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GPS Based Autonomous Flight Control System for an Unmanned Airship

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ABSTRACT
An unmanned airship, also known as a Unmanned aircraft System (UAS) or a remotely piloted aircraft is a machine which functions either by the remote control of a navigator or pilot. The unmanned airship uses the autonomous flight, navigation and guidance based on the telemetry command of ground station. The Autonomous Flight Control System (AFCS) [1] plays a key role in achieving the given requirements and missions. This paper introduces the overall design architecture of the hardware and software of the flight control systems in a 50m long unmanned airship
Keywords – AFCS, COS,DLG, HILS,PMC

I. INTRODUCTION

The airship is considered as a new means for the applications in civil and military services for heavy cargo transportation and stratospheric platform for communication. The stratospheric platform airships are considered as an alternative to satellites to increase the capability of communication networks. To meet the modern trends, the research of unmanned airships are developing .This paper presents a brief introduction of AFCS components of 50m unmanned airship [2].The unmanned airship used is a non- rigid type and the overall length of the hull is 50m, maximum diameter 12.5m, and a fitness ratio of 4.The helium is used for inflating the envelope whose total volume is about 4090m3 and inverted Y- type tail fins are attached at the rear of the hull. The propulsion system consists of a gas turbine engine, generator, and two propellers that are installed at an electric motor with a tilting system. This tilting system provides a tilting angle from -90° to +120°. The maximum speed of the flight is about 22m/s and the pressure is 5km with the payload of 100kg. Figure 1. Shows the 50m unmanned airship. The AFCS controls the dynamics of the airship automatically [6] and manages all the information of the installed subsystem. The proposed airship has 6 types of onboard subsystems:Flight control system, electric system, propulsion system, pressurization system, communication system and mission payload system

II. DESIGN REQUIREMENTS OF AFCS

The mission requirements of the AFCS of this unmanned airship should meet the following functions [3] Accepting up- link commands and data from the Ground Control Stations(GCS).Carrying out the commands on a flying airship.Monitoring the current status of the subsystems and detecting the fault and failures on the platform Sending the downlink data to the GCS through the air borne data terminal (ADT) Providing the autopilot system to control a flying airshipairspeed hold, altitude hold mode of autopilot. Determining the position and the altitude with the data acquired fron the navigation system. Performing the flight mission such as point navigation and station keeping by the guidance algorithm. Coping with the emergency and performing a function of return home automatically.During these operations, both the component and equipment of all hardware system should withstand vibration, temperature and humidity requirements as follows:

Temperature : -20 to +50 degree Celsius
Vibration : 15 to 2000Hz psd of .01g2/ Hz
Shock : peak acceleration of 20g with 9ms sinewave
Humidity : not greater than 95%.

III. AFCS ARCHITECTURE

The figure 2. Shows the AFCS hardware which has several modules such as flight control computer (FCC), GPS/ INS based navigation systems, test boom for measuring the airdata, servo actuator for control surface, and switching module for controlling the propulsive system.

IV. Flight Control Computer (FCC):

The flight control computer adopts a Commercial Off-shelf (COS) system with ¾ ATR long 7 slot chassis with a power PC 750 single board computer, PCI Mezzanine Cards (PMC) serial I/O module, VME discrete I/O module, VME relay output module, VME analog input module and VME analog output module.

