Micro Unmanned Aircraft Systems Aviation Rulemaking Committee (ARC)

ARC Recommendations Final Report

April 1, 2016

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1. BACKGROUND

The Federal Aviation Administration (FAA) chartered the Micro Unmanned Aircraft Systems (UAS) Aviation Rulemaking Committee (the "ARC") to provide recommendations to the FAA Administrator on a regulatory framework for the classification and operation of micro UAS. The FAA contemplated a micro UAS classification in the Operation and Certification of Small Unmanned Aircraft Systems Notice of Proposed Rulemaking (Small UAS NPRM), published on February 23, 2015. After reviewing comments to the Small UAS NPRM, however, the FAA decided that further engagement with industry stakeholders was needed before conducting rulemaking to address the regulatory framework for classification and operation of micro UAS.

The stated objective of the ARC was "to consider recommendations for a performance-based standard that would allow for micro UAS to be operated over people who are not directly participating in the operation of the UAS or under a covered structure," which would ultimately contribute to an enforceable rule imposed by the FAA.[1]

2. OBJECTIVES AND SUMMARY OF ACTIVITIES OF THE ARC

ARC Membership

The ARC was composed of members representing a diverse set of aviation stakeholders, including the UAS industry and other stakeholders. The ARC members were:

- 3D Robotics (3DR)
- Academy of Model Aeronautics (AMA)
- American Institute of Aeronautics and Astronautics (AIAA)
- Air Line Pilots Association (ALPA)
- Aircraft Owners and Pilots Association (AOPA)
- American Association of Airport Executives (AAAE)
- Association for Unmanned Vehicle Systems International (AUVSI)
- Alliance for System Safety of UAS through Research Excellence (ASSURE)
- ASTM International
- AT&T
- Consumer Technology Association (CTA)
- DJI
- Experimental Aircraft Association (EAA)
- General Aviation Manufacturers Association (GAMA)
- GoogleX
- GoPro, Inc.
- Helicopter Association International (HAI)
- Horizon Hobby
- ICON Aircraft

[1] The ARC was established specifically to address flight operations over people. The ARC was not chartered to establish a weight based category as described by the micro-UAS classification in the NPRM.

- Intel Corporation
- National Agricultural Aviation Association (NAAA)
- National Association of REALTORS® (NAR)
- National Association of State Aviation Officials (NASAO)
- News Media Coalition
- Professional Aerial Photographers Association, International (PAPA)
- Small UAV Coalition
- Toy Industry Association

ARC Objectives

The FAA charged the ARC with the following three objectives:

1. Develop recommendations for a performance-based standard for the classification of micro UAS.
    - The charter stipulated that, in developing the recommendation, the ARC should consider, at a minimum, current and past research on human injury thresholds, hazard and risk assessment methodologies, and acceptable levels of risk to persons not directly participating in the operation.

2. Identify means-of-compliance for manufacturers to show that unmanned aircraft meet the performance-based safety requirement.
    - The charter advised the ARC to evaluate the use of consensus standards as a means of compliance, developing standardized test methods, and other means to demonstrate compliance with the standard. The charter further advised the ARC to consider and recommend how the FAA and manufacturers should determine compliance with the performance-based standard.

3. Recommend operational requirements for micro UAS appropriate to the recommended performance-based safety requirement.

ARC Meetings

The ARC met during a 3-day period from March 8 - March 10, 2016, for the purpose of education and information gathering, and a second 3-day period from March 15 - March 17, 2016, for discussions and deliberations. FAA Administrator Huerta addressed the ARC in the first week of these meetings, thanking the members for their participation in the ARC and stating the Agency's support for FAA-stakeholder collaboration.

The first day began with an introductory briefing from the FAA and industry co-chairs, followed by an open discussion for the members to raise questions and share thoughts regarding the three main objectives of the ARC. This discussion focused on the members' shared goals of facilitating innovation in the burgeoning UAS industry while maintaining or improving the current level of safety in the National Airspace System (NAS) and of people on the ground. The FAA briefed the ARC on the relevant regulatory framework – i.e., the proposed part 107 of Chapter 14 of the Code

of Federal Regulations.[2] Proposed part 107 contains specific rules to allow the operation of non-hobby or non-recreational small UAS (less than 55 lbs.) in the NAS. The FAA informed the ARC that any recommendations regarding small UAS operations over people will be bound by the regulatory requirements in part 107 (commonly known as the "Small UAS NPRM" or "part 107"). Although the ARC was not aware of the contents of the small UAS final rule, it made assumptions about what these requirements will be based on the NPRM.

