AUTONOMOUS FLYING CONTROLS TESTBED

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ABSTRACT

The Flying Controls Testbed (FLiC) is a relatively small and inexpensive unmanned aerial vehicle developed specifically to test highly experimental flight control approaches. The most recent version of the FLiC is configured with 16 independent aileron segments, supports the implementation of C-coded experimental controllers, and is capable of fully autonomous flight from takeoff roll to landing, including flight test maneuvers. The test vehicle is basically a modified Army target drone, AN/FQM-117B, developed as part of a collaboration between the Aviation Applied Technology Directorate (AATD) at Fort Eustis, Virginia and NASA Langley Research Center. Several vehicles have been constructed and collectively have flown over 600 successful test flights.

DISCLAIMER

ACRONYMS, ABBREVIATIONS, SYMBOLS

AATD - Applied Aviation Technology Directorate, Fort Eustis, Virginia
LaRC – NASA Langley Research Center, Hampton, Virginia
SUAVeLAB – Small Unmanned Aerial Vehicle Laboratory, LaRC
COTS – commercial-off-the-shelf
RCMAT – radio controlled miniature aerial target
GPS – global positioning system
FLiC – Flying Controls Testbed
SOM – Self Organizing Map
UAV – unmanned aerial vehicle
MEMS - Micro-Electro-Mechanical Systems

INTRODUCTION

The project and resulting flight tests described herein are primarily motivated by the desire to conceive, develop, implement, and flight test highly experimental and perhaps even controversial flight control technologies in a relatively low cost and low risk platform. Simulations provide a useful development tool but the focus here is to develop a testbed to demonstrate these control approaches in actual flight. For example, one candidate control approach being considered is a multiple-model controller with dynamic models based on Kohonen's self organizing map (SOM) [1]. The self organizing map embodies a computational method that emulates the long term modulation of lateral inhibitory feedback among neurons during development. The result, a topologically ordered array or lattice of feature detectors, has been shown to provide the basis for modeling highly nonlinear dynamic systems [2]. Some initial experimental work, as well as simulation studies for flight control applications have been reported recently [3-6].

A proposal was submitted in June 2002 and consequently accepted by the NASA Langley Creativity and Innovation (C&I) initiative to develop such a test platform. The initial goal of the project was to develop a small test platform controlled by a commercially available autopilot capable of stabilizing, navigating and recording flight data for a small aerial vehicle in the 2-5 kg range, obviously unmanned and at least initially, remotely piloted. Concurrently, the Applied Aviation Technology Directorate (AATD) at Fort Eustis expressed a desire to collaborate on the development of a small UAV based on the availability of surplus target drones, AN/FQM-117B, referred to generically as a radio controlled miniature aerial target (RCMAT) [7]. These planes are roughly a 1/9 scale version of a MiG-27, constructed almost entirely of styrofoam, 1.7 m wingspan, 1.87m length, powered by a 9.83 cc, 1.42 kW glow fuel engine, with a total vehicle weight of approximately 3.63 kg. AATD provided several RCMATs for initial outfitting of standard radio control gear to assess the suitability of these for flight test purposes. The first flight of the most basically equipped version of the FLiC was hand launched on August 2, 2002. A typical hand launch is depicted in Figure 1.

After some modest initial modifications, including landing gear and rudder, it was determined that these planes would be ideal to pursue the goals of the project. Consequently, work began in earnest to install a COTS autopilot, a Micropilot™ MP2000, into one of the styrofoam MiGs in September 2002. The MP2000 provides stabilization using MEMS technology rate gyros, airspeed and altitude control with pressure measurements, navigation with a GPS receiver and utilizes an ultrasonic sensor for AGL measurements used during auto takeoff and landing. Details are available in the referenced technical manual [8].

More recently, an upgraded version of the autopilot, the Micropilot MP2028g, has been installed. Additionally, another test vehicle was constructed and flown employing the Piccolo™ autopilot by Cloud Cap Technology. The UAV Backup Switch, a fully independent mechanism to assert manual RC control or engage the failsafe configuration upon loss of a watchdog signal from the autopilot, was developed by another industry partner, ElectroDynamics. The autopilot and UAV Backup Switch installation is shown in Figures 2 and 3. A recent photo of the FLiC configured with sixteen aileron segments is shown in Figure 4.

