NATO UNCLASSIFIED

NORTH ATLANTIC TREATY ORGANIZATION
ORGANISATION DU TRAITE DE L'ATLANTIQUE NORD

MILITARY AGENCY FOR STANDARDIZATION (MAS)
BUREAU MILITAIRE DE STANDARDISATION (BMS)
1110 BRUSSELS

Tel : 707.55.79
Fax : 707.57.18
masarmy@hq.nato.int

17 January 1997 MAS(ARMY)412-NRS/2402

Army Board Distribution List No. 5

STANAG 2402 NRS (EDITION 2) - DANGER AREAS FOR LAND LAUNCHED UNMANNED AERIAL VEHICLES FOR USE BY NATO FORCES OPERATING IN A GROUND ENVIRONMENT ON MILITARY RANGES

References:

a. MAS(ARMY)011-NRS/2402 dated 22 May 1996

b. MAS(ARMY)454-MIS/2402 dated 17 December 1987 (Edition 1)

1. The enclosed NATO Standardization Agreement which has been ratified by nations as reflected in page iii is promulgated herewith.

2. The references listed above are to be destroyed in accordance with local document destruction procedures.

3. AAP-4 should be amended to reflect the latest status of the STANAG

ACTION BY NATIONAL STAFFS

4. National staffs are requested to examine page iii of the STANAG and, if they have not already done so, advise (insert as appropriate) through their national delegation as appropriate of their intention regarding its ratification and implementation.

G.B. FERRARI
Major-General, ITAF
Chairman, MAS

Enclosure:
STANAG 2402 (Edition 2)

STANAG No. 2402
(Edition 2)

NORTH ATLANTIC TREATY ORGANIZATION
(NATO)

MILITARY AGENCY FOR STANDARDIZATION
(MAS)

STANDARDIZATION AGREEMENT
(STANAG)

SUBJECT: DANGER AREAS FOR LAND LAUNCHED UNMANNED AERIAL VEHICLES FOR USE BY NATO FORCES OPERATING IN A GROUND ENVIRONMENT ON MILITARY RANGES

Promulgated on 17 January 1997

G.B. FERRARI
Major-General, ITAF
Chairman, MAS

RECORD OF AMENDMENTS

No.	Reference/date of amendment	Date entered	Signature

EXPLANATORY NOTES

AGREEMENT

1. This NATO Standardization Agreement (STANAG) is promulgated by the Chairman MAS under the authority vested in him by the NATO Military Committee.

2. No departure may be made from the agreement without consultation with the tasking authority. Nations may propose changes at any time to the tasking authority where they will be processed in the same manner as the original agreement.

3. Ratifying nations have agreed that national orders, manuals and instructions implementing this STANAG will include a reference to the STANAG number for purposes of identification.

DEFINITIONS

4. Ratification is "The declaration by which a nation formally accepts the content of this Standardization Agreement".

5. Implementation is "The fulfilment by a nation of its obligations under this Standardization Agreement".

6. Reservation is "The stated qualification by a nation which describes that part of this Standardization Agreement which it cannot implement or can implement only with limitations".

RATIFICATION, IMPLEMENTATION AND RESERVATIONS

7. Page iii gives the details of ratification and implementation of this agreement. If no details are shown it signifies that the nation has not yet notified the tasking authority of its intentions. Page iv (and subsequent) gives details of reservations and proprietary rights that have been stated.

STANAG 2402
(Edition 2)

NAVY/ARMY/AIR

NATO STANDARDIZATION AGREEMENT (STANAG)

DANGER AREAS FOR LAND LAUNCHED UNMANNED AERIAL VEHICLES FOR USE BY NATO FORCES OPERATING IN A GROUND ENVIRONMENT ON MILITARY RANGES

Annex : A. Guidelines for the Production of Land Launched Unmanned Aerial Vehicle Danger Areas on Military Ranges

Related documents: None

AIM

1. The aim of this agreement is to standardize the method by which the danger areas on military ranges for land launched unmanned aerial vehicles (UAV) are determined.

AGREEMENT

2. Participating nations agree:

   a. That the terminology defined in this agreement and the allowances recommended for the various hazards shall, where possible, be used in the preparation of national danger areas.

   b. That UAV danger areas for all ranges intended for use by NATO forces shall be based on the principles in this agreement and that the data used to determine the dimensions of each danger area shall be available on request to the forces of NATO countries.

   c. To consider this STANAG as a basis for continuing a working relationship on the preparation of danger areas for individual UAV.