To provide a substantive baseline of the relevant science for the ARC's recommendations, the first 3-day period of the ARC's meetings included presentations from a selection of experts from academia, research and testing facilities, U.S. and international governmental agencies, the U.S. military, industry standard-setting bodies, and the UAS and insurance industries; including, specifically, the National Aeronautics and Space Administration (NASA), the National Institute of Standards and Technology (NIST), RTCA, the Department of Defense (DOD), and the FAA UAS Centers of Excellence. These presentations covered topics such as current and past research on human injury thresholds, hazard and risk assessment methodologies, acceptable levels of risk to persons not directly participating in the operation or under a covered structure, and other proposed civil aviation authority UAS regulatory frameworks and their supporting rationale. A list of the presentations is included as Appendix A to this report.

The second 3-day period focused on development of a recommendation of a regulatory framework for small UAS operations over people, with the twin goals of ensuring the safety of the NAS and people on the ground, and encouraging innovation in the UAS industry. After identification and discussion of the unique risks associated with flight over people and potential mitigations for those risks, the ARC developed recommendations for performance-based standards that would allow for a UAS to be operated over people not directly participating in the operation of the UAS or under a covered structure,[3] with a reasonable degree of safety.

3. EXECUTIVE SUMMARY

The ARC membership represented diverse interests and viewpoints. Although some decisions were not unanimous, the ARC reached consensus on all of its recommendations to the FAA, as reflected in this report. The recommendations in this report reflect the final statements of the ARC.

The ARC was focused on flight over people, and in furtherance of that goal, identified four small UAS categories, defined primarily by level of risk of injury posed, for operations over people. For each category, the ARC recommends a risk threshold that correlates to either a weight or an impact energy equivalent and, to the extent necessary to minimize the risks associated with that category, additional performance standards and operational restrictions. A chart summarizing the ARC's recommendations is attached as Appendix B to this report.

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[2] *See* The Operation and Certification of Small Unmanned Aircraft Systems Notice of Proposed Rulemaking, 80 FR 9544, Feb. 23, 2015.

[3] UAS operations over people who are participating directly in the operation of a small UAS or who are under a covered structure are already permitted under the proposed part 107. The ARC's recommendations therefore apply specifically to operations over people who do not fall into those two categories. For ease of communication, however, this report will simply refer to flight or operations over people, without repeatedly qualifying that this means people who are not participating in the operation of the small UAS or under a covered structure.

Each category is presumed to be subject to the restrictions of proposed part 107 (other than the restriction related to flight over people), including but not limited to altitude and time of operations restrictions.

Under Category 1, a small UAS may operate over people if the weight (including accessories/payload, e.g., cameras) is 250 grams or less. Based on the data the ARC received, the ARC believes that the level of risk of injury posed by this category of UAS is so low that no performance standards and no operational restrictions beyond those imposed by the proposed part 107 are necessary. To demonstrate that a small UAS qualifies for Category 1 operations over people, the manufacturer of the UAS must either: (1) label the product retail packaging of the small UAS with the actual weight of the aircraft or a general statement that the aircraft weighs 250 grams or less; or (2) declare that the aircraft weighs 250 grams or less, and submit that declaration to the FAA in a form and manner acceptable to the FAA.

Under Categories 2, 3, and 4, a small UAS may operate over people if it does not exceed the impact energy threshold specified for each category, as certified by the manufacturer using industry-consensus test methods, and if its operator complies with operational restrictions specified for each category. Because the level of risk increases between Categories 2, 3, and 4, the performance-based standards and operational restrictions are scaled-up in each category to mitigate the increased risks.

Under Category 2, a small UAS may operate over people if the manufacturer of the UAS certifies to the FAA that the UAS does not, in the most probable failure modes, exceed the typical or likely impact energy threshold, and if it complies with industry consensus performance standards. The operator must also comply with the operator instruction manual, must maintain minimum set-off distances of 20 feet above people's heads, or 10 feet laterally away from people, and may not operate so close to people as to create an undue hazard to those people.

Under Category 3, a small UAS may operate over people if the manufacturer of the UAS certifies to the FAA that the UAS does not, in the most probable failure modes, exceed the typical or likely impact energy threshold, and if it complies with industry consensus performance standards. Flight over crowds or dense concentrations of people is never permitted under this category. In addition to that restriction, Category 3 UAS may only operate over people if: (1) the operation is conducted over a closed- or restricted-access work site with the permission of the site's owner or operator; or (2) overflight of people is limited to those who are transient or incidental to the operation, i.e., the overflight of people is incidental to the operation and is not sustained. Additionally, the performance standards and operational restrictions that apply to Category 2 operations also apply to Category 3.

