NATO STANDARD

ARSP–02, Volume IV

DANGER AREAS/ZONES FOR UNMANNED AERIAL SYSTEM – APPLICATION

Edition A, Version 1
RATIFICATION DRAFT 1
MONTH YEAR

NORTH ATLANTIC TREATY ORGANIZATION

ALLIED RANGE SAFETY PUBLICATION

Published by the
NATO STANDARDIZATION OFFICE (NSO)

INTENTIONALLY BLANK

NORTH ATLANTIC TREATY ORGANIZATION

NATO STANDARDIZATION AGENCY (NSA)

NATO LETTER OF PROMULGATION

Date

1. The enclosed Allied Range Safety Publication ARSP-02, Volume IV, Edition A, Version 1, DANGER AREAS/ZONES FOR UNMANNED AERIAL SYSTEM – APPLICATION, which has been approved by the nations in the Military Committee Land Standardization Board, is promulgated herewith. The agreement of interested nations to use this publication is recorded in STANAG 2470.

2. ARSP-02, Edition A, Volume IV, Edition A, Version 1, is effective upon receipt.

3. This NATO standardization document is issued by NATO. In case of reproduction, NATO is to be acknowledged. NATO does not charge any fee for its standardization documents at any stage, which are not intended to be sold. They can be retrieved from the NATO Standardization Document Database (https://nso.nato.int/nso/) or through your national standardization authorities.

4. This publication shall be handled in accordance with C-M(2002)60.

Dimitrios SIGOULAKIS
Lieutenant General, GRC (A)
Director, NATO Standardization Office

INTENTIONALLY BLANK

RESERVED FOR NATIONAL LETTER OF PROMULGATION

INTENTIONALLY BLANK

RECORD OF RESERVATIONS

CHAPTER	RECORD OF RESERVATION BY NATIONS
Note: The reservations listed on this page include only those that were recorded at time of promulgation and may not be complete. Refer to the NATO Standardization Document Database for the complete list of existing reservations.	

INTENTIONALLY BLANK

RECORD OF SPECIFIC RESERVATIONS

[nation]	[detail of reservation]
Note: The reservations listed on this page include only those that were recorded at time of promulgation and may not be complete. Refer to the NATO Standardization Document Database for the complete list of existing reservations.	

INTENTIONALLY BLANK

TABLE OF CONTENTS

INTENTIONALLY BLANK

CHAPTER 1
INTRODUCTION

1.1 UNMANNED AERIAL SYSTEM (UAS) DANGER AREA/ZONE (UDA/Z)

1. An Unmanned Aerial System (UAS) Danger Area (UDA) is defined as that area in which a UAS or debris may fall as a result of missile intercept, flight termination or malfunction where the risk of death or injury exceeds some threshold. Range Safety is the combination of organisational, training and technical measures to ensure the risk outside the UDA does not exceed this threshold and hence the risk to general public, civilian and military personnel is not unacceptable. A UAS Danger Zone (UDZ) extends this into 3-dimensions. The UDZ template is three-dimensional but is normally displayed as two dimensional template with a height restriction. Traditionally, UDA have been developed using deterministic methodology and UDA are extended into UDZ by using a constant height above the UDA. The level of risk associated with the UDA or UDZ may have been assessed but has not been explicitly quantified. In order to quantify the levels of risk we have to use a probabilistic methodology.

2. UAS Danger Areas/Zones developed using deterministic principles, where a number of worst case assumptions are used, can be considered conservative. This often results in the use of large areas or zones and can constrain training. The probabilistic methodology can be used to provide more complex solutions:

a. Specific Range Danger Areas/Zones (RDA/Z) to account, for example, for local terrain and local meteorological conditions, can be derived.

b. The methodology can be applied to a specific situation using realistic data so that range space can be optimized.

c. Probabilistic analyses can provide information that can be used for risk management purposes.

d. Probabilistic analyses can provide information that can be used to diagnose problems for conceptual or existing ranges.

3. It is important to note that the use of a probabilistic methodology is not a universal remedy. Whilst it has many advantages over deterministic methodology, probabilistic models have to be developed and data needs to be gathered and analyzed for use in these models and this may not be a simple or quick process.

4. Whereas Weapon Danger Areas (WDA) are traditionally classified by weapon type and role, the general principles described here apply to all UAS systems and no such distinctions need to be introduced.

1.2 AIM

1. The aim of this document is to describe the general principles to be applied for the development and production of a UDA.