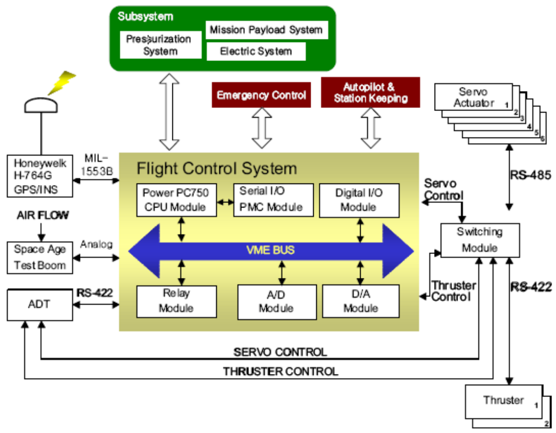

Figure 1. Autonomous Flight Control System

The VISTA SCORE power PC Model PC 750 features a multichip module containing a power PC 750 CPU running at 200 MHZ with separate 32Kbytes instruction and data caches and provides 32 Mbytes of DRAM memory with error detection and correction, 16 Mbytes of Flash for program storage and execution, 512 Kbytes of Boot Prom and an internal L2 Tag combined with a dedicated 512KB L2 cache interface. The additional features include two asynchronous RS-232 and two synchronous/ asynchronous RS-432 serial ports, an 8 bit discrete parallel I/O port and a 10/100 BaseT Ethernet interfaces.

Figure 2. Flight Control Computer

The PMC serial I/O module offers 8 channels of serial communications including 4 RS-423 asynchronous and 4 RS- 422 synchronous with DMA control engine and 8 Kbytes of dual – ported buffer memory. This module is mainly used to provide additional RS-422 channels for communication of FCC with Airborne Data Terminal (ADT), Airborne Imagery System (AIS), electrically driven thruster, transponder etc. The VME relay output module has 64 double- pole , double throw (DPDT) premagnetised relays, which are composed of 32 single pole , double throw (SPDT) 3- pin contacts plus 32 single pole single throw(SPST) 2- pin contacts with any level of AC/DC voltages up to 300 volts and 1 amp maximum. These relays are dedicated to power control and power control loop- back signals for several subsystems such as pressurization system, engine controller, transponder, airborne camera, left/ right inverters and cooling fan. The VME analog input module , implements 32 single ended channels with 12 bit analog to digital converter, receives signals from temperature sensors, pressure sensors and voltage sensors to monitor the current status for envelope, ballonet and ambient of the airship. The VME analog output module provides 24 independent digital to analog converters with 12bit resolution outputs analog command signals to control surface actuators [4].

V. GPS / INS BASED NAVIGATION SYSTEM:

To measure the attitude, position and velocity information, the airship adopts GPS/INS hybrid navigation system as a main navigation sensing unit. Figure 2. Show the navigation unit. This uses a Digital Laser Gyro (DLG) and a 3 allied signal accelerometers and GPS receiver module for pure inertial, GPS –only and blended GPS/ INS solutions. The acquired information is feedback to FCC through MIL-STD 01553B interface. The major specifications of hybrid navigation system are shown in table 1.

Position Accuracy - INS only (CEP) - INS/GPS (SEP)	 1.0 nmi/hr 16 m
Velocity Accuracy - INS only (rms) - INS/GPS (rms)	 1.0 m/sec 0.03 m/sec
Heading (rms)	0.02 deg
Roll and Pitch (rms)	0.01 deg
Operating Ranges - Attitude - Angular Rate - Acceleration	 unlimited 600 deg/sec 21 g
Weight	8.4 kg

Table 1.Specifications of Navigation System

VI. AIR DATA BOOM

To measure the air flow speed, the space age control 100600 straight – node air data boom is installed on the front of the nose cone of the airship. This boom contains static and total head pressure pickups and angle of attack and sideslip vanes. The vanes also called airflow direction transmitters or flow angle sensors are coupled to precision potentiometers to provide an electrical signal indicating airflow direction relative to the airship body axis. Figure 3. shows the air data boom and table 2. gives the air data boom specifications.

