Surviving the improbable

real time damaged aircraft model identification and reconfiguring control

Worldwide civil aviation safety statistics indicate that 'in-flight loss of control' remains the second major cause of fatal accidents. Recent loss of flight control accidents and incidents have shown that non-conventional adaptive control strategies can take these malfunctions into account and assist the pilot in recovering the crippled airplane. The GARTEUR Action Group FM-AG(16) on Fault Tolerant Control has investigated these potential improvements in aircraft survivability, by demonstrating the capabilities and viability of novel fault tolerant flight control techniques using high-fidelity nonlinear simulation models based on realistic failure scenarios validated against flight data. Delft University of Technology is contributing to this action group, and has tested these techniques in the Simona Research Simulator.

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Especially in civil aviation, all developments focus on the improvement of safety levels and reducing the chances that critical failures occur. When one analyses recent aircraft accident statistics, it is clear that a significant portion is attributed to "loss of control in flight". A recent worldwide civil aviation accident survey for the 1989 to 2003 period, conducted by the Civil Aviation Authority of the Netherlands (CAA-NL) and based on data from the National Aerospace Laboratory (NLR) indicates that this category counts for as much as 17 % of all aircraft accident cases, and this number is slightly increasing over the years. Contributing to this 17 % of all accidents are among others the following accidents: Japan Airlines flight JL123 where a Boeing 747 lost its vertical fin and its hydraulics. The reason for this was an explosive decompression through a crack in the rear bulkhead. United Airlines flight UA232 is another interesting example where a McDonnell Douglas DC10 lost its hydraulics and made an emergency landing at Sioux City. Also, El Al flight 1862 can be mentioned in this category where a Boeing 747 lost two engines and part of its hydraulics and crashed on the Bijlmermeer in Amsterdam. Finally, the most recent example is the DHL cargo flight which suffered a surface-to-air missile impact and also lost all hydraulics.

In the case of the United and DHL accidents, the aircraft ultimately succeeded to make an emergency landing, but this was entirely owed to the superb airmanship of their highly experienced cockpit crews. However, this has led to a common conclusion: from an aeronautical-technical point of view, with the technology and computing power available at this moment, it might have been possible to design an intelligent flight control system which is capable to assist the (possibly less experienced) pilot to recover the aircraft in the situations above on the condition that non-conventional control strategies would have been available. These non-conventional control strategies involve the so-called concept of Fault Tolerant Flight Control (FTFC), where the control system is capable to detect the change in the aircraft behaviour and to adapt itself so that it can handle the perturbed aircraft dynamics. One possibility is model reference adaptive control, where a flexible model based control strategy is making use of an online updated aircraft model. In this situation it is important to incorporate also some form of control allocation in order to make use of some alternative steering channel(s) in the aircraft. One control allocation example is applying differential thrust by modulating the engine thrust levels individually instead of together. By doing so, the pilot has some means of directional flight control. This principle has successfully been applied by the United and DHL crews in the situations described before. Differential thrust has been applied in the NASA research project on Propulsion Controlled Aircraft, where a McDonnell Douglas MD-11 prototype has flown a complete flight pattern, including landing, with engine thrust control only. Another interesting NASA project is intelligent flight control systems (IFCS), where a McDonell Douglas (fig. 1) F-15 Eagle research aircraft of NASA has been flown by means of self-learning neural networks (working in a similar fashion as the neurons in our brains), in order to optimize aircraft performance in both normal and failure conditions. However, these neural networks have the inherent property of being somewhat "unpredictable" in their way of computation since this control approach involves a kind of "black box".

The research work described here is closely related to the work in two projects that have been initiated recently, in which Delft