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WEAPON DANGER AREAS / ZONES FOR UNGUIDED WEAPONS – DETERMINISTIC METHODOLOGY – FACTORS AND PROCESSES

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RECORD OF SPECIFIC RESERVATIONS

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CHAPTER 1 INTRODUCTION

1.1. RANGE SAFETY

1.1.1.

The Range is a three dimensional space (zone) reserved, authorised and normally equipped for hazardous firings. Even if it is treated as two-dimensional space (area), usually an air danger height (see Chapter 3, paragraph 0303) has to be considered. Hence, this document is going to focus on Weapon Danger Zones (WDZ) rather than on Weapon Danger Areas (WDA).

1.1.2.

The aim of Range Safety is to minimise risk to the general public, civilian and military personnel arising from hazardous range activities to an acceptable level. Range Safety is the summation of a series of different issues that guarantee on the whole a safe procedure of firing. A survey is given in Annex A. Exterior safety (see paragraph 0103) is a main issue of Range Safety.

1.2. RISK

The dimensions of a WDZ can be calculated by deterministic and/or by probabilistic methodologies. The development of WDZ involves the line between acceptable (tolerable) and non-acceptable (non-tolerable) risk. Risk is the combination of the probability and the consequence of a hazard (see Chapter 2). The level of acceptance is a national issue and prescribed in national policies. Acceptance of risk does not mean that risk is non-existent. It refers to a willingness to live with a risk of a particular technical process or condition that is regarded as acceptable (tolerable) in the circumstances in question. ARSP-01 provides a basic methodology for containing unacceptable risk.

1.3. EXTERIOR SAFETY

Exterior safety relates to people who are not involved in the firing. To ensure exterior safety on the range surface and in the height appropriate WDZ are to be applied. Any WDZ directly marks the line between acceptable risk and non-acceptable risk when its development is based on risk analysis. Each WDZ is designed to allow a specific level of risk outside its three dimensional boundaries and in this way it is a proper subset of the Total Energy Zone (TEZ). The control of WDZ boundaries is a responsibility of Range Safety.

1.4. INTERIOR SAFETY

Interior Safety relates to personnel performing the firing. Special safety procedures are used to protect those persons.

1.5. OTHER ISSUES

Noise-, overpressure and toxicity hazards fall in this category. Safety in operation and operation controlling, pollution and contamination control and open fire protection, medical coverage, clearing duds and blinds as well as the training and exercising of personnel are other components of Range Safety.

1.6. HAZARDS OF A FIRING

A key element of Range Safety is the application of WDZ. To establish WDZ possible hazards involved in each firing have to be identified and analysed. The consequences and characteristic parameters of the ballistic flight of any projectile will influence the design and dimension of WDZ in relation to the expected hazards. The various connections and related factors are displayed in a diagram in Chapter 2 (Figure 2.1).

1.7. SCOPE OF THIS PUBLICATION

1.7.1.

This publication will relate only to factors and processes, which govern the development of <u>range</u> <u>independent</u> (universally valid) WDZ for <u>unguided weapons used in the direct or indirect firing mode</u>. It is the aim to make the description of the factors calibre/weapon independent whenever it is appropriate. Numerical values for factors will be given in ARSP-01 Volume II.

1.7.2.

Normally, the produced WDZ will be used for training purposes. In operational cases specific safety distances to weapons and weapon systems are needed which are not subject of ARSP-01 Volume I and II.

1.7.3.

Publishing an air danger height for the range or each weapon will ensure aircraft safety.

1.7.4.

Certain features of range design will affect the dimensions of the required WDZ. Protective structures (e.g. stop butts or special infrastructure like baffled ranges or indoor ranges) may be used to reduce WDZ dimensions to a minimum in a safe way. To go into detail on these options is not the subject of the ARSP-01 Volumes.

1.7.5.

Certain features of range design will affect the dimensions of the required WDZ. Laser hazards are considered in ARSP-04. When the laser is part of or connected to a weapon (system) the laser will be influenced by the weapon behaviour during firing. An item to consider also is the difference between the line of fire and laser beam both horizontally and vertically. The (Laser) Normal Hazard Zone as well as the Weapon Danger Zone will have to be taken into account when preparing for a firing exercise.

1.8. PRODUCING THE WDZ

The way a WDZ for a specific weapon will be developed is subject of ARSP-01 Volume II "Applications".

1.9. THE VOLUMES OF ARSP-01

1.9.1.

The ARSP-01 Volumes are only concerned with weapon systems currently in use by the armed forces of member nations and not with experimental systems or weapons, which have not completed their development.

1.9.2.

The WDZ models developed in these Volumes will be based on deterministic methodologies. In addition, the error budget for the free flight will be considered.

1.9.3.

The WDZ will be developed for unguided spin- or fin stabilised projectiles of all calibres (small, medium, large) and of all kinds including mortars, artillery rockets and sub-munitions released from carriers. The WDZ will cater for ricochets and fragmentation every time those events occur.

1.9.4.

Direct-fired rockets will be treated as fin-stabilised projectiles.

1.9.5.

Indirect fired rockets will be treated as fin-stabilised projectiles (artillery munition). Mortars are treated as fin-stabilised projectiles. Rifled mortars (spin stabilized) are treated as artillery projectiles.

1.9.6.

If for any unguided weapon a deterministic WDZ solution cannot be found a probabilistic approach is advised (ARSP-02 Volumes).

1.10. THE SERIES OF ARSP

The diagram in Figure 1.2 shows the position of the ARSP-01 Volumes (Deterministic Methodology) in relation to the issued/drafted/planned ARSP-02 Volumes (Probabilistic Methodology), ARSP-03 Volumes (Data Acquisition and Analysis) and ARSP-04 Volumes (Lasers).

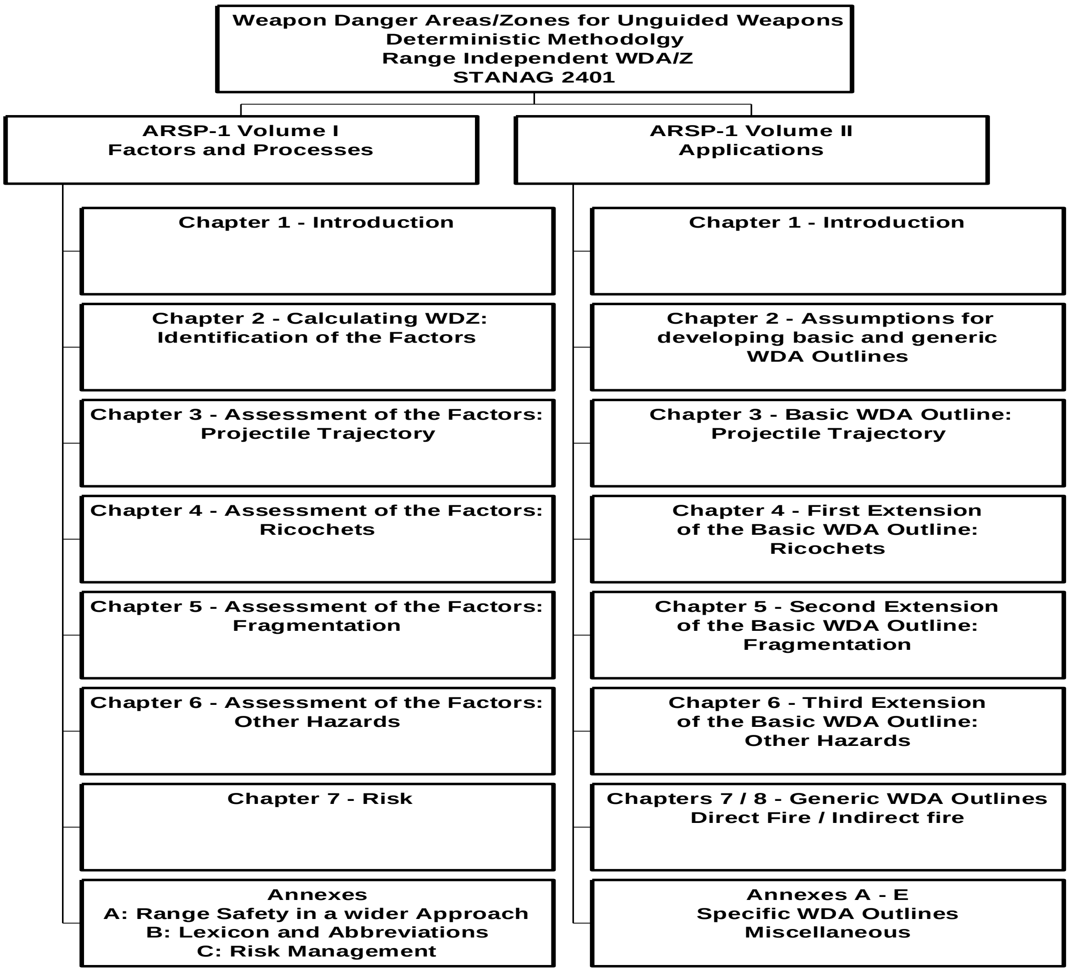

Figure 1.1: The two Volumes of ARSP-01 for the Deterministic Methodology

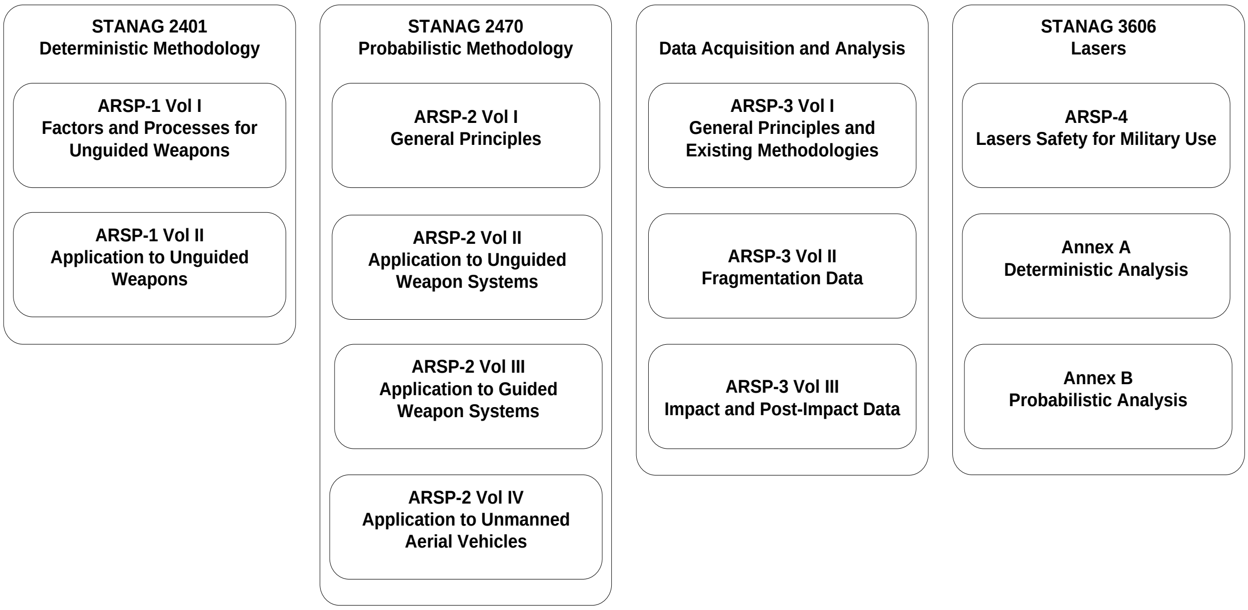

Figure 1.2: The Series of ARSPs and their Volumes

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CHAPTER 2 CALCULATING WDZ: IDENTIFICATION OF THE FACTORS

2.1. SOURCES OF HAZARDS AND ASSOCIATED FACTORS

2.1.1.

