

## INSTRUMENTATION AND OPERATIONALIZATION OF A SYSTEM FOR FLIGHT TEST OF UAV

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**Abstract.** For the development of control algorithms that allows good flight performance and stability of unmanned aerial vehicles (UAV) it is necessary to have accurate and validated flight dynamic models of these aircrafts. The parameters of this flight dynamic models are obtained by different techniques of parameter estimation, among them is high featured the aerodynamic modeling by flight test. In order to realize the flight parameter identification it is necessary to monitor several flight parameters such as altitude, speed, attitude and anemometric data and the deflection of the control surfaces. This paper presents the integration and test of a flight test data acquisition system (*Icasim*), as well as the development of subsystems that allow data acquisition and processing of flight data of the Vector-P, which is a medium-sized UAV.

**Keywords:** Unmanned Aerial Vehicles (UAV), testing in flight, *Icasim*, system of acquisition

### 1. INTRODUCTION

For the development of control algorithms that enable the performance and stability in flight of unmanned aerial vehicles (UAV) is necessary to have models of the dynamics of flight validated these aircraft. The parameters of the flight dynamics models are derived aerodynamic stability and control, in which these parameters are estimated using techniques of identification of parameters, among them there is mainly based on the modeling aerodynamic test flight. In order to perform these tasks of identification, they must be monitored several parameters of flight of the aircraft. This paper presents the integration and operation of a data acquisition system for test flight (*Icasim*) that has built its system of attitude sensors (*crossbow*), anemometer probe ( $\alpha$ ,  $\beta$ , altitude, temperature) and other subsystems allowing the monitoring of deflection of control surfaces and the rotation of the engine.

### 2. O VECTOR-P

The Vector-P is unmanned aerial vehicles manufactured by *Intellitech Microsystems* (USA) in composite material, the Figure 1 shows the Vector-P in the takeoff maneuver. Originally the Vector-P has a link data for tracking by the earth station operating in the frequency range of 900 MHz with up to 40 miles (62 km) with direct target, this link allows the scheduling of flight (to upload waypoints using *Horizon* see Fig 2), as well as monitoring of variables related to flight or status of the system such as: data from the GPS (Time, Longitude, Latitude, Speed, Altitude), the inertial data (Pitch, Roll, Yaw), data Pitot (Air Speed), making static (altitude), ADs (the main battery voltage (Micropilot) and the battery of servos), the throttle position, among others.

The Vector-P was purchased by the Department of Mechanical Engineering of Aeronautics-ITA to serve as a testing platform for their academic development.

The vehicle came to the Institute in August 2007 and at the time the existing data on it were few. The manufacturer had not provided the information of the same aerodynamic model, derived from stability, position of CG, moments of inertia, etc. The lifting of the prior model of Vector-p was made with data from geometry using the software J2.



Figure 1. Unmanned aerial vehicles Vector-P

## 2.1 Specifications

The main specifications of the Vector-P are presented in Tab. 1.

Table 1. Main specifications of the Vector-P.

Wingspan	101 inches (2.57 meters)
Fuselage Length	5 feet (1.524 meters)
Max Speed	100 knots (185 km/hr)
Cruise Speed	70 knots (129 km/hr)
Landing Speed	~40 knots (74 km/hr)
Engine	75cc, 7.5 hp 3W 2-stroke reverse rotation gasoline engine. Options range from 62 to 100cc, quoted on request.
Propeller	Biela 24x10
Max Range	280 miles (519 km), depending on fuel on board.
Max Altitude	10,000 ft. (3 km) MSL
Max Takeoff Weight	75 lbs (34 kg)
Empty Weight	43.5 lbs. (19.7 kg)

## 2.2 The autopilot of Vector-P

The Vector-P has an automatic guidance system that is installed by the manufacturer. The automatic pilot is produced by *MicroPilot*, a company that develops autopilots for small UAS.

