GHANA
CIVIL AVIATION AUTHORITY

ADVISORY CIRCULAR
AC 28-004

Assessment of Risk for RPAS Operators (ARRO) Methodology

SECTION 1 GENERAL

1.1 PURPOSE

The purpose of this Advisory Circular is to equip the RPAS Prospective Operator with knowledge to understand the expected requirements for successful application and grant of an approval to either operate an RPAS in Category B or continue on to the Certification Process for Category C operations.

1.2 STATUS OF THIS ADVISORY

CIRCULAR This AC is an original issuance.

1.3 BACKGROUND

Safety has always been the overriding consideration in the conduct of all aviation activities

(1) Remotely Piloted Aircraft Systems (RPAS) come in various shapes, weights and sizes. Not only do they come in different shapes and sizes, but they also have different performance characteristics and limitations.

(2) This unique nature of RPAS exerts unprecedented pressure on the Regulator to not only consider the RPAS or the kind of operation being conducted, but to consider holistically the combination of RPAS and operation.

(3) The Joint Authorities on rulemaking for Unmanned Systems (JARUS) released a methodology called “SORA - Specific Operations Risk Assessment.” which aims to help resolve this issue of matching the RPAS to the operation. SORA seeks to propose safety mitigation measures based on the RPAS- Operation scenario in a methodical and uniform manner.

(4) The information presented in SORA is available for all States to implement and Ghana is subsequently implementing this methodology taking cognizance of the peculiarities of Ghana's RPAS industry. The methodology in Ghana is termed – Assessment of Risk for RPAS Operations (ARRO).

1.4 APPLICABILITY

(1) All RPAS Operators who answer “Yes” to any of the questions in Job Aid RP-004 shall be required to go through the ARRO Methodology. Excerpt of Job Aid attached as Appendix 2.

(2) The scope and detail required will depend on the size and complexity of the RPAS Operator.

(3) RPAS manufacturers of all weight categories shall complete the ARRO Methodology unless it can be proven to the satisfaction of the Authority that the intended user(s) of the RPAS shall not answer yes to any of the questions contained in Job Aid RP-004.

1.5 RELATED DIRECTIVES

The following directives are directly applicable to the guidance contained in this advisory circular—

- Ghana Civil Aviation Directives Part 28
- Ghana Civil Aviation (Air Navigation Services) Directives Part 19
- Ghana Civil Aviation (Air Navigation Services) Directives Part 24
- Ghana Civil Aviation (Flight Standards) Directives

1.6 RELATED READING MATERIAL

(1) ICAO Manual on Remotely Piloted Aircraft Systems (RPAS) (Doc 10019)
(2) ICAO Annex 2

1.7 GLOSSARY

1.7.1 DEFINITIONS

(1) **Air Risk Index:** The Air Risk Index is a measure of the probability of a mid-air collision (MAC) between the RPAS and manned aircraft.

(2) **Airspace Density:** A measure of the number of manned flights per given area of the airspace. Starting from 5 to 1 with 5 being the densest.

(3) **Assurance:** It is the proof that a mitigation measure does what it says it can do.

(4) **Command and Control (C2) link:** The data link between the remotely piloted aircraft and the remote pilot station for the purposes of managing the flight.

(5) **Ground Risk Index:** The Ground Risk Index relates to the risk of a person being struck by the RPAS or the damage to property on the ground in the case of loss of control.

(6) **Integrity:** Also known as the safety gain, is how useful a mitigation measure is in improving safety or helping you achieve your SPT.

(7) **Light RPAS:** An RPAS with a maximum take-off weight greater than or equal to 7 kg.

(8) **Mitigation Strategies:** Measures taken to reduce the impact of identified hazards inherent in an RPAS-Operation scenario. A mitigation strategy may have a low, medium or high robustness.

(9) **Operational Volume:** consists of the normal (Flight Geography) and contingency operating area.

(10) **Robustness:** It is the sum of the integrity and assurance of a mitigation measure.

