GUIDELINES FOR THE REGULATION OF LIGHT UAV SYSTEMS

1. INTRODUCTION

The routine operations of Civil UAV Systems are likely to be severely restricted in the short-term until a number of significant technical problems have been resolved (e.g. the provision of an adequate "Sense & Avoid" capability). Until the solutions to such problems are available and UAVs can achieve parity with manned aircraft in respect of freedom of operation, civil UAVs are likely to remain segregated from manned aircraft and be confined to flight above sparsely populated areas.

A review of the UAV Systems market has highlighted that UAV systems that are capable of operating under such constraints tend to be light UAVs and that this trend is likely to continue for the foreseeable future.

These operational constraints are not unique to UAVs. Pilotless aircraft in the form of "model aircraft" have been flying within these limitations for many years and have achieved an acceptable safety record. Most nations currently have provisions within their national legislation to allow model aircraft to operate with no or limited airworthiness requirements in place, provided operational constraints in terms of where and when the model aircraft is operated are enforced. Furthermore, in the past these model aircraft have, on a case-by-case basis, been allowed to operate commercially in performing aerial work tasks – effectively operating as UAVs.

With this background, the UAV-TF considered whether to produce guidelines for the regulation of light UAVs based on similar principles and restrictions to those applied to model aircraft and which, if adopted, would enable a harmonised approach for the routine operation of light UAV systems. Without such an initiative, it was anticipated that light UAV regulation and safety standards would evolve internationally in a diverse and regionalized manner. Furthermore, responses obtained from a questionnaire developed by the UAV-TF and sent to National Aviation Authorities, indicated that most nations had yet to address the regulation of light UAV systems and that National Aviation Authorities supported the development of such guidelines.

Consideration has therefore been given in this Annex as to whether UAVs that have no greater capability than existing model aircraft may be allowed to operate without obtaining airworthiness certification, subject to the UAV system complying with similar limitations and conditions to those applied to model aircraft.

Light UAVs covered by these guidelines are those with a maximum take-off mass below 150kg, and a maximum speed not exceeding 70kts, that are operated within 500 metres of the UAV-pilot and not more than 400 ft above ground level.

(Note - 500 metres is chosen as the maximum distance at which the UAV-pilot may reasonably be expected to maintain visual contact with a UAV capable of 70kts whilst also monitoring the sky around the UAV for conflicting traffic. The 400 ft limit is also intended to prevent conflict with other traffic).

UAVs under 150kg are excluded from the scope of Regulation (EC) 1592/2002 through the provisions of Annex II to that regulation. Consequently, responsibility for regulatory control of UAVs under 150 kg is vested with National Aviation Authorities and not with EASA. Some UAVs below 150kg mass may have maximum level speeds in excess of 70kts, and so cannot easily and reliably be operated without exceeding the 500 metres and 400 ft limitations. Such UAVs are not covered by these guidelines and National Aviation Authorities may still need to develop additional national policy and procedures for the appropriate regulation of such systems. However, it is recommended that such UAV systems abide by the basic regulatory concept developed within the main body of this document. It is expected that once sufficient experience of operating UAVs has been gained, these guidelines could be expanded to address all UAVs under 150 kg mass..

2. REGULATORY CONCEPT

To provide a starting point for the development of guidelines for the regulation of light UAV systems, a proposal from Industry to base the concept on FAR Part 103 (Ultralight Vehicles) was accepted by the Working Group. Although at first sight it may appear that ultralight vehicles used for recreational purposes bear little relationship to light UAV systems, some parallels do exist and furthermore the stand alone nature of this document made it easily amenable to change and provided a complete regulatory concept in one simple document.

Historically there has been a trade-off between the level of airworthiness and operational standards. Recreational activities tend to have minimal airworthiness standards applied and are regulated more by operational requirements which dictate where and when they may fly. The converse is true for commercial activities and public transport. The rationale for this approach stems from the level of risk and cost that people are prepared to tolerate and their level of direct involvement in the activity. However, the level of risk for third parties should remain constant and independent of the type of operation being conducted.