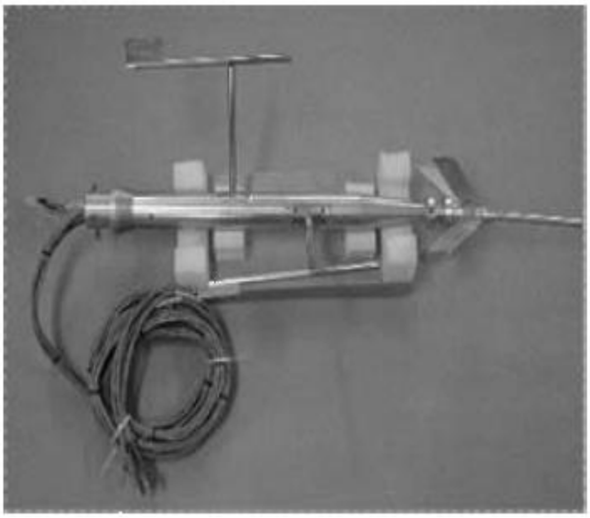

Figure 3.Air Data Boom

Type	Dual conductive plastic
Resistance	5K ohms
Linearity	±0.5%
Electrical Travel	±170°(±5°) from center tap
Power Rating at 70℃	1.0 Watt
Resistance Tolerance	±20%
Mechanical Travel	360° continuous
Mechanical Life	20+million shaft revolutions
Operating Temperature	-55° to +125℃

Table 2. Air Data Boom Specifications

VII. SERVO ACTUATOR FOR CONTROL SURFACE:

Servo actuators are designed to control and operate the unmanned airship's control surfaces such as rudder, left elevator and right elevator. Two servo actuators are engaged to each control surface with a hinge, which is designed to reduce the hinge moment down and to increase the reliability. Each servo actuator is composed of Poly- Scientific Clifton Precision 308vs.1 planetary gear heads which are coupled to 400w brushless DC servomotor with an encoder and a servo controller. The servo controller has been designed to convert a 12 bit command signal from RS- 485 port to 20 KHZ Pulse width modulation (PWM) signal. The final signal can be converted to the physical position and feedback of the state of the servo actuator is provided. The specifications of the servo actuator are shown in table 3 and figure 4. shows the servo actuator of the control surface.

BLDC Motor - Rated power - No load speed - Stall torque - Weight	400 Watt 5000 rpm 11.8 N·m 2.5 kg
Planetary Gearheads - Reduction rate - Max continuous torque - Backlash - Weight	308 : 1 120 N·m 2 deg 3.7 kg
Performance - Max hinge moment - Angular range - Resolution - Max angular rate - Steady state error	120 N·m -75 deg ~ +75 deg 0.1 deg 28 deg/sec less than 5 %
Total weight	less than 13 kg

Table 3. Specifiactions of Servo actuator

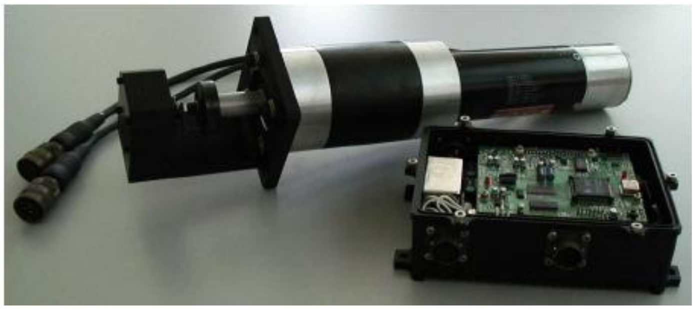

Figure 4. Servo Actuator

VIII. SOFTWARE DESIGN OF AFCS

The flight software system manages the proper control of all hardware and subsystem components connected to AFCS and carries out the automatic control algorithms associated with the major activities. The flight software is implemented with C- language under the Vx Works real time OS environment. The structure of the software design is given in figure 5. The basic module of the flight software is a task processor related with each subsystem and other activities. The data type for the data communication system is defined by using the bit field structure [5].

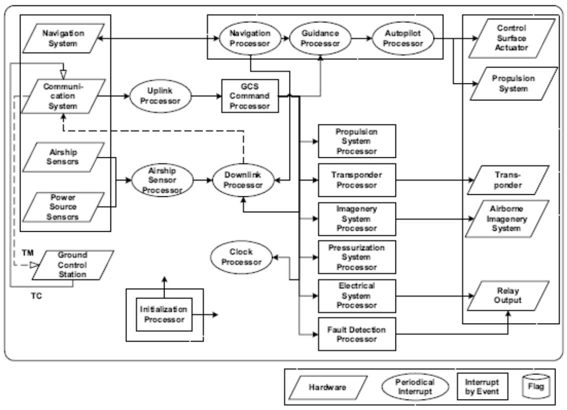

Figure 5. Software Structure of Flight control

To perform the function of autonomous flight, navigation and guidance, several autopilots and guidance flight modes are designed and implemented by control laws as in figure 8. The autopilot inner loops consists of the pitch hold, altitude hold, velocity hold and heading hold mode. Based on these autopilot functions the outer guidance loop can be selected and worked by the ground control station selection command.