(11) **Small RPAS:** An RPAS with a maximum take-off weight equal to or below 1.5 kg

1.7.2 ABBREVIATIONS

(1) **AC** – Advisory Circular

(2) **ACAS** – Airborne Collision Avoidance System

(3) **AGL** – Above Ground Level

(4) **ARI** – Air Risk Index

(5) **BVLOS** – Beyond Visual Line of Site

(6) **CONOPS** – Concept of Operations

(7) **DAA** – Detect and Avoid

(8) **FLARM** – Flight Alarm

(9) **GCAA** – Ghana Civil Aviation Authority

(10) **GRI** – Ground Risk Index

(11) **ICAO** – International Civil Aviation Organisation

(12) **MTOW** – Maximum Take-Off Weight

(13) **ROC** – RPAS Operator Certificate

(14) **RPAS** – Remotely Piloted Aircraft Systems

(15) **SPI** – Safety Performance Indicators

(16) **SPT** – Safety Performance Target

(17) **TCAS** – Traffic Collision Avoidance System

(18) **VLOS** – Visual Line of Site

SECTION 2 UNDERLYING CONCEPTS

(1) The basic assumption of ARRO is that the SPIs and SPTs for RPAS Operations are the same for the whole industry irrespective of how, when, where and with what equipment is being used.

(2) SORA, on which the ARRO is based on, considered some SPIs and SPTs and scientifically determined what measures will need to be in place for the attainment of those targets.

(3) ARRO divides the RPAS-Operation scenario into three categories – A, B & C – in order of increasing complexity of the mitigation required.

(4) Category A Operations are considered low risk operations provided the operation is conducted within the predetermined specified limitations which can be found in the RPAS Advisory Pamphlet (AC 28-001) attached to this AC as Appendix 1. When a small or light RPAS meets the specified operational requirements in the Advisory Pamphlet it shall not be subjected to the ARRO process.

(5) Categories B and C Operations are considered as high-risk operations. The difference between the two categories is that Category B requires only an Authorization for a discrete period of time and environment whereas a Category C Operation will require a further Certification Process leading to the grant of an ROC.

(6) To operate an RPAS in controlled airspace, two requirements must be met:

a) A safety requirement ensuring that the operation is safe to conduct in the Operational Volume; and

b) A requirement for regulatory compliance with Ghana Civil Aviation (Air Navigation) Directives Part 19 and ICAO Annex 2.

(7) These requirements must be addressed to GCAA through either:

a) Demonstration of compliance to both requirements;

b) Demonstration of an alternate means of compliance to the requirements; or

c) Waiver of the requirement(s) by GCAA.

Note: Approval to operate in a particular airspace shall be done with concurrence from the ANSP.

(8) All airspace in Ghana and within Ghana's FIR are controlled airspace.

SECTION 3 BENEFITS OF ARRO

(1) What ARRO does is to ensure or give the assurance that the RPAS Operation will stay within operational boundaries and confinements to enable the achievement of the SPTs.

(2) It eliminates the need for subjectivity of the GCAA official.

(3) Eliminating the need for subjectivity ensures standardization not only across operators in the same country but also across States which in turn ensures fairness, competition and ultimately an inherently safe industry.

(4) ARRO also enables the documentation of the decision process for the approval of an RPAS-Operation scenario.

SECTION 4 ASSESSMENT PROCEDURE

4.1 OPERATIONAL CATEGORY DETERMINATION

(1) An Applicant for an RPAS registration or authorization shall answer or be asked, by the GCAA official processing the application, the questions on in Job Aid RP-004.

(2) Not answering "Yes" to any of the questions places the operation of the RPAS in Category A - Low Risk.

(3) However, if an Applicant answers "Yes" to any one of the questions, the Applicant shall be required to submit a CONOPS in accordance with AC 28-003

(4) For a Category C Operation, the submitted CONOPS shall serve as the basis for developing the Applicant's Operations Manual. The Operations Manual shall adequately address all remaining applicable requirements in the Ghana Civil Aviation Directives and standard practices.

4.2 SAIL DETERMINATION

(1) Based on the submitted CONOPS, the SAIL value of the RPAS Operation is determined.

(2) SAIL stands for the Specific Assurance and Integrity Level of an RPAS-Operation. In other words, it can be said that the SAIL determines the Robustness that an RPAS-Operation scenario will stay within the determined operational boundaries.

(3) The SAIL value is determined, as per Table 1, from the final determination of the GRI and the ARI. The final determination of these Indices is derived after all, some or even none of the inherent ground and air risks, associated with the RPAS-Operation scenario, have been mitigated by the Prospective RPAS Operator.

