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COVER SHEET

Access 5 Project Deliverable

Deliverable Number: PD006

Title: Classification of Unmanned Aircraft Systems

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Abstract:
Category, class, and type designations are primary means to identify appropriate aircraft certification basis, operating rules/limitations, and pilot qualifications to operate in the National Airspace System (NAS). The question is whether UAS fit into existing aircraft categories or classes, or are unique enough to justify the creation of a new category/class. In addition, the characteristics or capabilities, which define when an UAS becomes a regulated aircraft, must also be decided. This issue focuses on UAS classification for certification purposes.

Several approaches have been considered for classifying UAS. They basically group into either using a weight/mass basis, or a safety risk basis, factoring in the performance of the UAS, including where the UAS would operate. Under existing standards, aircraft must have a Type Certificate and Certificate of Airworthiness, in order to be used for "compensation or hire," a major difference from model aircraft. Newer technologies may make it possible for very small UAS to conduct commercial services, but that is left for a future discussion to extend the regulated aircraft to a lower level.

The Access 5 position is that UAS are aircraft and should be regulated above the weight threshold differentiating them from model airplanes. The recommended classification grouping is summarized as follows:

CLASSIFICATION	WEIGHT BAND	REGULATORY TEMPLATE
Mini	< 330 lb (150 Kg)	Not Regulated (AMA guidance, AC 91.57)
Small	330 lb – 12,500 lb	Regulated – FAR 21.17 (b) (FAR 23 +/-)
Large	> 12,500 lb	Regulated – FAR 21.17 (b) (FAR 25 +/-)

Status:

Access 5-Approved

Limitations on use:
This proposal is limited to UAS regulated as aircraft (greater than 330 pounds gross weight).

ACCESS 5 POSITION PAPER

Project: Access 5 **Paper Number**: G-01

Regulation Reference: 14 CFR Parts 1 and 21

Date: November 1, 2004

Status:

Proposal	Draft Position	Closed	SEIT-Approved	Access 5-Approved
			X	

Subject: UAS Classification/Categorization for Certification

Statement of Question/Issue:
The Federal Aviation Administration (FAA) does not have a separate category or class designated for Remotely Operated Aircraft (ROA), also referred to as Unmanned Aircraft System (UAS) and Unmanned Air Vehicle (UAV). Category, class, and type designations are primary means to identify appropriate aircraft certification basis, operating rules/limitations, and pilot qualifications to operate in the National Airspace System (NAS). The question is whether UAS fit into existing aircraft categories or classes, or are unique enough to justify the creation of a new category/class. In addition, the characteristics or capabilities, which define when an UAS becomes a regulated aircraft, must also be decided. This issue focuses on UAS classification for certification purposes. Since an airworthiness certificate is required for regulated civil aircraft to operate in the NAS (generally considered in the U.S. to be that non-segregated or unrestricted airspace available to general aviation and commercial users), the resolution of this issue will have a significant impact on the definition of a certification basis and airworthiness standards for UAS. Classification for pilot rating purposes will be addressed in a separate position paper.

Discussion:
The discussions first address the question of whether UAS should be regulated, followed by UAS classification approaches.

<u>Requirements for Regulation</u>

The first question is to decide whether UAS are regulated aircraft. An alternative would be to consider UAS as "air vehicles," or model aircraft. Remote-control model aircraft have been flying for many years, and are not regulated. Advisory Circular 91-57 Model Aircraft Operating Standards provides guidance for model aircraft operators, but is not regulation. So why should UAS be treated any different than model aircraft? One answer is that a significant difference between model aircraft and UAS is their capability and the desire for UASs to operate in controlled airspace. Model aircraft generally fly in uncontrolled airspace, within line-of-sight of the pilot, not for commercial purposes, and do not have airworthiness certificates. UAS are

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intended to operate in controlled airspace, beyond line-of-sight of the pilot, and potentially for commercial purposes.

Therefore, the requirement for UAS to be treated as a regulated aircraft is due to the intent to operate UAS in controlled airspace for civil/commercial purposes. Also, UAS are aircraft because they meet the definition of aircraft (a device that is used or intended to be used for flight in the air [ref 14 CFR 1]).

