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# TECHNICAL NOTE: A PROPOSAL FOR THE AUTOMATIC DETECTION OF FAILURES IN THE AIRCRAFT INSTRUMENTATION WITHOUT SENSOR DUPLICATION

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## ABSTRACT

Although the flight computer and the electricity generator are duplicated it is not common practice to duplicate the sensors of the instrumentation due to their very high level of reliability. Lot of measures can be estimated from subsets of another measures. From the confrontation of the estimations with the respective measurements we can generate failure hypotheses with an attributed probability that must further be validated by other failure hypotheses till a point we must ask the pilot about his own judgment about the behaviour of a sensor or a set of sensors. This way when it is detected a significant discrepancy between a measure and the correspondent estimation it is generated a tree of fuzzy rules that led to a conclusion with an estimated probability or a set of conclusions ranked by their estimated probabilities. In this work we make a first sketch of the hypotheses generation engine from which results a tree of fuzzy rules and a failure hypotheses combination engine that solves this tree of fuzzy rules. From the Hamming theorem about error correcting codes, the number of sensor failures that we can detect or even correct increases with the number of ways we can estimate the same measurement. By other words with more sensors we can detect and even correct more sensor failures.

***Keywords:*** aircraft failures, sensors, measurements, accelerometer.

## INTRODUCTION

It is common practice in aeronautical engineering to duplicate the flight computer and the electricity generator and other vital components as hydraulic circuits. Nevertheless due to their very high reliability it is not common practice to duplicate the various sensors as the altimeter and the speed meter. In this work we show how it is possible to detect and even correct a failure of one or two of the sensors confronting its *measure* with an *estimation* obtained from a combination from other sensors.

### Some examples of measures estimations and hypotheses generation

From two successive samples of the altimeter and speed meter it is possible to detect and even correct failures in these sensors. To complete the detection of failures in the speed meter it is necessary to have a numerical simulator that estimates the next value $V(t+\Delta t)$ from the actual read value $V(t)$ and trajectory angle $\gamma(t)$, assuming constant the trajectory angle during $\Delta t$, the flight computer sample time interval. Comparing this simulator estimate with the next value read by the speed meter, $V(t+\Delta t)$, we can detect or even correct failures in this sensor. By other side if the speed meter has no errors, then if:

$$\Delta t\ V(t) \sin \gamma(t) >> h(t+\Delta t)-h(t) \text{ or } \Delta t\ V(t) \sin \gamma(t) << h(t+\Delta t)-h(t)$$

then it must be concluded that there is a malfunction in the altimeter and thereafter the altitude must be estimated through an inertial form. Nevertheless the altimeter can have no malfunction and the above discrepancy be a consequence of a failure in the trajectory angle meter. To disambiguate this latter hypothesis the pilot can be asked about his own judgement about the behaviour of this sensor.

In a fighter aircraft the centripetal acceleration through a horizontal curve, Gflyup(t), measured by the accelerometer can be compared with $V(t)\ \omega(t)$, where the angular speed is measured by the yaw sensor and the angular speed can be estimated by $\omega(t)\sim \Delta\gamma/\Delta t$, and this latter estimate can be compared with the measure of this sensor.

**Detection of Failures of a Military Aircraft Accelerometer**

Since the centripetal acceleration during a horizontal curve can be estimated by:

$$\text{Gest}= \omega(t)\ \ (\ V(t+\Delta t) + V(t)\ )\ /\ 2$$

If the measure of the accelerometer, *Gflyup*, is very different from the above estimation then we have five possible explanatory hypotheses:

*(i)*-There is no malfunction in the accelerometer and there is a failure in the speed meter and/or a failure in the yaw sensor

*(ii)*-There is a failure in the accelerometer and since there are no malfunctions in the yaw and speed sensor, so we must substitute the measures of the accelerometer by the above estimation *G*est

*(iii)*-There are malfunctions in the accelerometer and in the speed meter, so *G*est must be recalculated from estimations of the speed obtained with a numerical simulator

*(iv)*-There are malfunctions in the accelerometer and in the yaw sensor so *G*est must be recalculated from the estimation of $\omega(t)$ by $\Delta\gamma/\Delta t$, assuming that the trajectory angle sensor is working properly

*(v)*-There is a malfunction in the accelerometer, in the yaw sensor and in the trajectory angle sensor, so *G*est must be recalculated from a estimation of trajectory angle from two successive samples of the GPS

Assuming that the altimeter is working properly we can verify if the speed meter and the trajectory angle meter have no malfunctions calculating

$$\Delta h_{est}=(\ V(t+\Delta t) + V(t)\ )\ /\ 2 \quad \sin \gamma(t)\ \Delta t$$

So if $\Delta h \sim \Delta h_{est}$ we can conclude that the speed sensor and the trajectory angle sensor have no malfunctions and so we can substitute the accelerometer measure by the estimate *G*est.