APPENDIX 3-4:

Impact Energy Method For Establishing The Design Standards For UAV Systems

This Appendix describes a method for obtaining a first outline of the airworthiness standards which should be applied to UAV systems. The method compares the hazard presented by a UAV with that of existing conventional aircraft to obtain an indication of the appropriate level of requirements which should be applied. The most significant feature of this proposal is that it relies on a comparison with existing conventional aircraft design requirements which contribute to a currently accepted level of safety, and avoids controversial assumptions about future contributions to that level of safety from operational, environmental or design factors.

1 COMPARISON CRITERIA

The capability of a vehicle to harm any third parties is broadly proportional to its kinetic energy on impact. For the purposes of the comparison method it is assumed that there are only two kinds of impact; either the impact arises as a result of an attempted emergency landing under control, or it results from complete loss of control. More precisely, the two impact scenarios are defined as:

a. *Unpremeditated Descent Scenario* - A failure (or a combination of failures) occurs which results in the inability to maintain a safe altitude above the surface. (e.g. loss of power, WAT limits etc).

b. *Loss of control scenario* - A failure (or a combination of failures) which results in loss of control and may lead to an impact at high velocity.

Unpremeditated Descent Scenario:

For many air vehicles the likelihood of the unpremeditated descent will be dominated by the reliability of the propulsion systems. For the calculation of kinetic energy at impact the mass is the maximum take-off mass and the velocity used is the (engine-off) approach velocity. i.e.

For aeroplanes V = 1.3 X Stalling Speed (Landing configuration, MTOW)

For Rotorcraft V = Scalar value of the auto-rotation velocity vector,

For Airships/Balloons V = The combination of the terminal velocity resulting from the static heaviness, and the probable wind velocity.

Loss of Control Scenario:

For the calculation of kinetic energy at impact for the loss of control case the mass is the maximum take-off mass and the velocity used is the probable terminal velocity. i.e.

For aeroplanes V = 1.4 X Vmo (the maximum operating speed)

For Rotorcraft V = Terminal velocity with rotors stationary.

For Airships/Balloons V = Terminal velocity with the envelope ruptured/deflated to the extent that no lifting medium remains.

For each scenario the kinetic energy has been calculated for a selection of 28 different civil aircraft; (21 aeroplanes, and 7 rotorcraft). The results are shown in Figures 1 and 2. On each Figure the “applicability region” for each of the existing aeroplane and rotorcraft codes is shown. These regions have been established using practical constraints based upon the sample of the existing fleet, plus any weight and speed limitations specified in the applicability criteria of the codes of airworthiness requirements.

2 METHOD OF COMPARISON

To obtain the indication of the level of requirements appropriate to a UAV system the following steps are carried out:

a. Calculate the kinetic energy of the UAV for each scenario.

b. Using these values and Figures 1 and 2 separately, determine the appropriate code to be applied with the intent of preventing the occurrence of each scenario. i.e:

Figure 1 will provide an indication of the standards to be applied to any feature of the design whose failure would affect the ability to maintain safe altitude above the surface.

Figure 2 will provide an indication of the standards to be applied to any feature of the design whose failure would affect the ability to maintain control, (particularly rate of descent). Clearly, this must include primary structure.

If it is found that the aircraft fits within the region for more than one code, then this would indicate that it may be appropriate to apply a combination of standards. (e.g. JAR-25 with reversions to JAR-23 in some areas, or JAR-23 with Special Conditions taken from JAR-25).

c. Construct a certification basis which addresses the same aspects of the design as the existing codes and to the level indicated by the kinetic energy comparison. Clearly, Special Conditions will need to be considered for any novel features of the design not addressed by the existing codes. However, the extent of such special conditions should be comparable with the general level of airworthiness identified.

Note: In addition, operational requirements may dictate the inclusion of particular design features which may in-turn necessitate the inclusion of additional certification requirements. For example, the Rules of the Air specify that an aircraft operating over a congested area must be able to maintain a safe altitude following the failure of one power unit.