1.3 SCOPE OF THIS PUBLICATION

1. This publication is relevant to the development of UDA/Z for all UAS systems. This publication is concerned primarily with:

a. Assessing the various hazards associated with launch, flight, and recovery of land launched UASs.

b. Assessing the risk to personnel operating on military ranges and the general public.

c. Discussing the factors for which allowance should be made when determining the extent of the UDA/Z.

2. It is intended to give guidance on some methods that have been used in the past and to give an indication of the detail and quality of information required.

3. Figures regarding required reliability and tolerable risk are not given as it is considered that the responsibility for setting them lies with the country in which the UAS is to be launched.

4. Detailed safety advice applicable to specific UAS in service use may be published later in AOPs. The application of UDA in order to define UAS RDA is the responsibility of the appropriate national authority.

5. This agreement is concerned with the determination of UAS danger areas and all references to danger areas indicate UAS danger areas unless otherwise stated.

1.4 VOCABULARY AND ABBREVIATIONS

1. The following terms are defined for the purpose of this ARSP only. No formal agreement exists for their employment in any other context.

a. Buffer zone is the three-dimensional area between a weapon danger boundary and a range danger boundary designed to increase the margin for error in UDA/Z calculations.

b. Debris zone is the three-dimensional area between the flight termination boundary and the weapon danger boundary.

c. Launch danger area is the space around the UAS in which personnel are at risk from system launch hazards and therefore the presence and protection of personnel is closely controlled.

d. Range safety equipment is the material used by the range authorities to control the UAS or terminate the flight.

e. Visual flight safety officer is a nominated person who is responsible for the termination of UAS flight if the UAS is observed to cross a flight termination boundary.

f. Flight Termination System is a system fitted to a UAS used to terminate flight in the event of a designated flight terminate line being transgressed.

2. Other technical terms and abbreviations used in this publication are provided in the Lexicon.

1.5 RELATED DOCUMENTS

1. This is one of a sequence of Allied Range Safety Publications (ARSPs) that are concerned with the development of WDA/Z for a variety of weapon systems. The proposed framework is shown in Figure 1.1. Brief descriptions of each ARSP are given below:

a. Volumes in ARSP-1 cover the deterministic methodology:

(1) Volume I (Reference 1) contains a description of the factors that are relevant to the use of unguided weapons.

(2) Volume II (Reference 2) contains a description of the application of the factors from Volume I, and provides generic danger area outlines together with nation dependent numerical values for the factors.

b. Volumes in ARSP-2 cover the probabilistic methodology:

(1) Volume I contains the principles to be applied when generating a probabilistic solution for unguided weapons.

(2) Volume II contains a description of the application of these principles to unguided weapons.

(3) Volume III contains a description of the application of these principles to guided weapons (GW).

(4) Volume IV contains a description of the application of these principles in generating an Unmanned Aerial Systems (UAS) Danger Area.

c. Volumes in ARSP-3 cover the acquisition and analysis of data for use with both deterministic and probabilistic methodologies:

(1) Volume I will provide Data Collection General Principles and explain current techniques.

(2) Volume II is a description of trials procedures and data analysis for fragmentation data.

(3) Volume III will contain a description of trials procedures and data analysis for impact and post-impact models.

d. ARSP-4 contains a description of the factors that are relevant to the use of lasers and a description of the application of these factors to lasers.and ensures the safe use of military lasers among allied forces.

e. The colours in Figure 1 represent the following:

Green - Ratified documents

Yellow – In construction

Red – To be written

1.6 IMPLEMENTATION OF THE AGREEMENT

1. This ARSP is implemented when the necessary orders / instructions putting the principles and procedures detailed in the agreement into effect have been issued to the forces concerned.