The autopilot of Vector-P already includes all systems necessary for its operation, including inertial sensors, accelerometers and gyrometers, manufactured in MEMS technology (Micro-Electro-Mechanical Systems) and GPS. The structure of the control system of automatic pilot has been configured and the user has only to choose some parameters.

## 2.3 Horizon

The automatic comes with a software of ground station, the *Horizon*. Through this software the user makes the configuration of the auto drivers and the planning and monitoring of flights.

The planning of the flight is to mount a mission that the vehicle must meet. To mount the task the user must insert a file or program in-flight information and the system of units, the configuration of drivers, the location of the waypoint, the altitude, the form of flight between two consecutive waypoints.

The location of the waypoints is what defines the flight as the vehicle should do.

The monitoring of the flight is done in real time at *Horizon*, where the user can view the map superimposed on the route which the vehicle is traveling.

Figure 2 shows a screen of *Horizon*, the circles are programmed waypoints. In the flight shown in Figure 2, the vehicle was configured for flight manual, the line that follows the design of the circuit that shows the plane was flown

by the pilot. At the bottom center of the screen you can see the virtual instruments for monitoring the flight, including speedometer, altimeter and artificial horizon. The software also makes a datalog data of each flight for later analysis.

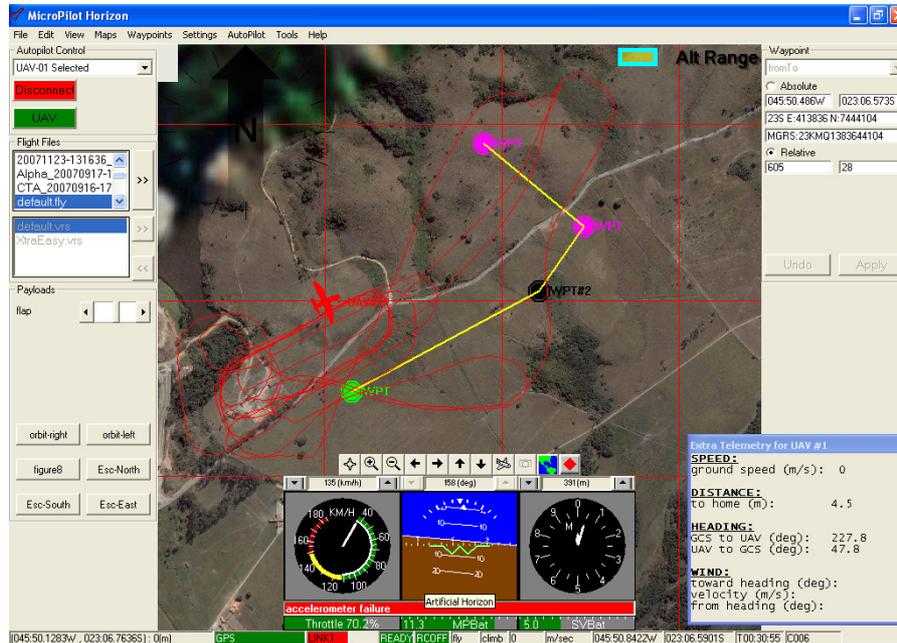


Figure 2. Screen in one of Horizon flights of Vector-P.

### 3. ICASIM

To ensure greater reliability in the data using inertial sensors, GPS and more accurate anemometer, and provides data from the positioning of control surfaces and to allow greater freedom to access the data recorded, the platform flight (Vector-P) was equipped with a monitoring system for flight Icasim Flight Test Equipment (IFTE) TRM/916. The Icasim was developed by *Simtec* (Swiss) that allows the recording of all desired data and display in subsequent owner or other program capable of accessing your files, thus allowing further analysis of the flight and providing data to identify the model of the aircraft thus it can be developed further flight control system using the model identified by the test in flight.