Under Category 4, a small UAS may operate over people, including flights over crowds or dense concentrations of people prohibited in Category 3, if the manufacturer of the UAS certifies that the UAS does not, in the most probable failure modes, exceed the typical or likely impact energy threshold, if the UAS complies with industry consensus performance standards, and if the operation is conducted in compliance with a documented, risk mitigation plan, which was developed and adopted in accordance with industry consensus standards for conducting risk mitigation. The performance standards and operational restrictions that apply to Category 2 operations also apply to Category 4.

To demonstrate that a small UAS qualifies for Categories 2, 3, or 4 operations over people, the manufacturer of the UAS must: (1) declare that the small UAS meets industry consensus standards

applicable to the category; (2) submit that declaration to the FAA in a form and manner acceptable to the FAA; (3) label the product or product retail packaging in accordance with industry consensus standards; and (4) provide an operating manual to the operator that includes operator instructions for flight over people. The operator is responsible for knowing what category of operations his or her UAS qualifies for, and what operational limitations he or she must follow.

4. ARC RECOMMENDATIONS

4.1 Recommendations for a Performance-Based Standard for the Classification of UAS Operated Over People

The ARC began its discussion using traditional aviation risk models, considering: (1) risks to the safety of people and property in the air; (2) risks to the safety of people and property on the ground; (3) risks associated with aircraft integrity; and (4) risks associated with crew capability. **After considerable discussion, the ARC determined that the unique risk posed by flight over people (unique in that the risk is not already addressed by proposed part 107) is injury or death to persons on the ground.**

The ARC then discussed to what extent the risk of injury to persons on the ground is acceptable and what measurement to use to quantify the level of risk. Among others, the group referenced the presentations of Paul Wilde from the FAA (Public Risk Criteria and Rationale for Commercial Launch and Reentry), Joseph Pellettiere from the FAA (Historical Basis for FAA Occupant Safety), and Dr. Narayan Yoganandan from the Medical College of Wisconsin (Human Injury Tolerance to Impact: Biomechanical Studies), and discussed the work of Dr. Natasha Neogi from NASA (Hazards Considerations for Micro-Unmanned Aerial Systems (μUAS) Overflight of Populated Areas) and the traditional models of aviation risk continuum (from commercial aviation to micro UAS) to couple risk of harm and societally acceptable risk levels.

The ARC also considered what flight "over people" means. With the guidance of FAA staff in the room, the ARC came to understand that this term means flight of a UAS *directly above* one or more persons. Any flight not directly over people already will be permitted under proposed part 107, with certain proposed limitations. As noted above, what is the unique risk to operating over a person is the increased risk that the UAS will strike that person when in failure mode, thus adding an operational risk factor to be mitigated.

The ARC agreed to establish risk thresholds based on the probability that direct impact with a person on the ground from a UAS would cause an injury that qualifies as level 3 and above on the Abbreviated Injury Scale (AIS).[4] AIS level 3 injuries are classified as "serious."[5] The working

[4] The AIS was developed by the Association for the Advancement of Automotive Medicine (AAAM), which describes the AIS as: "an anatomically based, consensus derived, global severity scoring system that classifies each injury by body region according to its relative importance on a 6-point ordinal scale (1=minor and 6=maximal)." *See* http://www.aaam.org/about-ais.html. Explanations of the AIS were presented to the ARC by several presenters.
[5] In a presentation on the historical basis for FAA occupant safety, an FAA presenter provided the following examples of level 3 injuries to the head: small penetrating skull, sinus thrombosis, ischemic brain damage, basilar fracture/LOC 1-6 hours.

assumption for this conclusion is that the UAS is presumed to be in a probable failure mode (such as a loss of power) and to fall down, impacting a person. Risk posed to people on the ground by lateral impacts, such as a forward-speed loss-of-control scenario, are already addressed by proposed part 107. The ARC did not attempt to quantify the current risk of such a failure mode, or an acceptable failure rate, or to specify the acceptable probability of a human impact occurrence. On guidance from the FAA, the ARC adopted a conservative assumption that any UAS flown over people may experience a failure. Therefore, the ARC's recommendations focus on the severity of injury that is acceptable assuming the UAS makes impact with a person.

Based on the information received, the ARC agreed that the metric used to quantify an acceptable probability of an AIS level 3 and above injury should be the impact energy of the small UAS, expressed in joules (J)/centimeter^2 (cm^2). For a particular model of small UAS to qualify for operations over people, the manufacturer of that model will therefore have to certify that the product's impact energy, as measured by a test established by an industry consensus standards body, does not, in the most probable failure modes, exceed a specified threshold. The intent of the test should be to establish the typical or likely impact energy of the most probable failure mode, and not simply the worst case condition.