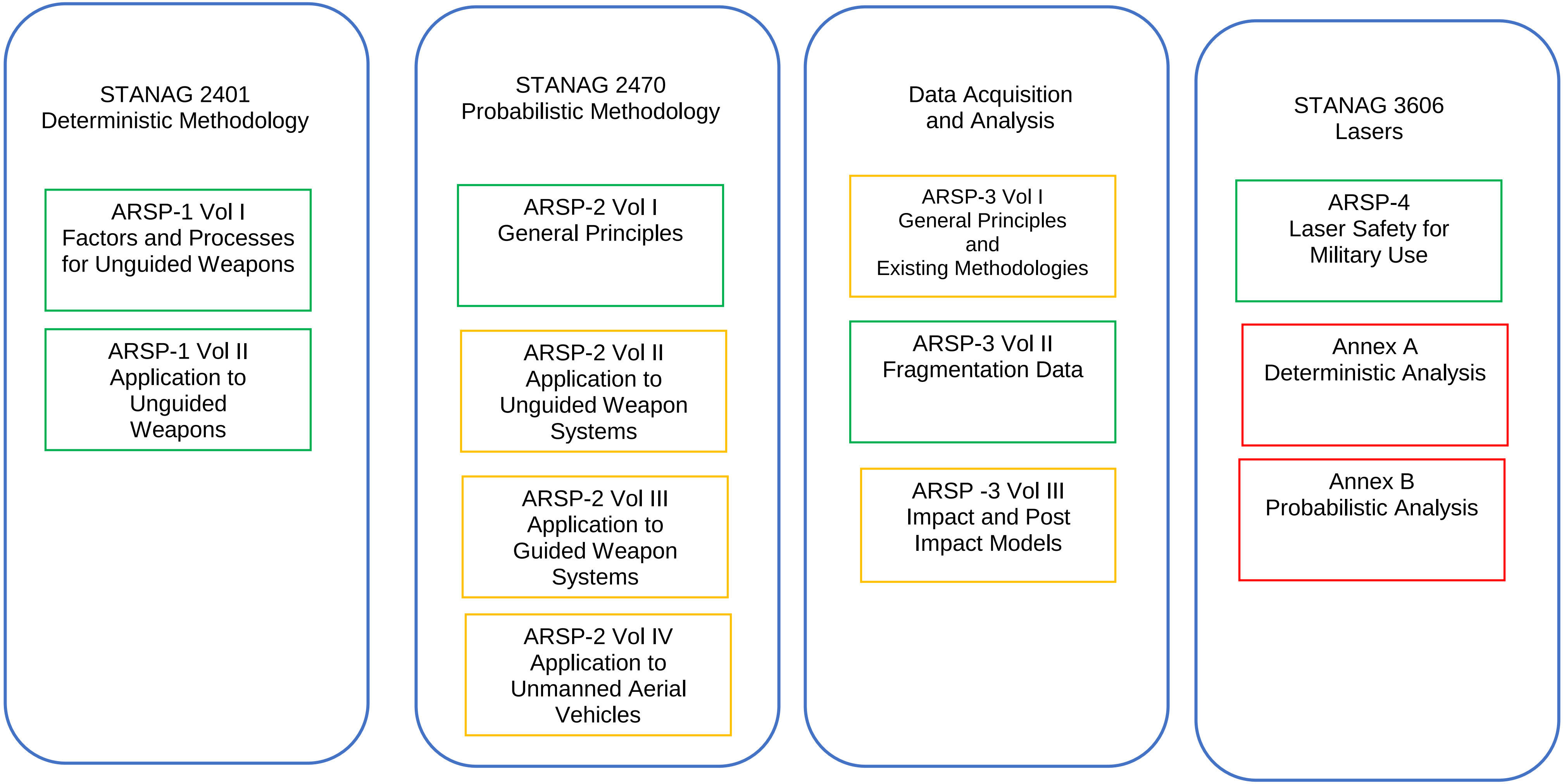

Figure 1 - Framework of each Allied Range Safety Publications (ARSP).

CHAPTER 2
GUIDELINES FOR THE PRODUCTION OF LAND LAUNCHED UNMANNED AERIAL SYSTEM DANGER AREAS ON MILITARY RANGES

2.1 INTRODUCTION

1. Unmanned Aerial Systems (UAS) are being used for an increasing number of functions, either as independent units or as parts of intelligence, surveillance, target acquisition and reconnaissance (ISTAR) management systems with input to a larger battlespace picture. UAS come in many shapes or sizes from full size remotely controlled aircraft to micro models. The planned use of a UAS will dictate the way in which it is regulated and operated. There are three main categories of use; as a target or target towing System, as a sensor platform and as a weapon platform. Although these categories of use are not mutually exclusive on operations it would be unusual to train in or practice more than one role with the same UAS on a range at one time, because of the complexity of the resulting danger area.

2. When considering range safety requirements for UAS, it is necessary to ensure that an appropriate balance exists between the need to minimise risks to both military and civilian personnel and the need to achieve realistic training. Modern UASs are extremely complex systems. They are becoming faster, more manoeuvrable and have longer flight duration and are, consequently, potentially more hazardous in their operations when compared to earlier generation, simpler UAS. In general, nations have tended to base their range safety criteria, not upon any coherent mathematical foundation, but the use of largely empirical methods and by the adoption of common sense safety precautions directed by UAS performance characteristics and in some cases as the result of post-accident investigations. Therefore, it is desirable to agree a scientific basis on which danger areas can be constructed. If it is intended to operate the UAS outside a military range then clearance should be obtained from the appropriate national aviation authority.

