Modelling, Simulation and Flight Test

HOW TO SPOT AN ACCIDENT BEFORE IT HAPPENS

The emergence of the design and development of eVTOL aircraft is driving an explosion of new companies and aero engineering activity around the world. These companies range from heavily funded organisations to simple ideas and concepts from start-ups and individuals. There is one thing that all of them have in common, they are all new designs that have never been fully proven and tested in the real world. This means that there is no historical/empirical data against which they can be benchmarked. The challenges of these designs are further compounded by the fact that many of these organisations are completely new to the domain. Whilst there are good designs demonstrated in the conceptual stage, there may be a lack of awareness as to what tools are suitable for further development, testing, simulation/modelling, through to aircraft certification, and the associated level of fidelity required for each. Whilst the use of gaming technology provides adequate preliminary information for marketing and concepts it is unsuitable when considering flight test and certification.

Ensuring that safe aircraft are developed means the reliance on a range of good practices as a solid foundation. This good practice should involve the avoidance of losses of control. It might be viewed as acceptable when writing web applications that the odd bug may get through resulting in a system crash, however this attitude should not carry across into aircraft design, any event leading to loss of control is bad regardless as to whether people are hurt or not and should be avoided at all costs.

One such good practice is to examine where the likes of response modelling, high fidelity simulation, and uncertainty analysis come in to play and why such approaches have been used by the established aircraft industry for decades.

The approach is quite simple, define the manoeuvres to be performed during the next set of test flights. Run these manoeuvres through a high fidelity offline simulation (Response Modelling) using a baseline Flight Model that has been developed from the design data, with an understanding as to how the values are calculated and their impact on the aircraft behaviour. It should be possible to repeat this manoeuvre ad-infinitum and get the same results, this requires a truly deterministic simulation and so cannot be performed with a pilot in the loop.

The baseline model is the core design model that it is believed to be a good/accurate representation of the aircraft. However, it is unlikely to be a true representation of the aircraft, this is where the uncertainties lie. From the baseline model there should be multiple variants developed. These add changes to the aircraft characteristics/contributions based upon the areas where possible uncertainties exist. The size of the uncertainties depends upon how confident you are of the data you have produced. For example, if the model is built using basic airfoil section data and simple gaming simulation techniques, then the uncertainties are likely to be large. If wind tunnel data or CFD has been used, the interaction of multiple rotors on each other and the mass and inertia built up from accurate measurements or a test rig, so the uncertainties are likely to be less. Uncertainties are not applied in isolation either, they need to be combined and scaled based upon the likelihood that multiple errors will exist simultaneously. The uncertainties should be understood as to where they come from and what likely changes they will make to the overall response.

Now the same manoeuvre that was flown on the baseline model should be flown on ALL the possible variants (Uncertainty Analysis). This is where the ability to repeat the manoeuvre time and again comes into play. From all these cases, the responses need to be evaluated to identify any areas where the aircraft exceeds defined limits. These limits could be guidelines/safety factors, they should not be outside the regions where the data has been calculated, and should also look out for areas where the aircraft completely diverges. If there are any of the variants that exceed the limits or diverge, then that manoeuvre should not be tested until more information is known and the level of uncertainty can be demonstrably reduced. It does not matter if only one of the variants exceeds the limits, the fact is that with high levels of uncertainty an exceedance can occur and it’s possible that your aircraft really is that variant.

Once the limiting manoeuvres have been identified, then the real-time simulation can take place. The test pilot should be able to fly the same manoeuvres and be able to fly all the different variants (High Fidelity Simulation). This enables an understanding as to how the manoeuvres feel and any possible avoidance/recovery techniques can be rehearsed. Once this has taken place, only then is it time to fly.

Whilst the above approach may seem to be lengthy, using the right simulation tools and evaluating all the possible combinations scenarios ahead of flight, it is possible to avoid any upsets or instabilities that could result in a loss of control as they will all have been identified ahead of time. Even if flying unmanned aircraft in unpopulated areas, avoiding a single incident will reap huge benefits in avoiding rebuild time and costs, not to mention the possible impact on the organisation’s and the eVTOL industry’s image.

After each flight, the results can be compared to those found with the multiple variants to see which was closest. The test flight should then be replayed through the baseline simulation model (Re-Prediction Analysis) to identify where the errors between the real aircraft and the simulation model lie. Parameter identification can then be used to establish any corrections that may be required. With a refined model now updated from the previous flight tests, so the relevant uncertainty values can be reduced and the next set of tests evaluated. In this way the flight test envelope can be expanded.

In order to be able to run a full envelope expansion process, high fidelity engineering and real time simulation tools need to be utilised. Within the long established aerospace industry, these have been developed over many years, usually in house. With the new eVTOL industry, a lot of companies do not have the luxury of developing their own tools and so they start to look towards what already exists. This is leading them to gaming simulation technology, believing it will suffice. However, without then spending even more man hours trying to write plug-ins to patch a system that was never intended to support a complete Aircraft Design Flight Test, envelope expansion program, the gaming tools are quite simply, inadequate. It doesn’t matter how cheap the gaming system is if the outcome is that the aircraft experiences a loss of control incident.

The j2 Universal Tool-Kit was developed from the ground up to support the development of any aircraft from conceptual design through to flight test and pilot training simulation. This tool is able to run offline, real-time simulations on baseline and variant models without the user having to write any code. The integrated flight test data matching capability will automatically identify the corrections needed from flight test data and track all the changes made to maintain workflow and assure quality. The software is already used by mainstream aircraft OEM’s to develop new designs as well as Simulator Manufacturers to develop flight models for Full Flight Pilot Training Simulators.

The j2 Universal Tool-Kit has been used for tilt-rotor and multi-copter development for many years and has a strong track record in the accommodation of multi rotors air vehicles and the ability to handle quickly evolving flight control systems, power delivery changes and rotor interactions within the design, analysis and simulation arenas.