FINAL GRI	RESIDUAL ARI			
	A	B	C	D
<2	I	II	IV	VI
3	II	II	IV	VI
4	III	III	IV	VI
5	IV	IV	IV	VI
6	V	V	V	VI
7	VI	VI	VI	VI

Table 1: SAIL Value Determination

(4) The Intrinsic GRI can be mitigated by one or a combination of the following:

a. Reducing the number of people at risk.

b. Reducing the effect of the impact dynamics once control of the operation is lost.

c. Development of Emergency Response Plan (ERP) by the applicant in the event of loss of control of the operation.

(5) An example of a GRI that is mitigated will be surveying a road after morning rush hour.

(6) A final GRI of value greater than 7, shall not be approved by the Authority.

(7) Table 2 is used to determine the Intrinsic GRI Value of an RPAS Operation.

MTOW OF RPAS (x)	0kg < x ≤ 1.5kg	1.5kg < x ≤ 7kg	7kg < x ≤ 25kg	x > 25kg
OPERATIONAL SCENARIOS				
VLOS/BVLOS over controlled ground area	1	2	3	4
VLOS in sparsely populated environment	2	3	4	5
BVLOS in sparsely populated environment	3	4	5	6
VLOS in populated environment	4	5	6	8
BVLOS in populated environment	5	6	8	10
VLOS over gathering of people	7	8	9	10
BVLOS over gathering of people	8	9	11	12

Table 2:Intrinsic GRI Determination

(8) The mitigations prescribed to reduce the Initial ARI are divided into two categories – RPAS Operator Proposed Mitigation or Strategic Mitigation and Tactical Mitigation which is based on the Residual ARI after implementation of the Strategic Mitigation.

(9) For simplicity, ARRO, allows the Prospective Applicant to manipulate proximity i.e. density of manned aviation as the Strategic Mitigation measure.

(10) Airspace Densities have been classified from Class 5 to Class 1 with 5 being the densest and 1 being the least dense. Nevertheless, in Ghana, the minimum derived initial airspace density is a Class 3 taken at enroute altitudes and at peak hours.

(11) As per Figure 1, the red areas are denoted as Class 5, the yellow as Class 4 and white as Class 3.

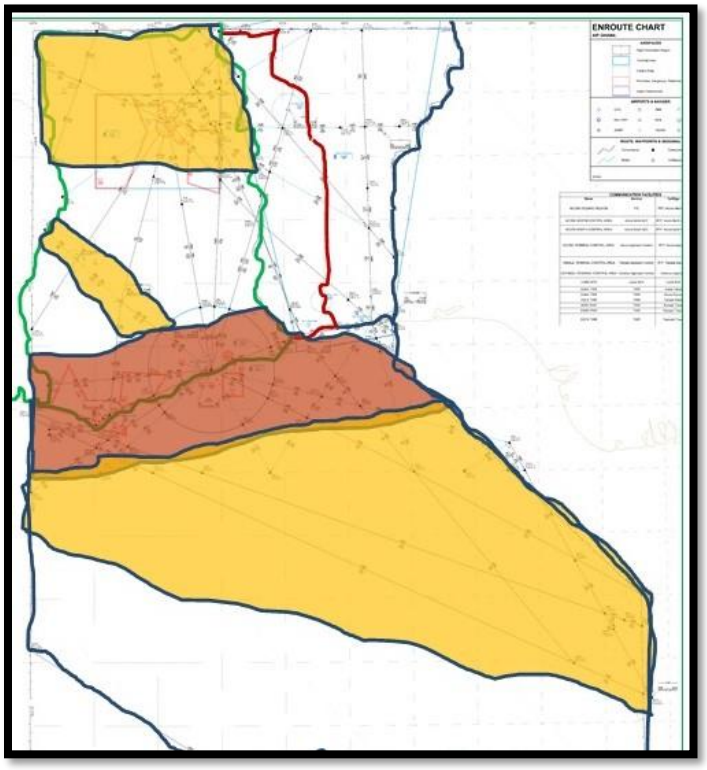


Figure 1: Airspace Densities

(12) To reduce the initial ARI the operator provides evidence that demonstrates that the intended operation is more indicative of another airspace density and that the risk of encounter corresponds to a lower risk index, hence, reducing the initial ARI to a Residual ARI.

(13) If an operator agrees that the Initial ARI applicable to their operation and Operational Volume is correct, then this Initial ARI becomes their Residual ARI. The initial ARI is determined using the potential risk of encounter based on known airspace densities.