DEFINITIONS

3. The following terms and definitions are used for the purpose of this agreement:

   a. Range Danger Area - That area associated with the range in which unauthorised ships, personnel and equipment

			may need to be controlled for reasons of safety.
b.	Unmanned Aerial Vehicle	-	An unmanned vehicle flying over the surface of the earth which is not a guided missile. It is aerodynamically supported, controllable and usually recoverable.
c.	Flight Termination System	-	A system fitted to a UAV used to terminate flight in the event of a designated flight terminate line being transgressed.

GENERAL

4. This agreement is concerned primarily with assessing the various hazards associated with launch, flight and recovery of land launched UAV and discussing the factors which should be considered when determining the extent of the danger zone. Detailed safety advice applicable to specified UAV danger areas in order to define range danger areas is the responsibility of the appropriate national authority. This agreement is concerned with the determination of UAV danger areas and all references to danger areas indicate UAV danger areas unless otherwise stated.

IMPLEMENTATION OF THE AGREEMENT

5. This STANAG 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.

ANNEX A TO
STANAG 2402
(Edition 2)

GUIDELINES FOR THE PRODUCTION OF LAND LAUNCHED UNMANNED AERIAL VEHICLE DANGER AREAS ON MILITARY RANGES

BACKGROUND

1. Unmanned aerial vehicles (UAV) are increasingly being used for both surveillance purposes and as targets for weapon systems. When considering range safety requirements for UAV, 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 UAV 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 UAV. 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 UAV performance characteristics and in some cases as the result of post-accident investigations. It is, therefore, desirable to agree a scientific basis on which danger areas can be constructed. If it is intended to operate the UAV outside a military range then clearance should be obtained from the appropriate national aviation authority.

SAFETY CONSIDERATIONS AND HAZARDS

2. The hazards associated with UAV flights can be considered in 4 distinct operational phases; they are:

a. Launch.

b. Flight.

c. Recovery.

d. Overflying of personnel on ranges.

LAUNCH

3. General. There are a number of different methods used to launch UAV. The launch phase can be divided into 2 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.

4. Launch Phase Part 1. The hazards associated with the first part of the launch phase can be assessed under 6 main headings:

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

(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 UAV 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 UAV will be under stress prior to launch and can fail; propellers are a good example. In addition, some UAV 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 UAV 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 afflux, 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 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.

5. Launch Phase Part 2

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

(1) A failure within the system which causes the UAV 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 UAV 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.

(2) The UAV is brought down on command by the operator or range safety staff. A recovery attempt could be commanded if the UAV 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.

b. The danger area for the second part of the launch phase will be made up of 3 parts:

(1) The permissible flying area within which the UAV 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 UAV and the flight should be terminated if it appears that the destruct boundary will be transgressed.

(2) An area determined by the maximum distance that the UAV could travel, after flight has been terminated at the destruct boundary.

(3) The area covered by the debris of the UAV if it breaks up on impact with the ground; this should include the effects of ricochet.

6. Launch Danger Area. 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.

7. Wind Corrections. In many cases it will be necessary to impose wind restrictions on launch or to apply a wind correction to the launch danger area.

FLIGHT

8. The UAV 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. 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 is one that terminates the UAV flight and returns the UAV to the ground either on command or automatically in the event of a failure within the UAV which render it unsafe.) The FTS may, for example, stop the engine and deploy a parachute to bring the UAV down or move the aerodynamic controls in such a way as to put the UAV into a spiral dive. Alternatively an explosive component initiated by the FTS can be used to cause the UAV to break up. To be classed as a safety feature a FTS should terminate the flight of the UAV whenever a malfunction occurs within the FTS.

9. The reliability of the FTS is crucial to the safe operation of the UAV 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 UAV 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.

10. A UAV, 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 UAV 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 UAV 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, will be used to produce the danger area.

11. When a UAV is used as a target for an exercise munition in the air 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.

12. Where there are several ways in which a UAV 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 UAV 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.