There are various main sources for hazards a fired projectile may cause: the projectile's trajectory, projectiles interaction with targets and surface (ricochets, back splashing projectile- and target parts), fragmentation (incl. debris) and other hazards.

2.1.2.

The following flow chart shows these characteristic sources besides other ones and their associated factors that have to be considered when developing WDZ. The assessment of the factors related to these flow charts is the subject of the Chapters 3 - 6. In Chapter 7 and Annex C special factors regarding risk assessment (in the wider area of risk management) for WDZ calculation will be presented. Type of targets will be addressed in ARSP-01 Vol. II (Chapter 2).

2.1.3.

Article/paragraph numbers in the individual blocks refer to the articles/paragraphs in which these factors are addressed. A selection of often-used terms, definitions and abbreviations is contained in Annex B (Lexicon).

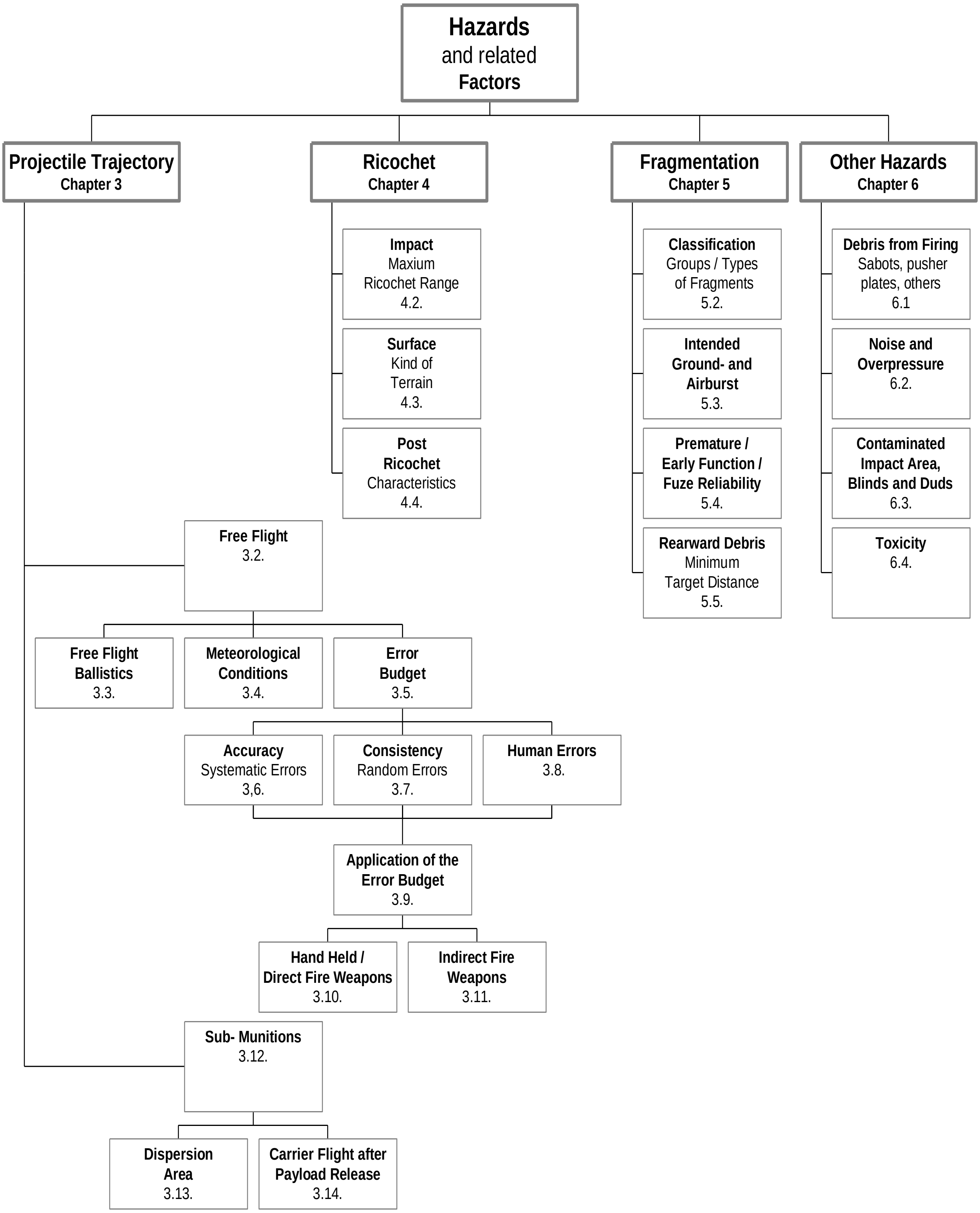

Figure 2.1: Hazard Diagram

CHAPTER 3 ASSESSMENT OF THE FACTORS: PROJECTILE TRAJECTORY

3.1. INTRODUCTION

The ballistic flight of a projectile results in a sequence of possible hazardous events, which contribute to the WDZ. Following the diagram in Figure 2.1, the first step is to examine the free flight of the projectile and their sub-munitions if designed for. Most attention is given to indirect fired projectiles.

3.2. FREE FLIGHT

3.2.1.

The free flight (first trajectory) of a projectile starts at the muzzle of the barrel or tube (for sub-munitions at the point of release) and terminates

a. when hitting an obstacle like the target or impacting the surface (including PD fuses),
b. in the proximity of the target (by using PROX fuses),
c. after a pre-set time (TIME fuses, e.g. airburst),
d. when destroying itself if designated for.

3.2.2.

The trajectory of a carrier (a payload ejecting projectile) in the event of a fuse failure (payload not ejected) must also be calculated for the WDZ. For base-burn, rocket-assisted projectiles and artillery rockets a special WDZ has to cater for the possibility of motor failure or reduced effects.

3.3. FREE FLIGHT BALLISTICS

3.3.1.

No reliable WDZ for general use can be published, unless the ballistic properties of the projectile in free flight have been accurately determined during development. To take into account the effects of free flight it is necessary to have the ability to calculate the complete trajectory of the projectile for any given sets of ballistic data, meteorological conditions and topographical data. Trajectories can be calculated by specific software programs (based on common ballistic models as Point Mass Model, Modified Point Mass Model (for both models see STANAG 4355). Those programs must be proved to deliver reliable results. The input/output data and the software programs have to be at least as good as the calculated WDZ. The general use of standardised software for fire control is optional.

3.3.2.

A selection of ballistic input data (not all relevant for the variety of considered projectiles) is:

a. Weapon system and type of projectile
b. Muzzle velocity (and number of charge) or releasing velocity (sub-munitions)
c. Quadrant/super-elevation
d. Fuse setting (e.g. time of flight, distance)
e. Ballistic coefficients (e.g. drag coefficients)
f. Meteorological conditions (esp. range wind (speed and direction))
g. Relative height to sea level.

3.3.3.

For calculating WDZ additional data are required (data to be produced by using the standards of the International Civil Aviation Organisation (ICAO) or specific weather conditions):

a. Maximum ordinate (vertex, for determining air danger height)
b. Maximum range or range for given elevations (a contribution to the WDZ length)
c. Time of flight
d. Angle of impact (for estimates of possible ricochets)
e. Maximum Ricochet Range (MRR) or critical elevation (QE_{crit}), see Chapter 4, paragraph 0402
f. Range of the projectile in case of no burner/motor function (artillery, only for Base Burn (BB) projectiles and Rocket Assisted Projectiles (RAP))
g. Ejection point, including height (carriers)
h. Range of empty carriers after ejecting the payload
i. No fuse function (full trajectory without ejection point)
j. Impact media (e.g., hard [steel] or soft [earth])

3.3.4.

Further inputs for trajectory calculations of indirect fired projectiles are:

a. Weapon and target coordinates, range (or elevation) and azimuth to target
b. Meteorological data (METGM STANAG 6022, METCM STANAG 4082, METB STANAG 4061)
c. Fire Control Input (FCI) data or data from firing tables (STANAG 4119).

3.3.5.

For WDZ vertical hazards must be taken into account for aircraft safety (see Figure 3.1). Vertical hazards encompass the vertex (maximum ordinate) of the free flight and following ricochets, and fragment heights (Normal Burst Safety Distance (NBSD), see Chapter 5, 0503).

3.3.6.

A common practice is to set a fixed level above the entire range for airspace safety. The altitude will be calculated by the maximum vertex of all expected trajectories.

a. For indirect fired projectiles including artillery rockets it is recommended to use either the vertex of the free flight trajectory of the highest elevation on which the firing is planned or the vertex of the Maximum Ricochet Range trajectory (Chapter 4, paragraph 0402) whatever is greater.

b. For direct fire weapons the maximum vertex of all first trajectories and possible ricochets after impact are necessary. This method requires real post-impact data from trials. In case of missing data for direct fire weapons and low angle fire the vertex of the Maximum Ricochet Range belonging to that kind of weapon, will give a safe choice for example.

c. For HE projectiles fired in the direct or indirect firing mode the maximum fragment radius (Chapter 5, paragraph 0503) should be added to the chosen vertex height depending on the fuse design.

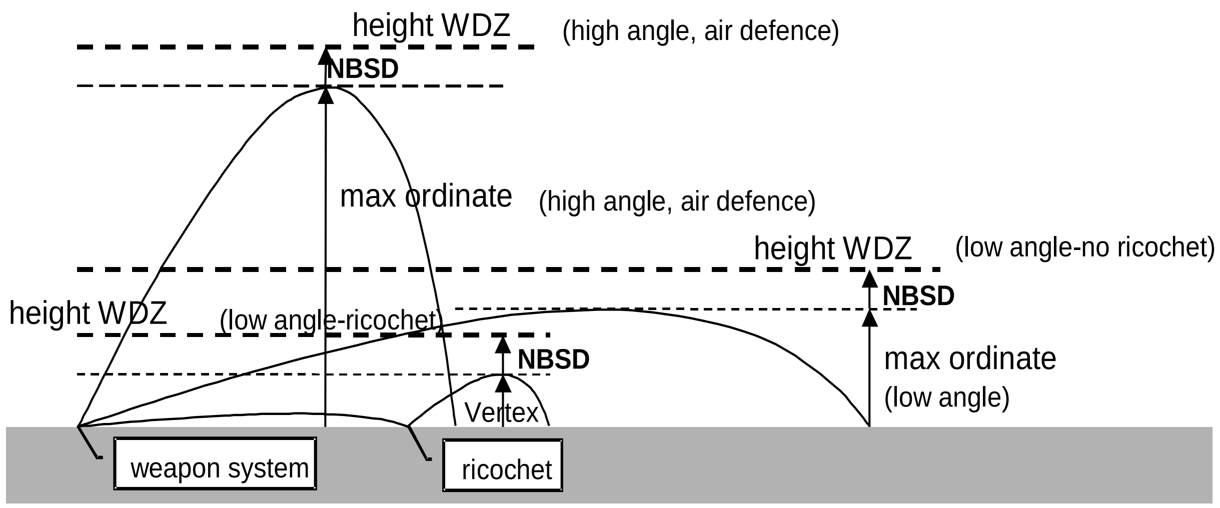

Figure 3.1: Air Danger Height (In contrast, see figure 4.1.)