Classification and Categorization for Airworthiness

Currently, manned aircraft are broken into classes/categories based upon their characteristics or intended use. The existing aircraft classes reflect a grouping by similar characteristics of propulsion, flight, or landing (e.g., airplane, rotorcraft, glider, balloon, landplane, and seaplane). Existing aircraft categories reflect a grouping based on intended use or operating limitations (e.g., transport, normal, utility, acrobatic, limited, restricted, and provisional). In addition, aircraft are also identified by type. Aircraft of the same type are similar in design (e.g. Cessna 182A through Z are all of the C182 type).

Several approaches have been considered for classifying UAS. The issue is to determine the characteristics and/or capabilities that distinguish UAS from unregulated vehicles and each other. One significant consideration is that no matter what new and different capabilities UAS may offer, they must initially be prepared to fit into the existing NAS and regulatory structure. The existing NAS infrastructure must be able to serve its existing clients without disruption, and there is limited experience with UAS in the NAS on which to base significant changes. Nonetheless, given the wide range of unmanned aircraft sizes and capabilities, from approximately one pound micro UAV that would fit in a person's hand, to a UAV similar in size and weight to a transport category aircraft, there are a multitude of parameters that could be used to classify unmanned aircraft. They basically group into either using a weight/mass basis, or a safety risk basis, factoring in the performance of the UAS, including where the UAS would operate. The characteristics/capabilities considered were:

- Weight/Mass
- Kinetic Energy (variation of weight/mass)
- Safety risk / Operating Location
- Casualty Expectation (variation on safety risk)

Each of these options are addressed below.

Weight/Mass

The primary method for classifying aircraft for regulatory purposes is based on the weight or mass of the aircraft. Historically there has been a trade-off between the level of airworthiness and operational standards. Recreational activities tend to have minimal airworthiness standards applied. They are also 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

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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. With this in mind, the question was discussed whether UAS having no greater capabilities than existing model aircraft, should be allowed to operate without airworthiness certification under similar limitations and conditions to those governing models. There is no intent to change the regulatory environment for model aircraft in any way. The issue detailed here is concerned with the regulatory environment for UAS performing civil/commercial flight tasks.

Federal Aviation Regulation (FAR) 103 classifies powered vehicles up to 254 pounds empty weight as ultra lights, which are not certificated but are regulated procedurally. European and Australian studies on unmanned aircraft have listed 150 Kg (approximately 330 lbs) as the dividing line between regulated and unregulated unmanned aircraft. Unregulated 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 meters of the UAV pilot, and not more than 400 ft above ground level. A distance of 500 meters was chosen as the maximum distance which a UAV pilot may reasonably be expected to maintain visual contact with a UAV capable of 70kts, while monitoring the sky around the UAV for conflicting traffic. The 400 ft limit is also intended to prevent conflict with other traffic.

The 150 Kg mass limit has been determined following a review of the worldwide UAV fleet. This showed that the majority of UAVs employed worldwide for civil, research, or dual-purpose operations, have a mass of less than 150kg. Further analysis also indicates that this trend is likely to continue for the foreseeable future. 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 therefore, were outside the scope of these guidelines. 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.

Above 150kg (330 lbs), the next weight/mass based breakpoints for manned aircraft are 1320 lbs for light sport aircraft, and up to 12,500 lbs for small aircraft. Aircraft weighing more than 12,500 lbs are considered to be large aircraft. The origin of the 12,500 lb breakpoint is not clear. However, anecdotal evidence indicates that it dates back to the beginning of regulations for aircraft, and that it was established at a natural breakpoint between the large "transports" of the day and the typical smaller personal airplanes. At that time, the Boeing 247 and the later DC-3 were the smallest aircraft used for scheduled airline service but were significantly larger than most other airplanes. The 1320 lbs breakpoint between light sport aircraft, and small aircraft, was driven by nominal design and manufacturing capability for safe and affordable aircraft for recreation or sport pursuits. The small aircraft category is the lightest weight class for commercial purposes.

Kinetic Energy

The European approach, documented in the Civil Aviation Authority (CAA) Cert Standards for Civil UAVs, and Joint Aviation Authorities (JAA) UAV Task Force Report, uses a matrix

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including kinetic energy for various UAV configurations. The process essentially quantifies a level of risk. The energy is calculated for two failure scenarios, and the resultant numbers are compared with existing manned aircraft levels to point toward regulatory standards that would be deemed applicable, such as FAR 23 or FAR 25.