13. The locus of the UAV 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.

RECOVERY

14. There are 2 principal methods of recovery. They are:

a. Those where normal flight is terminated at a predetermined point and the UAV 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 UAV danger area reduces as the UAV reduces altitude. However, FTS are often ineffective below a certain height and so the UAV 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.

OVERFLYING OF PERSONNEL ON RANGES

15. Whilst target UAV are normally operated over cleared range areas, there are occasions when the overflight of personnel by other types of UAV is essential. For example, long-range reconnaissance UAV systems need very large range areas over which to practise 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 UAV to overfly with a level of risk such as to be as low as reasonably practicable, as agreed by the appropriate national authority.

16. 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, i.e. service user, civilian, etc. If the predicted risk is considered acceptable then the overflight of personnel could be agreed.

17. This procedure is able to reflect good or bad performance for the UAV system and also take account of the varying population density on the range. An example of this approach is given at Appendix 1.

GENERAL SAFETY CONSIDERATIONS

18. 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.

19. Where UAV guidance relies significantly on operator skill there will remain the risk that aerial vehicles 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.

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

TYPES OF RISKS

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

   a. The individual risk to each range user during each flight of the UAV.

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

ASSESSMENT

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

   a. The reliability of the UAV.

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

   c. The duration of the flight.

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

To calculate these figures the following procedure is recommended.

3. Calculation of the Probability of an Accident Occurring

   a. Estimated rate of an unscheduled recovery is NUR/HOF

   Where: NUR = Number of unscheduled recoveries from previous flights
   HOF = Hours of flight to date

   b. The ratio of debris area to the range area is A_d/A_r

   Where: A_d = Debris area (m^2)
   A_d must be less than A_r

   c. The estimated rate of incidents with an unscheduled recovery

   $(NUR/HOF)*(A_d/A_r)$ per hour of flight

   d. Let the probability of an incident be λ

l = (rate of incident)*(Planned hours of flight)

= $((NUR/HOF)*(A_d/A_r))*n$

Where n = planned hours of flight

e. Probability of no incidents

= $(e^{-\lambda}*\lambda^0)/0! = e^{-\lambda}$

= $1-\lambda$ where λ is small

f. Probability of one or more incidents

= $1-(1-\lambda)$

= λ

g. Probability of at least one or more incidents, for n hours of flight and N men on range

P_{hit} = 1*N

= $(NUR/HOF)*(A_d/A_r)*n*N$

4. 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 UAV 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 (A_d). The area (m^2) over which the UAV 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 UAV structural strength and hardness of ground will determine this characteristic.

c. 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; i.e. if buildings, etc., 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.

5. Authority to Fly. The range authority permits the UAV 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. The risk to an individual member of the range staff is assessed using the calculations described in paragraph 3 and setting the number of personnel N to 1.

Example

6. Scenario. In this example the following assumptions are made:

a. The UAV 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 UAV operations are taking place.

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

d. The UAV 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 vehicle.

7. There are therefore 2 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 (a)

b. Hypothetical probability of a person not clearing area, given above warnings, and UAV descending on its parachute P_{nc} (b)

c. Estimated probability of parachute failure, (number of failures/number of recoveries) P_{pf} (c)

d. Ratio of debris area to range area - parachute deployed A_{d1}/A_r (d)

where A_{d1} is the debris area for UAV with parachute deployed and A_r is the total area of the range overflown by the UAV.

e. Ratios of debris area to range area - parachute failure/ crash descent A_{d2}/A_r (e)

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 UAV on parachute

= (a)*(b)*(d) (f)

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

= (a)*(c)*(e) (g)

h. Estimated rate for: (f) OR (g)

= (f)+(g) (h)

i. From paragraph 3.d. above the probability an incident, λ

= rate * hours of flight

= (h)*n (i)

j. From paragraph 3.g. above the probability of one or more incidents where a person is hit by debris, for n hours of flight and N men on the range, P_{hit}

= λ * N

= (i) * N (j)

g. Allocating Values to this Example.

NUR	5					
HOF	160					
P_{nc}	0.01					
P_{pf}	0.025					
A_{d1}	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

9. Risk Evaluation. If an appropriate national authority had set a P_{hit} of no greater than 1 in 10^6 (1.OE-6) then the UAV in this example would not be allowed to undertake a 4 hour flight when the number of people on the range exceeded 65. The individual range worker would be well below this level of risk.