4.1.1 Category 1 Performance Standards

The ARC believes that there are small UAS that pose a level of risk that is so low that they are relatively safe to operate over people without being subjected to regulation beyond proposed part 107. As explained below, for this category of UAS, the ARC recommends a maximum risk impact threshold of a 1% chance of AIS level 3 or greater injury, based on kinetic energy transfer at impact. The impact kinetic energy transfer standard and industry consensus standards are more fully explained in the Category 2 discussion. For simplicity, the ARC recommends using a weight-based measure instead of an impact kinetic energy measure for Category 1.

The ARC was presented with several studies and analytical methods that could be used to assess the risk of a weight-based category of small UAS allowed to operate directly over people. The presentation from Dr. Paul Wilde of the FAA discussed methods used for assessing individual and collective public risk for commercial space launches. He provided one example, subject to certain assumptions, where a UAS weighing 0.55 lbs. (250 grams) operated over people had a probability of serious injury or fatality consistent with existing levels of safety for non-participating people when exposed to aviation risks. The presentation from Dr. David Arterburn from ASSURE's University of Alabama, Huntsville correlated various human injury thresholds with risks associated with sporting events where people are exposed to risks from fast moving balls and other objects that could cause an injury or, in extreme cases, a fatality, yet the public is generally accepting of those risks.

In addition, Dr. Arterburn's study showed results that suggest the kinetic energy-based injury calculation was overstated as it relates to UAS because of the differences between a simple ball and actual UAS design. Specifically, UAS were found by ASSURE to deflect and tumble on impact, resulting in only an average 38% kinetic energy transfer during an impact, and therefore a significantly lower expected severity of injury compared to shrapnel impacts that were the basis of those prior estimates of harm, taken from studies of explosives and ordinance effectiveness.

Finally, considerations on very light-weight UAS were completed during the FAA Registration Task Force Aviation Rulemaking Committee in November/December 2015 (the "Registration ARC"). The Registration ARC considered a paper by MITRE that looked at risks of small UAS impact to people on the ground, based on assumptions in earlier studies.[6] That paper contains a graph of probability of fatality vs. kinetic energy that was used to select an 80 J limit on kinetic energy as a measure of potential lethality. This level of total kinetic energy, and a variety of assumptions, was then used by the Registration ARC to calculate a weight threshold of 250 grams for registration.

With all of these factors in mind, because of the low level of risk of injury posed by flying objects weighing 250 grams or less, the ARC recommends no performance-based standards be required for unmanned aircraft in this category. The manufacturers will be required to indicate on the retail packaging the actual flying weight, or a statement that the aircraft weight is less than 250 grams. To provide flexibility in the future, the ARC does, however, recommend that the FAA invite industry to create voluntary, non-binding standards for product marking of UAS weighing 250 grams or less to make it clear to users that these UAS meet the requirement to operate over people.

4.1.2 Category 2 Performance Standards

Category 2 prescribes the performance standards and operational restrictions for operations over people that are conducted by unmanned aircraft that weigh more than 250 grams, but still present a 1% or less chance of "serious" injury (AIS level 3 or greater) to a person in the event of impact. The standard to determine whether the UAS meets the risk criteria will be an impact energy threshold based on information presented to the ARC, and calculated by the FAA in J/cm^2. During its meetings, the ARC was presented with information from Canada and the commercial space industry suggesting that this calculation would result in a value of 12 J/cm^2 and that a quadcopter UAS weighing in the range of 4 to 5 pounds would qualify, depending on its design characteristics and operating instructions. The ARC recommends that the FAA calculate this exact impact energy threshold for the proposed flight-over-people rule.

For a small UAS to qualify for Category 2 operations, the manufacturer must certify that the UAS does not, in the most probable failure modes, exceed the typical or likely impact energy threshold, in accordance with industry consensus testing standards. The operator of the small UAS will also be subject to certain operational restrictions, which are discussed below in Section 4.3.2.

To facilitate the development of industry consensus standards for Category 2 that are acceptable to the FAA Administrator, the ARC recommends that the industry consensus standards must do the following:

(1) Establish a test to measure the typical or likely impact energy of the small unmanned aircraft in the most probable failure modes to determine whether it meets the specified impact energy threshold. Testing may be subject to manufacturer defined operating limitations, if any. The impact energy threshold used in the standards may account for the energy

[6] "A New Paradigm for Small UAS," Andrew Lacher and David Maroney, available at https://www.mitre.org/sites/default/files/pdf/12_2840.pdf ; "Lethality Criteria for Debris Generated From Accidental Explosions," Jon Henderson, available at http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA532158.

dissipation caused by the physical design of the small unmanned aircraft and likely impact scenarios.