To provide a measure of “equivalence”, the regulatory concept developed here uses impact kinetic energy as a basic criterion. Impact kinetic energy is directly linked to the ability of a UAV to cause damage and injury. It provides both an absolute measure for the showing of compliance and a relative standard for identifying “equivalence” with model aircraft. Kinetic energy is also an all-encompassing criterion applicable to all aircraft types, is easy to measure and can be readily estimated during the design process.

It is emphasized that there is no intent to change the regulatory environment for model aircraft in any way. The proposal detailed here is concerned with the regulatory

environment for UAV systems performing Aerial Work tasks. The relevance of model aircraft to the matter at issue is their safety record and how this may be read-across to UAVs of equivalent capability.

3. DETAILED PROPOSALS FOR LIGHT UAV SYSTEMS

1 Applicability.

A light UAV system consists of an air vehicle that:

(a) Is used or intended to be used for unmanned operation in the air;
(b) Does not have any national or foreign airworthiness certificate;
(c) Has a maximum take-off mass of less than 150Kg;
(d) Is not capable of more than 70knots (CAS) at full power in level flight;
(e) Has an impact kinetic energy that does not exceed 95KJ when assessed against both a high speed and free-fall impact scenario, and calculated as follows:
  (1) Kinetic energy = 0.5*Max. Operating Mass*(1.4 * Max. Level Speed)^2
  (2) Kinetic energy resulting at impact from a free fall from a height of 400ft

3 Inspection requirements.

(a) Any person operating a light UAV system shall, upon request, allow the Authority to inspect the light UAV system to decide the applicability of these requirements.
(b) The pilot or operator of a light UAV system must, upon request of the Authority, furnish satisfactory evidence that the light UAV system is subject only to the provisions of these requirements.

5 Exemption.

No person may conduct operations that require a deviation from these requirements except under a written exemption issued by the Authority.

7 Certification and registration.

(a) A light UAV system is not required to meet the airworthiness certification standards specified for aircraft or to have a certificate of airworthiness. However, the design, construction and initial flight-testing of the light UAV system must be overseen by the responsible National Aviation Authority or by a body approved by the Authority to carry out such an oversight.
(b) The operator of a light UAV system is not required to meet any aeronautical knowledge requirements to operate the air vehicle or to have a pilot or medical certificate. However, every operator of a light UAV system must be identified and demonstrate a basic ability to control the air vehicle.
(c) A light UAV system is not required to be registered or bear markings of any type.

9 Hazardous operations.

(a) No person may operate a light UAV system in a manner that creates a hazard to other persons or property.
(b) No person may allow an object to be dropped from a light UAV if such action creates a hazard to other persons or property.
(c) A Light UAV is not permitted to perform aerobatic manoeuvres.

11 Daylight operations.

No person may operate a light UAV system except between the hours of sunrise and sunset and when environmental conditions are such that the UAV pilot can adequately perform his function of preventing aerial collisions.

13 Operation near aircraft; right-of-way rules.

(a) Each person operating a light UAV system shall maintain vigilance so as to see and avoid aircraft and shall yield the right of way to all aircraft.

(b) No person may operate a light UAV system in such a manner that the air vehicle creates a collision hazard with respect to any other aircraft.

(c) A light UAV shall not fly at a height exceeding 400ft a.g.l.

15 Operations near people or property.

(a) No person may operate a light UAV system such that the air vehicle approaches within 150m of any congested area of a city, town, or settlement.

(b) No person may operate a light UAV system such that the air vehicle approaches within 100m of any person, vehicle or structure not forming part of the operation.

(c) During take-off and landing a light UAV shall not fly within 50m of any person other than the UAV pilot.

(d) A light UAV is prohibited from operating within (TBD) metres of any object or installation that would present a risk to safety in the event of damage due to any impact of the said light UAV.

(e) No person may operate a light UAV system at any public flying display except with the prior permission in writing of the Authority.

17 Operations in certain airspace.

No person may operate a light UAV system within controlled airspace unless that person has prior authorization from the ATC facility having jurisdiction over that airspace.