3.4. METEOROLOGICAL CONDITIONS

3.4.1.

The trajectory of a projectile is influenced by atmospheric conditions, which is a major effect for indirect fired projectiles. Air density and wind are the most significant. A tail wind will increase the range of a projectile fired at a given elevation and similarly a cross wind will cause a lateral deviation and a head wind will reduce the range. All other wind directions between them are also important for WDZ calculations. When firing rocket-propelled projectiles, it is of particular importance to have updated information about the wind conditions in the boost phase part of the trajectory. Rockets are especially susceptible to crosswind during this phase. Low air pressure and high temperatures will result in a greater projectile range. When firing at increased altitudes, air pressure and temperature are also significant. All these effects need to be considered when calculating WDZ.

3.4.2.

Generally, meteorological (met) conditions will be incorporated into the fire control input if applicable. Basic met conditions will meet the requirements of the ICAO standards. Local orders and procedures will determine the sources from which to take the meteorological data.

3.4.3.

For weapons without fire control systems (e.g. hand held weapons), the firer will make adjustments for met conditions, otherwise extra margins of safety will often be added. For direct fire weapons utilising fire control systems, and indirect fire weapons it is assumed that some data on wind speed, wind direction, temperature and atmospheric pressure will be available before firing, and that the effects of meteorological data will have been considered during trajectory calculation. An extra safety allowance needs to be added for the variability of meteorological data (cf. sub-paragraph 3.11.4d).

3.5. ERROR BUDGET

The error budget encompasses different sources of errors mainly for first trajectories. The errors are divided into random and systematic errors, which are described below and displayed in a scheme (Figure 3.2) in sub-paragraph 3.7.4. For indirect fire (excluding rockets), the overall error budget is contained in STANAG 4635 (“The NATO Error Budget Model” representing the NATO Armaments Error Budget (NAEB)). Here, for indirect fire a reduced NAEB (abbreviated EB) is considered.

3.6. ACCURACY

3.6.1.

For a mission, accuracy is a systematic error and measured by the distance between the mean point of impact (MPI) and the aiming point. This distance is called bias or MPI error. From occasion to occasion (or from salvo to salvo), the bias may have its own distribution which means the dispersion of the MPI around the aiming point.

3.6.2.

The bias originates in irregularities, which are specific to each weapon system. Systematic errors in met conditions also contribute to the bias. When firing the same gun under identical conditions, zeroing can reduce the bias.

3.7. CONSISTENCY

3.7.1.

The consistency or round-to-round (RTR) error of a firing is determined by the dispersion of the impacts around the mean point of impact (MPI). The finite number of projectiles fired on a single occasion under identical conditions being distributed around the MPI will produce precision errors in range and deflection. This dispersion is due to random variations in meteorological and firing conditions (e.g. weapon system, projectile, charge). Thus, RTR errors are random errors.

3.7.2.

Generally, RTR errors are based on normal distributions. For direct fire the RTR errors are measured in standard deviations (sd) in range and height (for vertical targets), which may be transformed into a single sd (circular distribution). For indirect fire, the precision errors are normally characterised by probable errors (PE) in range and in deflection (for horizontal targets). PE data are laid down as <u>one</u> PE (equivalent to $0.6745 \bullet$ sd) data (in range and deflection) in firing tables. The errors taken into account for these PE values are listed in Annex I of STANAG 4144. As opposed to MPI errors, RTR errors cannot be reduced by zeroing. For details, see ARSP-01 Volume II (Annex E, Appendix 1).

3.7.3.

When systematic errors are known, they may be combined with RTR errors by standard formulas as a total error, and included in the WDZ calculations.

3.7.4.

A diagram (Figure 3.2) displays relations between RTR and MPI errors and the resulting total error $\sqrt{\text{RTR}^2 + \text{MPI}^2}$.

- The RTR error varies with each projectile causing the dispersion around the MPI. This is known as consistency.
- The MPI error is the same for each projectile of the series and causes the bias. This is known as accuracy.
- Firing a series of n projectiles on one Occasion $x \leq n$

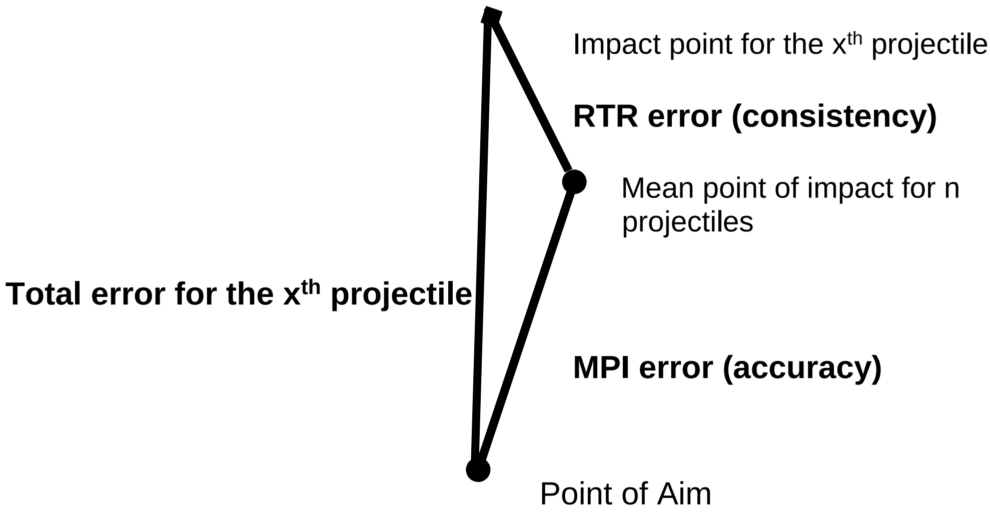

Figure 3.2: Total Error

3.8. HUMAN ERROR

3.8.1.

Unpredictable human error is the inevitable consequence of having a human component in most weapon systems (deliberate human error is not considered in this agreement). The problem of unpredictable human action is greatest for weapon systems where the largest single safety factor is the allowance made for gross human error. These considerations are mostly applicable to small calibre projectiles.

3.8.2.

For direct fire (mounted weapons), the task of aligning sight and target is largely mechanised. When firing from a static position, the aiming error will be small and is best combined with weapon system errors as an overall system error. When firing from a moving vehicle/platform, the aiming error may be greater and a separate allowance should be made. For indirect fire, weapon systems may be subject to gross error from a variety of causes: wrong charge loading, incorrect munition data (including fuse setting) for the aiming system, wrong target or gun position, inaccurate meteorological (met) data.

3.8.3.

For the ARSP-01 Volumes I and II misdirected shots or wrong target engagements, wrong charge loading, incorrect munition data, or wild firing will not be taken into account. Range control, skill and discipline are described in Annex A.

3.9. APPLICATION OF THE ERROR BUDGET

When error budgets are used for the development of WDZ it is advisable to distinguish between two different modes of engagement: Firing with hand held/direct fire weapons or firing in an indirect mode (see for definition the Lexicon in Annex B).

3.10. HAND HELD WEAPONS / DIRECT FIRE WEAPONS

Predictable but inevitable human errors have to be taken into account. The error budget for mounted direct fire weapons will normally be smaller than that for hand held weapons (see paragraph 3.8.). In either case, a measure for aimer error can be determined by evaluating aimer error statistics. For overall valid WDZ, a maximum deviation is to be established.

3.11. INDIRECT FIRE WEAPONS

3.11.1.

Because of extended ranges up to 40 km and more of artillery firings, the error budget for indirect fire is a significant issue. The EB (see paragraph 3.5) lists MPI and RTR errors (see sub-paragraph 4) which affect the projectile's accuracy and consistency for different delivery techniques. The EB is only valid for the first trajectory and does not cater for any ricochet. In comparison ricochets significantly contribute to the size of the WDZ, the EB has minor significance for its dimensions (only if ricochets are expected).

3.11.2.

For indirect fire, it may be assumed that the delivery of the first projectiles is not accurate because of some missing or incorrect/old data. Limited to one occasion the total error of the first shots can be handled by identifying a sufficiently large impact area, and firing these shots into its centre to enable adequate corrections for the following shots (corrected fire technique). In this case, RTR and MET errors are contributions for calculating artillery WDZ.

3.11.3.

Indirect fire WDZ can be delivered as ready-to-use (they will not be influenced directly by applying real data for the EB). However, prior to the development of WDZ the EB is used to calculate RTR-errors in range and deflection (STANAG 4144). Another method is to give extra allowances for the (unknown for the first shots) RTR and MPI errors to be incorporated into a basic WDZ calculation. By applying the methods of the EB in an iterative process during firing, the fitting WDZ will then be developed step by step by using true data for the errors.

3.11.4.

The following basic errors (of EB) and their type (ME (= MPI Error) or RE (= RTR Error)) may not apply to the whole of the variety of the considered projectiles and mostly they are applied to indirect fire weapons.

a. **Launch Errors** resulting from variations in weapon locations (gun point) [ME], firing direction [ME], verification of the gun [ME], aiming data of the gun [RE], muzzle velocity [ME, RE], tip-off errors [RE]

b. **In-flight Errors** resulting from variations in MET conditions [ME; RE], projectile aerodynamic data [ME, RE], fuse setting parameters [RE], propulsion errors (e.g. BB-element burn time error) [ME, RE].

c. **Muzzle Velocity** variations occur for the following reasons: Barrel wear [ME], charge composition (type) [ME], new propellant (lot) [ME], charge temperature [RE], round to round variation [RE], projectile mass/size [RE], ram depth inconsistency [RE].

d. **Error Sources** in the indirect fire MET messages are instrumentation errors [ME]; errors in measuring wind, temperature, pressure, humidity [all ME]. Modelling error: Error from modelling of the MET messages [ME]. Spatial error: Error from the distance (space staleness) between sonde measurement and the actual trajectory of the projectile for each height zone [ME]. Time error: Error from time staleness between the sonde measurement and the real trajectory of the projectile for each height zone [RE].

3.11.5.

Joint RTR/MPI error formulas (for standard normal distributions) for some indirect fire delivery models are listed in STANAG 4635 and ARSP-01, Volume II (Annexes C and E).

3.11.6.

Often, only the sd data from trials or PE data from firing tables are known, from which the WDZ have to be determined. In that case, it is recommended to add an extra margin of safety to accommodate those above-described errors, which are not covered by these data.