3. When a UAS is used as a platform for a weapon system the UAS becomes an Unmanned Combat Air Vehicle (UCAV). In this case the UDA for the UAS must be combined with the specific WDA for the weapon system. The WDA is created separately to the UDA and is applied from the point or area of release; ARSP 1 Vol I and II, and ARSP 2 Vol I, II and III apply. However, the combined effects of the weapon system and the UAS must be considered in the event of a failure, especially when considering any impact danger area.

2.2 SAFETY CONSIDERATIONS AND HAZARDS

1. The hazards associated with UAS flights can be considered in four distinct operational phases, they are:

a. Launch.

b. Flight.

c. Recovery.

d. Overflying of personnel on ranges

2.3 OUTLINE OF ACTIVITY

1. To derive a UDA some or all of the following activities is required:

   a. Development of a UAS system performance model.

   b. Analysis of the UAS flight failure modes and the resultant hazards.

   c. Derivation of the Air Danger Height (ADH).

   d. Derivation of the Total Energy WDA.

   e. Derivation of the Launch Danger Area.

   f. Identification of the flight termination / destruct boundaries.

   g. Derivation of the UDA when a FTS is fitted.

   h. Assessment of the reliability of the FTS (where applicable).

   i. Conducting a risk assessment.

   j. Considering the method of wind correction if applicable.

CHAPTER 3
UAS LAUNCH

3.1 INTRODUCTION

1. There are a number of different methods used to launch a UAS. However, the launch phase can be divided into two parts:

   a. The period up to and including the moment of leaving the launcher or runway.

   b. The period of flight from leaving the launcher to achieving an altitude where normal recovery can be effected and the flight phase begins.

3.2 LAUNCH PHASE PART 1

1. The hazards associated with the first part of the launch phase can be assessed under six main headings:

   a. **Explosive Hazards.** The explosive hazards are those associated with the normal process of Jet Assisted Takeoff/Rocket Assisted Take-off (JAT/RAT) and the abnormal functioning of any other explosive or pyrotechnic component of the UAS.

      (1) JAT/RAT operation produces hazards from the motor afflux and the debris it creates. The possibility of a JAT/RAT motor bursting must also be considered.

      (2) Other explosive components that may be present include such items as explosive bolts for releasing parachutes and pyrotechnic flares for enhancement when the UAS is used as a target. The premature operation of these devices during the launch phase and the effect on personnel should be considered.

      (3) Any electrical circuits associated with the initiation of explosive devices should be single fault safe. It is necessary to assess separately each explosive device as safe and suitable for service as required by appropriate national authorities.

   b. **Mechanical Failure.** Launchers that rely on stored energy, such as air pressure or tensioned cables, have hazards associated with the mechanical failure of their component parts. Many parts of the UAS will be under stress prior to launch and can fail; propellers are a good example. In addition, some UASs are restrained using mechanical linkages to allow thrust to develop. The possible effect of the failure of these mechanical components should be assessed with regard to the safety of the launch crew and range staff and appropriate hazard distances identified.

   c. **EMC.** The control system and the firing circuits may be vulnerable to electromagnetic interference. Consideration should be given to their compatibility with the specified electrical/electromagnetic environment.

   d. **Acoustic Hazard.** Acoustic levels in the vicinity of the launcher are often high, both from the UAS engine and from the launcher mechanism. Hearing protection will generally be required for those personnel in the immediate area of the launcher. Acoustic levels should be measured and a distance defined within which hearing protection should be worn.

e. **Toxic Hazard.** Toxicity associated with rocket motor efflux, fuel and other system components should be established and if found to be above an acceptable level as defined by appropriate national authorities, risk reduction measures are recommended; *e.g.,* operators may need to wear Personal Protective Equipment (PPE), respirators or breathing apparatus.

f. **Environmental Hazards.** The environmental hazards associated with fuel spillages and chemical leakages should be assessed and risk reduction measures taken if appropriate.

3.3 LAUNCH PHASE PART 2

1. The hazards associated with the second part of the launch phase, from the launcher or runway to a safe recovery height, include those associated with the discard of any launch stores and with the UAS hitting the ground with high energy, usually when it is too early for the recovery system to function fully. This can happen for one of two reasons:

a. A failure within the system which causes the UAS to crash. In this case the failure modes, such as an asymmetric launch in the case where a JAT/RAT motor acting as one of a cluster fails to function, should be identified. Once identified the effect of the failure mode on the UAS trajectory should be identified and possible points of impact identified. These should be plotted and account taken of the resulting debris dispersion. This can either be modelled or measured as a result of previous incidents.

b. The UAS is brought down on command by the operator or range safety staff. A recovery attempt could be commanded if the UAS was exhibiting characteristics such that its further flight was considered more hazardous than a ground impact in the launch danger area. The trajectory and debris dispersion should be accounted for.