(14) In order of increasing risk of mid-air collision, the ARI is classified from ARI-A to ARI-D.

(15) ARRO encourages an open dialog between the applicant and the Authority to determine what is acceptable evidence for reduction in airspace density.

(16) Although the static generalized risk (i.e. ARI) is conservative, there may be situations where that conservative assessment may be insufficient. In those situations, the Authority may raise the ARI to a level that is higher than that advocated by ARRO.

For example, an operator surveys a forest near an airport for beetle infestation. The airspace was assessed ARI-B. The airport is hosting an airshow. The Authority informs the operator that during the week of the airshow, the ARI for that local airspace will be ARI-D. The operator can either equip for ARI-D airspace or suspend operations until the airshow is over.

(17) Table 3 is used to determine the Initial ARI of an RPAS Operation.

Operational Environment	Initial Generalised Density Rating	Initial ARI
Airport/Heliport Environment		
OPS in Airport/Heliport Environment in Class B, C or D airspace	5	ARI-D
OPS in Airport/Heliport Environment in Class E airspace or in Class F or G	3	ARI-C
Operations above 400 feet AGL but below Flight level 600		
OPS >400ft AGL but <FL600 in a Mode-C Veil or Transponder Mandatory Zone (TMZ)	5	ARI-D
OPS >400ft AGL but <FL600 in controlled airspace	4	ARI-C
Operations below 400 ft AGL		
OPS <400ft AGL in a Mode- C Veil or Transponder Mandatory Zone (TMZ)	3	ARI-C
OPS <400ft AGL in controlled airspace	2	ARI-B
Operations above Flight Level 600		
OPS >FL600	1	ARI-B
Operations in Atypical or Segregated Airspace		
OPS in Atypical/Segregated Airspace	1	ARI-A

Table 3: Initial ARI Determination

4.3 TACTICAL MITIGATION

(1) A Tactical Mitigation is a mitigation applied after take-off and for the air risk model it takes the form of a "mitigating feedback loop." This feedback loop is dynamic in that it reduces the rate of collision by modifying the geometry and dynamics of aircraft in conflict, based on real time aircraft conflict information.

(2) Tactical Mitigations are applied to mitigate any residual risk of a mid-air collision needed to achieve the applicable airspace safety objective. The residual risk is the remaining collision risk after strategic mitigations are applied.

(3) Tactical Mitigations will take the form of either "See and Avoid" (i.e. operations under VLOS) or may require a system which provides an alternate means of achieving the applicable airspace safety objective (operation using a DAA, or multiple DAA systems).

(4) A "See and Avoid" under VLOS does not exempt the operator from performing the full ARRO risk analysis.

(5) For VLOS operations that fall into a Residual ARI greater than "A", the applicant shall have a documented VLOS de-confliction scheme, in which the applicant explains which methods will be used for detection, and define the associated criteria applied for the

decision to avoid incoming traffic. In case the remote pilot relies on detection by observers, the use of phraseology will have to be described as well.

(6) Tactical Mitigation Performance Requirement (TMPR) provides tactical mitigations to assist the pilot in detecting and avoiding traffic under BVLOS conditions. The TMPR is the amount of Tactical Mitigation required to further mitigate the risks that could not be mitigated through Strategic Mitigation (residual risk). The amount of residual risk is dependent on the ARI. Hence, the higher the ARI, the greater the residual risk, the greater the TMPR.

(7) Since the TMPR is the total performance required by all tactical mitigation means, tactical mitigations may be combined. When combining multiple tactical mitigations, it is important to recognize that the mitigation means may interact with each other, depending on the level of interdependency. This may negatively affect the effectiveness of the overall mitigation. Care must be exercised not to underestimate the negative effects of interactions between mitigation systems. Regardless whether mitigations or systems are dependent or independent, when acting on the same event unintended consequences may occur.

(8) **High TMPR (ARI-D)**: This is airspace where either the manned aircraft encounter rate is high, and or the available Strategic Mitigations are Low. Therefore, the resulting residual collision risk is high, and the TMPR is also high. In this airspace, the RPAS may be operating in Integrated Airspace and will have to comply with the operating rules and procedures applicable to that airspace, without reducing existing capacity, decreasing safety, negatively impacting current operations with manned aircraft, or increasing the risk to airspace users or persons and property on the ground. This is no different than the requirements for the integration of comparable new and novel technologies in manned aviation. The performance level(s) of those Tactical mitigations and/or the required variety of Tactical mitigations is generally higher than for the other ARIs.

