A PROPOSED METHODOLOGY FOR RISK ASSESSMENTS FOR TEMPORARY LIGHTNING EXPOSURES

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Abstract

Lightning protection risk assessment methodologies such as those included in IEC 62305-2 and the detailed risk assessment proposed for inclusion in NFPA 780-2011, Annex L are based on a yearly average of lightning activity and human exposure for a given location. However, in most locations the probability of lightning activity is not consistent over all 12 months of a year. The actual risk of a temporary operation conducted during a period of high lightning incidence is much greater than what would be calculated using average lightning incidence; while the same operation conducted during a period of lower than average lightning activity would be less risk than calculated using existing methods. This paper will address a proposed methodology for dealing with lightning risk assessments for temporary scenarios. Two example scenarios will be discussed. The first case will be a short-term, improvised field ammunition storage site, used in a fast-moving military operation where there isn't enough time and/or resources available for a conventional LPS to be installed. The second case will address the risk where a protected safe haven is not available for ammunition transports awaiting unloading during a period where the expected lightning frequency is low.

1. Introduction

Lightning protection risk assessment methodologies are now maturing to the point they are becoming more commonly used and accepted by the applicable authorities having jurisdiction. It is becoming recognized that a one-size-fits-all lightning protection system requirement for explosives structures and associated operations is not always economically reasonable and in some cases not logistically feasible. Questions are being raised as to whether it makes sense to continue to apply the same protection standards and enforcement to an old, remote building containing several boxes of small-arms ammunition as should be applied to a building housing a large quantity of high explosives or one used to conduct an operation that is know to have an above-average sensitivity to a lightning environment [1]. Numerous technical papers describing the use of lightning risk assessment methodologies in explosives applications have been presented at recent DoD Explosives Safety Seminars; providing alternatives that could help in reducing operating costs, enhancing safety and improving new designs by tailoring the protection specifically to the lightning threat associated with the event [1][2][3]. Each of these papers describes a scientifically-based, detailed assessment with risk factors based on internationally accepted methodologies such as IEC 62305-2 [4], Strike-QRA [1], and the detailed risk assessment method to be included in NFPA 780-2011, Annex L [5]. It is believed to be widely agreed that a simplified, subjective risk assessment such as the simplified risk assessment currently included in NFPA 780-2008, Annex L [6] is insufficient to provide the level of detail and accuracy necessary for assessment of critical operations or those that could result in catastrophic losses of personnel and assets.

Among the primary factors considered in any lightning risk assessment is the value of average lightning strikes per square kilometer per year. They are most accurate where there is a consistent lightning threat or where there are decades of data on the number of strikes per square kilometer per year for the specific area of interest. As lightning risk assessments are getting greater acceptance and use the question has arisen as to whether such an assessment can be used for a one time event that may be exposed to a lightning environment for a short period of the year. This paper will provide a discussion on a proposed methodology to address the use of a lightning risk assessment for a temporary lightning exposure, along with the limitations of such an assessment.

2. Lightning Risk Assessment Principles

Risk is generally defined as the product of the probability of an event occurring and the consequences of the event. However, for some risks there is not always a consistent consequence to the occurrence of a given event. This is true for lightning risk assessments as there is a wide variety of probability in the severity of any one event. In the case of lightning risk assessments, this general risk formula is often expressed as:

$$R = (N)\,(P)\,(L)$$

where:
risk (R) is the product of the number of dangerous events (N) times the probability of damage per event (P) times the expected yearly loss resulting from the event (L). In most detailed risk assessments, the overall risk due to lightning is broken down into specific risk categories which can be computed independently using specific risk components based on location of strike, source of damage, type of damage and type of loss. For the purpose of this paper we will only deal with probabilities of damage per event and expected losses in generic terms and focus primarily on the number of dangerous events.