Impact kinetic energy is directly linked to the ability of a UAS to cause damage and injury. It provides both an absolute measure for showing compliance and a relative standard for identifying "equivalence" with model aircraft. Kinetic energy is also an all-encompassing criterion applicable to all aircraft types. It is easy to measure and can be readily estimated during the design process. The kinetic energy approach assumes that there are only two kinds of impacts: 1) the impact arises as a result of an attempted emergency landing under control, or 2) the impact results from complete loss of control. For the emergency landing scenario, the calculation of kinetic energy at impact is the maximum take-off weight/mass (MTOW) times the (engine-off) approach velocity (1.3 X stalling speed (landing configuration, MTOW)). For the loss of control scenario, the calculation of kinetic energy at impact is the maximum take-off mass times the probable terminal velocity (1.4 X Vmo). 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 UAS to cause damage or harm is constrained, no matter what the circumstances of the crash or the characteristics of the UAS. 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 UAS 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.

A UAS with a mass of less than 150kg, not capable of more than 70kts calibrated airspeed at full power in level flight, has a kinetic energy level on impact of less than 95KJ (kilo joules) in both of the two operating scenarios.

The 70kts maximum speed limit has been applied based on the capability of existing model aircraft fleet. The capability considered pilot workload, the ability of the pilot to retain control while possibly performing other operational tasks, and the pilot reaction time necessary to ensure that the UAS does not pose a hazard to 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 UAS operations.

A single kinetic energy limit is stipulated, which a UAS must not exceed when assessed against both impact scenarios. This limit has been established following a UAS worldwide 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 UAS worldwide survey. As the intent is to provide "equivalent" regulation with model aircraft, the 75kg, 70kts limitations must take precedence in

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setting the energy level. The UAS worldwide survey was not detailed enough to identify exact weights in many cases, and so it is unknown how many UAS 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 UAS.

No unique kinetic energy based breakpoints were established as a classification schema. The CAA and JAA proposals would establish breakpoints at the existing airworthiness regulations – microlight, Very Light Aircraft, JAR 23 single engine, JAR 23 twin engine, and JAR 25 aircraft.

Safety Risk or Operating Location

UAS could also be classified according to the airspace where they intend to operate, or adopt a "safety target" approach of setting an overall safety objective for the aircraft within the context of a defined mission role and operating environment. The JAA UAV task force report defines the "Safety Target" methodology as a top-down approach, which focuses on safety critical issues that could affect achievement of the safety target, and allows potential hazards to be addressed by a combination of design and operational requirements. For example, uncertainties over the airworthiness of an aircraft may be addressed by restricting operations to defined areas from which third parties are excluded. Claimed advantages of the Safety Target approach are that it facilitates concentration on the key risks, and is not constrained by the need to compile and comply with a comprehensive code of airworthiness requirements covering all aspects of the design.

Under a Safety Target philosophy constructed on the basis of an assessment of third party risks, the acceptability of a UAS would have a dependency on the frequency and duration of missions. Under such a system, limitations on the frequency and duration of missions may be part of the justification of acceptable airworthiness. The use of such a philosophy could place the FAA in the position of giving permission for one commercial operator to fly his/her UAS in preference to a competitor on the basis of an assessment of the relative airworthiness of the competing fleets. The complexity of that task would be compounded by the prospect of the various operators using markedly different philosophies to compile their safety cases. Such a system would be very difficult to administer in a transparently equitable manner. In contrast, certification of the UAS, based on defined codes of airworthiness requirements, provides for common standards that are not dependent upon mission frequency and length, and so avoids a direct and contrary dependency between airworthiness and utilization for commercial gain. Also, the application of defined airworthiness standards to UAS would build upon past experience and existing knowledge, which has delivered for manned aircraft a level of safety for third parties, which is acceptable to the general public.

However, it should be noticed that typical codes of airworthiness requirements, such as FAR/JAR/CS 25, include one prominent safety objective oriented requirement "1309," whereby, it is required to show that there is an inverse relationship between the probability of a failure condition and its consequences. This "1309 approach" has often been useful to assess new technologies or novel design features (such as fly-by-wire) not covered by existing requirements. Guidelines to solve possible conflicts between "1309" and other specific airworthiness

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requirements may be proposed such as in the core of 25.1309, or on a case by case basis through special conditions.

One potential classification schema uses five classes of UAS that are delineated by class of airspace for operations, population density, pilot qualification, and equipage requirements. The minimum size under this schema is under 100 grams weight/mass.