2. The danger area for the second part of the launch phase will be made up of three parts:

a. The permissible flying area within which the UAS may fly until a safe recovery height is reached. The boundary at the edge of the area, called the destruct boundary, should not be crossed by the UAS and the flight should be terminated if it appears that the destruct boundary will be transgressed.

b. An area determined by the maximum distance that the UAS could travel, after flight has been terminated at the destruct boundary.

c. The area covered by the debris of the UAS if it breaks up on impact with the ground. This should include the effects of ricochet.

3.4 LAUNCH DANGER AREA

1. The launch danger should be calculated to contain all the consequences of potential hazards from both parts of the launch phase. Personnel should normally be excluded from the danger area with the exception of those authorised as essential launch personnel. Mitigating the hazards for these personnel through protection should be considered.

3.5 WIND CORRECTIONS

1. In many cases it will be necessary to impose wind restrictions on launch or to apply a wind correction to the launch danger area to cater for any wind induced travel of the UAS or debris.

INTENTIONALLY BLANK

CHAPTER 4
UAS FLIGHT

4.1 INTRODUCTION

1. The UAS should fly the intended track under normal conditions and, when its mission has been completed, should be recovered according to set procedures. If a fault occurs during flight and it can be determined that early recovery would be successful, the mission should be terminated and recovery initiated. The size of the danger area associated with this phase of flight depends on whether it is fitted with a Flight Termination System (FTS) or not. (A FTS terminates the UAS flight and returns the UAS to the ground either on command or automatically in the event of a failure within the UAS which render it unsafe). The FTS may, for example, stop the engine and deploy a parachute to bring the UAS down or move the aerodynamic controls in such a way as to put the UAS into a spiral dive. Alternatively an explosive component initiated by the FTS can be used to cause the UAS to break up. To be classed as a safety feature a FTS should terminate the flight of the UAS whenever a malfunction occurs within the FTS or when commanded.

2. The reliability of the FTS is crucial to the safe operation of the UAS in flight. A Failure Mode Effects and Criticality Analysis (FMECA) and/or a Fault Tree Analysis (FTA) should be performed on the FTS to demonstrate the consequences of component failures within it to establish the overall theoretical reliability. The criticality element should be completed to establish the consequences of single and double failures. The probability of such a single or double failure occurring should be ascertained either from a reliability parts count of the FTS or from the experience of a large number of FTS operations. If the probability of failure can be shown to be acceptably small, the in-flight danger area will consist only of the “footprint” resulting from FTS operation. Moreover, such a footprint is likely to be variable with height and wind and will depend upon a multiplicity of factors including the reaction time of the operator who terminates the flight, any delay in operation of the FTS and any inaccuracies in the UAS positional data which are available to the operator. The nature of these factors will vary from system to system and each will need to be assessed independently.

3. A UAS, fitted with a FTS, is inherently safer in operation than one without. However, it is accepted that there is often not room in a small UAS to fit the necessary equipment, neither is it always cost-effective. Under these circumstances it is necessary to perform a FMECA/FTA on the entire UAS system and ascertain the probability of any critical failure modes occurring. The consequences of possible failure will be assessed against their probability of occurrence and the worst that could occur, within the probability level set. This will be used to produce the danger area.

4. When a UAS is used as a target in the air for a weapon system, its break-up characteristics need to be considered. Differing modes of flight termination can produce variable distributions of fragment size and kinetic energy. These need to be assessed and the worst case assumed. Often it is possible to reassess the results in the light of service experience after a significant number of targets have been destroyed. Further, it is necessary to assess the effects of the FTS being damaged during an engagement.

5. Where there are several ways in which a UAS can be brought back to ground, their interdependence must be assessed and the worst case assumed throughout the flight. An example of this would be a target UAS fitted with a FTS. During those parts of its flight where it was not being engaged the FTS footprint would apply. However, once it was being used as a target, the larger of the FTS and break-up footprints would have to be used.

6. The locus of the UAS position is applied to the range such that no part of the applicable footprint goes outside the range boundary. This can be produced manually prior to a sortie or alternatively, if the range has the facility to generate traces within a computer, a moving dynamic danger area can be produced. The criticality and subsequent validation of the computing system would need to be examined if this method were employed.