The number of lightning flashes influencing a structure and its services depends on the dimensions and the characteristics of the structure and of the services, on the environmental characteristics of the structure, and on the lightning ground flash density in the region where the structure and the services are located. For lightning protection assessments, the number of dangerous events is primarily the product of the ground flash density (Ng) and the equivalent collection area characteristic of the structure (A_e)[1], while also taking into consideration correction factors based on the relative location of the structure. This makes the ground flash density a very important parameter in the risk assessment because of its prominence in the determination of the number of dangerous events.

Lightning protection risk assessment methodologies such as those included in IEC 62305-2 and the detailed risk assessment proposed for inclusion in NFPA 780-2011, Annex L are based on a yearly average of lightning activity for a given location. However, in very few locations (such as possibly the tropics) is the probability of lightning activity consistent over all 12 months of any given year. Generally, there are more days with lightning activity in the spring, summer and early fall than in the winter.

The probability of lightning damage per event is generally related to the physical characteristics of a structure or operation and to the susceptibility of the contents. Examples of some of the physical characteristics of a structure or facility that influence the probability of damage per event are the construction techniques and materials used, the number and location of incoming services, and shielding provided for protection against lightning electromagnetic pulse (LEMP). These characteristics are typically not time-variant. While it is possible for the susceptibility of the contents to change with time, this is generally true only in those cases where the contents of a structure change.

The expected loss resulting from a lightning event is generally related to the value of the structure and its contents, protection measures provided, and the exposure of personnel to the threat. The expected loss resulting from a lightning event is not as constant as the probability of damage. The most relevant example of a time-variant factor associated with the expected loss is the exposure of personnel. The number of personnel exposed to a potentially hazardous event will depend upon the status of the operation being performed (i.e. explosives operations, maintenance, security, etc.). Another potentially time-variant factor that has a bearing on the expected loss is the quantity and configuration (i.e. containment, barricaded, substantial dividing walls, etc.) of explosives material associated with the structure or operation.

The accuracy of a lightning risk assessment is maximized where there is a consistent exposure to the lightning threat and consistent probability of the type and amount of loss experienced during the period of the assessment. If one were to attempt to perform a lightning risk assessment for a specific location for a specific period, the accuracy of the assessment would be highly dependent upon the accuracy of the data available for the number of expected events and the expected probability of the loss of failure per event.

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[1] The symbol for equivalent collection area used in NFPA 780, Annex L is A_e. The equivalent symbol used in IEC 62305-2 is A_d.

Where the expected loss and probability of such loss is very high, the accuracy of the number of strikes per square kilometer used in the assessment is critical.

3. Proposed Methodology

3.1 General

In Section 2, we gave the general formula for the calculation of lightning risk components. One of the key factors in each risk component is the number of dangerous events (N). The number of dangerous events is dominated by the ground flash density (N_g) and the equivalent collection area characteristic of the structure (A_e). In order to assess the lightning risk for an operation that would involve a temporary lightning exposure (less than one year continuous), it will be necessary to address how to determine the proper ground flash density to be used in the assessment. Section 3.2 provides recommendations on how to address Ng.

While the relationship is fairly straightforward as to the affect of duration of the operation on the ground flash density, the affect may not be so obvious for the calculation of the expected losses. The basic formula for the calculation of various types of loss (L_x) can be reduced to $L = k\ L_f$, where L_f is a function of the product of the ratio of endangered persons to total persons exposed (np/nt) and the ratio of total number of hours persons are exposed to the total number of hours in a year (t/8760). The factor, k. is a factor associated with the risk of fire and any special provisions taken to reduce the consequences of the fire, along with consideration of any special hazards present. For many explosives operations, one may consider that all personnel in the structure are likely to be at the same level of risk. Where this is not true, the ratio is likely to be consistent for a given operation. The primary variation in the loss will be in the ratio of the total exposure in hours (t) to the total number of hours in the period of interest (T).