(2) Address impact of exposed rotating parts to risk analysis with a focus on serious injury (AIS level 3 or greater).
(3) Require the manufacturer of the small unmanned aircraft to provide an operating manual to the operator, which must include operator requirements for flight over people.
(4) Define how the product shall be labeled to show operators that the manufacturer has declared that the UAS is in compliance with the standard.

4.1.3 Category 3 Performance Standards

This category prescribes the performance standards and operational restrictions for limited operations over people (as described in Section 4.3.3. below) that are conducted by UAS that present a level of risk of "serious" injury (AIS level 3 or greater) that is incrementally higher than the level of risk of injury presented in Category 2. Specifically, the ARC recommends that a small UAS be permitted to conduct limited operations over people (as defined below) if that UAS presents a 30% or lower chance of causing an AIS level 3 or greater injury upon impact with a person. The ARC recommends that the FAA also establish an impact energy threshold for this risk level based on information presented to the ARC, in J/cm^2.

For a small UAS to qualify for Category 3 operations, the manufacturer must certify that the UAS does not, in the most probable failure modes, exceed the typical or likely impact energy threshold as determined by industry consensus standard testing. The operator of the small UAS will also be subject to certain operational restrictions, which are discussed below in Section 4.3.3.

To facilitate the development of industry consensus standards for small UAS that qualify for Category 3 operations over people that are acceptable to the FAA Administrator, the ARC recommends that the industry consensus standards must do the following:

(1) Establish a test to measure typical or likely impact energy of the small unmanned aircraft when the aircraft is operating in the most probable failure mode to determine whether it meets the specified impact energy threshold. Testing may be subject to manufacturer defined operating limitations, if any. The impact energy threshold used in the standards may account for the energy dissipation caused by the physical design of the small unmanned aircraft and likely impact scenarios.
(2) Address the impact of exposed rotating parts to safety analysis with a focus on serious injury (AIS level 3 or greater).
(3) Require the manufacturer of the small unmanned aircraft to provide an operating manual to the operator, which must include operator requirements for flight over people.
(4) Define how the product shall be labeled to show operators that the manufacturer has declared that the UAS is in compliance with the standard.

Operations in this category allow limited operations over people and do not allow flight over crowds or dense gatherings of people. Operational limitations and restrictions for this category are described in section 4.3.3 below.

4.1.4 Category 4 Performance Standards

This category prescribes performance standards and operational restrictions for operations over people that are conducted by UAS that present the same level of risk of "serious" injury as Category 3, but that involve sustained flight over people beyond what is permitted in Category 3, specifically flight over crowds and/or dense gatherings of persons. Because an increased number of people on the ground may be subjected to overhead flight of longer duration, the ARC recommends prescribing additional operational mitigations for this category. Specifically, the ARC discussed the various risk factors presented in the week-one presentations and determined that, along with other factors, operator qualifications are an important mitigation in sustained operations of this category UAS over crowds of people and should be included in a mission-appropriate manner through a risk mitigation plan, similar in nature to already established FAA "Congested Area Plan" processes. As a result, the ARC included this requirement in operational restrictions described below.

Category 4 includes operations conducted by UAS operators that present the same risk as UAS conducting Category 3 operations over people, but without Category 3 operational limitations, and therefore require a risk mitigation plan specific to the operation (discussed below in Section 4.3.4). The industry consensus standards for this category are also the same as the standards for Category 3, but with the addition of the risk mitigation plan, which may include coordination with the FAA or event sponsor, municipality or local law enforcement, and pilot training, experience and certification commensurate with the increased risk, as determined by an industry consensus standard.

In addition to safety of persons on the ground, the recommended addition of engagement with appropriate third parties is intended to address concerns about the social acceptance of operating a UAS over large gatherings or events. It is the ARC's recommendation that this facilitation of local engagement, while not intended as a delegation of jurisdiction over UAS operations, will be helpful to address community concerns.

To facilitate the development of industry consensus standards for small UAS that qualify for Category 4 operations over people that are acceptable to the FAA Administrator, the ARC recommends that in addition to Category 3 requirements, the industry consensus standards must:

(1) Require a risk mitigation plan that addresses, at a minimum: (a) higher operator qualifications than the proposed part 107; and (b) the method of compliance with the risk mitigation plan, including the possibility of engagement with appropriate local entities.
(2) Consider materials and components of the UAS to determine if the materials pose additional potential risk of collateral serious injury to people on the ground, in addition to injury caused by initial impact.