Figure 1. Typical hand launching of AN/FQM-117B

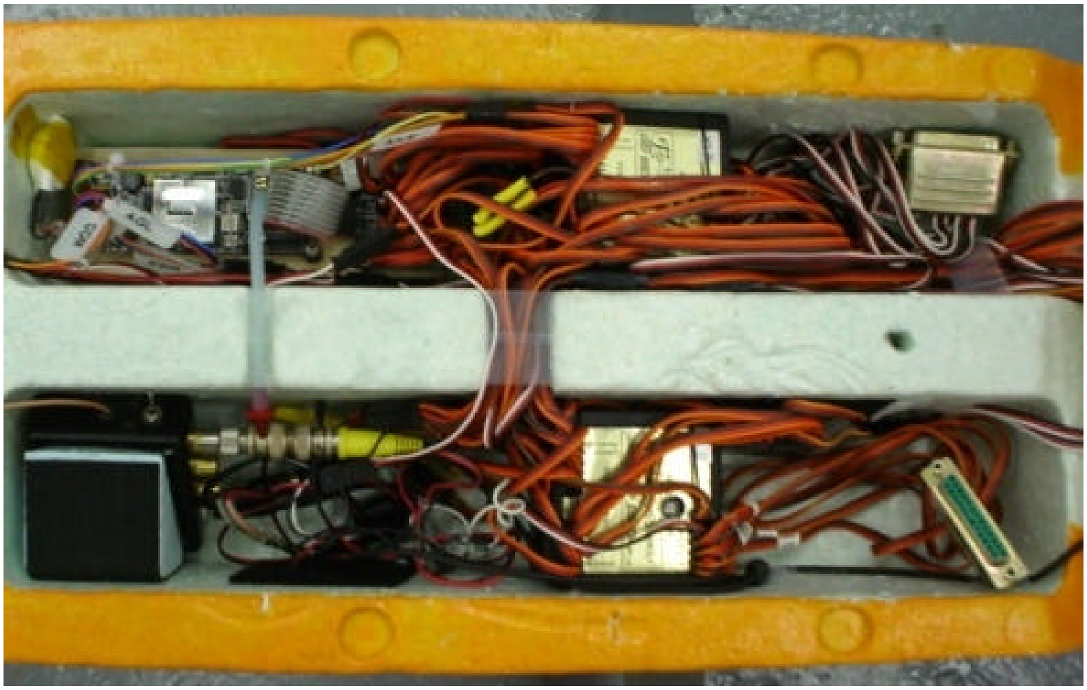

Figure 2. Autopilot and safety switch installation in the FLiC

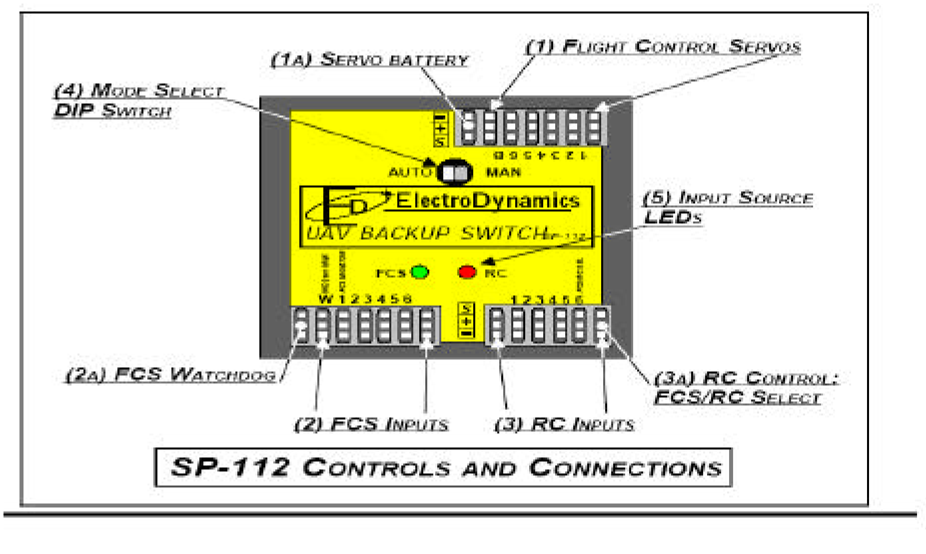

Figure 3. UAV Backup Switch

Figure 3. FLiC configured with 16 Aileron Segments

CURRENT FLIGHT TESTING

The initial modifications and flight testing phase, including the first fully autonomous flights was reported earlier [9]. The project has matured to the point where the primary focus is implementing the concepts embodied in the proposed experimental controllers and conducting the subsequent flight tests. As a preliminary step in this process, some simple proportional-integral-derivative (PID) controllers were designed and coded to control the nosewheel steering during the takeoff roll and airspeed in level flight with the throttle. Following the successful implementation of those controllers, several SOM based controllers to control airspeed were designed, implemented and flight tested in March 2005.