3.2 Considerations on how to Pro-Rate the Ground Flash Density (Ng)

Since the ground flash density is such an important factor in a lightning risk assessment, it is important to keep in mind that the accuracy of the value used is highly dependent on the data source and sample size. The two most common methods to determine ground flash density in use today are the use of data from lightning detection networks and the calculation of ground flash density from thunderstorm days taken from isoceraunic maps. There are several formulas available from which one can calculate the ground flash density from the number of thunderstorm days, but the simplest formula and the one used in most risk assessments assumes the ground flash density (strikes per square kilometer) is one tenth of the number of thunderstorm days [4]. While it is often the case that the simplest relationship is not the most accurate relationship, the determination of the number of thunderstorm days per year is not the most accurate technique either. This value is based on the observation and recording of thunder being heard at a number of recording locations (which is likely some distance from the structure under consideration). In the case of ground flash density taken directly from lightning detection networks, there is also an inherent inaccuracy depending upon the number of sensors used in the network, the accuracy of the error correcting software, and, most important, the number of years of data available.

By definition, any month or several months period will likely experience greater than the average number of strikes to earth per square kilometer per year for some months and less than the average number of strikes per square kilometers per year for other months. For those cases where the operations in a structure are not consistent or where the operation may be at a temporary location, some types of losses will be overestimated during some periods and underestimated during other periods if a yearly average technique is used. The amount this will (or should) affect the calculated risk will depend upon whether the month or months the operation is being conducted is coincident with the period that the ground flash density is above average.

Current lightning risk assessments [4][5][6] are based on yearly averages of ground strike density, probability of failure, and expected losses (including the exposure of personnel to dangerous conditions). The accuracy of this data is greater when the data sample size is integrated over the period of several years or decades. Conversely, the data is least accurate where the sample size is smallest (based on number of years of data available) or where the time window for the temporary exposure is smallest (for example a week or less). It is our recommendation that the minimum number of days that should be considered (i.e. minimum sample size) for the lightning risk assessment of a temporary event be one month. Justification for this recommendation is given below.

The ground flash density maps generally available to those conducting a lightning risk assessment provide only yearly averages. This same information can be provided from national lightning detection networks for a specific latitude / longitude location by specific request. Local lightning detection networks are sometimes available which provide the required ground strike data by month. However, in very few cases is this data available down to the specific day of the month.

Even if this data were available, the variability in the probability of lightning activity on any given day based on previous history of lightning on that day is more or less random. For example, Table 1 provides a breakdown of 20 years of data from a localized lightning detection network. The top row provides a breakdown of total number of strikes per square kilometer recorded for the local area over a 20 year period. The middle row provides an indication of the number of days by month over this 20 year period there was lightning recorded in the area. As you can see from the table, there was no month in which the average number of days with lightning activity exceeded one per month. This would make the prediction of the specific day on which a lightning event would occur on any one day to be totally random. If we were to take the example of the probability of lightning occurring at this location during the period 13-15 July, we see that there was lightning activity recorded 11 days during the month of July during the 20 year period. This results in a probability of (3)(11)/(31)(20) or approximately a 1 in 19 chance of lightning occurring some time during the 3 day period. It is suggested that better success could be provided by local weather forecasts.

Table 1. Breakdown of Lightning Flash Density by Month (20 year sample)

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Total strikes/ km^2	0	0	0	21	10	45	30	30	5	7	0	1	149
Total # days w/ lightning activity	0	0	0	2	5	9	11	14	2	6	0	1	50
Average strikes/ km^2/yr	0	0	0	1.05	0.5	2.25	1.5	1.5	0.25	0.35	0	0.05	7.45

3.3 Proposed Methodology

To illustrate the relationship of number of flashes to ground (Ng) and the duration of exposure of the event (T) on the calculated risk, it is probably best to work some academic examples. These examples are purely academic and the values of probability, loss and collection area will be set not to reflect typical conditions but to simplify the math so the user can focus on the method and not the math. It also better allows the relationship between ground flash density and duration of exposure on the calculated risk to be understood.