4.2 Means-of-Compliance for Manufacturers to Show that Small UAS Meet the Performance-Based Safety Requirement

4.2.1 Manufacturer's Declaration

To demonstrate that a small UAS qualifies for Category 2, 3, or 4 operations over people, the ARC recommends that the manufacturer of the UAS be required to declare (self-certify) that the small UAS meets industry consensus standards for operation over people. This recommendation is the outcome of a robust discussion that also considered, and rejected, two alternatives: (1) FAA certification of conformity with standards; and (2) mandated third-party certification (such as by an independent laboratory). The consensus view was that FAA certification would be impractical and too slow to keep up with the rapid pace of technology development, and thus this method of certification was unanimously rejected. The ARC also concluded that mandatory third-party laboratory certification would impose an unnecessarily high burden in light of the simple type of test that is contemplated (a drop test measuring impact energy transfer). The ARC was unanimous in recommending manufacturer self-certification for Categories 1, 2, and 3. There was also consensus for self-certification for Category 4.

4.2.2 Category 1 Means-of-Compliance

To demonstrate that a small UAS qualifies for Category 1 operations over people, the ARC recommends that the manufacturer of the UAS be required to: (1) label the retail product packaging of the small UAS with either the actual weight of the small unmanned aircraft or a general statement that the small unmanned aircraft weighs 250 grams or less; or (2) declare that the small unmanned aircraft weighs 250 grams or less and submit that declaration to the FAA in a form and manner acceptable to the FAA.

4.2.3 Category 2 Means-of-Compliance

To demonstrate that a small UAS qualifies for Category 2 operations over people, the ARC recommends that the manufacturer of the UAS be required to: (1) declare that the small UAS meets applicable industry consensus performance standards for operation over people; (2) submit that declaration to the FAA in a form and manner acceptable to the FAA; and (3) label the product or product retail packaging in accordance with industry consensus standards.

4.2.4 Category 3 Means-of-Compliance

To demonstrate that a small UAS qualifies for Category 3 operations over people, the ARC recommends that the manufacturer of the UAS be required to: (1) declare that the small UAS meets applicable industry consensus standards for operation over people; (2) submit that declaration to the FAA in a form and manner acceptable to the FAA; and (3) label the product or product retail packaging in accordance with industry consensus standards.

4.2.5 Category 4 Means-of-Compliance

To demonstrate that a small UAS qualifies for Category 4 operations over people, the ARC recommends that the manufacturer of the UAS be required to: (1) declare that the small UAS meets applicable industry consensus standards for operation over people; (2) submit that declaration to the FAA in a form and manner acceptable to the FAA; and (3) label the product or product retail packaging in accordance with industry consensus standards.

4.3 Recommended Operational Requirements for Small UAS Appropriate to the Recommended Performance-Based Safety Requirement

4.3.1 Category 1 Operational Requirements

Recognizing the low risk of injury posed by UAS with a weight (including accessories/payload, e.g., cameras) of 250 grams or less, the ARC recommends no operational restrictions for UAS in this category.

4.3.2 Category 2 Operational Requirements

For UAS above 250 grams and meeting the risk level for Category 2 operations over people, the ARC recommends the following operational restrictions:

(1) The operator must comply with the manufacturer's operator manual for the small UAS, developed in accordance with industry consensus standards.
(2) The small UAS must be operated at a minimum distance of 20 feet above people's heads, or 10 feet laterally away from, people. Notwithstanding these minimum distance requirements, the small UAS must always maintain a safe distance from people so as not to create an undue hazard to those people.

4.3.3 Category 3 Operational Requirements

The ARC recommends that operators conducting Category 3 operations over people be bound by the same operational restrictions as operators conducting Category 2 operations over people (i.e., comply with the manufacturer's operator manual and maintain specified minimum set-off distances). To mitigate the additional level of risk of "serious" injury posed by small UAS conducting Category 3 operations over people, the ARC recommends the following additional operational restrictions for this category:

Flight over crowds or dense concentrations of people is never permitted under Category 3. In addition to that restriction, Category 3 UAS may only operate over people if:

(1) The operation is conducted over a closed- or restricted-access work site with the permission of the site's owner or operator; or
(2) Overflight of people is limited to those who are transient or incidental to the operation, i.e., the overflight of people is incidental to the operation and is not sustained.

4.3.4 Category 4 Operational Requirements

This category provides additional operational flexibility for operations over people by UAS that present the same level of risk of "serious" injury as Category 3. Specifically, the ARC recommends that small UAS that satisfy the same impact energy threshold as UAS conducting Category 3 operations be permitted to operate over people without the place and manner restrictions of Category 3, if the operation is conducted in compliance with a documented risk mitigation plan, which was developed and implemented in accordance with industry consensus standards.

The ARC recommends that the industry consensus standard include the requirement of a preparation of risk mitigation plan that must address, at a minimum: (a) operator qualifications; (b) the method of approval and compliance with the risk mitigation plan, including the possibility of engagement with appropriate local entities. The ARC suggests that the standard-setting body may want to consider, as a reference, similar requirements for manned aircraft in 14 CFR 137.51.