19 Operations in prohibited or restricted areas.

No person may operate a light UAV system in prohibited or restricted areas unless that person has permission from the controlling agency.

20 Flight restrictions in the proximity of certain areas designated by notice to airmen.

No person may operate a light UAV system in airspace designated in a Notice to Airmen relating to temporary restricted airspace established for reasons of aviation safety or national security, unless authorized by ATC

21 Visual reference with the light UAV.

No person may operate a light UAV system except by visual reference with the air vehicle. The air vehicle shall remain visible to the operator without the aid of visual aids other than prescription corrective lenses.

24 Flight Termination System

A light UAV shall not fly unless it is equipped with a Flight Termination System that will immediately terminate its flight in the event of a failure of its control system, including the flight control data link, and which will limit the potential of the light UAV to cause damage or harm. The person in charge of a light UAV must satisfy himself/herself that the FTS is in working order prior to the flight commencing.

4. DISCUSSION OF PROPOSAL

1. Application

A light UAV system is described as consisting of an air vehicle used or intended to be used for unmanned operations in the air, with a mass of less than 150kg, is not capable of more than 70kts calibrated airspeed at full power in level flight and has a kinetic energy level on impact of less than 95KJ in both of two operating scenarios. The Light UAV must also not be subject to any national or foreign airworthiness certification.

The mass limit has been determined following a review of the worldwide UAV fleet (see Enclosure 3 Appendix WG II-1). This showed that 23 of the current 29 UAV types (79%) employed worldwide in purely civil, research or dual-purpose operations[1], have a mass of less than 150kg. A further analysis[2] also indicates that this trend is likely to continue for the foreseeable future with 65% of those UAV types entering service, market ready or being developed, also under 150kg. It was also noted that those UAVs with weights higher than 150kg tended to be designed for autonomous flight beyond the visual range of the operator, and were therefore outside the scope of these guidelines. By chance, (or by design), Annex II of EC Regulation 1592/2002 exempts UAVs with an operating mass of less than 150kg from the provisions of the regulation and places regulatory control of these types with National Aviation Authorities. In setting the boundary conditions for a light UAV to operate within a restricted operational area, it therefore seems appropriate to choose the 150kg mass limit. To ensure strict compliance with EC 1592/2002, the mass of any floats or safety equipment fitted to the air vehicle must be included within this limit.

The 70kts maximum speed limit has been applied based on a judgement of the capability of the existing model aircraft fleet, pilot workload, the ability of the pilot to retain control whilst possibly performing other operational tasks and the pilot reaction time necessary to ensure that the UAV does not hazard persons or property by passing through the buffer zone around the intended operating area. There is seen to be little benefit in higher speeds for aircraft that are restricted to operating within unassisted visual range of the pilot/operator. However, this is an area that would benefit from further discussion and could be broadened to include the experience of existing model operators and the advice of specialists in human factors, licensing, and operations. However, the imposition of this absolute speed limit at this time is seen as a prudent, precautionary position to take at this early stage of civil UAV operations.

Enclosure 3 Appendix WG II-4 of this report details an approach to setting UAV safety standards “equivalent” to manned aircraft using impact kinetic energy as the defining criterion. In developing these guidelines for the regulation of light UAV systems, a similar approach is taken, with equivalence being shown against the existing model aircraft fleet. Two scenarios are considered: i) a free-fall from 400ft (the maximum

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1 Analysis of “Application” CC+DP+RV and “Status” IS

2 Analysis of “Application” CC+DP+RV and “Status” ES+MR+DC

altitude permitted), and ii) maximum impact speed (set as 1.4 x maximum operating speed for fixed wing aircraft, or the terminal velocity in the case of rotorcraft and lighter than air machines). These two scenarios represent the extremes of the operating envelope and compliance with the energy criteria derived from these scenarios will ensure that the ability of the UAV to cause damage or harm is constrained no matter what the circumstances of the crash or the characteristics of the UAV. In the maximum impact speed scenario, the factor of 1.4 has been added based on existing regulatory requirements for manned aircraft flutter prevention. Above this speed, it could be expected that the UAV would structurally fail and break-up. Note that the "free-fall" scenario is intended to address descent of the aircraft out of control, due to failures of primary structure or critical systems. Examples of such failures for a rotorcraft would be the unrecoverable loss of main rotor speed, or separation of a main rotor. For a lighter-than-air aircraft such failures could include the rupture or complete separation of the gas envelope.