(9) **Medium TMPR (ARI-C)**: A medium TMPR will be required for operations in airspace where the chance to encounter manned aircraft is reasonable and or the Strategic Mitigations available are medium. Operations with a medium TMPR will likely be supported by systems currently used in aviation to aid the pilot with detection of other manned aircraft, or on systems designed to support aviation that are built to a corresponding level of robustness. Traffic avoidance manoeuvres could be more advanced than for a low TMPR.

(10) **Low TMPR (ARI-B)**: A low TMPR will be required for operations in airspace where the probability of encountering another manned aircraft is low but not negligible and or where Strategic Mitigations address most of the risk and the resulting residual collision risk is low. Operations with a low TMPR are supported by technology that is designed to aid the pilot in detecting other traffic, but which may be built to lesser standards. For example, for operations below 400ft, the traffic avoidance manoeuvres are expected to mostly be based on a rapid descent to an altitude where manned aircraft are not expected to ever operate.

(11) **No Performance Requirement (ARI-A)**: This is airspace where the manned aircraft encounter rate is expected to be extremely low, and therefore there is no requirement

for a TMPR. It is generally defined as airspace where the risk of collision between an RPAS and manned aircraft is acceptable without the addition of any Tactical mitigation.

(12) The performance of a tactical mitigation is affected by the equipage of both the RPAS and threat aircraft, on an encounter by encounter basis. A tactical mitigation mitigates encounter risk using a set of subfunctions of the detect and avoid routine, namely see or detect, decide, command, execute, and feedback loop. Equipage that aids these sub-functions increases the overall performance of the tactical mitigation system.

(13) Tactical Mitigation equipage is not homogeneous within the airspace. Different airspaces have a different mix of equipage. General aviation aircraft tend to be less well equipped than commercial aircraft. There will be differences in the mix of general aviation and commercial aircraft from one location or airspace to another. Based on aircraft equipage, a specific tactical system (e.g. FLARM, ACAS, etc.) could mitigate the risk of a collision in some airspaces and not in others.

(14) Therefore, the applicant needs to understand the effectiveness of their tactical mitigation systems within the context of the airspace in which they intend to operate and select systems used for tactical mitigation accordingly. A TCAS II/ACAS-II equipped RPAS will not mitigate all encounter risks in an area where sailplanes equipped with FLARM are known to operate.

4.4 ASSIGNMENT OF OPERATIONAL OBJECTIVES

(1) ARRO uses SAIL to evaluate the defenses within the operation in the form of Operational Safety Objectives (OSO) and to determine the associated level of robustness.

(2) The various OSOs are grouped based on the threat they help to mitigate. They are a consolidated list of common OSOs that historically have been used to ensure safe RPAS operations (See Table 4). They represent the collected experience of many experts and is therefore a solid starting point to determine the required safety objectives for a specific operation.

(3) The letters O, L, M and H have the following meaning respectively:

a. Optional

b. Low

c. Medium

d. High

OSO Number	Description	SAIL					
		I	II	III	IV	V	VI
Technical issue with the RPAS							
OSO 1	Ensure the operator is competent and/or proven	O	L	M	H	H	H
OSO 2	RPAS manufactured by competent and/or proven entity	O	O	L	M	H	H
OSO 3	RPAS maintained by competent and/or proven entity	L	L	M	M	H	H
OSO 4	RPAS developed to authority recognized design standardsh	O	O	O	L	M	H
OSO 5	RPAS is designed considering system safety and reliability	O	O	L	M	H	H
OSO 6	C3 link performance is appropriate for the operation	O	L	L	M	H	H
OSO 7	Inspection of the RPAS (product inspection) to ensure consistency to the ConOps	L	L	M	M	H	H
OSO 8	Operational procedures are defined, validated and adhered to	L	M	H	H	H	H
OSO 9	Remote crew trained and current and able to control the abnormal situation	L	L	M	M	H	H
OSO 10	Safe recovery from technical issue	L	L	M	M	H	H
Deterioration of external systems supporting RPAS operation							
OSO 11	Procedures are in-place to handle the deterioration of external systems supporting RPAS operation	L	M	H	H	H	H
OSO 12	The RPAS is designed to manage the deterioration of external systems supporting RPAS operation	L	L	M	M	H	H
OSO 13	External services supporting RPAS operations are adequate to the operation	L	L	M	H	H	H
Human Error							
OSO 14	Operational procedures are defined, validated and adhered to	L	M	H	H	H	H
OSO 15	Remote crew trained and current and able to control the abnormal situation	L	L	M	M	H	H
OSO 16	Multi crew coordination	L	L	M	M	H	H
OSO 17	Remote crew is fit to operate	L	L	M	M	H	H
OSO 18	Automatic protection of the flight envelope from Human Error	O	O	L	M	H	H
OSO 19	Safe recovery from Human Error	O	O	L	M	M	H
OSO 20	A Human Factors evaluation has been performed and the HMI found appropriate for the mission	O	L	L	M	M	H
Adverse operating conditions							
OSO 21	Operational procedures are defined, validated and adhered to	L	M	H	H	H	H
OSO 22	The remote crew is trained to identify critical environmental conditions and to avoid them	L	L	M	M	M	H
OSO 23	Environmental conditions for safe operations defined, measurable and adhered to	L	L	M	M	H	H
OSO 24	RPAS designed and qualified for adverse environmental conditions	O	O	M	H	H	H