Operators conducting Category 4 operations over people would also be bound by the other operational restrictions as operators conducting Category 2 and Category 3 operations over people (i.e., they must comply with the operator manual and maintain specified minimum set-off distances).

5. ADDITIONAL RECOMMENDATIONS

The ARC is unanimous in its belief that operator knowledge is very important to the safety of the NAS. One purpose of airman certification requirements is to assure adequate operator knowledge. It is the understanding of the ARC that pursuant to proposed part 107, the only means of achieving airman certification will be to take an *in-person* knowledge test and submit to a Transportation Security Administration (TSA) background check – even for operation of UAS in the lowest risk category (Category 1, under 250 grams). The overwhelming majority of ARC members believe that the in-person test requirement and TSA background check are unduly burdensome for operators of Category 1 UAS, and may be detrimental to safety by discouraging compliance for operators of such small UAS. The overwhelming majority of the ARC members believe that the same or higher level of safety and compliance can be reached by allowing online knowledge testing and eliminating or reconsidering the TSA vetting process.

Faced with burdensome requirements, it would not be unusual for even well-meaning operators to fly the smallest UAS without traveling to a test center to satisfy knowledge and other requirements. In that case, rather than enhancing safety, the requirements would be an impediment to safety. Those same operators are far more likely to participate in online instruction and take an online test, thus assuring knowledge of the airspace. The ARC urges the FAA to consider less burdensome requirements on operators of UASs in Category 1. Specifically, the ARC recommends changing

airman certification requirements to allow online testing to satisfy knowledge requirements, and to work to eliminate in-person visits and background checks.

It should be noted that representatives of ALPA, NAAA, HAI, and PAPA did not agree that online testing and the elimination of background checks were properly informed or appropriate recommendations for the ARC. The organizations all strongly maintain the position that an individual intending to exercise the privileges permitted under proposed part 107, which include commercial small UAS operations, should fully comply with the necessary training and certification as currently described in part 107, no matter the size or complexity of the aircraft. Their concerns were centered on the lack of data submitted during the ARC indicating this UAS category is not a proven security risk, or that testing will not enhance safety. In addition, data was not provided to the ARC indicating that security and testing requirements for this category would discourage compliance. The dissenting groups also stated that training, experience, and evaluation of skills and knowledge for initial certification and a revalidation of those skills periodically, such as is required for other airman certificates, should be required for these UAS and that proposals waiving such requirements were outside of the charter for this ARC.

6. APPENDICES

Appendix A Presentations to the ARC

Presenter	Presentation
Christine DeJong, ASTM	Standards – Improving Safety and Reliability in Aviation
Joseph Pellettiere, FAA	Historical Basis for FAA Occupant Safety
Mark Wuennenberg, Transport Canada	Transport Canada Small UAV Regulations
Dr. Natasha Neogi, NASA	Hazards Considerations for Micro-Unmanned Aerial Systems (μUAS) Overflight of Populated Areas
Adam Jacoff, NIST	Development of Standard Test Methods to Evaluate Micro Unmanned Aerial Systems for Emergency Response Application
Nick Kray, ASSURE/GE Aviation	Initial Briefing: UAV Evaluations for GE Aviation Turbofan Ingestion
Dr. Javid Bayandor, Virginia Tech	High Fidelity Micro UAS Collison Modeling and Damage Assessment Strategy
Dr. Tom Aldag, ASSURE/Wichita State University	Airborne Collision – ASSURE FAA Center of Excellence Research
Al Secen, RTCA	Overview RTCA and SC-228 Minimum Performance Standards for UAS
Dr. Narayan Yoganandan, ASSURE/ Medical College of Wisconsin	Human Injury Tolerance to Impact Loads: Biomechanical Studies
Dr. David Arterburn, ASSURE/University of Alabama, Huntsville	Ground Collision Severity Research
Jonathan Daniels, Praxis Aerospace Concepts	Reapplication of Processes Established by FAR 65.104 to Micro and Small UAS
Dr. Roland Weibel, MIT Lincoln Labs	Risk-Based Standards for Operating Small Unmanned Aircraft Over People
Dr. Christopher Draper, Simpson College	Using Energy-based Risk Approaches to Define Safe Operating Areas
James Cole and Matthew Zurasky, NSWC Dahlgren	Brief Description of Navy Analysis Capabilities
Antonio Marchetto, EASA	The EASA Technical Opinion – Introduction of a Regulatory Framework for the Operation of Unmanned Aircrafts
Christopher Sacco, US Navy PMA-263	Navy and Marine Corps Small Tactical Unmanned Aircraft Systems Program Office Overview of Operations and Logistics
Dr. Paul Wilde, FAA	Public Risk Criteria and Rationale for Commercial Launch