In these theoretical examples we will consider a large production or manufacturing facility located in southeast North Carolina. Guthrie and Rousseau [2][3] and IEC 62305-2 [2] identify the risk components that may be applicable for a lightning risk assessment for a structure or operation. For simplicity, in this example we will not consider all of the risk components that may be applicable for the application but will instead consider only the risk of physical damage due to a direct strike to the structure (R_B). The structure is in a remote area without other structures in the vicinity. The equivalent collection area of the structure is 0.01 km^2 (107,636 ft^2) and the ground flash density (Ng) is 6 flashes per square kilometer per year. We will assume that all personnel working in the building could be endangered as a result of physical damage due to a direct strike. In this structure there is only a 6 month contract to deliver a specific product. IEC 62305-2, Clause 6.2 identifies that the risk of physical damage due to a direct strike (R_B) is the product of the number of dangerous events resulting from a direct strike (N_D) times the probability of physical damage to the structure due to the strike (P_B) times the loss to the structure related to physical damage due to a strike to the structure (L_B).

To compute the risk of damage due to a direct strike, we will first compute the number of dangerous events from a direct strike (N_D). The number of dangerous events is primarily a function of the ground flash density and collection area. In this case, the size of the structure was selected to make the math easy so N_D = 0.06 strikes per km² per year to the structure. The probability of loss due to a strike to a structure is a function of the protection level provided and characteristics of the structure. Since this factor will essentially be a constant in this example and the purpose of the example is to show the relationship between risk and exposure to the lightning environment, we will consider that there is no protection provided and each event is likely to result in physical damage (P_B = 1). The loss considered in this case (L_B) is primarily related to the ratio of the number of endangered persons to the total number of persons in the structure and to the time in hours per year for which the persons are present. Considering the case where the operation is conducted only one-half year, the Loss factor will be 0.5 and the risk of physical damage due to a direct strike would be 0.03 losses per year. This assumes that the average number of flashes per square kilometers per year will all occur in the period in which the operation is planned.

Let us now run the same example and only consider the six month period that the operation is conducted. Let us assume that all of the 6 strikes to ground per year will occur in the six month period consisting of April through September. To show the extremes, we will consider the case where the operations are conducted during the period October through March and the case where the operations are conducted April through September. For the period October through March, the number of dangerous events is zero (Ng=0); therefore the resulting risk of physical damage is zero. For the period April through September the number of events during the period will be 6 (N_D = 6), there is no LPS provided for the operation (P_B = 1), all personnel in the structure will be subjected to the danger (np/nt = 1), and the operation will be conducted during the entire 6 month period by 3 persons for one 8 hour shift each day (t/T = 4380/4380 = 1). The resulting risk (R_B) = (0.06)(1)(1)(1) = 0.06. This is twice the value of the calculation taken from the standard when the assessment is considered over a one year period.

Table 2 forwards the results of some additional calculations showing the affect of the ground flash density on the risk due to damage from a direct strike when only a portion of a year is considered. In the examples used for this table, we will consider an R&D facility manned by a total of 6 people for a total of 12 hours per day. Three of the people at the site are not directly involved in explosives operations and are located in a safe area on the other side of a substantial dividing wall. The building does not have a lightning protection system installed (P_B=1) but does have a sprinkler system and fire-proof compartments. The explosives material being handled in the structure is not susceptible to the LEMP associated with a spark. The construction of the structure and the low explosives yield involved in the operation will ensure there is no risk to either the environment or surroundings. As given in Section 3.1, L = k L_f. Based on the description of the scenario given above and the tables given in IEC 62305-2, Annex C, k = 2 and L_f = (0.5)(0.5) = 0.25. This reflects a loss due to a direct strike to the structure (L_B) of 0.5 as given in Table 2.