A single kinetic energy limit is stipulated which a light UAV must not exceed when assessed against both impact scenarios. This limit has been established following a survey of existing model aircraft. The survey concluded that setting a mass limit of 75kg would be comparable with the majority of the existing model fleet. Note the difference here with the 150kg limit established from the UAV survey. As the intent is to provide "equivalent" regulation with model aircraft, the 75kg, 70kts limitations must take precedence in setting the energy level. The UAV worldwide survey was not detailed enough to identify exact weights in many cases, and so it is unknown how many UAVs may be disadvantaged through the setting of this limitation. However, the boundary has to be drawn somewhere, and this is seen as a defendable position given the level of maturity of civil UAV systems.

Combining the 70kts maximum level speed specified above, with a mass of 75kg, provides a kinetic energy limit of 95KJ. A UAV with a maximum speed below 70kts could have a correspondingly higher mass within the same kinetic energy limit as detailed in the following chart:

Mass of UAV (Kg)	Maximum achievable speed in level flight - (Vmax) – Kts	1.4 Vmax (m/s)	Kinetic Energy at 1.4 Vmax (KJ)
60	70	50	76
70	70	50	89
75	70	50	95
80	68	49	95
90	64	46	95
110	58	42	95
130	53	38	95
150	49	36	95

The impact velocity arising from the "free-fall" scenario will depend upon the aerodynamic drag characteristics of the falling object and so will be specific to the

particular design of UAV. Assuming negligible aerodynamic drag, an object dropped from 400ft will hit the surface at 95kts and the kinetic energy at impact will be 95KJ if the mass of the object is 80Kg. Should the object in fact exhibit significant aerodynamic drag, (without reliance upon any onboard parachute deployment system), the impact velocity will be less and so a higher mass may be permissible. For illustrative purposes, the table below shows the relationship between the mass and cross-sectional area of a bluff-body, (with a non-dimensional drag coefficient of about 0.9), arising from the proposed 95 KJ limit.

Mass of body Kg	Cross-sectional area of bluff body Square Metres	Kinetic Energy at impact Kilo Joules
80	0 (Negligible drag)	95
115	0.5	95
130	1.0	95
150	1.5	95

Interpretation

UAV systems up to 80kg -

From the data presented above it can be seen that any UAV with a mass of less than 80kg will meet the "free-fall" criterion whatever its drag characteristics and so it need only be considered against the maximum impact speed scenario. If the mass is 80kg the maximum achievable level speed must not exceed 68kts. If the mass is less that 75kg the maximum achievable level speed must not exceed 70kts.

UAV systems above 80kg -

The data presented for the "free-fall" scenario shows that if the proposed UAV has a mass in excess of 80kg the constructor will have to provide a justification that the drag of the airframe, falling from a height above the surface of 400ft, will be sufficient to prevent the impact energy exceeding 95KJ.

The potential application of the "free fall" criterion is perhaps best illustrated by considering the example of an airship UAV with a total mass of 150kg.

A 150kg unmanned airship will be eligible under these provisions if it can be shown that:

- The maximum achievable level speed of the airship is less than 49kts,
- Any significant masses (with negligible drag) that might fall from it in the event of structural failure do not exceed 80kg, and
- The drag of the ruptured/deflated envelope is sufficient to limit the descent velocity of the complete airship falling from 400ft, to the same extent as a bluff body of 1.5m^2 reference area.

No constraint has been placed here on the amount of fuel that can be carried. However, it is believed that the energy limit imposed and practical design constraints will in effect limit the fuel capacity available.