#### 3.1 Technical Data

The TRM/916 is a small computer running a Linux system, an interface control panel directly in which it has a display of 320x240, as Fig. 3



Figure 3. TRM/916

The TRM/916 has a LAN Ethernet interface for communication and has a compact flash memory card of 256MB memory and mass storage where the recorded data of the units coupled to it. See Figure 4, (1) The TRM/916 has external connections with: (2) Module AD (PotiAMP) for reading potentiometers for sensing the surface of control, (3)

inertial unit (Crossbow AHRS400), (4) GPS Receiver 1Hz, (5) Anemometric probe of evidence and the power cord from the system.



Figure 4. (1) TRM/916, (2) PotiAMP, (3) Crossbow AHRS400, (4) GPS antenna and (5) Anemometric probe.

### 3.2 Operation

The TRM/916 as shown in Fig.5 has buttons that allow the interface to start and stop recording, switch between the modes of display where you can verify the data from each sensor (see Fig. 6 which shows the screen to the unit inertial), but can also start the process of shutting down *Icasim*.

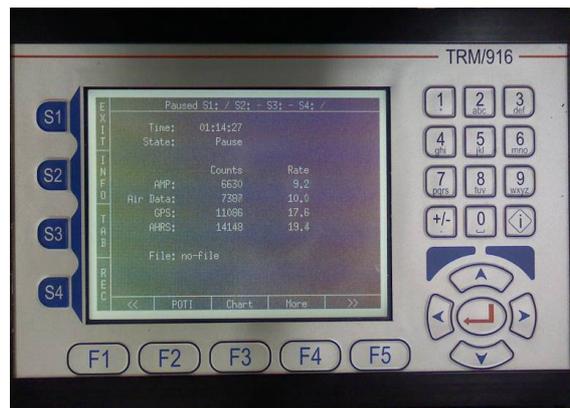


Figure 5. TRM/916 showing the control buttons S1 to S4, the F1 and F4 and directional keypad on the right.



Figure 6. Scoreboard inertial unit (left layout, right photo). Which contains information from the inertial AHRS unit such as: Pitch, Pitch-rate, roll, roll-rate, Heading, Yaw, Acc x-, y-Acc, Acc-z, x-Mag, Mag-y, and z-Mag Temp.

### 3.3 The sensors

The following will describe the sensors used in *Icasim*.

### 3.3.1 Inertial unit

The unit used is the inertial AHRS-400CC-200 manufactured by Crossbow. The Crossbow AHRS400CD is a solid state system for sensing the attitude and position for loaded applications, such as UAVs. Their high reliability in their technology with MEMS inertial subsystem provides attitude and direction in static and dynamic measurements that are beyond the traditional systems of gyroscopes and accelerometers, which can be used in different environments. The AHRS400 to their performance through the use of the algorithm of the Kalman filter to determine the roll, pitch and direction stabilized both in static and dynamic conditions; the Kalman filter continuously corrects the error of measuring the attitude and direction by using the references of gravity and magnetic north. The output data is supplied in digital format (RS-232) as well as analog. The manufacturer offers a proprietary program (Gyroview see Fig.7) which provides for the acquisition and recording of data from inertial unit, thus facilitating the testing and development with it. The AHRS is the block diagram, shown in Fig. 8 and Fig. 9.