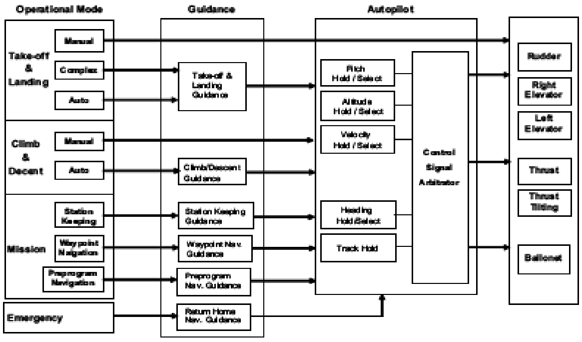

Figure 6. Autopilot and Guidance Flight Mode

IX. SIMULATION AND EVALUATION

The system components and the hardware are subjected to test procedures to evaluate the performance of the airship. This test includes the acceptance test and the interface test with other subsystems. For the testing of autopilot and guidance algorithm, a non-linear 6 degree of freedom simulation program for the unmanned airship was developed which is used for the simulation and for the checking of the designed control laws. Figure 7. shows the Hardware – In-the- Loop System (HILS) simulator structure, where the final test of AFCS is carried out.

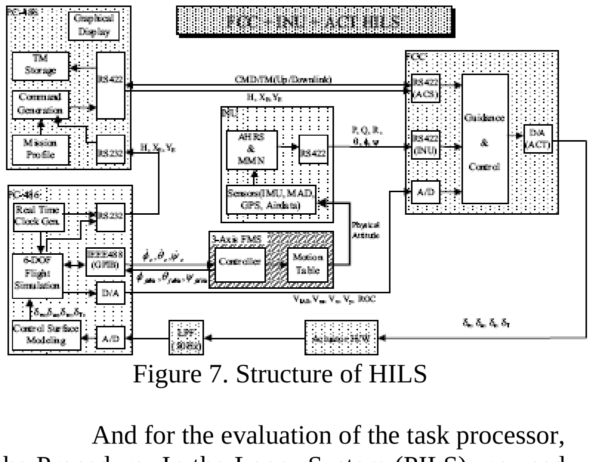

Figure 7. Structure of HILS

And for the evaluation of the task processor, the Procedure- In-the-Loop- System (PILS)was used for the verification of the performance and debugging of the error of the coding algorithm. After the subsystem level tests, the AFCS should be installed in the unmanned airship and the ground integration test will be performed to verify the operation with the working of the engine.

X. CONCLUSION

An AFCS is designed for an unmanned airship with its hardware and software structure. The various requirements for the design were presented and the autopilot and guidance algorithm has been developed. The unmanned airship with the autopilot were simulated and tested using the HILS structure and the various flight conditions were examined.

REFERENCES

[1] E.H.J. Pallett, T. Eng.(CEI), A.M.R. Ae. S., F.S.L.A.E.T,“ Automatic Flight Control “, *Granada, London Toronto, Sydney, NewYork.*

[2] Kim, D.M.et., “Development of an Unmanned Airship System”, *Proceeding of 4th International Airship Convention And Exibition*, July 2002.

[3] Yeom, C.H. et al., “System Integration Standard for KARI 50m Unmanned Airship”, *KARI Technical Report,* May 2002.

[4] Ahn, I.G. et al., “Development Standard of Flight Control System for KARI 50m Unmanned Airship”, *KARI Technical Report,* May 2002.

[5] Ryu, H. et al., “Design of FCC Software for KARI Unmanned Airship”, *KARI Technical Report,* May 2002.

[6] Donald McLean, “Automatic Flight Control Systems”, Prentice Hall International, series In Systems and Control engineering, 1990.