The approach adopted makes no assumption on the type of UAV and is intended to be all encompassing so that all types of UAVs are handled in the same way. While it is undoubtedly true that conventionally configured fixed wing UAVs will be limited to a somewhat lower mass than the maximum 150kg on account of their low drag, the full weight limit may be achievable by other types of light UAVs, e.g. an airship, when it can be demonstrated that the impact energy is no greater than that stipulated. The kinetic energy limit has been set based on experience with model aircraft. The aim is to limit, for the time being, the capability of this category of UAV to that already permitted for large model aircraft. It is expected that these limits will be reviewed once several years of experience with civil UAV operations has been gained. The current proposal is seen as a reasonable and defendable position to take based upon existing experience with model aircraft and represents a suitably cautious approach to take at this time.

3. Inspection requirements.

Standard clause

5. Exemption.

Standard clause

7 Certification and registration.

Under these provisions, a light UAV may overfly persons directly associated with the Aerial Work task. To protect these personnel, who have some degree of involvement in the activity (and presumably a good knowledge of the risks involved), yet who may not have direct control of the air vehicle, it is appropriate to set a safety level somewhat higher than that associated with recreational flyers. This proposal attempts to do so by applying some additional operational limitations beyond those of Part 103 and by imposing a degree of airworthiness approval.

The level of airworthiness approval is not intended to be onerous. However, to preserve equivalence with large model aircraft, it follows that regulation of light UAV systems by National Aviation Authorities should be no less demanding than that applied to large model aircraft. In this regulatory guidance, airworthiness is controlled by inspection of the design and construction, plus “function & reliability” flight testing of significant duration to ensure against the presence of poor stability, control and performance characteristics. Oversight of these functions could be undertaken either by the National Aviation Authority or by some other accredited body.

As Light UAVs will be operating over persons associated with the Aerial Work task, UAV pilots should be required to demonstrate a basic ability to control the air vehicle.

9 Hazardous operations.

It is prohibited to operate a light UAV system, or allow objects to be dropped from the air vehicle, in such a manner as to create a hazard to persons or property.

In addition, recognising that the flight assessment undertaken in the function & reliability flight tests must be essentially qualitative, it is considered prudent to supplement the assurance gained through such testing by prohibiting aerobatics when operating for aerial work purposes, thereby further guarding against the possible consequences of poor handling qualities and a high kinetic energy impact following loss of control.

11 Daylight operations.

A Light UAV system should only be operated in daylight hours and when the UAV pilot has the ability to "see and Avoid" effectively.

13 Operation near aircraft; right-of-way rules.

A light UAV will yield the right of way to all other aircraft. This is necessary as there are no requirements on the UAV pilot to have any knowledge of the Rules of the Air.

To minimise the potential for conflict, a light UAV will be segregated from other aircraft by limiting its maximum height above the ground to 400ft.

15 Operations over congested areas.

Restrictions are placed on a light UAV to ensure a safe separation distance from any person or property not involved in the aerial work activity.

These guidelines also prohibit an Aerial Work activity that involves aerial inspection of any object or installation that would present a risk to public safety in the event of damage due to any impact of the light UAV. (E.g. Chemical/gas storage areas).

17 Operations in certain airspace.

The use of controlled airspace is prohibited unless prior authorisation has been granted from the relevant ATC facility having jurisdiction over that airspace.

18 Operations in prohibited or restricted areas.

No person shall operate a light UAV system in prohibited or restricted airspace without permission.

20 Flight restrictions in the proximity of certain areas designated by notice to airmen.

The operator of a light UAV system must not operate in temporary restricted airspace.

21 Visual reference with the light UAV.

In the absence of any "Sense and Avoid" system, the UAV pilot must ensure safe separation between the UAV and any other air vehicle or ground based obstacle. In order to perform this task effectively, the UAV pilot must ensure that the light UAV remains visible at all times and the UAV pilot can see sufficiently beyond the air vehicle to observe any potential collision hazard and make any necessary flight path corrections in a timely manner.

24 Flight Termination System

In the absence of any formal airworthiness approval on which to place reliance on the integrity of the light UAV system's design and construction, the air vehicle must be fitted with a Flight Termination System (FTS) that will immediately terminate the flight and limit the light UAV's potential to cause damage or harm.