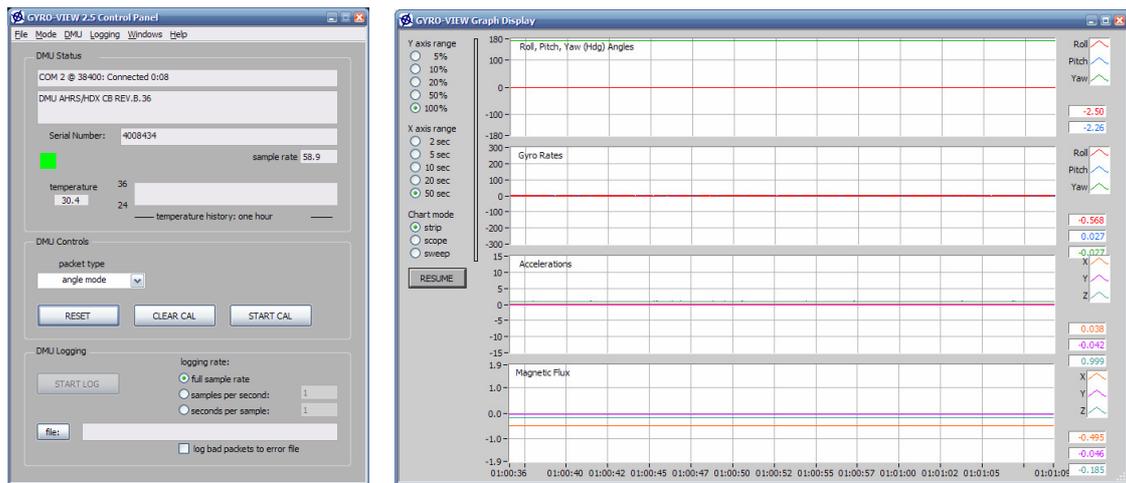


Figure 7. Gyroview interface. (on the left control panel of Giroview, which contains the connection settings and acquisition, to the right of the Graphics Window Giroview, which shows the data for roll, pitch and yaw (HDG), turns, accelerations and magnetic flux).