Casualty Expectation

This technique estimates the probability of an UAS mishap inflicting fatal injury to a person on the ground considering factors, such as reliability, population density, lethal impact area, etc. The technique is explained in a paper written by Frank Grimsley for the American Institute of Aeronautics & Astronautics (AIAA), and is summarized below.

The paper describes a methodology for determining what overall system reliability is required to be equivalent to FAA safety requirements. Department of Defense flight test ranges have developed a causal expectation methodology used to calculate the probability of casualty. The method allows them to generate flight paths for UAS that minimizes risk to people on the ground. The methodology takes into account the reliability of the system, the kinetic energy of the system, its size and the population density to insure that the risk of a UAS over flight is known so the test ranges can manage that risk acceptable levels. This methodology can be used to calculate the required system reliability for a large range of UAS sizes by expanding it to a more general case of aircraft flying in national airspace. The calculations will then be used to propose overall system levels of safety for various categories of UAS based on size.

Casualty expectation is defined as the probability of being killed by a falling UAS or aircraft. The problem can be approached by defining a casualty expectation as the probability of a UAS catastrophic failure combined with the probability of hitting and killing someone on the ground. The probability of hitting someone can be determined from the population density and area defined by the area of the debris field generated by a UAS crash. The probability of killing someone can be determined by the kinetic energy of the debris. The history of risk exposure to people on the ground from over flight by manned aircraft is measurable in terms of casualty expectation. Several sources of mishap rate information show that using one mishap per million flight hours is a reasonable number when compared to mishap trends.

Access 5 Position:

The Access 5 position is that UAS are aircraft and should be regulated above the weight threshold differentiating them from model airplanes. Under existing standards, aircraft must have a Type Certificate and Certificate of Airworthiness, in order to be used for "compensation or hire," a major difference from model aircraft. Newer technologies may make it possible for very small UAS to conduct commercial services, but that is left for a future discussion to extend the regulated aircraft to a lower level.

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Regulatory coverage already addresses conventional aircraft over virtually all weight ranges envisioned for UAS. A major challenge in bringing UAS into the NAS for civil use will be the satisfaction of both government regulators and other civil users that UAS are as safe as manned aircraft for operations in the NAS. While High Altitude Long Endurance (HALE) UAS will not be carrying people, they will be in proximity to other airspace users, just as other manned aircraft are, and they will be capable of putting people and property on the ground at risk. Central to meeting this need will be a classification basis that treats them similarly to manned aircraft by using similar regulations as a starting point. Another is the need for "transparency" to the NAS, and its supporting operational and air traffic considerations when bringing UAS into the system. The initial process of certifying an UAS would build on appropriate existing manned regulatory standards with adjustments, as specified in FAR 21.17b. Thus, there are benefits of simplicity and consistency in using similar weight groupings for UAS. Also implicit in these weight groupings is a simplified recognition of energy levels and the potential for damage or injury with appropriate levels of regulatory oversight to achieve safe operation in the NAS. It has been noted that, if confronted with a complex matrix of weights, energies, and end purposes with which to vary UAS certification levels, most manufacturers would probably simplify the choices anyway. Simplification would minimize certification costs and logistical issues, and the regulatory agencies would prefer the reduced certification workload.

In order to reduce the potential for confusion, the amount of additional rule making, and to fit into the current system, **Access 5 recommends a weight-based method of classifying UAS using weight groups consistent with existing practices for the near term (see the table below.)** The weight method avoids any presumption of the purposes for which the aircraft will be used in service, which most of the other methods either implicitly or explicitly assume. Classifying UAS according to their purpose would not be economical, since it could require a separate certification for each purpose or mission, and limit the economy of scale that could be achieved with a multipurpose UAS. The weight method also contains the dominant factor (weight) in each of the other proposals.

The proposed classification breakdown also recognizes that UAS typically carry more fuel than manned aircraft of similar weight, and therefore provides guidance under FAR 23 to a lower weight than existing manned classifications to emphasize the importance of equivalent levels of safety compared to manned aircraft. UAS weighing more than 330 lbs (150 Kg) gross weight would require a type certificate and certificate of airworthiness to operate in the NAS. The 1320 lb breakpoint between light sport manned aircraft and small manned aircraft is not appropriate for commercial UAS use, and also bisects an area of considerable UAS population, so the only classes of regulated UAS would be small and large aircraft. *Note that the mechanism by which all UAS will achieve certification in the near future will be through FAR 21.17b, using the noted regulatory sections merely as guides (indicated by +/-). The true certification basis for each UAS will be established between the applicant and the FAA as provided in FAR 21.17b until specific regulatory standards for UAS are promulgated.*

