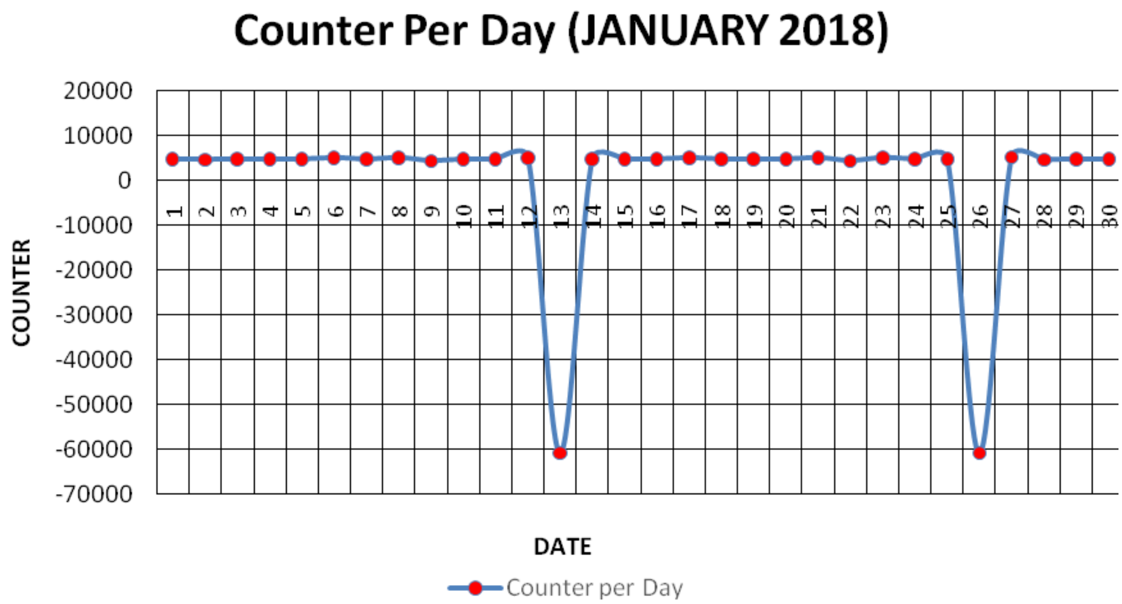

Figure 7. Counter Decrement Value/sec Chart for 2018 January

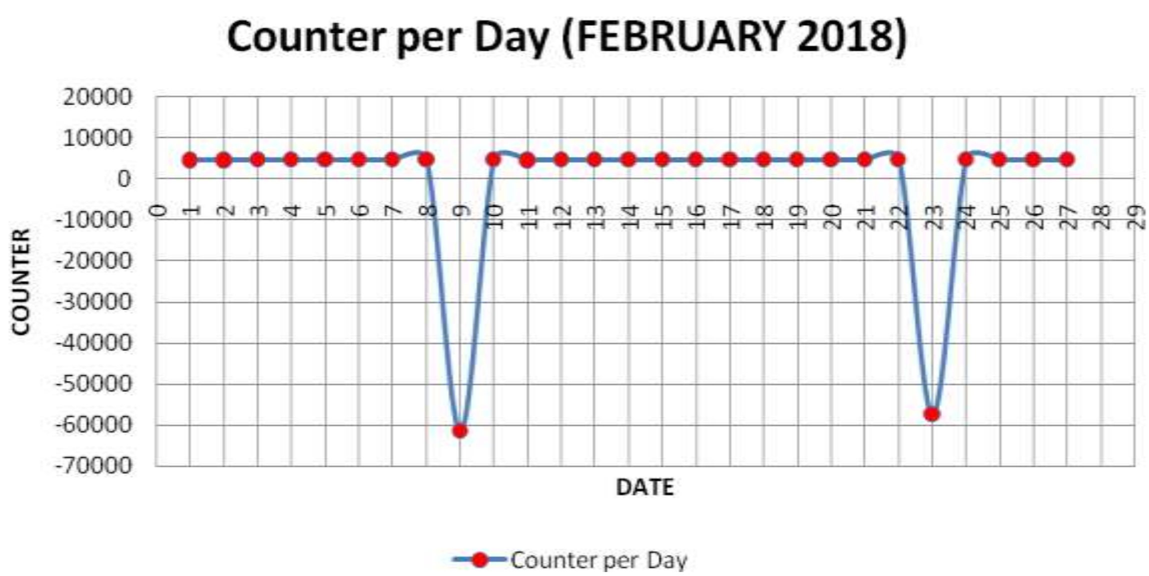

Figure 8. Counter Decrement Value/sec Chart for 2018 February

As an example, we can see Long Time Telemetry (LTT) data shown in figure 9. There is a system reset condition at 2018, 9th February on 13:01:00 UTC; the indication parameter values for all three reaction wheels are changed. These changes only possible if a system reset occurs that make each parameter of all satellite subsystems going back to initial setting, such as angular velocity parameter of the three satellite axis.