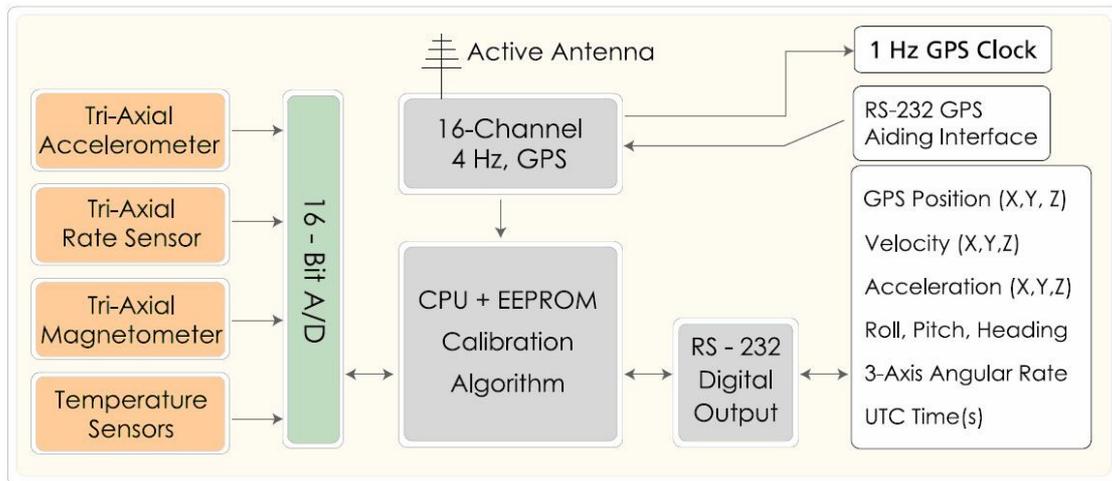


Figure 8. Diagram of Block NAV-AHRS

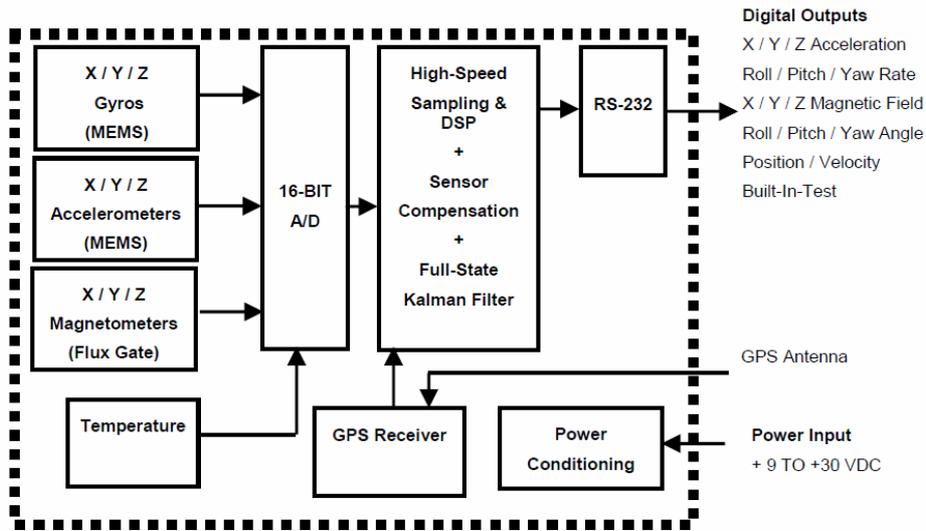


Figure 9. System Architecture NAV420CA

### 3.3.2 Anemometric Probe

The anemometric probe provides for *Icasim* information to the vehicle speed, angle of attack, sideslip, static pressure and temperature of ambient air with values already calibrated in the units used for identification and sensitivity sufficient for the low-speed flight from Vector -P.

### 3.3.3 GPS

The GPS is integrated *Icasim* used in the system of the TRM / 916 and has only one output connection for external antenna. The refresh rate is 1Hz, the Fig. 10 and Fig. 11 shows the GPS data obtained during a test in ground in CTA (Aeronautic Technologic Center - São José dos Campos, SP-Brazil)

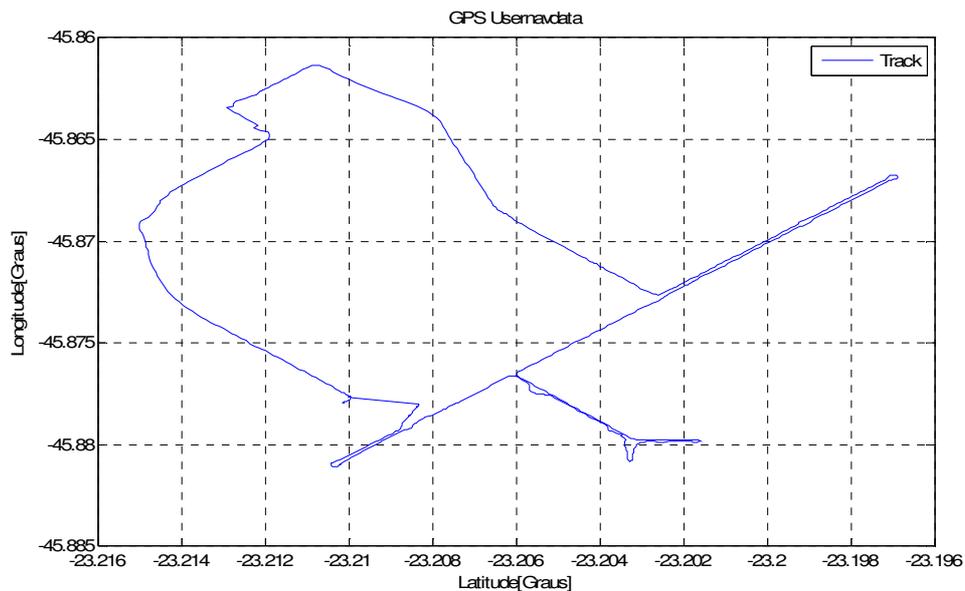


Figure 10. Trajectory obtained from GPS in CTA



Through a code developed in Matlab data variables are conditioned in order to present the correct values and scale in time and correct, because the sensors have different rate of acquisition, after the conditional variables are plotted in graphs for analysis of data from flight. The plotted data are grouped so as to facilitate the analysis, for example, the attitude data can be grouped into individual graphs for each axis, as well as graphs where the data are grouped to the values of the sensor in other areas.

#### 4. MODIFICATIONS IN VECTOR-P

For the platform flight (Vector-P) was equipped with *Icasim*, some changes were needed on the aircraft such as:

##### 4.1 Batteries

Adding a set of batteries composed of 04 lead acid batteries connected in series totaling 6V/4.5A on a pack of 24V.