CHAPTER 5
UAS RECOVERY

5.1 INTRODUCTION

1. There are two principle methods of recovery:

   a. Those where normal flight is terminated at a predetermined point and the UAS is brought to ground using an alternative system, such as a parachute. When a FTS is fitted, an analysis should be performed to demonstrate the reliability of the recovery system and a danger area produced which is variable with altitude and which takes account of wind.

   b. Those where normal flight is continued up until the moment of recovery; for example a conventional landing on grass or tarmac, or capture in a net. Normally a UAS danger area reduces as the UAS reduces altitude. However, FTS are often ineffective below a certain height and so the UAS may become more dangerous in the event of a failure during the later stages of a recovery approach. The recovery approach should take account of this potential hazard.

INTENTIONALLY BLANK

CHAPTER 6
OVERFLYING OF PERSONNEL ON RANGES

6.1 INTRODUCTION

1. Whilst target UAS are normally operated over cleared range areas, there are occasions when the overflight of personnel by other types of UAS is essential. For example, long-range reconnaissance UAS systems need very large range areas over which to practice and the clearance of all personnel from the range is often impractical and unnecessarily restrictive. Under these circumstances a system must be employed that permits the UAS to overfly with a level of risk such as to be As Low As Reasonably Practicable (ALARP), as agreed by the appropriate national authority.

2. Using a computer it is possible to calculate the risk to personnel on the range prior to each flight. A knowledge of the reliability of the system is used to provide an estimate for the probability of an incident resulting in injury. This probability is then checked against a value set by an appropriate national authority, taking account of the category of person using the range, *e.g.,* service user, civilian and general public. If the predicted risk is considered acceptable then the over flight of personnel could be agreed.

3. This procedure is able to reflect good or bad performance for the UAS system and also take account of the varying population density on the range. An example of this approach is given at Annex A.

INTENTIONALLY BLANK

CHAPTER 7
GENERAL SAFETY CONSIDERATIONS

7.1 INTRODUCTION

1. Danger areas should be reviewed periodically and in particular when there is a modification to any component which may alter the failure probability/impact probability.

2. Where UAS guidance relies significantly on operator skill there will remain the risk that the UAS could be poorly controlled to such an extent that safety may be compromised. This aspect cannot be assessed accurately and the risk is reduced on most ranges by the requirement for an independent control of the FTS by the Range Safety Officer (RSO). The hazard cannot, however, be ignored and so the RSO should ensure that:

a. All drills described in the relevant training manuals are strictly followed.

b. Range standing orders are clearly written, regularly reviewed and strictly enforced.

c. Copies of all relevant approved danger areas are held at the range.

d. Range maps/charts are up to date, show all relevant features in their correct positions and are overlaid with accurately drawn and correctly aligned danger areas traces.

e. Supervision of the flight controller is such as to minimise the possibility of gross human error or negligence.

f. Current meteorological information is used.

INTENTIONALLY BLANK

CALCULATION OF THE RISKS INVOLVED ON RANGES WHEN PERSONNEL ARE OVERFLOWN BY AN UAS

A1.1 TYPES OF RISK

1. Two separate risks need to be assessed regarding the operation of a particular UAS:

   a. The Individual risk to each range user during each flight of the UAS.

   b. The risk of an incident occurring on the range to any personnel associated with the range.

A1.2 ASSESSMENT

1. In conducting an assessment the range authorities need to know the following:

   a. The reliability of the UAS.

   b. The UAS debris area in the event of a crash.

   c. The duration of the flight.

   d. The number and type of personnel on the range.

2. To calculate these figures the following procedure is recommended:

A1.3 CALCULATION OF THE PROBABILITY OF AN ACCIDENT OCCURRING

1. Estimated rate of an unscheduled recovery is as follows:

$$NUR/HOF$$

Where, NUR is the Number of Unscheduled Recoveries from previous flights and HOF is the Hours of Flight to date.

2. The ratio of debris area to the range area is as follows:

$$A_d/A_r$$

where, A_d is the debris area (m^2) and A_r is the available range area. A_d must be less than A_r.