Time	U_UMPB	XAngVel	XAng	XSpeed	YAngVel	YAng	YSpeed	ZAngVel	ZAng	ZSpeed
02/09/2018 12:27:10	15.97	0.021935	1049.3	0	-0.061035	-2817.7	5485.7	-0.008583	-60.1	0
02/09/2018 12:29:10	15.97	-0.007629	1049.1	0	-0.063896	-2825.2	5489.5	0.019073	-60.6	0
02/09/2018 [illegible]:31:40	15.92	0.005722	1049.7	0	-0.063896	-2832.7	5488.3	-0.029564	-60.5	0
02/09[illegible]	[illegible]	0.021935	1049.4	0	-0.061989	-2840.4	5486.4	0.013351	-60.3	0
02/09[illegible]	[illegible]	-0.022888	1049.7	0	-0.066757	-2848	5485.3	-0.001907	-61	0
02/09[illegible]	[illegible]	-0.017166	1049.7	0	-0.068665	-2853.1	5484.2	0.008583	-61	0
02/09[illegible]	[illegible]	0.013351	1050.2	0	-0.063896	-2860.6	5480.7	-0.022888	-60.7	0
02/09/2018 12:41:00	16.06	0.014305	1049.8	0	-0.063896	-2868.2	5479	0.025749	-60.7	0
02/09/2018 12:43:00	16.06	-0.020027	1050.3	0	-0.065804	-2875.8	5475	-0.012398	-61.1	0
02/09/2018 12:45:00	16.06	0.021935	1050.4	0	-0.058174	-2883.4	5471.5	-0.000954	-60.6	0
02/09/2018 12:47:00	16.06	-0.016212	1050.3	0	-0.067711	-2890.9	5469.3	0.014305	-61.2	0
02/09/2018 12:49:00	16.06	0.01049	1050.9	[illegible]	[illegible]	[illegible]	5467.4	-0.024796	-61	0
02/09/2018[illegible]	[illegible]	0.009537	1050.5	[illegible]	[illegible]	[illegible]	5464.6	0.022888	-60.9	0
02/09/2018[illegible]	[illegible]	-0.019073	1050.9	[illegible]	[illegible]	[illegible]	5465.3	-0.01049	-61.4	0
02/09/2018[illegible]	[illegible]	0.021935	1050.9	[illegible]	[illegible]	[illegible]	5466.9	-0.004768	-60.8	0
02/09/2018[illegible]	[illegible]	-0.019073	1050.9	[illegible]	[illegible]	[illegible]	5463.8	0.015259	-61.4	0
02/09/2018 12:[illegible]:00	16.06	0.007629	1051.4	0	[illegible]068665	-2936.4	5465.8	-0.024796	-61.1	0
02/09/2018 13:01:00	16.06	0	0	0	0	0	0	0	0	0
02/09/2018 13:03:00	16.06	0	0	0	0	0	0	0	0	0
02/09/2018 13:05:00	16.06	0	0	0	0	0	0	0	0	0
02/09/2018 13:07:00	16.06	0	0	0	0	0	0	0	0	0
02/09/2018 13:09:00	16.06	0	0	0	0	0	0	0	0	0
02/09/2018 13:11:00	16.06	0	0	0	0	0	0	0	0	0
02/09/2018 13:13:00	16.06	0	0	0	0	0	0	0	0	0
02/09/2018 13:15:00	16.04	0	0	0	0	0	0	0	0	0
02/09/2018 13:17:00	16.06	0	0	0	0	0	0	0	0	0
02/09/2018 13:19:00	16.06	0	0	0	0	0	0	0	0	0
02/09/2018 13:21:00	16.06	0	0	0	0	0	0	0	0	0
02/09[illegible]	[illegible]	0	0	0	0	0	0	0	0	0
02/09[illegible]	[illegible]	0	0	0	0	0	0	0	0	0
02/09[illegible]	[illegible]	0	0	0	0	0	0	0	0	0
02/09[illegible]	[illegible]	0	0	0	0	0	0	0	0	0
02/09[illegible]	[illegible]	0	0	0	0	0	0	0	0	0
02/09/2018 [illegible]:33:00	15.97	0	0	0	0	0	0	0	0	0
02/09/2018 13:35:00	15.97	0	0	0	0	0	0	0	0	0
02/09/2018 13:37:00	15.97	0	0	0	0	0	0	0	0	0

Time Before Reset System Recorded on Log Telemetry

Time Reset System

Angular Velocity X, Y, and Z When Reset System

Time When Reset System Recorded on Log Telemetry

Figure 9. LAPAN-A3/LAPAN-IPB satellite Long Time Telemetry Data

To make sure if the system reset really happen at that time, we need some additional data such as telemetry log data. The last telemetry data before the system reset happen is on 12:29:59 UTC with counter value $FF99 as shown in figure 10 below. And the first telemetry data after system reset is on 13:35:29 UTC with counter value $0076 as shown in Figure 11 below.