##### 4.2 Addition of TRM916, the anemometer probe the and PotiAMP

Figure 13 illustrates some of the modifications necessary to Vector-P, listed below:

- Add to the nose of the aircraft would leave a hole that exposed the tip of the necessary evidence anemometer.
- Add a "cradle" to put the TRM916 and ensure its fixation even in flight.
- Add a setting for the module PotiAMP (fixed internally the fuselage).



Figure 13. Vector-P after the changes where you can see the anemometer probe and TRM/916

##### 4.3 Modification of the servos actuator for reading position

To facilitate the reading of the position of the surfaces was chosen to add a electronic board servos actuators small enough to be inserted inside the servo (internal circuit) without the need for external mechanical changes and is able to provide the following information: a) temperature interface of the servo motor (to detect overheating in case of mechanical stress) and b) the position of the arm of the servo actuator, allowing the feedback of position for testing in flight, or the control algorithm used in UAV. The position signal provided by the inner plate to the servo has a high coupling impedance and conditioning sufficiently able to protect the internal electronics of the servo control of any short-circuits the terminals of the signal or the external noise which might impair the control of position the servant and hence the loss of control of the aircraft.

Coupled to the servo power cord was attached a small external circuit that allows you to: a) power to the internal circuit stabilized to ensure the accuracy of the signal of position provided with the same problem of low voltage characteristic of work of slaves and high noise caused by servants of the high-current high-performance and b) provide the signals of temperature and position enough filtered and great immunity to noise added due to the length of drivers in the large UAV subjected to noise generated by devices on board. Due to the frequency of cutting required for active filters require an arrangement with RC passive components large in size, which prevented the small size of the circuit, it was necessary to remodel the filters in the laboratory because of the active ingredients work with the bias current out of specification, thus achieved by using passive components of reduced size and still obtain the correct information allowing the filtered signal.

#### 4.4 Board conditioning and reading of RPM

As Module PotiAMP of *Icasim* has as input voltage levels of 1.25V to 3.75V, while the output signals of reading the servo board are of 3V to 0.7V, which makes it necessary to add a circuit for conditioning for the range of reading for PotiAMP thus have the greatest advantage of the resolution of the AD.

There are two ways to monitor the "engine" of the Vector-P, you can track the throttle servo through PotiAMP or monitor the rotation of the engine through the hall sensor that was added to the motor shaft, where the signal is monitored by the AD a microcontroller that determines the rotation of the pulse sensor hall at a DC voltage proportional to rotation. Figure 14 below shows the calibration curve over to the curve with the data measured in this test circuit developed.

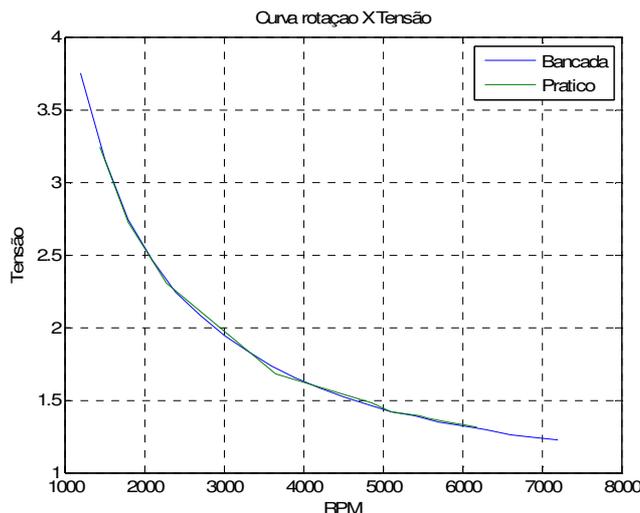


Figure 14. Calibration curve overriding the curve with the data measured in the test circuit for reading the rotation of the engine.