3. The estimated rate of incidents with an unscheduled recovery is as follows (per hours of flight):

$$(NUR/HOF)\times(A_d/A_r)$$

4. Let the probability of an incident be, λ

1= (rate of incident) x (planned hours of flight)

$$1=(NUR/HOF)\times(A_d/A_r)\times n$$

where, n is the planned hours of flight

5. Probability of no incidents is as follows:

$$\left(e^{-\lambda} \times \lambda^{o}\right) / (0!) = e^{-\lambda}$$

where, λ is small:

$$= 1 - \lambda$$

6. Probability of one or more incidents:

$$= 1 - (1 - \lambda)$$

$$= \lambda$$

7. The probability of at least one or more incidents, for *n* hours of flight and *N* personnel on range is:

$$P_{hit} = 1 \times N$$

$$P_{hit} = (NUR/HOF) \times (A_d / A_r) \times n \times N$$

NOTES;

a. Flight reliability. Flight reliability is defined as the ratio of the number of successful hours of flight achieved to the number of unscheduled recoveries or crashes (*HOF/NUR*). An initial estimate of the figure may be obtained from the mean time between failures for critical components within the UAS divided by the flight time. When sufficient experience has been obtained, the actual achieved reliability is employed in the above calculations.

b. Area of debris throw. the area (m^2) over which the UAS or its debris is likely to spread in a worse case impact with the ground. The kinetic energy and angle of impact together with the UAS structural strength and hardness of ground will determine the characteristics. The distance travelled by any fragment can be modelled as if it were a projectile.

8. It should be noted that although the analysis assumes that personnel are evenly distributed about the range the actual failure is considered to be a random event. Concentrations of people do occur on range *e.g.,* if buildings are overflown or troops are engaged in communal activities and therefore the probability of an incident does not define the seriousness of the incident which may result in no casualties, a single casualty or many casualties. This is known as a contagious distribution, *i.e.* groups may be affected and others missed, but on average for a large number of flights the estimated probability figure would be the result obtained.

A1.4 AUTHORITY TO FLY

1. The range authority permits the UAS to fly if the calculated probability of an incident is less than that set by the appropriate national authority. The appropriate national authority may set different values for service personnel, range staff and the general public.

A1.5 EXAMPLE SCENARIO

1. In this example the following assumptions are made:

   a. The UAS is launched and recovered in safe areas but during the sortie it flies over personnel deployed in a training area.

   b. Personnel deployed on the range are warned that UAS operations are taking place.

   c. Personnel have been briefed on the UAS operation, including the unscheduled recovery procedures, *i.e.* an emergency descent not in the recovery zone.

   d. The UAS is programmed to descend on a parachute which on occasions fails to operate as designed.

   e. In the event of an unscheduled recovery, audible and visual signals are emitted from the aerial System.

2. There are therefore two emergency situations and associated debris areas which have to be considered. The example combines these different situations into a probability of one or more incidents.

   a. Estimated rate of unscheduled recovery:

$$NUR/HOF$$

   b. Hypothetical probability of a person not clearing area, given above warnings and UAS descending on its parachute:

$$P_{nc}$$

   c. Estimated probability of parachute failure, (number of failures / number of recoveries):

$$P_{pf}$$

   d. Ratio of debris area to range area – parachute deployed:

$$A_{di}/A_r$$

   where, A_{di} is the debris area for UAS with parachute deployed and A_r is the total area of the range overflown by the UAS.

   e. Ratios of debris area to range area – parachute failure / crash descent;

$$A_{d2}/A_r$$

   where, A_{d2} is the debris area for a crash situation.

f. Estimated rate of, unscheduled recovery AND person not clearing area AND hit by UAS on parachute:

$$=(a)\times(b)\times(d)$$

g. Estimated rate of: Unscheduled recovery AND parachute failure AND person being hit by debris:

$$=(a)\times(c)\times(e)$$

h. Estimated ratio for: (*f*) or (*g*):

$$=(f)+(g)$$

i. From paragraph A103. 4. above the probability an incident, λ:

$$=(h)\times n$$

where, (*h*) is the rate and *n* is the hours of flight.

j. From paragraph A103. 7. above, the probability of one or more incidents where a person is hit by debris, for *n* hours of flight and *N* personnel on the range, P_{hit}:

$$=\lambda\times N$$

$$=(i)\times N$$

k. Allocating values to this example:

NUR	5					
HOF	160					
P_{nc}	0.01					
P_{pf}	0.025					
A_{di}	10					
A_{d2}	250					
A_r	5E+07					
n	4					
N	1	50	65	500	1000	2000
A	0.03125					
B	0.01					
C	0.025					
D	2E-07					

E	5E-06					
F	6.3E-11					
G	3.9E-09					
H	4E-09					
I	1.6E-08					
J	1.6E-08	7.9E-07	1.0E-06	7.9E-06	1.6E-05	3.2E-05

A1.6 RISK EVALUATION

1. If an appropriate national authority had set a P_{hit} of no greater than 1 in 10^6 (1.0E-6) then the UAS in this example would not be allowed to undertake a four hour flight when the number of people on the range exceeded 65. The individual range worker would be above this level of risk.