3.12. SUB-MUNITIONS

Certain projectiles for direct and indirect fire are designed to function as a carrier: e.g. Kinetic Energy Time Fused (KETF) projectiles, Improved Conventional Munitions (ICM). Carrier or particular rockets unload special devices (e.g. bomblets/grenades, smoke or illumination canisters, sub-calibre projectiles) which have a portion of the inherent velocity of its carrier. The trajectories of those devices originate at the point of unloading (c.f. fuse setting) and are called secondary trajectories. They have adherent the error budget of the carrier and their subsequent own error budget, which is similar to the above one. The calculation of the secondary trajectories often requires special simulation models that are adapted to the payload. These models deliver additional data for the design of the WDZ for the carrier shell and its payload. Other particular issues as failure modes at different stages, in addition to proper functioning, must be considered.

3.13. SUB-MUNITION DISPERSION AREA

3.13.1.

Released bomblets/grenades normally produce an elliptically shaped pattern around the impact point of the central bomblet/grenade. The covered area is part of the WDZ. The dimension of the pattern depends on the parameters of the ejection point (height, trajectory angle, carrier velocity, ejection velocity and error budget, met conditions and sub-munition trajectories).

3.13.2.

Special artillery carriers release sensor fused sub-munitions that also produce dispersion areas on the range surface. Those sub-munitions may descend on parachutes and thus their error budget is strongly affected by meteorological conditions. At a pre-set height, the detection will begin and further on, the sub-munitions will be armed. It is recommended to use the detection radius as basis for calculating the WDZ. Sensor fused sub-munitions may have a self-destroying mechanism, which will be activated when the sub-munition is on the range in an undefined position. The maximum range of the explosively formed penetrator determines the radius of the circle to protect against this hazard.

3.13.3.

Illumination, smoke devices or the like are treated similarly.

3.13.4.

In the following Figures 3.3 and 3.4 those points are displayed, which have to be considered when developing WDZ for carriers (e.g. smoke, illumination, ICM) and special carries with sensor-fused sub-munitions. Only the range components are shown. Deflection/lateral components are also required (see ARSP-01 Volume II).

3.14. CARRIER FLIGHT AFTER PAYLOAD RELEASE

3.14.1.

The trajectory of an empty carrier (cf. ICM) and its base plate after unloading can be seen as secondary. The empty carrier may be unstable and will have a different impact point than the same projectiles with fuse malfunction. When calculating WDZ for carrier shells it is also necessary to take into account the free flight of the complete carrier (no unloading) up to the point of impact and associated ricochets. The empty carrier may travel further than the residual range of the full round. Its ballistic is covered in STANAG 4355.

3.14.2.

Some carriers (cf. mortars, rockets) will break apart by fuse activation with help of detonation devices. The WDZ has then to cater for the carrier parts, which will travel like large fragments and other debris.

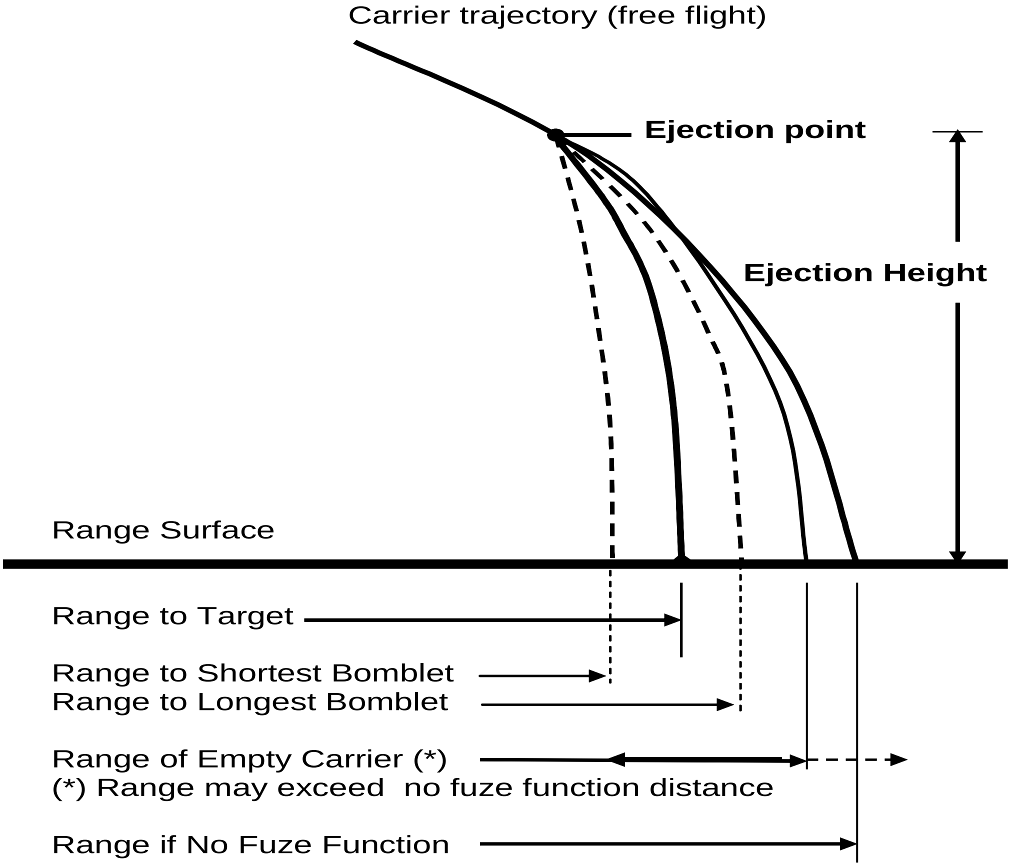

Figure 3.3: Carrier (example ICM)

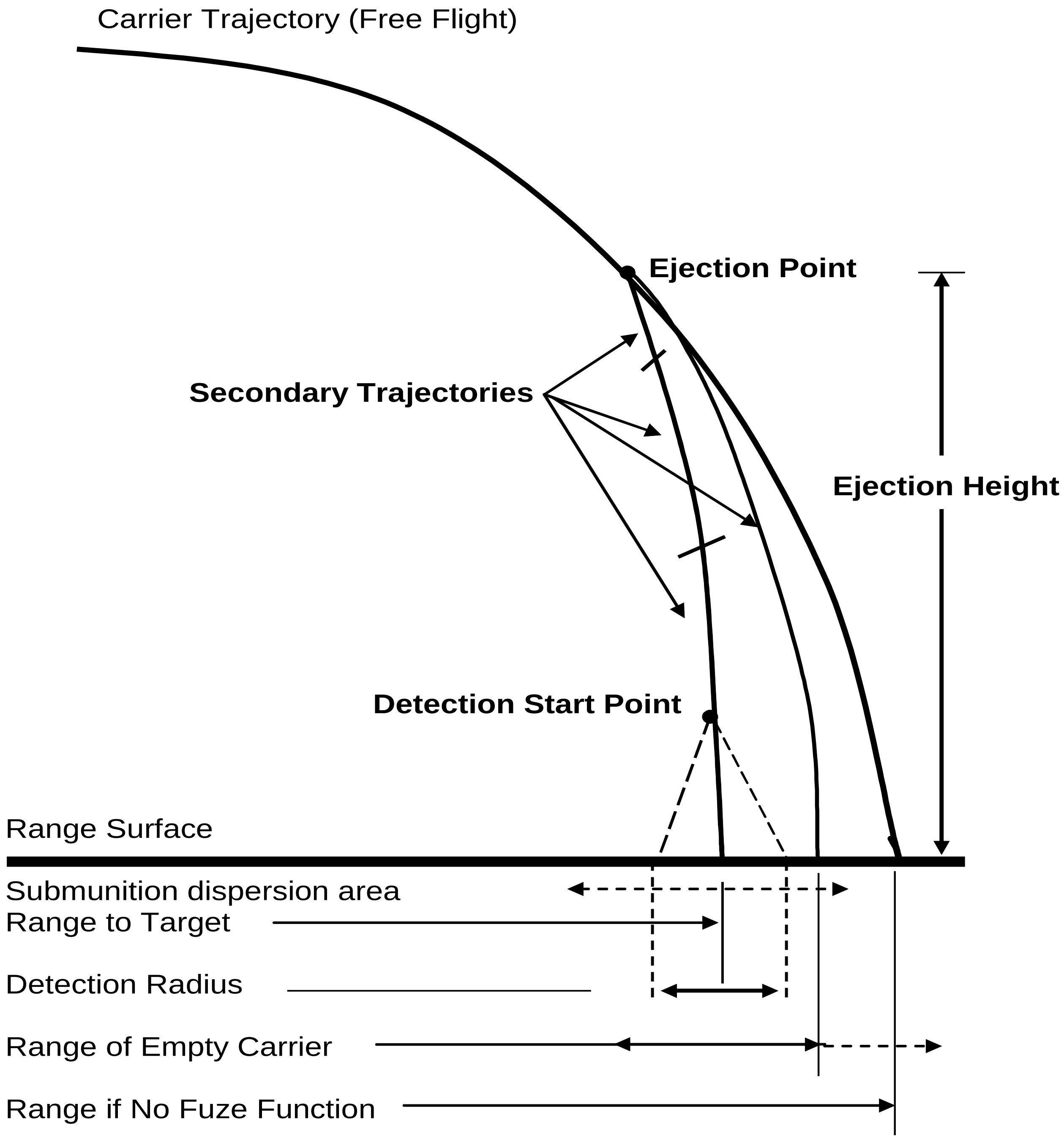

Figure 3.4: Carrier with Sensor Fused Sub-Munitions

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CHAPTER 4 ASSESSMENT OF THE FACTORS: RICOCHETS

4.1. INTRODUCTION

When a projectile impacts on its (designated) target or/and the target surrounding area ricochets may occur. A ricochet implies a change in velocity, hence in speed and direction induced in a projectile. The range, deflection and height of possible ricochets are to be combined with the WDZ of the first trajectories. Whether or not ricochet can occur has a major effect on the size and shape of the required WDZ.

4.2. IMPACT

4.2.1.

A ricocheted projectile induces a second trajectory after impact unless the projectile breaks apart. The term *break-up* is used where pieces of a projectile, which are not formed through explosively induced fragmentation, occur upon impact. Ricochet and break-up behaviour is influenced by the impact media and the projectile calibre, rigidity, nose shape, stabilisation mode and impact velocity. It is also influenced by the type of the projectile (e.g. ball or hard-core projectile, HE/KE - projectile, empty carrier of a base ejection projectile).

4.2.2.

Ricocheting is associated more with direct fire than with indirect fire weapons because of the shallow angle of impact coupled with the predominantly inert nature of direct fire projectiles. Each weapon/munition has its generic ricochet danger area dependent on the type of terrain or target engaged and on the data of the first trajectory at impact. For the deterministic methodology, the full length and width of the ricochet danger area can be estimated by applying the Maximum Ricochet Range (MRR). This formula works as a worst-case assumption for ground-to-ground firings, which is the greatest range of a projectile at which ricochets may occur and contains multiple ricochets.

4.2.3.