Table 2 considers the following scenarios:

- Case 1 – provides the basic calculation for the structure and operation based on the operation being performed year round. This calculation will be the baseline for comparison to the other methods of calculating the risk. The total number of hours in a year is calculated as 24 hours per day times 30 days times 12 months. This will make it easier to make the calculations when we consider one month or multiple months.
- Case 2 – considers an analysis of the same site, operation, and time of operation but it considers that the probability of lightning activity is consistent over the period of the year (6/12 = 0.5/month). It then considers the risk if the operation is conducted only during a single random month. (1/12 of Case 1)
- Case 3 – considers the same situation but assumes that the operation will be conducted during one of the 6 months that experience 1 flash per square kilometer.
- Case 4 – considers the case for the other 6 months that has no lightning activity.
- Case 5 – represents the example combining 3 months of Case 3 with 3 months of Case 4.
- Case 6 – considers the case where the entire 6 months that contains the lightning activity is considered in one case. (6 times Case 3)
- Case 7 – addresses the remaining 6 month period where there is no lightning activity. (6 times Case 4)
- Case 8 – represents the combination of 6 month periods when compared with the yearly average. (Case 6 + Case 7 and the same as Case 1)

Table 2 – Relationship between consideration of Ng / calculated risk (R) / and Tolerable Risk (R_T).

Case	Ng	n_p/n_t	t	T_{total}	N_D	P_B	L_B	R	R_T	Prorated R_T	R/Prorated R_T
1	6	0,5	4320	8640	6,00E-02	1	0,5	3,00E-02	1,00E-05	1,00E-05	3 000
2	0,5	0,5	360	720	5,00E-03	1	0,5	2,50E-03	1,00E-05	8,33E-07	3 000
3	1	0,5	360	720	1,00E-02	1	0,5	5,00E-03	1,00E-05	8,33E-07	6 000
4	0	0,5	360	720	0,00E+00	1	0,5	0,00E+00	1,00E-05	8,33E-07	-
5	3	0,5	2160	4320	3,00E-02	1	0,5	1,50E-02	1,00E-05	5,00E-06	3 000
6	6	0,5	2160	4320	6,00E-02	1	0,5	3,00E-02	1,00E-05	5,00E-06	6 000
7	0	0,5	2160	4320	0,00E+00	1	0,5	0,00E+00	1,00E-05	5,00E-06	-
8	6	0,5	4320	8640	6,00E-02	1	0,5	3,00E-02	1,00E-05	1,00E-05	3 000

The interesting point to observe in the table is the ratio of calculated risk to tolerable risk can be maintained as long as the level of tolerable risk is reduced by the same percentage as the amount of time the operation is performed. This reduction in the number of hours of exposure acts to keep the loss value constant. In Case 2, (where the lightning frequency is considered to be constant over the period of a year) the calculated risk for a one month operation is reduced due to the reduction in exposure (t) and the number of expected events (Ng). However, the ratio of calculated versus tolerable risk is maintained if the value of tolerable risk is reduced to 1/12 of that selected for a year. If it is considered that the lightning activity is not consistent across a period of a year (see Case 3 and Case 4), then the ratio is not maintained. For example, the scenario given in Case 3 would be equivalent to an area that experiences 12 ground flashes per square kilometer per year. Case 5 assumes that the process is conducted over a six month period that combines 3 months with activity with 3 months without activity to compare this case with those previous cases. In the last 3 cases we will once again consider the calculations over a 12 month period but we will do this by considering the cases by 6 month period where there are 6 strikes per square kilometers and 6 months with no lightning activity. It can be seen that the calculated risk for the 6 month period with lightning activity (Case 6) is the same as that calculated for a year in Case 1 but the risk ratio is twice as high because the period of operation is ½ year. Once both 6 month periods are combined (see Case 8), the ratio of calculated to tolerable risks is seen to be the same as that when the operation is considered over the period of a year (Case 1).

The data in the table confirms the suggestion that the risk of physical damage can be calculated for periods of less than a year if the number of strikes per square kilometer (Ng), the total number of hours in the period under consideration (T), and the tolerable risk (R_T) are all pro-rated. If these values are not pro-rated, the calculated risk will be either greater or less than the average value (depending upon the period chosen) when the same structure is considered over the period of one year. The required level of protection would not be consistent with the tolerable risk (R_T) for a year if R_T is not prorated to the period of observation.