TYPICAL FLIGHT TESTING

A typical flight test maneuver performed by the FLiC is a series of step changes in pitch. The maneuver is initiated after achieving steady level flight at the prescribed altitude and airspeed, as preprogrammed by the autopilot. An initial test is performed to check the response to a step change in the pitch command from zero to five degrees. Figure 5 shows the response from such a test. After the successful completion of the initial pitch response, a series of step changes in the pitch command is executed, shown in Figure 6.

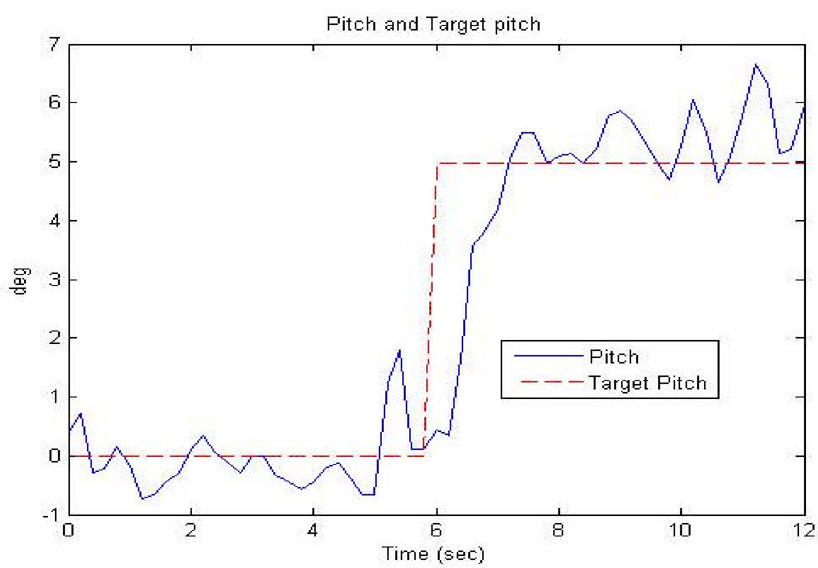

Figure 5. Response to programmed series of Pitch Step Changes

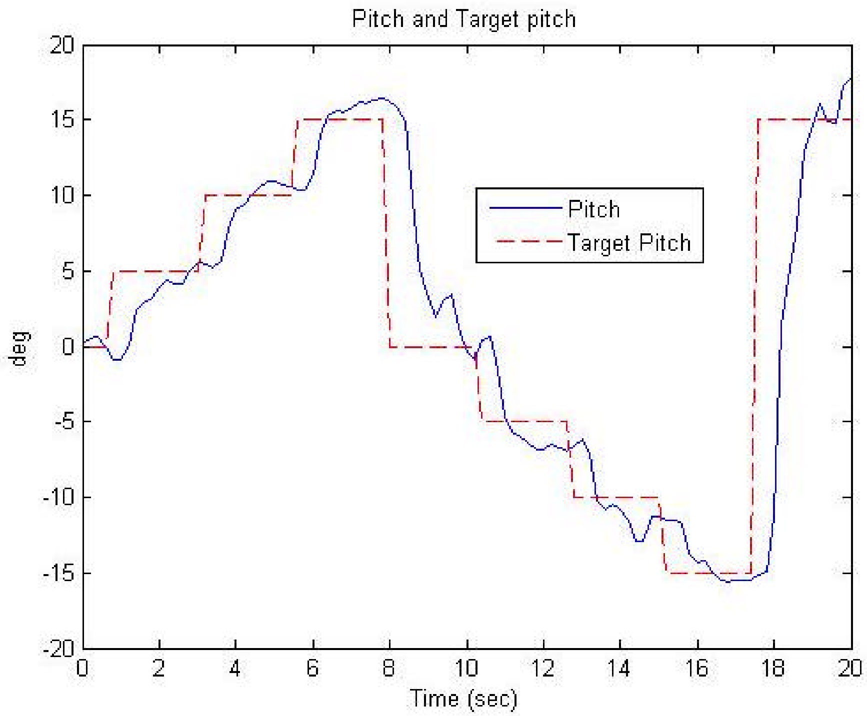

Figure 6. Response to a series of programmed pitch step changes

A PROTOTYPICAL AUTONOMOUS FLIGHT

A typical fully autonomous flight from takeoff roll to landing is depicted with the plots of airspeed and altitude in Figure 7.