The gun quadrant elevation (QE) to reach the MRR on flat ground is defined as the Critical Quadrant Elevation (QE_{crit}). This value is weapon dependent. The QE_{crit} is the quadrant elevation that results in an angle of descent equal to the Critical Impact Angle (IA_{crit}). IA_{crit} is the angle at which the probability of ricocheting is taken to be zero. For spin-stabilised projectiles, it is common to take 533 mils (30 degrees) for that angle as a conservative choice. The QE_{crit} for fin-stabilised projectiles will be smaller as they have different ricochet behaviour. Further advice on estimating the MRR or QE_{crit} of spin and fin-stabilised munitions will be given in ARSP-01 Volume II.
(Observe Figure 4.1, including assumption and note, below)

Assumption: No combination of first trajectory, followed by one or more richochets, will cause a projectile to travel further than MRR. Near the individual IA crit, the energy of the ricochet is very low, so the expected travel distance of ricochet is very limited.

Note: MRR is always shorter than MAX RANGE

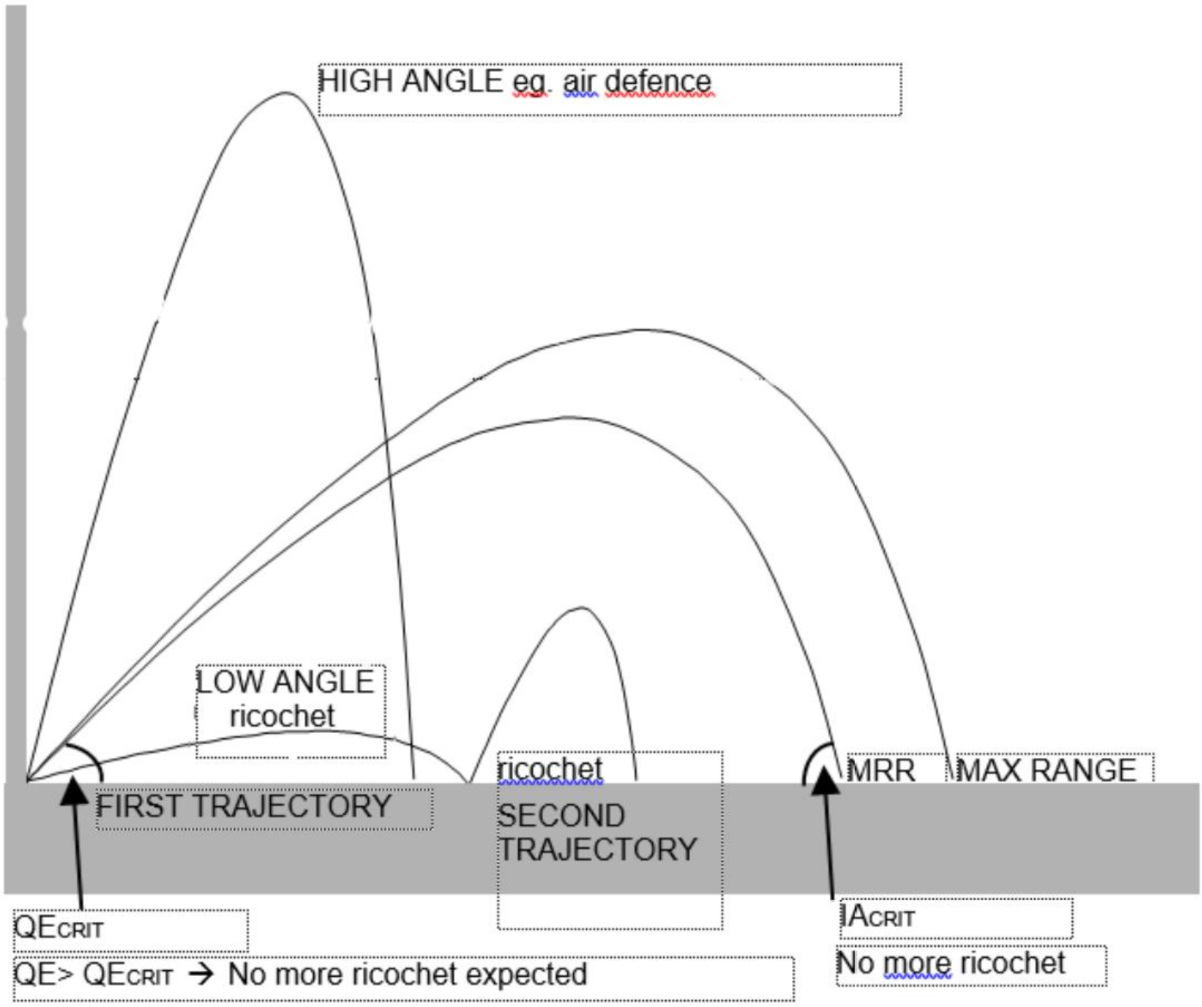

Figure 4.1: MRR Visualisation (In contrast, see figure 3.1)

4.2.4.

When a projectile ricochets the distance to which it might travel will depend on several factors, which include:

a. Projectile related factors:

(1) Physical properties: mass, velocity, rigidity.
(2) Mode of stabilisation.
(3) Yaw angle and yaw rate.

b. Target related factors:

(4) Type of target and surrounding area (e.g., hard [steel], soft [earth]).
(5) Slope of surface.

c. Engagement related factors:

(6) Angle of incidence with the target surface.
(7) Post ricochet stability and drag (and degree of damage to the projectile).

4.2.5.

Forward ricochet travel. Theoretical prediction of forward ricochet distance considers the above variables. It is assumed that no combination of first trajectory followed by one or more ricochets will cause a projectile to travel further than the MRR. If the ricochet length is expected to be significant then meteorological conditions should be considered when calculating the MRR (a free flight trajectory). Note: The MRR distance of a projectile is always shorter than its maximum range.

4.2.6.

Backward ricochet travel. In case of direct fire towards armoured targets with spin, stabilised hard-core ammunition under specific conditions to the impact solid hard cores may travel backwards in direction to the gunner with lethal effects. This concerns mostly small calibre (up to 12.7 mm) projectile because of the normally short target engagement distances. It has been proven that rejected kernels may fly backwards having spin like normal spinning projectiles. Significant ranges can be reached; the MRR method is not applicable - it needs special treatment.

4.2.7.

If the projectile does not completely break up upon impact, it may ricochet. For small deflections in elevation and azimuth, the more stable and rigid projectiles may travel, after ricochet, with low yaw and with levels of drag not significantly greater than before impact, such a process is described as ‘stable ricochet’. Ranges several times greater than for a normal high drag ricochet may be possible. The impacts on the surface for a spinning projectile will not be symmetrical and will be distorted due to gyroscopic and frictional forces.

4.2.8.

Fin stabilised HE/KE munition and cone stabilised training munition may not have such complicated behaviour after ricocheting. The degree of damage when impacting and shallow ricochet angles will affect the MRR length.

4.2.9.

Fin stabilised mortars, fired in the high register role, do not normally produce ricochets. New mortar systems will also fire in the low register. In this case, mortars, handled as fin stabilised projectiles, may ricochet as well as rifled mortars.

4.2.10.

The **maximum ricochet width** can be determined by experiment. Ricochet trials are costly and time consuming and only a few appropriate data are currently available. In the absence of data, it is recommended to take specific fractions of MRR for that parameter (see ARSP-01 Volume II, Chapter 4, Table 4.1).

4.2.11.

When a projectile detonates/breaks up at impact a **fragment danger area** is the only consequence. For HE projectiles the normal burst safety distance (see Chapter 5) may be applied.

4.3. SURFACE

4.3.1.

The slope of the ground within the impact area will affect the construction of the WDZ. No natural surface is uniform and therefore all MRR calculations are estimates. Forward slope at the impact point will increase the impact angle so that the IA_{crit} will be reached at a range shorter than the MRR for horizontal ground. Reverse slope will have the opposite effect, increasing the MRR. The majority of slopes on the range surface will have no significant effect on range safety. However, when engaging targets in a mountainous region, MRR calculations need to take account of the effects of significant slope in the WDZ determination. When firing air-to-ground with higher impact angles than for direct fire long range ricochets (of undamaged projectiles) with significant change of azimuth after ground impact may occur (for more details see Annex D of ARSP-01 Vol. II).

4.3.2.

The nature of the impact surface will affect the distance to which ricochets may travel. Direct or indirect fire weapons will strike both hard and soft surfaces (see ARSP-01, Vol. II, Chapter 2). If MRR is being used as contribution for the WDZ length, the target impact media will have no effect for range. The lateral displacement, however, will change depending on the strike velocity, angle of strike and the amount of deformity of the projectile.

4.4. POST RICOCHET

For special engagements or for using non-deterministic approaches post ricochet trajectories have to be determined. This problem applies mostly to spin-stabilised munition. Typically, a point mass model is applied to calculate the post ricochet trajectory if the projectile remains stable after ricocheting. The choice of model parameters depends on various factors including the availability of post ricochet data (from trials; as in the case of free flight) and predicted degree of damage to the projectile.

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CHAPTER 5 ASSESSMENT OF THE FACTORS: FRAGMENTATION

5.1. INTRODUCTION

When the projectile impacts fragments are created by the effect of the explosive filler or by the effect of its kinetic energy. The overall spread of fragments has to be contained in the WDZ.

5.2. CLASSIFICATION

5.2.1.

Fragments encompass all parts of a projectile and can be grouped as follows.

a. **Natural Fragments.** Variable sized parts of a projectile body, which are the results of the high explosive filler. Those fragments are thrown out with a high velocity.

b. **Controlled (pre-formed) Fragments.** Defined geometrical structures, such as cubes/balls, which are designed to be propelled outward at high velocity by the effect of the explosive filler or by kinetic energy, spin and fuse action (e.g. Kinetic Energy Time Fuse (KETF) airburst ammunition).

c. **Projectile Fragments.** Variable sized parts of a kinetic energy projectile that are produced as a result of high-speed impact (e.g. Frangible (FAPDS), PELE or APFSDS projectiles

d. **Other Hazardous Objects** that can be treated as fragments

(1) Slugs and explosively formed penetrators. These come from shaped charge warheads or sub-munitions. The range of those particular projectiles can be large. In the case of sub-munitions, their direction may not be predictable when self-destroying.

(2) Primary debris. Primary debris of a projectile (mostly HE, HEAT) occurs by fuse functioning. This debris is not designed for any assignment but may also be hazardous. Parts of the primary debris can have longer ranges than other fragments. Depending on the kind of the projectile this group may include for example bolts, nuts, pins, screws, parts of electronic devices, fuse debris, carrier shell debris (for example artillery Illumination projectile: drogue parachute support, main parachute support and candle loading assembly, base plate and others. For this specific WDA see ARSP-01 Vol. II Annex C3 (C.3.6.)).

(3) Secondary debris. Debris generated from the impacted target is called secondary. For instance, hard targets may produce high velocity fragments or projectiles origin from the target impact itself especially when engaging with hard-core ammunition (cf. 4.2.6, 4.2.11 and 5.5).

5.2.2.

Calculations of fragment trajectories are usually based on the database of static detonations of HE/HEAT projectiles in specific semi-circular arenas or similar facilities. In addition, simulation models may give the necessary fragment data. It is recommended to select for each zone of the arena the most dangerous fragment (called the representative fragment) and to use this set of fragments for calculating the fragment danger zone.

5.2.3.

The lack of data for fragment trajectories (e.g. suitable drag) is a major issue. Significant data are the fragment shape, mass and initial velocity. The velocity has to be fitted for the in-flight bursting projectile with data of the projectile (e.g. velocity, angle of trajectory) at the point of detonation. Generally, for WDZ purpose, the determination of trajectories of fragments or explosively formed penetrators will be calculated by a 2-dimensional point mass model in range and height. Parameter variations of the input data are recommended for simulating the fragment WDZ.