3. WORKED EXAMPLES

3.1 Application to Global Hawk

Global Hawk is a High Altitude Long Endurance (HALE) UAV produced by Northrop Grumman in the USA with a primary role of reconnaissance/surveillance. Global Hawk is powered by a single turbofan engine. Its estimated characteristics are: a gross weight of 25,600lbs (11,600kg), a maximum operating speed (V_{MO}) of 345kts and a stall speed (V_S) of 95kts. Using these parameters gives energy levels of 0.177 (unpremeditated descent scenario) and 3.53 (Loss of control). These are illustrated in Figures 1 & 2 and indicate that JAR-25 standards are applicable throughout.

3.2 Application to Predator

The RQ-1A Predator UAV from General Atomics is a Medium Altitude Long Endurance (MALE) UAV which has seen extensive operational experience within the military. Powered by a single piston-engine, the estimated parameters for Predator are: MTOW of 1,900lbs (855kg), Vmo of 120kts and Vs in the region of 56kts. For the “unpremeditated descent” scenario, this equates to energy levels of 0.0046 (JAR-23 single-engine) and for the “loss of control” scenario 0.024 (JAR-23 single-engine). The certification basis for the Predator would therefore be JAR 23.

3.3 Application to Hunter

Hunter from IAI is a short range UAV which was/is operated by the armies of USA, Israel, Belgium and France. The Hunter comes in both standard and endurance versions and is powered by 2 Motto-Guzzi engines. The two versions of the aircraft have gross weights of 726 kg and 952 kg respectively. The values for each version and each scenario are shown in Figures 1 and 2. Although there is a small overlap with JAR-VLA in one case, it can be seen that the guideline standard is JAR-23 for both versions of the aircraft.

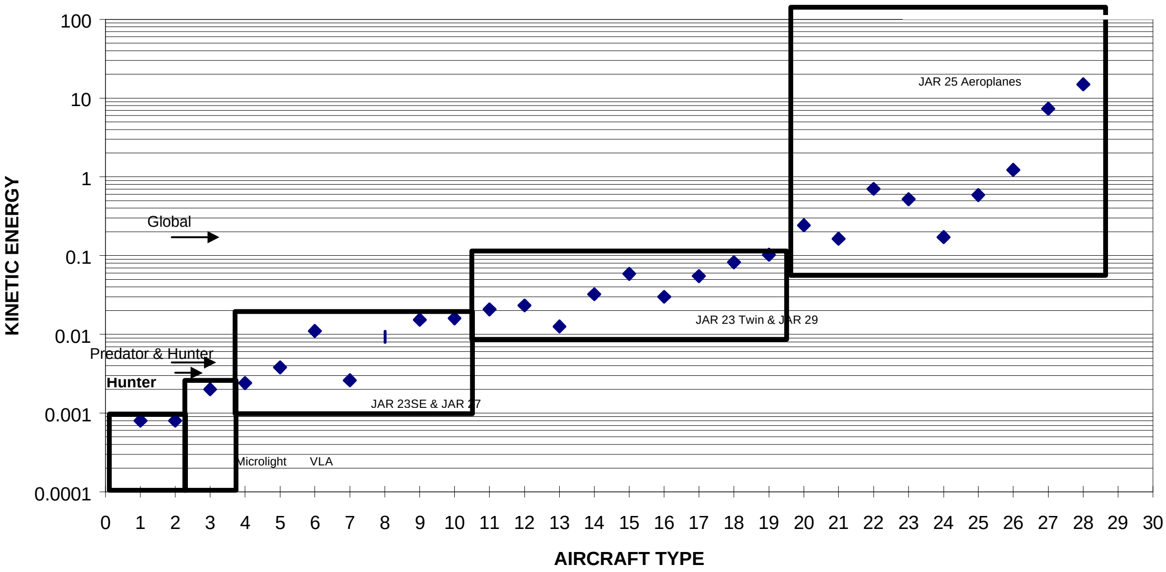
3.4 Application to StratSat

StratSat is an unmanned communications airship intended for long duration missions stationed above population centres. For this aircraft the “unpremeditated descent” analysis indicates that a standard equivalent to JAR-23 as applied to single-engine aeroplanes would be appropriate. The “loss of control descent” analysis indicates that standards equivalent to a combination of JAR-25 and JAR-23 Commuter Category should be applied to reduce the probability of such an event. Thus the basis for civil certification of this aircraft should be the airship equivalent of JAR-23 supplemented as necessary by requirements from JAR-25 and JAR-23 Commuter.