INTENTIONALLY BLANK

LEXICON

Air Danger Height (ADH). The Air Danger Height (ADH) is the maximum height Above Ground Level (AGL) at which hazards may exist ADH is measured in feet. (GoT)

Buffer zone. The three-dimensional area between a weapon danger boundary and a range danger boundary designed to increase the margin for error in WDA calculations.

Debris Zone. The three-dimensional area between the flight termination boundary and the weapon danger boundary.

Flight Termination System. The system fitted to a UAS used to terminate flight in the event of a designated flight terminate line being transgressed.

Hazard. Potential source of harm.

> Note: The term hazard can be qualified in order to define its origin or the nature of the expected harm
> (e.g. electric shock hazard, crushing hazard, cutting hazard, toxic hazard, fire hazard, drowning hazard).

Individual Risk (IR). The risk to a single person.

> Notes:
> 1. Annual individual risk has units of deaths per person per year.
> 2. Event individual risk has units of deaths per person per event.
> 3. Inidividual risk can be calculated for other consequences such as hit or injury.

Launch Danger Area. The space around the UAS in which personnel are at risk from system launch hazards and therefore the presence and protection of personnel is closely controlled.

Probability. A real number in the scale 0 to 1 attached to a random event.

> Note: It can be related to a long-run relative frequency of occurrence or to a degree of belief that an event will occur. For a high degree of belief, the probability is near 1.

Range Safety Equipment. The material used by the range authorities to control the UAS.

Risk. Combination of the probability of occurrence of harm and the severity of that harm.
Note: Frequency rather than probability may be used in describing risk.

Risk analysis Systematic use of available information to identify hazards and to estimate the risk.

Unmanned Aerial System. An aircraft which is designed to operate with no human pilot on board and which does not carry personnel.

Moreover, a UAS:

a. Is capable of sustained flight by aerodynamic means.
b. Is remotely piloted or automatically flies a pre-programmed flight profile.
c. Is re-usable.
d. Is not classified as a Guided Weapon or similar one shot device designed for the delivery of munitions.

Visual Flight Safety Officer. A nominated person who is responsible for the termination of UAS flight if the UAS is observed to cross a flight termination boundary.

Weapon Danger Area/Zone (WDA/Z) The WDA/Z as a proper subset of the TEA/Z, is a defined 2/3-dimensional space on the range, which is exposed to hazardous impacts or functioning of munitions, their fragments, or their sub-munitions, under normal firing conditions. There is an accepted low probability that munitions, fragments, sub-munitions or propelled debris may escape. The WDA/Z excludes gross human errors.

UAS Danger Area/Zone (UDA/Z) The UDA/Z is a defined 2/3-dimensional space on the range which is expected to contain the hazardous impacts and debris from the failure of a UAS. There is an accepted low probability that airframe components or propelled debris may escape. The WDA/Z excludes gross human errors.

REFERENCES

1. ARSP 01, Volume I, WEAPON DANGER AREAS/ZONES FOR UNGUIDED WEAPONS – DETERMINISTIC METHODOLOGY — FACTORS AND PROCESSES

2. ARSP 01, Volume II, WEAPON DANGER AREAS/ZONES FOR UNGUIDED WEAPONS – DETERMINISTIC METHODOLOGY — APPLICATIONS

3. ARSP-02, VOLUME 1, GUIDANCE OF THE DEVELOPMENT OF WEAPON DANGER AREA/ZONES - PROBABILISTIC METHODOLOGY- GENERAL PRINCIPLES

4. ARSP-02, Volume II, (Draft) GUIDANCE OF THE DEVELOPMENT OF WEAPON DANGER AREA/ZONES, PROBABILISTIC METHODOLOGY — APPLICATION TO UNGUIDED WEAPONS

5. STANAG 2921 (Edition 2) WEAPON DANGER ZONES FOR LAND LAUNCHED GUIDED MISSILES FOR USE BY NATO FORCES OPERATING IN A GROUND ENVIRONMENT, DATED 10 July 1997

6. STANAG 2402 (Edition 2) DANGER AREAS FOR LAND LAUNCHED UNMANNED AERIAL VEHICLES FOR USE BY NATO FORCES OPERATING IN A GROUND ENVIRONMENT ON MILITARY RANGES, DATED 17 January 1997

7. Proceeding 40860, Range-Safety of Surface-Launched Missiles, Ordnance Board, 1970

ARSP-02, VOL. IV(A)(1)