5.2.4.

It is a national prerogative to classify fragments as hazardous or not or to set thresholds. In this way fragments classified as non-hazardous may be excluded from fragment danger areas. Applying of risk assessment (see Annex C) is then recommended.

5.3. INTENDED GROUND- AND AIRBURST

5.3.1.

The fragment danger zone around the intended point of burst (ground or air) is the envelope of all computed fragment trajectories having their termination points on the range surface. For simplification it is recommended to draw a circle around the point of burst (surface co-ordinates) with a radius of the maximum range of all fragments (this radius is called Normal Burst Safety Distance (NBSD)) as danger area, and to take the maximum vertex as air danger height. This danger zone is the containment of all fragments. A reduced fragment range can be adopted if adequate protection for personnel is provided, or if a hazardous fragment threshold is established and accepted based on risk management.

Remark: Projectiles, which produce a (small) directed cone of small sub-projectiles by design (e.g. PELE, KETF) at functioning a circle with NBSD, may be significantly overrated. In this case, it is recommended to use the computed ground envelope of that cone.

5.3.1.

ARSP-03 Vol. II on Fragmentation Data contains details on collecting generic fragmentation data (including test procedures), calculating fragment trajectories and assessing fragments for WDZ (NBSD) or effectiveness.

5.4. PREMATURE/EARLY FUNCTION/FUSE RELIABILITY

The reliability of fuses is an issue with indirect firing of mortars or artillery, or firing over troops. When firing fuses suspected of having an unacceptable probability of functioning while in-flight consideration must be given to the potential fragments generated along the trajectory and the WDZ must take account of this. For example, the NBSD may be increased due to enhanced fragment spread if detonation occurs at any significant height above the ground (early function). If a premature function occurs at fuse arming distance the forward velocity of the projectile will reduce the rearward NBSD and increase the forward NBSD.

5.5. REARWARD HAZARDS (DEBRIS)

5.5.1.

When engaging hard targets with any kind of ammunition (e.g. with hard or soft core) severe back splash effects can occur. Fragments may be parts of the projectile itself (see Chapter 4 sub-paragraphs 4.2.6 and 4.2.11) and/or of the target and other material. To make the firing position safe a minimum target distance may be advised for each direct fire weapon. That distance can be established by definite trials or by worst-case analysis. This distance also takes into account if the projectile has explosive filling. If the minimum distance cannot be applied, appropriate protection must be provided for the weapon system serving personnel for firing at shorter distances.

5.5.2.

Recoilless weapons, rockets and missiles will produce rearward debris, which has to be taken into account when determining the WDZ (see ARSP-01 Vol. II, Annex A (A.1.4)).

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CHAPTER 6 ASSESSMENT OF THE FACTORS: OTHER HAZARDS

6.1. INTRODUCTION

Scattered fragments (debris) from firing are those hazardous objects of the munition, which are released **before** the designated functioning occurs. This encompasses e.g. sabots, pusher plates, charge particles, cartridges, tails of mortars, rearward particles from recoilless weapons. Usually that debris will have its own WDA around its point of origin.

a. Sabots are needed for spin or fin-stabilised munition of smaller calibre than the bore of the barrel. Normally a sabot is discarded at short distance from the muzzle and its parts are dispersed in range and deflection in front of the weapon system. When firing at high angle sabot-parts can have a wide spread, also rearwards, depending on wind direction and speed.

b. Pusher plates are released in a small cone along the direction of firing. Normally this cone is contained in the WDA of the accompanied projectile. When firing with pusher plates, sabot-like elements are also released which may have a wider spread (see paragraph a).

c. When firing recoilless weapons counter, mass particles are released backwards causing hazards. For example, see the specific WDA for rocket launch in ARSP-01 Vol. II Annex A (A.4.5.).

d. There are weapon systems, which do not capture automatically the used (ejected) cartridges. For example, machine guns may eject empty cartridges, which may be dangerous to personnel standing close by.

e. Debris from the propellants has small effect in front of the muzzle; normally it is covered by the WDA of the projectile.

6.2. NOISE AND OVERPRESSURE

6.2.1.

Firing noise has three main sources

a. The weapon (noise spreads spherically)
b. The projectile noise when travelling through the air
c. The detonation noise (HE projectiles) or impact noise at high energy (KE projectiles)

6.2.2.

The type of noise produced from the firing is weapon system dependent. The amplitude, or peak pressure, of the noise and its duration are the main factors in assessing potential damage. In general, terms hearing damage to personnel in the area of the firing weapon systems will be greatest if hearing protection is not worn, or worn incorrectly.

6.2.3.

Personnel involved with live fire activities must wear ear protection when the level of noise is equal to or greater than set forth in national standards.

6.2.4.

Using Noise Prediction Programs combined with a good knowledge of the meteorological conditions and the local topography can reduce noise to the surrounding communities. The following is advised:

a. Not to fire large calibre HE projectiles in state of inversion layers at atmosphere.

b. Taking into account the possibility of unexpected reflections of the noise.

6.2.5.

Generally, these programs can give useful indicators to avoid worst cases, based on available data. This will enable decisions to be made as to whether the weapon, which will produce the noise, should be fired from a particular location and at a particular time.

6.2.6.

Damage from overpressure has to be taken into account. Personnel exposed to overpressure will normally suffer ear and lung damage.

6.2.7.

Before a new weapon system enters service the position of the crew has to be investigated in order to be sure that the pressure level is acceptable. During this investigation, reflections from the zone around the weapon system have to be examined.

6.3. CONTAMINATED IMPACT AREA

6.3.1.

Procedures for blind/dud disposal are laid down in STANAG 2143.

6.3.2.

Impact areas for carriers may be contaminated with bomblets or sub-munitions, which may not have self-destructed and may be activated in a defined/an undefined time frame. Consequently, the WDZ has to account for the maximum range of fragments and explosively formed projectiles (see Chapter 5, sub-paragraph 5.2.1.d).

6.4. TOXICITY

Toxic hazards may arise on the firing point from propellant combustion products and in the target area from the operation/non-operation of the projectile. Range safety instructions and WDZ should specify the hazard(s) where necessary and provide clear directions to mitigate the risk.

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CHAPTER 7 RISK

7.1. INTRODUCTION

The term risk is addressed in Chapter 1, paragraph 1.2.. In the wider area of Range Safety, the application of Risk Management is a major tool (see paragraph 7.2. and Annex C). An example for risk calculation is in paragraph 7.3.. Also addressed are worst-case applications (see paragraph 7.4.).

7.2. RISK MANAGEMENT

7.2.1.

Risk management is the process of identifying, assessing, and controlling risks. Risk management is a **five-step process**. The five steps are:

a. Step **1**: Identify hazards
b. Step **2**: Assess hazards
c. Step **3**: Develop controls to determine residual risk and make risk decisions
d. Step **4**: Implement controls
e. Step **5**: Supervise and evaluate

7.2.2.

The risk management process is addressed in detail in Annex C.

7.3. CALCULATION OF THE RISK

7.3.1.

If a person knows about the level of risk and takes the decision of controlling that risk, nevertheless, and suffers injuries or death, he is responsible for his actions. The risk to be considered when developing WDZ is the **residual risk (R)** that personnel or material involved or not involved in the process, the hazards are coming from, causes loss, injury, or damage. The following issues give information for WDZ development.

7.3.2.

The following two different probabilities may characterise a WDZ

a. The **probability of escapement** (P_{esc}) stands for the probable event that a hazardous object will escape from a defined area/zone.

b. The **probability** of **hitting a specified area** (P_{hsa}) will assess this area outside the defined area with a graduated (specific) level of probability of being hit by a hazardous object leaving the defined area.

7.3.3.

The residual Risk **R** is a **joint probability** of three **independent** probabilities **P, T** and **C** (as defined in the following table).

a. $R = P * T * C$		
P	**T**	**C**
$P = P_{esc}$: probability of escapement alternatively $P = P_{hsa}$: probability of hitting a specified area	$T = T_r$: probability that a person (or object) is outside the range alternatively $T = T_s$: probability that a person (or object) is inside a specified area	C (= Consequence or Effect, taken as a probability) is the severity of an incident outcome expressed in personnel (C_p) or alternatively in asset (C_a) (object) loss.
P will be provided by procedures to calculate the WDZ	T will be an individual measure given by the user. T may be time dependent.	An explanation for C can be found in Annex C, Figure C.2 “Hazard Severity”.
Those methods can be applied to compute the WDZ	Those calculations will depend on the range on which the firing takes place and the surrounding areas. It is a range specific measure.	
Examples: $R = P_{esc} * T_s * C_p$ Risk to personnel in a specified area $R = P_{esc} * T_s * C_a$ Risk to equipment in a specified area $R = P_{esc} * T_r * C_p$ Risk to a person outside a specified area		

Table 7.1: Risk Formula

For the measures **Tr** and **Ts**, persons and objects are rated by different levels. Further information is given in Annex C, especially by Figure C.3.

7.3.4.

The risk **R** is often a specific measure for a fixed located danger area/zone (except the trivial cases T = 0 or T = 1).

7.3.5.

The probability P_{esc} is an upper boundary for P_{hsa} that means $\mathbf{P_{hsa} \leq P_{esc}}$. The measure P_{esc} is the sum of all P_{hsa}.

7.3.6.

Remark on the probabilities Tr and Ts: It takes time and manpower to provide sufficient good data for computing the probability T. Usually, Tr and Ts will be hardly known which is the reason why it is difficult to calculate the risk **R** exactly. Often, the only way is to set T = 1 and consequently C = 1. In doing so it is reasonable to give P_{esc} an adequate high level in its absolute value (which is recommended for practice). If P_{hsa} and T_s (T_r) are not known the probability of escapement P_{esc} should be set by national standards (e.g. 10^{-6}) to ensure a low residual risk level outside the WDZ.

7.4. WORST CASE

7.4.1.

In paragraph 7.3. the risk R (in its meaning as a <u>residual risk</u>) is defined as the product of three independent probabilities: **R = P * T * C**. There are two simple special cases of R (P and T taken as in the table of paragraph 0703).

a. R = 0 if P = 0 and/or T = 0 and/or C = 0

b. R = 1 if P = 1**,** T = 1 and C = 1

7.4.2.

The risk R is zero if the probability T is zero (if a projectile escapes from the danger area hitting a definitely empty (specific) area there will be no risk). In case it is assured P = 0 the measures C and T can take values between 0 and 1.

7.4.3.

If the WDZ is calculated using **worst-case methods** (fully deterministic without any probability) then P can be seen as a “0 - 1” probability (P = 1 inside the defined space and P = 0 outside). T and C can be taken arbitrary.

7.4.3.

In various cases, because of absence of essential data for probabilistic models, WDZ have to be calculated using worst-case methods by applying the 0 -1 probability. For almost all cases, it is impossible to calculate **the** worst-case danger zone (which is equivalent to the TEZ). It is only possible to create a WDZ for **a** worst case. The real worst case is often not known. Parameter variations could help to get closer to a reasonable worst case.