4. CONCLUSIONS

A simple method of comparing UAV systems with existing manned aircraft is presented together with examples of its application to specific projects. It is appreciated that no simple method can give a complete answer to the definition of the certification bases, and the conventional processes using judgement and debate will still be required. However, the method presented provides a useful tool in anticipating the general level of airworthiness requirements to be set.

FIGURE 1 - UNPREMEDITATED DESCENT SCENARIO

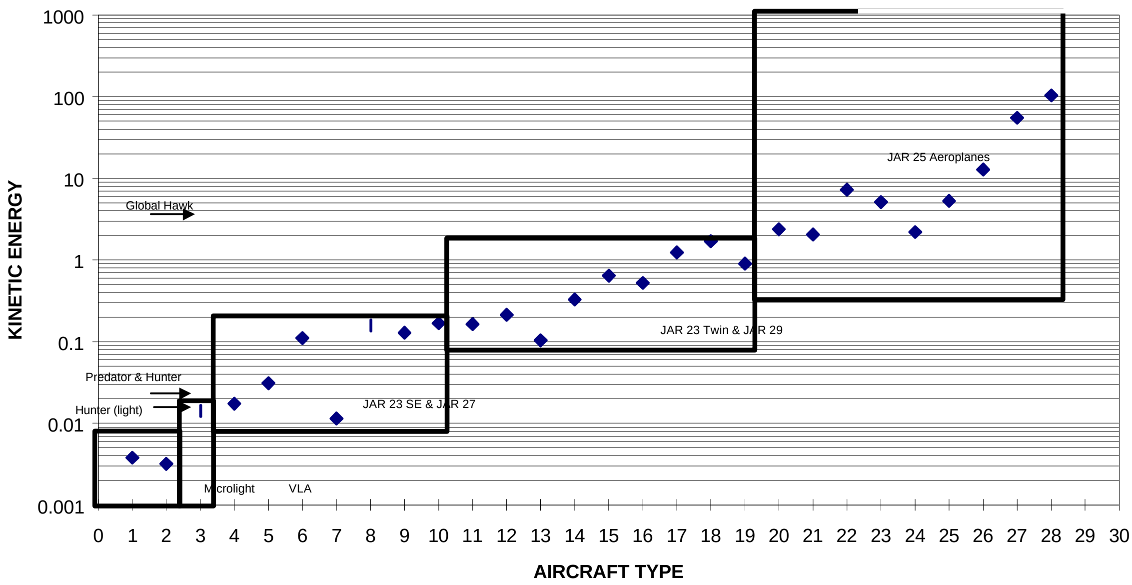


Kinetic Energy (as plotted) = (Mass (kg) X Velocity (kt)^2) / 10^9

Aircraft Key:

1. Flex wing microlight,
2. 3-axis microlight,
3. Piston Single - JAR-VLA
4. Piston Single 2 seat,
5. Piston Single 4 seat,
6. Large Piston Single
7. Helicopter 2 seat
8. Mid-size Helicopter
9. Mid-size Helicopter
10. Mid-size Helicopter
11. Piston twin
12. Piston twin,
13. Piston twin
14. Piston twin
15. Light Corporate Jet
16. Large Helicopter
17. Large Helicopter
18. Large Helicopter
19. Small Twin Turboprop
20. 50 seat Turboprop
21. 50 seat Turboprop
22. 100 seat airliner
23. Corporate Jet
24. Corporate Jet
25. 50 seat airliner
26. Single-aisle Airliner
27. Wide Body Airliner
28. Wide Body Airliner

FIGURE 2 - LOSS OF CONTROL SCENARIO



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12. Piston twin,
13. Piston twin
14. Piston twin
15. Light Corporate Jet
16. Large Helicopter
17. Large Helicopter
18. Large Helicopter
19. Small Twin Turboprop
20. 50 seat Turboprop
21. 50 seat Turboprop
22. 100 seat airliner
23. Corporate Jet
24. Corporate Jet
25. 50 seat airliner
26. Single-aisle Airliner
27. Wide Body Airliner
28. Wide Body Airliner