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The recommended classification grouping is summarized as follows:

CLASSIFICATION	WEIGHT BAND	REGULATORY TEMPLATE
Mini	< 330 lb (150 Kg)	Not Regulated (AMA guidance, AC 91.57)
Small	330 lb – 12,500 lb	Regulated – FAR 21.17 (b) (FAR 23 +/-)
Large	> 12,500 lb	Regulated – FAR 21.17 (b) (FAR 25 +/-)

- Since the "mini" group does not have true regulatory design and certification oversight, UAS in that weight range would be limited to the same operating restrictions as presently apply to model airplanes. Those applicants who choose not to adhere to the altitude, location, purpose of use, and other operating limitations applicable to that weight group would be required to meet the higher standards of and apply for certification in the "small" group to achieve full operational flexibility in the NAS.

- Rotorcraft would draw initial regulatory guidance from existing standards (AMA, AC 91.57 at weights below 330 lb, FAR 27 below 7,000 lb GW and FAR 29 above 7,000 lb GW) +/-.

- Lighter-than-air and other specialized designs would be treated similarly under existing FAR procedures and sections +/-.

Using such a classification scheme would ensure consistency with manned aircraft for each group of regulatory standards. Since Access 5 is working to gain civil UAS entry into the NAS in five years, this is particularly important in the near term when civil UAS experience is limited and it is not feasible to promulgate specific new regulations. This approach also provides material for special conditions under FAR 21.17b. Using special conditions, the manned standards and processes would provide a starting point and be adjusted by removing inapplicable requirements (such as seat belts), and adding needed new requirements (such as Detect, See and Avoid (DSA) coverage). The use of special conditions is indicated by +/-, to assure equivalent levels of safety to comparable manned aircraft and achieve a certification basis acceptable to FAA. It acknowledges the very good safety records achieved with manned aircraft under the existing system. It also recognizes the considerable long standing economic factors worldwide, such as tax formulae and insurance costs associated with existing regulatory weight groups, but not necessarily related to the aircraft themselves.

The kinetic energy method adds velocity component to the weight method. However, it was not clear what advantage this method would provide to maintaining/enhancing the safety of the NAS, or in reducing the cost to manufacture, certify, regulate, and operate UAS.

The risk-based methods (Safety Risk / Operating Location, Casualty Expectation) certify according to the mission/purpose and location of UAS flights. It is not clear what advantage this provides for civil UAS flight in the NAS. In the context of a "global" assessment of a complete UAS system, (including consideration of all contributory factors, such as operational role, sphere of operations, and aircraft airworthiness), it is likely that some form of safety target will have to be established. However, the specific issue is whether the "airworthiness" contribution to the overall safety target will be to a fixed standard defined by a code of airworthiness requirements,

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or will be variable, dependent upon the operational restrictions imposed in parallel. Note that the current codes of airworthiness requirements, as far as is practicable, avoid any presumption of the purposes for which the aircraft will be used in service. The risk-based methods assume a certain level of population density on the surface and density of airspace operations, neither of which will remain static over the life span of a civil UAS. They also effectively shift a significant burden (and ultimately cost) onto regulators and operators to maintain undefined and ongoing oversight of such factors in the operating environment that are normally inconsequential to manned aircraft operations, but which could change or negate the suitability of UAS certification under such classification schemes.

It is noteworthy that the conventional approach of applying a code of airworthiness requirements gives the aircraft designer the advantage of knowledge from the outset of the minimum acceptable standards applicable to all aspects of the design. This approach is well understood by the civil aerospace industry and is compatible with their existing infrastructure. This may not be so, if a risk-based approach were adopted.

Access 5 recognizes that UAS provide opportunities for new and unconventional designs not addressed by current FARs or processes. This weight-based classification proposal is intended to provide a means to safely introduce UAS into the NAS in the near term, while ongoing efforts can determine a more efficient way to capture the unique capabilities of UAS not reflected in the existing classification system, and while new regulatory material is developed based on initial experience. An UAS classification mechanism consistent with existing manned aircraft may not be the best, once civil UAS experience is in hand. **Access 5 also recommends that an ongoing effort be maintained to review experience as civil UAS enter the NAS, and develop a more appropriate classification rationale consistent with future revisions to the NAS infrastructure and regulatory standards.**

Project Coordination:

SEIT	ID	PM					

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