Table 4: Operational Safety Objectives Determination

4.4 ADJACENT AIRSPACE REQUIREMENTS

4.4.1 APPLICABILITY

This section shall be applicable to RPAS design and or manufacturing organisations.

4.4.2 RISK CONSIDERATIONS

To address the risk posed by a loss of control of the operation resulting in an infringement of the adjacent areas on the ground and or adjacent airspace, the following requirements for safety containment are defined in the ARRO:

a) The probability of leaving the operational volume shall be less than 10^{-4}/FH.

b) No probable failure of the RPAS or any external system supporting the operation shall lead to operation outside of the operational volume. Compliance with this requirement shall be substantiated by a design and installation appraisal and shall minimally include:

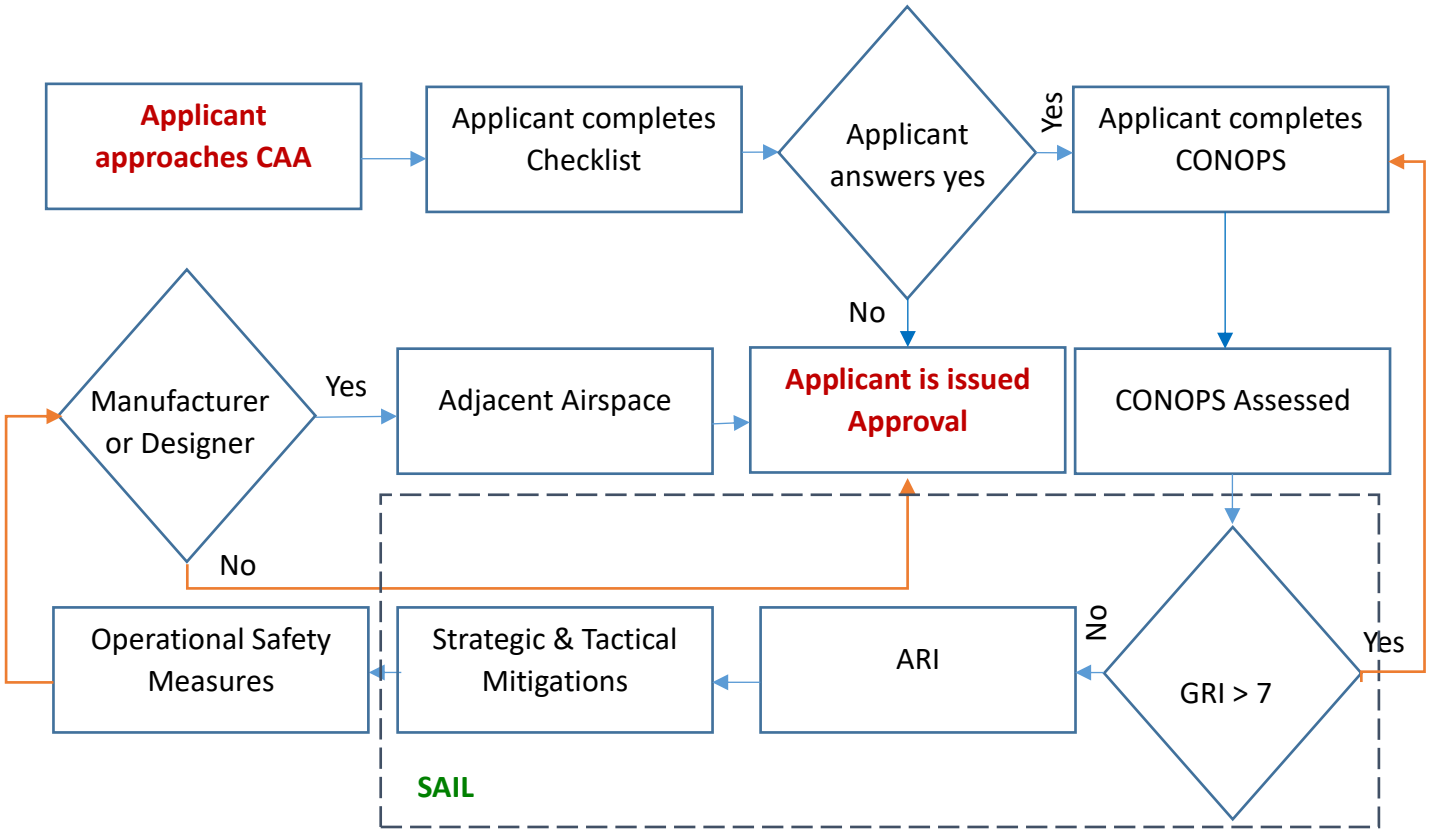
   i. design and installation features (independence, separation and redundancy);