Presenter	Presentation
	and Reentry
Jill Brown, NASA	CERTAIN (City Environment Range Testing of Autonomous Integrated Navigation)
Mark Dombroff, UAS Insurance Association	UAS Insurance Association
Dr. Joel Recht, CPSC	Identifying and Managing Risk

Appendix B Summary of ARC Recommendations

Micro UAS Aviation Rulemaking Committee Recommendations Summary				
	Category 1	**Category 2**	**Category 3**	**Category 4**
What is the weight or impact energy threshold for UAS to qualify for operations under this category?	UAS weighs 250 grams or less.	UAS causes less than a 1% chance of AIS level 3 or greater injury, as expressed in the rule by not exceeding an impact energy threshold defined by the FAA in J/cm².	UAS causes less than a 30% chance of AIS level 3 or greater injury, as expressed in the rule by not exceeding an impact energy threshold defined by the FAA in J/cm².	UAS causes less than a 30% chance of AIS level 3 or greater injury, as expressed in the rule by not exceeding an impact energy threshold defined by the FAA in J/cm².
Are there industry consensus performance standards with which the UAS must comply to qualify for operations under this category?	No, but the ARC recommends the FAA invite industry to develop voluntary consensus standards.	Yes. The industry consensus standard must, at a minimum: (1) establish a test to measure the typical impact energy of the unmanned aircraft to determine whether it meets the specified impact energy threshold; (2) study impact of exposed rotating parts to safety analysis; and (3) require the manufacturer of the unmanned aircraft to provide an operating manual to the operator.	Yes. The industry consensus standard must: (1) establish a test to measure the typical impact energy of the unmanned aircraft to determine whether the UAS meets the specified impact energy threshold; (2) address impact of exposed rotating parts to safety analysis; and (3) require the manufacturer of the unmanned aircraft to provide an operating manual to the operator.	Yes. The industry consensus standard must: (1) establish a test to measure the typical impact energy of the unmanned aircraft to determine whether it meets the specified impact energy threshold; (2) address impact of exposed rotating parts to safety analysis; (3) require the manufacturer of the unmanned aircraft to provide an operating manual to the operator; (4) consider materials and components of the UAS to determine if the materials pose additional potential risk of collateral injury to people on the ground, in addition to injury caused by initial impact; and (5) develop a risk mitigation plan for operations over people.
How do manufacturers demonstrate to the FAA that their UAS complies with industry consensus standards?	Either: (1) label the product retail packaging with the actual weight of the unmanned aircraft or with a general statement that the unmanned aircraft weighs 250 grams or less; or (2) declare that the unmanned aircraft weighs 250 grams or	(1) Declare that the UAS meets applicable industry consensus standards for operation over people; (2) submit that declaration to the FAA in a form and manner acceptable to the FAA; and (3) label the product and or product retail packaging in accordance with	(1) Declare that the UAS meets applicable industry consensus standards for operation over people; (2) submit that declaration to the FAA in a form and manner acceptable to the FAA; and (3) label the product and or product retail packaging in accordance with industry consensus	(1) Declare that the UAS meets applicable industry consensus standards for operation over people; (2) submit that declaration to the FAA in a form and manner acceptable to the FAA; and (3) label the product and or product retail packaging in accordance with

Micro UAS Aviation Rulemaking Committee Recommendations Summary				
	Category 1	**Category 2**	**Category 3**	**Category 4**
	less and submit that declaration to the FAA in a form and manner acceptable to the FAA.	industry consensus standards.	standards.	industry consensus standards.
Do the operators have to comply with operational requirements beyond those imposed by the proposed part 107?	No.	Yes. The operator must comply with the manufacturer's operator manual. The operator must also ensure that the UAS maintains a minimum distance of 20 feet above people's heads, or 10 feet laterally away from, people on the ground and must not create an undue hazard to people.	Yes. Flight over crowds or dense concentrations of people is never permitted under Category 3. In addition to that restriction, small UAS may only operate over people if: (1) The operation is conducted over a closed- or restricted-access work site with the permission of the site's owner or operator; or (2) Overflight of people is limited to those who are transient or incidental to the operation, i.e. the overflight of people is incidental to the operation and is not sustained. Operational requirements applicable to Category 2 (i.e., comply with the manufacturer's operator manual and maintain specified minimum set-off distances) also apply to Category 3.	Yes. In addition to the operational requirements for Category 2, the UAS may only operate over people if the operation is conducted in compliance with a documented risk mitigation plan, which may include, among other things, local coordination and pilot training commensurate with the risk, and which was adopted in accordance with industry consensus standards.