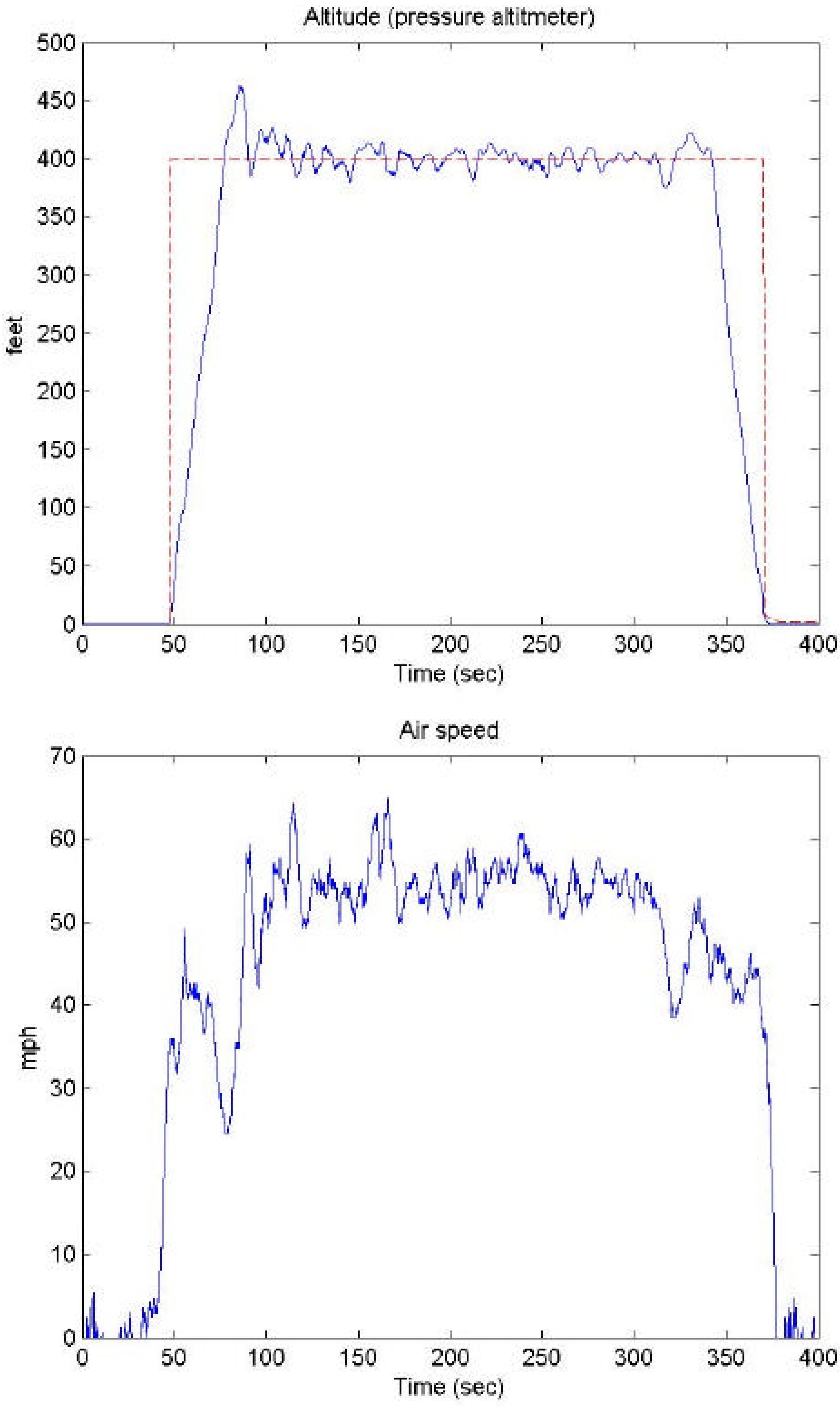

Figure 7. Altitude and airspeed for a typical fully autonomous flight

CONCLUSION

The initial goal of the Flying Control Testbed, to develop a small unmanned aerial vehicle controlled by a commercially available autopilot, has been achieved. The FLiC has completed over 600 successful test flights. The continuing research plans for the vehicle are to implement experimental control approaches such as self-organizing-map (SOM) based multiple model controllers as well as supporting the development of other adaptive control approaches. Other mission-oriented plans are under consideration by both Fort Eustis's Aviation Applied Technology Directorate (AATD) and NASA Langley Research Center's Small Unmanned Aerial Vehicle Lab (SUAVeLAB)

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