   ii. any relevant particular risk (e.g. hail, ice, snow, electro-magnetic interference…) associated with the CONOPS.

c) No single failure of the RPAS or any external system supporting the operation shall lead to operation outside of the ground risk buffer. Compliance with this requirement shall be substantiated by analysis and or test data with supporting evidence.

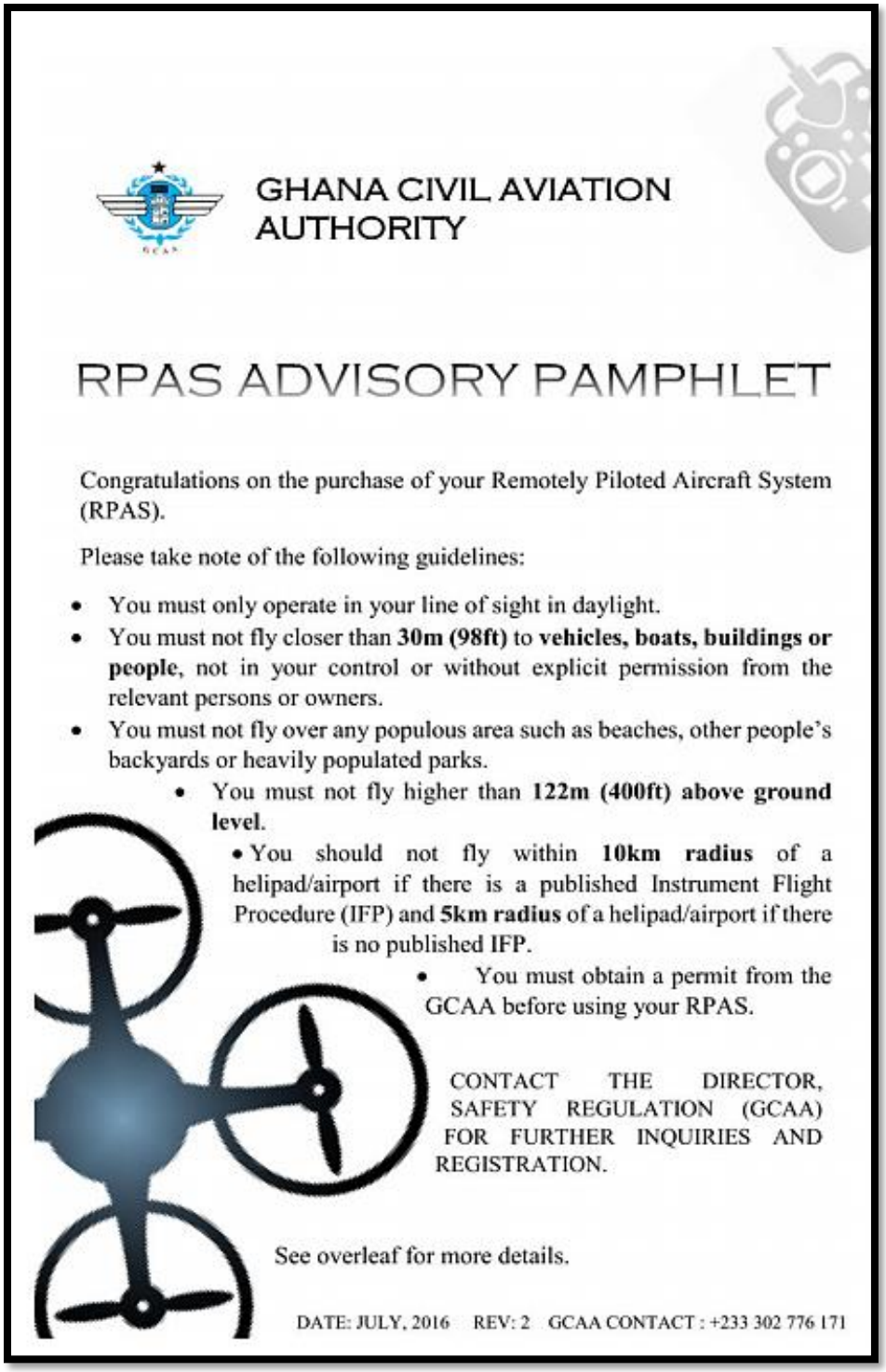
d) Software (SW) and Airborne Electronic Hardware (AEH) whose development error(s) could directly lead to operations outside of the ground risk buffer shall be developed to an industry standard or methodology recognized as adequate by the competent authority and or GCAA.