ANNEX A A SURVEY OF RANGE SAFETY UNDER THE ASPECT OF APPLYING WDZ

A.1.

Range Safety is the combination of organisational, training and technical measures taken to ensure that there are no unacceptable effects of the weapon and/or its associated munitions outside the designated **WDZ**, which marks the boundaries for an acceptable level of risk/danger around the corresponding firing range (weapon system and expected impact/target area).

A.2.

The Range Safety Organization (RSO) consists not only of the (safety and operational) personnel of the training/firing area, but also includes the designated safety personnel of the troops/units using the ranges. The responsibility of the unit's safety personnel is mostly directed toward the proper use of the weapons and its associated munitions. The Range Safety Personnel have overall responsibility, including safeguarding that no unauthorised persons enter the danger areas. Organisational measures taken by the RSO are for example:

a. Issuing Range Safety Instructions/Manuals to the troops using the training area

b. Marking the danger and/or target area in the field and on maps

c. Coordinating between multiple users of the same training area

d. Ensure that the units/troops use the correct firing range in combination with the designated weapon and munition combination

e. Operate an incident/accident report system.

A.3.

Training measures taken by the RSO are for instance:

a. Ensure that the troops/weapon crews/units have the required level of training

b. Instruct troops and safety personnel on Range Safety Instructions

A.4.

Technical measures taken by the RSO are for instance:

a. Construction of baffles and/or restrictions so that weapons can only be aimed in the desired/safe directions if necessary.

b. Limit the use of munitions-types to (e.g.) training or short-range munitions.

A.5.

The Weapon Danger Zone (developed in the series of ARSPs) does not guarantee 100% safety. There remains a zone outside in which the risk is below an acceptable level. The RSO is there to ensure that the conditions set for that WDZ are met. The WDZ (transformed into an outline of its shape - see ARSP-01 Volume II) gives the zone in which the (dangerous/harmful and underlying) effects of the (weapon systems and its munitions or) munitions are to be expected when used in a proper way. This means that the RSO has to ensure that any weapon is aimed at its assigned target, loaded with the correct munitions (cf. projectile and charge) and that all corresponding settings (e.g. fuses, fire control computers, etc.) are correct.

ANNEX B LEXICON AND ABBREVIATIONS

B.1. SELECTED DEFINITIONS USED IN THIS VOLUME

a. **Accuracy of Fire.** Accuracy of fire is the component of precision of fire, which is expressed by the closeness of the MPI, of groups of shots, at and around the point of aim. (AAP-6)

b. **Air Danger Height.** The Air Danger Height (ADH) is the maximum height above ground level (AGL) at which hazards may exist ADH is measured in feet.

c. **Back Splash.** Back splash is fragmentation or target debris thrown back towards the firing point as a result of projectile impact.

d. **Consistency/Dispersion.** Dispersion is the scatter pattern of hits around the Mean

e. **Carrier.** Projectile or shell with the ability of ejecting payload (e.g. illumination or smoke)

f. **Critical Impact Angle (IA_{crit}).** The IA_{crit} is the acute angle between the line of arrival of a projectile and the horizontal plane above which a ricochet should not occur.

g. **Direct Fire.** Direct fire is an engagement in which the target can be seen by the firer. (AAP-6)

h. **Early Burst.** An early burst occurs if the fuse, set to the proximity role, initiates the projectile beyond the position in the trajectory where proximity arming is complete, but before the intended burst height.

i. **Fragment Danger Area/Zone.** This is the two-/three-dimensional space around a burst of a projectile in which its fragments are expected to travel and impact.

j. **Hard Target.** Hard target refers to all material or surfaces which possesses sufficient strength and surface hardness in relation to a given ammunition that when impacted suffers little or no deformation. Severe backsplash effects may be generated (target and ammunition parts).

k. **Hazard.** A hazard is any real or potential condition that can cause injury, illness, or death of personnel and general public, or damage to or loss of equipment or property.

l. **Indirect fire**. Indirect fire is an engagement in which the target cannot normally be seen by the firer; the delivery means is laid mechanically or electronically using data derived from tables or computation (AAP-6).

m. **Indoor Range.** An indoor range is one, which is fully contained in a building or other structure.

n. **Maximum Ricochet Range.** The Maximum Ricochet Range (MRR) is the range corresponding to the angle of descent, which produces the $\mathbf{IA_{crit}}$ for the projectile.

o. Mean Point of Impact. The mean point of impact (MPI) is the location which is the arithmetic mean of the co-ordinates of the separate points of impact or burst of a finite number of weapons (projectiles or sub-munitions) fired or released at the same aiming point, under a given set of parameters. (AAP-6)

p. **Normal Burst Safety Distance (NBSD).** The Normal Burst Safety Distance from the point of burst beyond which it is improbable that any fragment from a bursting weapon will travel.

q. **Open (outdoor) Range.** An open range is one, which is exposed to the natural effects of light, wind and weather. The range may be completely open or contained partially by a structure.

r. **Premature.** A premature is the complete or partial function of a munition before the completion of the required arming delay of the fusing system.

s. **Probable Error (PE).** The probable error of a random variable is that deviation from the mean, which is as likely to be exceeded as not. **One** PE is the unit of measurement of the horizontal error lying wholly on one side of the mean point of impact both in range and deflection, i.e. plus, minus, left or right.

t. **Probability of Escapement.** The probability of escapement is the chance of munitions, a fragment or propelled debris leaving a defined space, often stated as chance or probability per operation or event, expressed as a percentage or as a decimal.

u. **Projectile.** A projectile is an object, capable of being propelled by a force, normally from a gun and continuing in motion by virtue of its kinetic energy. Projectiles are divided in Kinetic Energy Projectiles and Shells. (AAP-6)

v. **Range (Distance).** The range is the distance between any given point and an object or target. (AAP-6)

w. **Range (Zone).** The Range is a space reserved, authorised and normally equipped for hazardous firing (weapon/laser). (AAP-6)

x. **Range Safety.** Range Safety is the key element by which the risk of injury or damage when firing authorised weapons on a range is reduced to an acceptable level. It is achieved by procedures, which provide an accepted level of safety for personnel involved in firing, not involved personnel and the public.

y. **Ricochet Danger Area/Zone.** This is the two-/three-dimensional space, in which ricocheted projectiles may travel and impact. Multiple ricocheting may be included.

z. **Risk.** Risk is the combination of the probability and the consequence of a hazard.

aa. **Risk Assessment.** Risk Assessment is the systematic identification of hazards, severity and probability. It is used to estimate the risk to individuals or population, property or the environment.

bb. **Risk Analysis.** Risk analysis is part of the overall process of risk management. It contains hazard assessment and determination of risk level.

cc. **Risk Management.** Risk Management is the systematic application of management policies, procedures and practices to the task of analysing, evaluating and controlling risk.

dd. **Soft Target** (or Ground Target). Soft target refers to all surfaces or material which, when impacted will be penetrated or hold up the projectile (earth, sand, wood, thin aluminium or steel plates, canvas, cardboard – depending on the used munition).

ee. **Tolerable (Acceptable) Risk.** Tolerable (Acceptable) risk is the level of risk with which society/user is prepared to accept, to secure certain benefits, provided the risk is properly controlled.

ff. **Total Energy Area/Zone (TEA/Z).** The TEA/Z is the maximum possible two/three dimensional space around a firing point into which it is possible for weapons, fragments or impact debris to pass or fall.

gg. **Weapon Danger Area/Zone (WDA/Z).** The WDA/Z as a proper subset of the TEA/Z, is a defined two/three 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.

hh. **Weapon System.** The weapon system encompasses the delivery means and the munitions (cf. charge, primer, projectile) used.

B.2. LIST OF ABBREVIATIONS

ADH	Air Danger Height
APFSDS	Armour Piercing Fin Stabilised Discarding Sabot
ARSP	Allied Range Safety Publication
FAPDS	Frangible Armour Piercing Discarding Sabot
KETF	Kinetic Energy Time Fused
IA_{crit}	Critical Angle of Impact
MRR	Maximum Ricochet Range
MPI	Mean Point of Impact
NAEB	NATO Armaments Error Budget
NBSD	Normal Burst Safety Distance
PD Fuse	Point Detonating (Impact Action) Fuse
PE	Probable Error
PELE	Projectile with Enhanced Lateral Effect
P_{esc}	Probability of Escapement
P_{hsa}	Probability of hitting a specified area
QE	Quadrant Elevation
QE_{crit}	Critical QE
RSO	Range Safety Organization
RTR	Round to Round
sd	Standard Deviation (normal distribution)
TEA/Z	Total Energy Area/Zone
WDA/Z	Weapon Danger Area/Zone

ANNEX C RISK MANAGEMENT

This annex is based on US FM 5-19 (21 Aug 2006) “Composite Risk Management”. For more detailed and extended risk management see ISO 31000:2018.

C.1.

Risk management is the process of identifying, assessing, and controlling risks. Risk management is a five-step process. The five steps are:

a. Step **1**: Identify hazards
b. Step **2**: Assess hazards
c. Step **3**: Develop controls to determine residual risk and make risk decisions
d. Step **4**: Implement controls
e. Step **5**: Supervise and evaluate

C.2.

Steps **1** and **2** together comprise the risk assessment for WDZ development. In step **1** the hazards that may be encountered are identified. In step **2** the direct impact of each hazard is determined. Step **2** is completed in three sub-steps.

C.2.1.

Sub-step A assesses each hazard in relation to the probability of a hazardous incident. Figure C.1 (see next page) provides a summary of the five degrees of probability. The letters in parentheses following each degree (A through E) provide a symbol for depicting probability.

FREQUENT (A) Occurs very often, continuously experienced	
Single item	Occurs very often in service life. Expected to occur several times over duration of a specific mission or operation. Always occurs.
Fleet or inventory of items	Occurs continuously during a specific mission of operation, or over a service life.
Individual soldier	Occurs very often in career. Expected to occur several times during mission or operation. Always occurs.
All soldiers exposed	Occurs continuously during a specific mission or operation
LIKELY (B) Occurs several times	
Single item	Occurs several times in service life. Expected to occur during a specific mission or operation.
Fleet or inventory of items	Occurs at a high rate, but experienced intermittently (regular intervals, generally often).
Individual soldier	Occurs several times in career. Expected to occur during a specific mission or operation.
All soldiers exposed	Occurs at a high rate, but experienced intermittently.
OCCASIONAL (C) Occurs sporadically	
Single item	Occurs some time in service life. May occur about as often as not during a specific mission or operation.
Fleet or inventory of items	Occurs several times in service life.
Individual soldier	Occurs some times in career. May occur during a specific mission or operation, but not often.
All soldiers exposed	Occurs sporadically (irregularly, sparsely, or sometimes).
SELDOM (D) Remotely possible; could occur at sometime	
Single item	Occurs in service life, but only remotely possible. Not expected to occur during a specific mission or operation.
Fleet or inventory of items	Occurs as isolated incidents. Possible to occur sometime in service life, but rarely. Usually does not occur.
Individual soldier	Occurs as isolated incident during a career. Remotely possible, but not expected to occur during a specific mission or operation.
All soldiers exposed	Occurs rarely within exposed populations as isolated incidents.
UNLIKELY (E) Can assume will not occur, but not impossible	
Single item	Occurrence not impossible but can assume will almost never occur in service life. Can assume will not occur during a specific mission or operation.
Fleet or inventory of items	Occurs very rarely (almost never or improbable). Incidents may occur over service life, but rarely.
Individual soldier	Occurrence not impossible but may assume will not occur in career or during a specific mission or operation.
All soldiers exposed	Occurs very rarely, but not impossible.