4. Illustrative Examples

Some illustrative examples are given of the benefit of the development of a lightning risk assessment for applications where the lightning risk and exposure of an operation are not consistent across the period of several years. We will use 2 theoretical examples in this paper. In the first example, we will consider a short-term, improvised field ammunition storage site used in a fast-moving military operation. In the second example, we will consider the threat associated with an explosives truck holding area (or safe haven) that requires repair or significant maintenance and the risk assessment is used to determine scheduling by identifying when the risk will be at tolerable levels. It must be stressed that these examples are hypothetical and the numbers used are selected based more on simplicity of the example than the actual probability of damage and expected loss resulting from an event characteristic of such an application.

Table 1 provides a hypothetical breakdown of flash density by month of an area that experiences approximately 8 flashes to earth per square kilometer per year. As discussed in Section 3.2, this breakdown is based on 20 years of data for the latitude/longitude location of interest and will be used for the practical examples discussed below. The top row identifies the total number of flashes per square kilometer recorded by month for the entire 20 year period. The bottom row identifies the yearly average number of flashes to earth per square kilometer for each month when averaged over the 20 year period.

In this initial example we will consider the improvised field ammunition storage site used in a fast-moving military operation. The structure under consideration is a single Container Express (CONEX) container as described in MIL-HDBK-138B [7] used to transport and store the Strategic Configured Loads (SCL's) required for the operation. The CONEX container is barricaded as shown in Figure 1. Figure 2 provides an example of an artillery ammunition SCL load [8] which we will assume to be included in the ISO container of this hypothetical example. We will consider the size of the single ISO container in this example to be 2.4 m x 2.4 m x 6 m. For this example, we will consider the location of the operation to be in a large flat arid area, resulting in a location factor of 1.

It is anticipated that this operation will last approximately 3 months and is scheduled to begin the first of June. From Table 1, we find the average ground strike density for June to be 2.25 flashes per square kilometer, with both July and August averaging 1.5 flashes per square kilometer. This results in an average lightning ground flash density (Ng) of 5.25 flashes per square kilometer for the 3 month period. In this case, there is not enough time and/or resources available for the installation of a conventional lightning protection system (LPS) to be installed.

For simplicity, we will work this example considering only the risk of physical damage due to a direct strike to the structure (R_B). We will assume for the purpose of this exercise the probability of loss due to a direct strike, $P_{B,} = 10^{-3}$ even though this may or may not be the case. There is currently an on-going effort to assess the probability of loss due to a direct strike to an ISO container and progress in this effort will be reported by Covino and Struck at the 2010 DDESB Seminar.

The loss (L_B) considered in this example is related to the ratio of the number of endangered persons to the total number of persons in the structure and to the time in hours per year for which the persons are present, the amount of time of exposure, provisions against fire, and the possibility of a hazard to the surrounding area. There will be 2 explosives handlers working per shift for 2 each 8 hour shifts in support of the operation. Each of the workers is exposed to an explosives hazard for 2 hours of the 8 hour shift for the full 90 days of the operation ($n_p/n_t = 1$; $t/T = 0.167$). There is a risk of explosion ($r_f = 1$) but the barricades reduce the hazard for the surroundings to an average level of panic ($h_z = 5$). Manual fire fighting provisions are implemented but IEC 62305-2 specifies that for structures with the risk of explosion there is no reduction allowed against consequences due to fire ($r_p = 1$).

Figure 1 – Barricaded ISO Storage Containers

The loss in the structure due to physical damage, L_f, for this example becomes:

$$L_f = (n_p/n_t)\ (t/T) = (1) \times (4)(90)/(24)(90) = 0.167$$

resulting in the loss due to a direct strike of:

$$L_B = (r_p)\ (r_f)\ (h_z)\ (L_f) = (1)(1)(5)(0.167) = 0.835$$

From the dimensions of the ISO container given earlier, the effective collection area in this example is:

$$A_e = LW + 6H(L+W) + \pi 9H^2 = (2.4)(6) + (6)(2.4)(2.4 + 6) + (3.14)(9)(5.76) = 298.1\ \text{m}^2$$

