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| Project:  WP Name: Flight Computer Bench Test Report  WP Number:WP-AP-04 | Type of Test:  Inspection and Data Logging | Test Procedure:  Analyse Control Loop Logged Data |
| Test Article:  Flight Control Software | Part Number:  FC and AP | Serial Number:  - |
| Test Specification:  AT-03 | Test Equipment:  Overo and Ubuntu 10.04 Laptop or log data | |
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**Test Summary**

Testing the AHNS flight control subsystem is a multistage process with control update rates forming the first stage in acceptance testing. The control update rate test is performed using flight test data logged from the control and mode control unit loops. These flight computer logs are used to calculate the mean control update rate. The update rates achieved are found to be at a rate in excess of the 50Hz specified in SR-B-03.

A measure of stability augmentation performance was also proposed to be the controller delay. This is measured as the time between RC pilot angular rate commands and the plant reaching these rates. The controller delays established were less than 0.2 sec and were found to offer reasonable performance.

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# Test Objectives

The objective of this test is to perform acceptance testing of the flight control update rate. This includes

* Determining the mean and instantaneous update rates of the control thread to determine if these are greater than the 50Hz required in SR-B-03; and
* Quantifying the overall control delay using a tuned attitude controller and its response to stability augmented radio control commands

# Test Set-up & Equipment

The test can be reproduced using log file data as complete test result generation requires a series flight tests for attitude controller gain tuning.

## Using Logged Data

The equipment required includes

* Computer with MATLAB installed to review logged data; and
* The files in the docproject/unofficial\_ahns/logs SVN folder including
  + RCRateAttitude.m
  + ControlTester.m

## Using Platform Flight Test

The people and equipment required for a flight test include

* RC Pilot and GCS operator
* Linux Based Computer to run the GCS
* RC Transmitter
* LiPo 11.1v Battery
* Quadrotor platform with installed avionics including
  + IMU
  + Overo Fire with trunk/airborne/flight\_computer/main compiled and running with pre-tuned controller gains.
  + MCU with RC receiver attached and pulse capture/USART communications functioning
* Heliconnect router with GCS and Overo both connected

Note a completed list of flight test equipment and procedures is beyond the scope of this document. Flight test reports should be consulted or the AHNS 2010 Operations brief.

# Procedure

## Using Logged Data

The results of this test report are generated by using MATLAB to analyse four log files; two files collected from the flight computer (mcu.log and control.log) and two files collected from the GCS (a helicopter state log and an autopilot state log).

1. Analysis of the flight computer logs involves reading them into MATLAB with the script ControlTester.m
2. The script will plot the instantaneous control update rates of both the control and MCU flight computer threads and report the average update rate.
3. The flight test data from the GCS is for an attitude control thus the files are analysed with the script RCRateAttiude.m. The attitude control data plotted by default in the script is from one of the final controller tuning flights and thus represents the final level reached by AHNS 2010 with the attitude controller.
4. The logged GCS data should provide an indication of the system dynamics, specifically the time difference between the RC pilot command inputs and the response of the system. From this the control system delay can be calculated.

## Using Platform Flight Test

A complete list of flight procedures is beyond the scope of this document. For details the flight test reports should be consulted or the AHNS 2010 Operations brief. This test requires only that the control and MCU update logs are saved on the flight computer and that the autopilot and helicopter state log files are saved on the GCS. Once these files are available the logged data procedure can be followed.

# Results



Figure - Control Loop Update Rate



Figure - MCU Loop Update Rate



Figure - Roll Controller Logs, Kp = 0.41 Kd = 1



Figure - Pitch Controller Logs, Kp = -0.69 Kd = 2.5

# Analysis

is the plot generated from the flight computer control loop update rate log file. It is a representation of the time elapsed between success control loop updates on the Flight Computer. The update rate clearly exhibits a large variance suggesting the time between control updates is not fixed and instantaneous update rates can drop below 50 Hz. A mean update rate of 92.7 Hz for the control loop update rate is however calculated. Given the Flight Computer relies on the Linux kernel provided by OpenEmbedded it is not possible to force thread execution to 50 Hz; this requires a real-time kernel or even a microcontroller with interrupts.

The control system update rate is also determined by the MCU thread execution rate. The mode control update rate is important as this is the rate the engine PWM values are updated at. Figure 2 demonstrates a variance in instantaneous MCU execution rate with a trend towards lower update rates. However the mean update rate of 221.26 Hz for the MCU control transmission rate does not reduce the update rate of the control system below that of the control thread. The large update variance does suggest the engine command updates will not be uniform, forming a possible source of dynamic disturbances.

The use of USART link of 57600 to the MCU is a factor in the MCU thread update rate. During operation a periodic message request is sent from the flight computer; 3 bytes followed by the 5 bytes of data from the MCU. The updated commands are also sent as 8 bytes of data. The total transmission is therefore 16 bytes or 128 bits which at a baud rate of 57600 limits the maximum MCU hardware update to less than 450 Hz. The choice of baud rate however was limited based on the hardware crystal for the MCU and could not be increased without error introduction.

Figure 3 and Figure 4 provide some data on the controller delay. The reference control rates provided by the RC pilot lead the measured rates by between 0.1 and 0.2 seconds. This appears to provide a controllable quadrotor and thus acts as stability augmentation.

# Conclusions

The test has considered the update rate of the control and MCU threads on the flight computer and has found that their mean update rates are 92.7 Hz and 221.6Hz respectively. The control update from the flight computer is therefore the slowest of these rates at 92.7 Hz. As this mean is greater than the required 50 Hz in SR-B-03 the test AT-03 is passed and the requirement met. It should be noted that both update rates are variable and often stray below these means. The only solution to force a rate it however to use an interrupt based operating system or microprocessor for the flight computer. The attitude control delay with these update rates is approximately 0.1 to 0.2 sec.

# Recommendations

It is recommended that this test be performed whenever new threads or operations are added to the flight computer. It is also recommended that an alternative flight computer architecture is considered to avoid variation in the control thread update. Such considerations include interrupt driven operating systems or microprocessors.