Figure C.1: Hazard Probability

C.2.2.

Sub-step B addresses the severity of each hazard. It is expressed in terms of degree of injury or illness, loss of or damage to equipment or property, environmental damage, and/or other mission impairing factors such as lost combat power. The degree of severity estimated for each hazard may be based on knowledge of the results of similar past events. There are four degrees of hazard severity (I through IV). Figure C.2 provides a summary of the four degrees of hazard severity.

CATSTROPHIC (I)
Loss of ability to accomplish the mission or mission failure. Death or permanent disability. Loss of major or mission critical system or equipment. Major property damage. Severe environmental damage. Mission critical security failure. Unacceptable collateral damage.
CRITICAL (II)
Significantly (severely) degraded mission capability or unit readiness. Permanent partial disability, temporary total disability. Extensive (major) damages to equipment or systems. Significant damage to property or the environment. Security failure. Significant collateral damage.
MARGINAL (III)
Degraded mission capability or unit readiness. Lost day due to injury or illness. Minor damage to equipment or systems, property or the environment.
NEGLIGIBLE (IV)
Little or no adverse impact on mission capability. First aid or minor medical treatment. Slight equipment or system damage. Little or no property or environmental damage.

Figure C.2: Hazard Severity

C.2.3.

Sub-step C combines the results of sub steps A and B to create an estimate for the overall initial risk. This can be depicted on a risk assessment matrix as shown in Figure C.3.

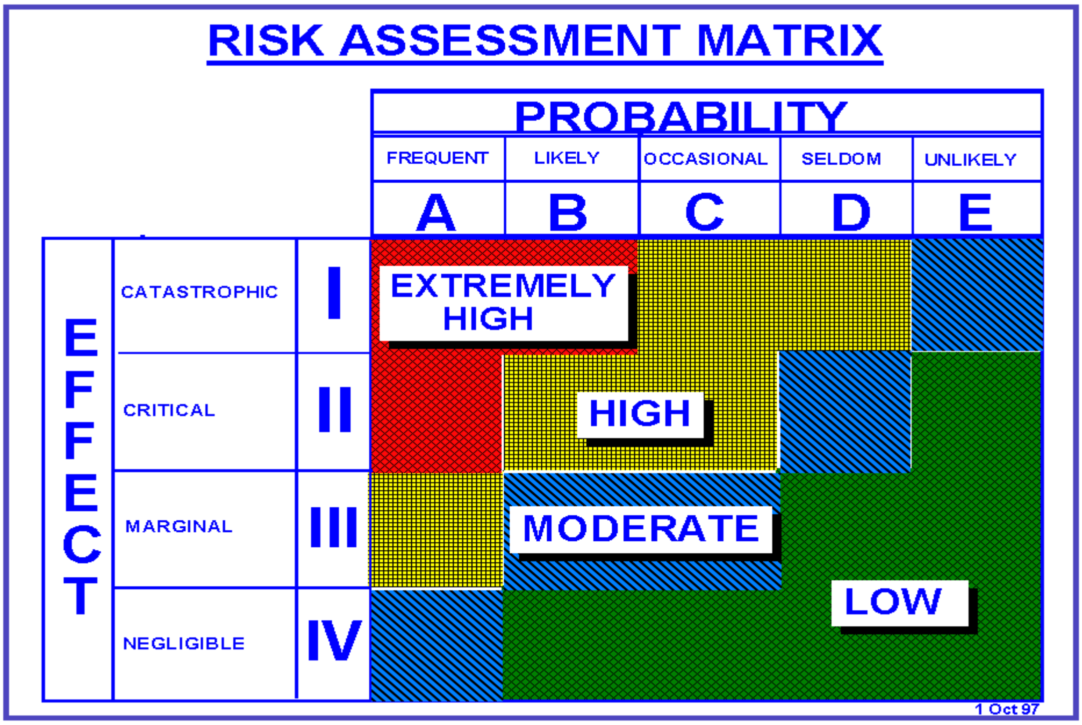

Figure C.3: Risk Assessment Matrix

C.3.

Step **3** is accomplished in **2 sub-steps**: <u>develop controls and make risk decisions</u>.

C.3.1.

<u>Sub-step A - Develop Controls</u>. After assessing each hazard, leaders develop one or more controls that either eliminate the hazard or reduce the risk (probability and/or severity) of a hazardous incident. When developing controls, they consider the reason for the hazard not just the hazard itself.

a. <u>Types of Controls</u>. Controls can take many forms, but fall into three basic categories: educational controls, physical controls, and avoidance.

(1) <u>*Educational controls*</u>. These controls are based on the knowledge and skills of the units and individuals. Effective control is implemented through individual and collective training that ensures performance to standard.

(2) <u>*Physical controls*</u>. These controls may take the form of barriers and guards or signs to warn individuals and units that a hazard exists. Additionally, special controller or oversight personnel responsible for locating specific hazards fall into this category.

(3) *Avoidance.* These controls are applied when leaders take positive action to prevent contact with an identified hazard.

b. Criteria for Controls. To be effective, each control developed must meet the following criteria:

(1) *Suitability.* It must remove the hazard or mitigate (reduce) the residual risk to an acceptable level.

(2) *Feasibility.* The unit must have the capability to implement the control.

(3) *Acceptability.* The benefit gained by implementing the control must justify the cost in resources and time. The assessment of acceptability is largely subjective.

c. Residual Risk. Once the responsible leader develops and accepts controls, he determines the residual risk associated with each hazard and the overall residual risk for the mission. Residual risk is the risk remaining after controls have been selected for the hazard. Residual risk is valid (true) only if the controls for it are implemented. As controls for hazards are identified and selected, the hazards are reassessed as in Step 2 and the level of risk is then revised. This process is repeated until the level of residual risk is acceptable to the commander or leader or cannot be further reduced.

d. Overall residual risk. This type of risk must be determined when more than one hazard is identified. The residual risk for each of these hazards may have a different level, depending on the assessed probability and severity of the hazardous incident. Overall, residual mission risk should be determined based on the incident having the greatest residual risk. Determining overall mission risk by averaging the risks of all hazards is not valid. If one hazard has high risk, the overall residual risk of the mission is high, no matter how many moderate or low risk hazards are present.

C.3.2.

Sub-step B - Make Risk Decision. A key element of the risk decision is determining if the risk is justified. The commander must compare and balance the risk against mission expectations. He alone decides if controls are sufficient and acceptable and whether to accept the resulting residual risk. If he determines the risk level is too high, he directs the development of additional controls or alternate controls, or he modifies, changes, or rejects the recommended course of action.

C.4.

Step **4**, implementing controls, requires that controls are integrated into appropriate verbal and written orders and instructions. Controls must be clear, simple, and understood at all levels.

C.5.

Step **5**, supervision and evaluation, requires that standards and controls are enforced. Evaluation is used to determine the effectiveness of each control measure and identifying and accurately assessing the probability and severity of hazards, as well as determining whether the level of residual risk was accurately estimated. **Figure C.4** provides an overview of the risk management cycle as a continuous process (application).

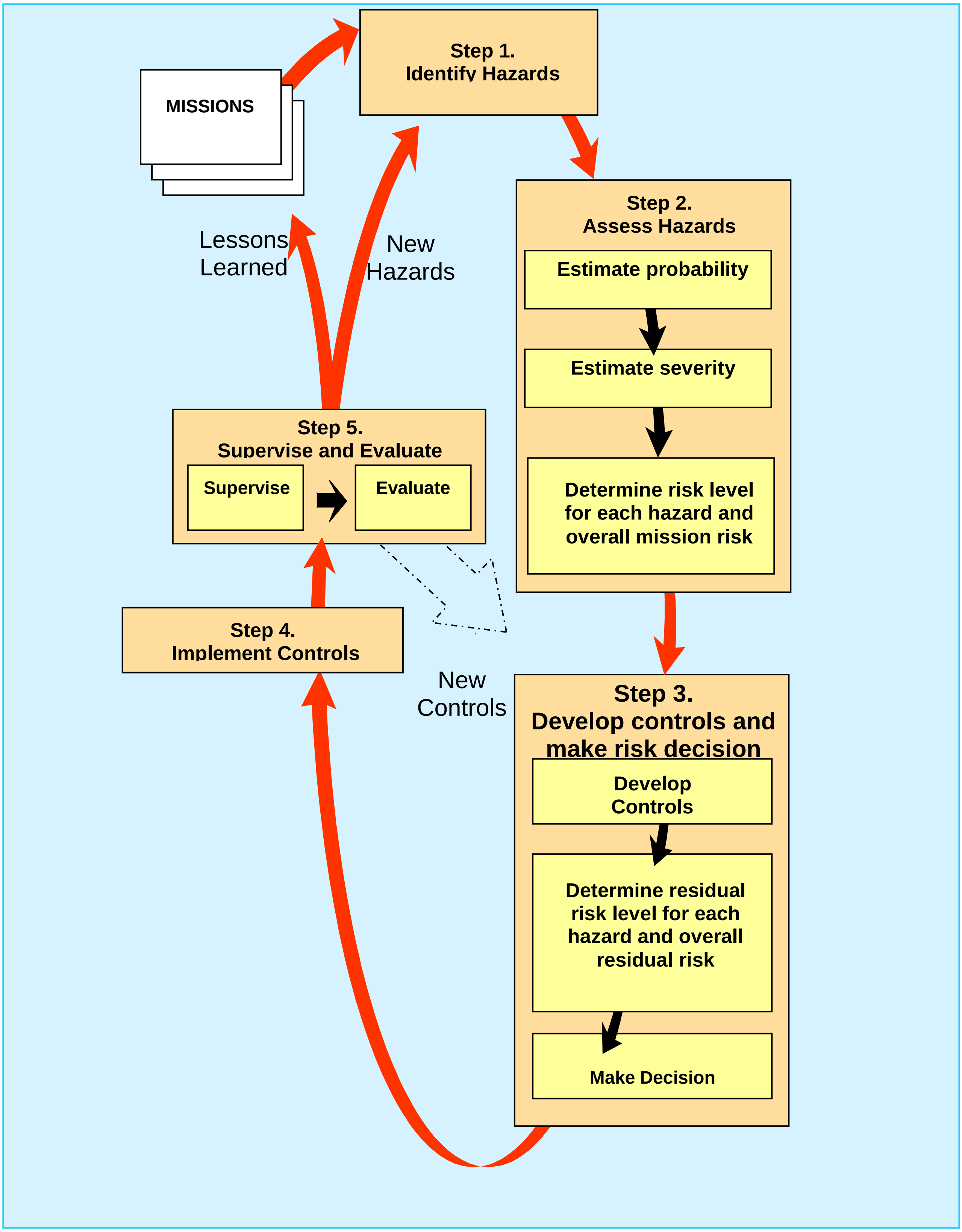

Figure C.4: Continuous Application of Risk Management

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