The number of dangerous events is:

$$N = (N_g)\ (A_e)\ (C_1)\ (10^{-6}) = (5.25)(298.1)(1)\ (10^{-6}) = 1.56\ (10^{-3})$$

Figure 2 - Mission-configured load of artillery ammunition (from ERDC/GSL TR-01-18)

The resulting risk of physical damage due to a direct strike to the structure (R_B) now becomes:

$$R_B = (N)\ (P_B)\ (L_B) = 1.56\ (10^{-3})\ (10^{-3})\ (0.835) = 1.32\ (10^{-6})$$

Using the tolerable level of risk given in IEC 62305-2 prorated for a 3 month period (2.5 (10^{-6})) we find that risk of physical damage due to a direct strike is less than the tolerable level so no additional protection is required. Again, the values given in this example are hypothetical and are given to illustrate the example of how the assessment should be performed.

The benefit of this exercise is to show the relative change in risk associated with the time of year the operation is conducted and a comparison with the value that would be obtained should the assessment consider the entire year. If we were to consider the average distribution of strikes per square kilometer given in Table 1 to be accurate for the specific location of the temporary storage location, then there would be none to minimal lightning threat to such an operation in the months November through March. If the operation was conducted during the period September through November, the risk would be reduced by a factor of 0.6/5.25 or 11.4% of the risk for June through August. If this risk was considered over the period of a year, the value of loss in the structure due to physical damage, L_f, would be reduced by (360/8760) resulting in a yearly L_B of 0.205. The resulting risk of physical damage due to a direct strike considering an entire year would be (7.45) (1.56) (10^{-3}) (10^{-3}) (1) (0.205) = 2.38 (10^{-6}) or approximately 1/4 the yearly tolerable level of risk of 1 (10^{-5}). This confirms the need for prorating the expected losses relative to the period of observation

There has also been some discussion on the use of such a technique to determine the risk associated with the temporary storage of a loaded ammunition transport vehicle in an unprotected area where a safe haven is not available. As discussed in Section 3.2, the estimate of the number of flashes to earth is least accurate when the sample size is smallest. It is not recommended that this procedure be implemented for temporary activities spanning a period of less than one month. For shorter periods, it would likely be more accurate to base the probability of a direct or nearby strike to earth on local weather forecasts as the indication of atmospheric conditions favorable to lightning are a better indication of the probability of ground flashes than a previous history of lightning activity for any given day. However, for periods exceeding one month, it could be of benefit to consider the monthly breakdown of ground flash density when the scheduling of maintenance operations can be controlled.

5. Summary and Conclusions

In summary, there exists a need for a method to conduct a lightning risk assessment for various scenarios that are one-time events or events that do not occur over a period of a year or more. The risk assessment methods currently available are based on a number of dangerous events and losses averaged over a one year period. The tolerable level of risk is also expressed in terms of probable average annual loss.

In considering the assessment of a risk of an operation lasting less than one year, it can be found that if one were to use the yearly assessment procedure the calculated risk will underestimate the actual risk for operations conducted during a period of the year when diurnal lightning activity is greater than average and overestimates the risk when the ground flash rate is less than average. It is shown that an accurate assessment of risk can be made where the evaluation period is less than a year if the level of tolerable risk is reduced by the same percentage as the time the period of observation considered. The reduction in number of hours of exposure is necessary to keep the loss value constant. It is concluded that the risk of physical damage can be calculated for periods of less than a year if the number of strikes per square kilometer (Ng), the total number of hours in the period under consideration (T), and the tolerable risk (R_T) are all prorated.

It is suggested that this method be evaluated in greater detail and considered for incorporation in Strike-QRA. It is however, recommended that a minimum assessment period of one month be used in conducting such assessments. The accuracy of the assessment decreases as the sample size decreases as it becomes more difficult to predict accurately the expected number of strikes per square kilometer for the period of observation.

6. References

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