SECTION 5 SUMMARY OF ARRO PROCESS



SECTION 6 APPENDICES

6.1 APPENDIX 1: RPAS ADVISORY PAMPHLET (AC 28-001)



GHANA CIVIL AVIATION AUTHORITY

RPAS ADVISORY PAMPHLET

Congratulations on the purchase of your Remotely Piloted Aircraft System (RPAS).

Please take note of the following guidelines:

- You must only operate in your line of sight in daylight.
- You must not fly closer than **30m (98ft)** to **vehicles, boats, buildings or people**, not in your control or without explicit permission from the relevant persons or owners.
- You must not fly over any populous area such as beaches, other people's backyards or heavily populated parks.
- You must not fly higher than **122m (400ft) above ground level.**
- You should not fly within **10km radius** of a helipad/airport if there is a published Instrument Flight Procedure (IFP) and **5km radius** of a helipad/airport if there is no published IFP.
- You must obtain a permit from the GCAA before using your RPAS.

CONTACT THE DIRECTOR, SAFETY REGULATION (GCAA) FOR FURTHER INQUIRIES AND REGISTRATION.

See overleaf for more details.

DATE: JULY, 2016 REV: 2 GCAA CONTACT : +233 302 776 171

6.2 APPENDIX 2: CONCEPT OF OPERATIONS (CONOPS) CHECKLIST

GHANA CIVIL AVIATION AUTHORITY

JOB AID RP-004
Concept Of Operations (CONOPS)

Date		**Control #**	
Action #		**Record ID#**	
Inspector(s) Name & ASI #		**Org Identifier**	
Location		**Project#**	
Action Taken		**RPAS REG. #**	

IF OPERATOR OR APPLICANT SELECTS YES TO ANY OF THE ITEMS BELOW, A SUBMISSION OF CONOPS SHALL BE REQUIRED.				
REFERENCE		**DESCRIPTION**	**YES**	**NO**
	1	Is the MTOW of RPA for the operation greater than 7kg		
	2	Is the RPAS operation meant for commercial purposes		
	3	Will the RPAS operation require a special authorisation as captured in GCAD Part 28		
	4	Is the RPAS operation considered as a BVLOS		
	5	Will the RPAS operation involve flights above 400ft A.G.L.		
	6	Will the RPAS operation involve flights within 10km radius of a helipad/airport if there is a published Instrument Flight Procedure (IFP) and 5km radius of a helipad/airport if there is no published IFP		
	7	Will the RPAS operation involve flights closer than 30m (98ft) to vehicles, boats, buildings or people not in the Operator's control or without explicit permission from the relevant persons or owners		
	8	Will the RPAS operations involve flights over any populous area such as beaches, other people's backyards or heavily populated parks		

End of Advisory Circular