Date and Time before reset system

```
2018/02/09 12:29:59 PCU Tele Command
Spacecraft Mode    : n/a - Mode 12
Command Counter    : 7940
Reset Counter      : 0050
Hammer Counter     : 0.02 d [FF99]

System Time        : 2018-02-09 12:29:25 ( $3A7A3D75 )
Tick System Time   : 2018-02-09 12:29:19 ( $3A7A3D36 )
Last Mode Change Time : 2018-01-27 00:26:37 ( $39C83C6B )
Tick UTC Seconds   : 2015-04-22 18:34:00 ( $05C193F7 )
```

Hexa Value before reset system

Figure10. Telemetry Log Data LAPAN-A3/LAPAN-IPB Satellite before System Reset

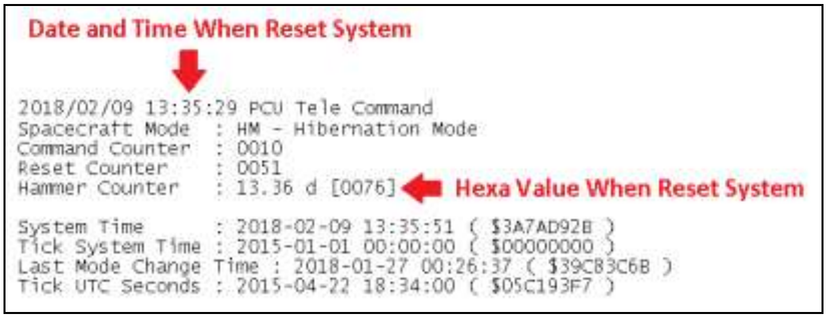

Figure11. Telemetry Log Data LAPAN-A3/LAPAN-IPB Satellite when System Reset

For more details, the summary of hammer counter reading based on long time telemetry data and short telemetry data can be seen in diagram below.

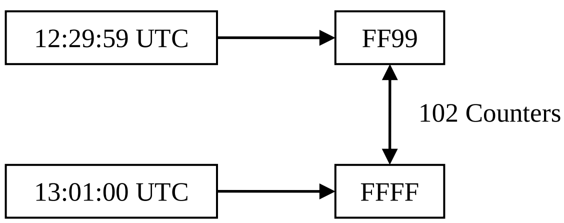

Figure 12. Hammer Counter Diagram

By using number of counter decrement values/second, then time predictions for system reset and time differences between prediction time and actual time are shoen in Table 4 below.

Table 4. Calculation of Counter Reset Prediction

Counter/sec	Time [FF99]	Reset System Time [FFFF]		
		Predicted	Reality	Δt (Second)
0.05591807	12:29:59	13:00:23	13:01:00	37
0.055768	12:29:59	13:00:28	13:01:00	32
0.055797079	12:29:59	13:00:27	13:01:00	33

Reset time prediction from calculation result show that the difference is not too far, just in seconds order. With tend to be same number of counter/sec from 2017 December up to 2018 February, and then the system reset time prediction will tend to be same too. From the result, in the future Author can use the same method to make prediction about system reset time. By early knowing the system reset time, Author can pass this information to operator on duty, then operator can prepare scenario so the LAPAN-A3/LAPAN-IPB satellite daily mission schedule execution (i.e. imaging, data downlink, etc.) doesn't coincide with system reset time. If the system reset time coincides with mission schedule the operator can decide not time coincides to upload the mission schedule and as replacement prepare the fault recovery procedure either using scheduler or by manual, then mission schedule can be uploaded after the fault recovery procedure.

IV. Conclusion

The result of counter reset prediction calculation shows that maximum time difference between system reset prediction times with system reset actual time (Δt) is 37 seconds slower. With below one-minute order of precision level, this method can be applied in the operation mission of LAPAN-A3/LAPAN-IPB satellite later so the operators can prepare some scenario to keep all missions going well after reset system condition.

V. Future Works

In the future some tools developments are needed to help operator to know when the reset system in daily operation occurs.

VI. Acknowledgement

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