Safety Memo of KU-Hawk

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In this paper, we developed a fixed wing micro air vehicle which can be piloted semi-automatically. But this vehicle doesn't contain FCS system. In order to decrease its total weight and size, we chose a system that gets flight data from vehicle to ground control system where computer calculates its flight condition and performance and operates to signal back to vehicle. We are trying to make smaller autopilot air vehicle through this system. First, we made wing span of 50cm air vehicle to be our proto-type model and tried to decrease its scale. It was possible to reduce the weight of the structure by using carbon/epoxy composite materials and MEMS IMU system.

Notations

We introduce the following notations :

n Life time in amount of charge / discharge cycle
e Endurance (h)
h Cruise Altitude (m)
L/D Lift-to-Drag ratio
ws Wind speed (m/s)
as Air speed (m/s)

1. System properties

The Vehicle

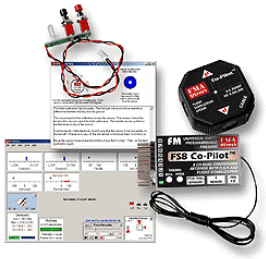
Name : KU-Hawk
Weight : 450g
Wingspan : 495mm
Propulsion : 1 Electric Brushless engine
Endurance : 15 minutes

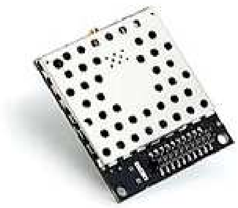
Transmission systems

- 2.4GHz analog transmitter for the video downlink. (80mW)
- Digital modem 868MHz for uplink and downlink telemetry and data (250mW)
- 72MHz RC transmitter for safety RC Link. (100mW).

Autopilot system overview

KU-Hwak System doesn't have FCS board inside. This system maintains its position by IR Gyro sensor, and gets current location data from GPS module and send it to GCS(Ground Control Unit). Then GCS calculates received data and send back the signal to adjust the current position related to target point.





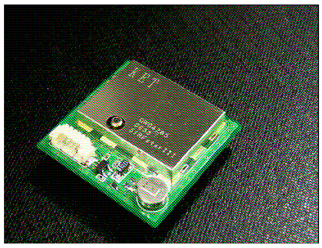


Figure 1 : IR Gyro   Figure 2 : RF Modem   Figure 3 : GPS Module

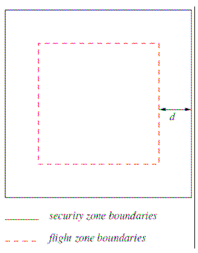
KU-Hawk system can fly with 2 types of flight control method by switch. One is manual and the other is Auto 1

Manual : Pilot commands are directly sent to flight commands.
Auto 1 : Calculated data from GCS and transmit the flight command from ground.

Above 2 types of mode can adjust by switch on controller and during the manual mode, GCS also calculate the flight condition and performance in order to control directly when the mode changes.

2. Flight Zone Computation

The fall distance without wind is : $L/D \times h$
The fall duration is :
The wind effect is : $\times$ ws
Therefore, we have (see figure 4): $d = L/D \times h +$ $\times$ ws



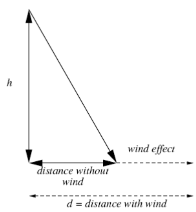


Figure 4 : distance between the Security zone and the Flight zone.
Figure 5 : How the previous distance is computed
The KU-Hawk cruise speed is approximately 17m/s. At this speed the maximum. Lift-to-Drag ratio is 1.1 with a nose-down attitude. In the worse case, we consider that the wind speed is 15m/s. The Li-Po battery commonly used have a 1000 charge and discharge cycle, and provides a 15 minutes endurance. Therefore we have a distance:

d=114 meters

3. Probability to exit a given flight zone

To prevent Micro Air Vehicle from causing accidents we need to classify flight failure and provide maneuvers and fail safes to prevent this failures to be responsible for an accident. To do so a Micro Air
Vehicle mustn't exit a given flight zone with the probability of 10−4 per flight hour.

Power supply failure

A power supply failure will automatically and immediately cause a crash of the MAV. We define the following events, which are independent:

A The battery of the Micro Air Vehicle is out of order.
B The Micro Air Vehicle crash outside of the borders of the flight zone.

P(A) = = 3.8 per hour

d = L/D × h + × ws

= 114m

P(B) = $\frac{\text{surface(stripe within distance d of t}}{\text{surface (flight zone)}}$

= 0.125

P(A B) = P(A) × P(B)

= 4.75 × per hour

To simplify the computation of the surface we considered that the flight zone was a 800 meters square.

GPS failure

If the Micro Air Vehicle lose the GPS fix more than 2s, the only way to avoid the MAV to exit the flight zone is the safety RC link. If the RC link is also lost we shut down the throttle to make it crash safely. We consider the events:

A GPS signal failure
B RC link failure
C Micro Air Vehicle crash outside the flight zone

Based on previous flight experience (more than 300 flights of 15 minutes average) we had one GPS fix failure during a flight. Therefore, the typical GPS failure probability is estimated to:

P(A) = = = 13.3 per hour

Based on FFAM estimated figures of year 2006 of 5 accidents due to lost of RC link per year and per club with 737 clubs and 23692 members (50 h/yr/member) we estimated the probability of losing RC link to:

P(B) = = 3.11 per hour

From previous section we have:

P(C) = 1.25

Therefore, as A, B, and C are independent events:

$$P(A \quad = P(A) \quad P(B) \quad P(C) = 5.17 \quad \text{per hour}$$

Autopilot failure

If the autopilot fails the only way to get the aircraft on the ground and inside the flight zone is to use the safety RC link. Let A = Autopilot fails and B = Lost RC link. Over more than 250 flight hours we hadn't experienced any autopilot failure, therefore:

$$P(A) \quad = 4$$

$$P(A \quad = P(A) \quad P(B) \quad 1.244 \quad \text{per hour}$$

References

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