#### 4. RESULTS OF FLIGHT

On May 14, 2009 was the first flight of Vector-P with already integrated with the system *Icasim*. Some data from the flight are shown, in the Fig. 15 (aerodynamic surfaces) and Fig. 16 (anemometer probe and GPS data). The flight is shown in Fig 17. The data from this flight will be analyzed and used to identify the parameters for model of aircraft.

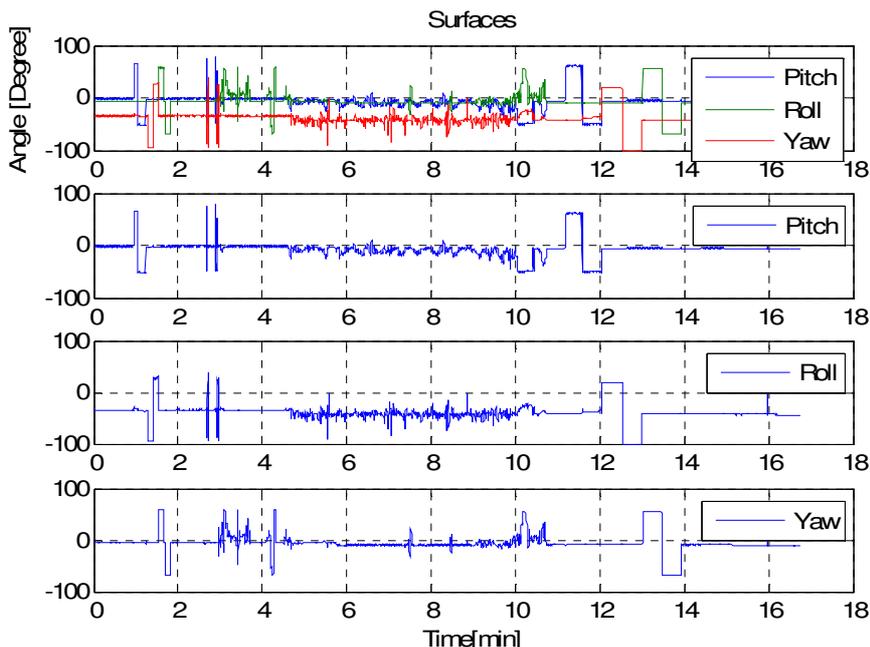


Figure 15. Graph with the deflections of control surfaces on the flight of the day May 14, 2009.

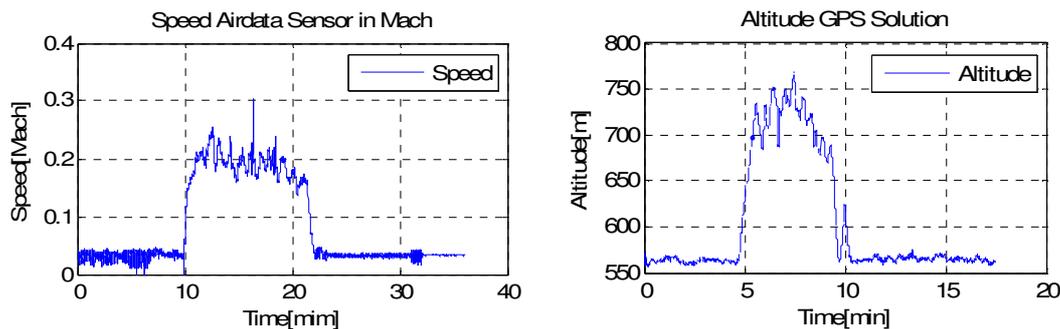


Figure 16. Left graph with data from the anemometer probe and right edge graphics with the GPS data for the flight of the day May 14, 2009.



Figure 17. Flight of Vector-P on May 14, 2009.

## 6. CONCLUSÕES

After tests on ground and in flight test can verify that the system in flight testing that has been integrated with Vector-P meets the needs of providing data for the aerodynamic modeling technique based on test flight allowing set up an automated tool identification so that you can easily raise the new model parameters associated with the Vector-P for academic studies in the ITA, or even for the removal of new parameters of the model of Vector-P if it change with the objective of change the dynamics of the same flight.

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