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DATA DEVELOPMENT TECHNICAL SUPPORT DOCUMENT FOR THE AIRCRAFT CRASH RISK ANALYSIS METHODOLOGY (ACRAM) STANDARD

Chris Y. Kimura
Ronald E. Glaser
Richard W. Mensing
Tom Lin
Timothy A. Haley
Andrew B. Barto
Martin A. Stutzke

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Lawrence Livermore National Laboratory

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4. MILITARY AVIATION

4.1 INTRODUCTION

For the ACRAM Standard [Ref. 4.1], military aviation is defined as the broad categorization of aviation activities performed by military personnel in fulfillment of their official duties. Such activities include passenger and cargo transport, in-flight refueling, flight training, etc. Activities associated with military operations areas (MOA) and training ranges, such as air combat training, low level navigation, personnel and stores drops, are not included. However, cruise phase of flight between an originating airfield and the MOAs, as well as training associated with takeoff and landing at an airfield, including touch and go's; simulated emergency landings, e.g., no flap, flameout; and missed approach/go-arounds, are included.

To quantify the risk of a military aircraft crashing into a facility it is necessary to estimate the number of military flights in the vicinity of the facility, the frequency of military aircraft crashes and the probability that the aircraft crashes into the facility. The latter requires knowledge about the location of aircraft crashes, given an incident leading to a crash, as well as some crash kinematics, e.g., glide or impact angle, heading angle, and skid distance.

To estimate military aircraft crash frequencies, relevant crash and flight information was solicited from the U.S. Air Force, Army and Navy safety agencies. Useable information for fixed wing and rotary wing (helicopter) aircraft were received from the Air Force. The Army provided data on Army helicopters. Data received from the Navy was judged to be of limited value for this application, and is not included in the estimates presented here. Analysis of available crash data and the resulting estimates of military aircraft crash frequencies are presented in Section 4.2.

Crash kinematic and crash location data were derived by reviewing Air Force aircraft mishap reports from 1976 to 1993. A database of aircraft crash data was developed as part of the DNA supported W78/W87 Minuteman III Weapon System Safety Assessment (WSSA) [Ref. 4.2]. That formed the basis for developing crash kinematics and crash location probability distributions. Data analysis and distributions are summarized in Section 4.3.

Section 4.4 includes a summary of some of the appropriate characteristics of military aircraft which are necessary for the structural analyses.

4.2 MILITARY AVIATION CRASH FREQUENCIES

Development of estimates of aircraft crash frequencies is based on an analysis of aircraft crash and flight data supplied by Air Force and Army safety agencies [Ref. 4.3-4.6] and the database of Air Force mishaps developed for the DNA supported Minuteman III WSSA [Ref. 4.2].

For the ACRAM Standard, the flight phases of interest for military aviation are

- Takeoffs at airfields in the vicinity of the facility of interest
- Landings at airfields in the vicinity of the facility of interest
- Overflights, during the cruise phase of flight, in the vicinity of the facility of interest

Analysis of the military crash data required the identification of the phase of flight in which the crash occurred as well as screening of crashes to delete those not applicable to crashes into structures, e.g., crashes involving taxiing and/or parked aircraft. This required a review of the individual accident reports/summaries to assign each accident to the proper phase and, occasionally, involved judgments in the applicability of an accident. Thus, there is some uncertainty in the estimates of crash frequencies in addition to inherent "statistical" variation due to the limited amount of historical data. Although recognized, this uncertainty is neither quantified nor included in the provided estimates of crash frequencies. Rather, the estimates provided are considered plausible point estimates of the appropriate frequencies.

Two analyses were considered in developing estimates for crash frequencies. One analysis is based on a review of the brief summaries of mishaps as provided by the Air Force/Army safety agencies. This approach is discussed and the resulting estimates of crash frequencies are presented in Section 4.2.2. The second analysis is based on the Air Force mishap database developed for the Minuteman III WSSA. This analysis and the resulting estimates are discussed in Section 4.2.3.

This Standard is expected to be applicable to facilities off an airfield and not in the immediate vicinity of a runway. Therefore, military takeoff and landing crashes were identified as "on runway" (i.e., crashes in which the initial impact occurred on the runway and the rolling/skidding aircraft departed the runway or remained on the runway) or "off runway" (i.e., the initial impact occurred off the runway). Although the off runway crashes include some that occurred on an airfield, the off runway crash frequency estimated from the historical data is considered a reasonable conservative estimate applicable for this Standard.

For military aviation the cruise phase of flight involved a number of different types of operations in addition to "normal" flight from one base to another. A significant part of the cruise portion of flight, particularly for military attack, fighter and trainer aircraft, involved maneuvers. Since this type of activity is not expected to affect facilities covered by this Standard, accidents occurring during maneuvers, air shows, and other special operations were not included in developing the estimated inflight crash frequencies. Deleting those accidents from consideration required that the mileage flown, which is the denominator of crash frequencies, be adjusted. Since the available military flight information is in flight hours, considerable judgment was involved in developing estimates of the number of miles flown during "normal" flight. Again, this needs to be recognized in using the provided estimates of crash frequencies.

Ideally, estimates of crash frequencies can be developed for each type of military aircraft. This was the goal in the second analysis (Section 4.2.3). Due to limited data and the reasonable expectation that actual frequencies are comparable for some subsets of aircraft, estimated crash frequencies are provided per aircraft type or group of types. The philosophy of this Standard is to use three subcategories of military aircraft:

Large aircraft: bomber and cargo aircraft such as the B-1, B-2, B-52, C-5, C-9, KC-10, C-21, C-130, KC-135 and C-141

Small aircraft: attack, fighter and trainer aircraft such as the A-7, A-10, A-37, F-4, F-5, F-15, F-16, F-106, F-111, F-117, T-33, T-37, T-38, T-39 and T-41

Helicopters: H-1, H-3, H-53 and H-60

Estimates of crash frequencies are provided for each subcategory as well as for all military aircraft. These combined estimates are based on a weighted average of the individual frequencies, weighted by the respective normalized number of takeoffs/landings and number of miles flown during "normal" flight. Application of the combined frequencies is appropriate only when (1) the distribution, among the different types of aircraft (e.g., T-38, F-16, B-52, ...), of the number of takeoffs/landings at the airfield of interest and (2) the distribution, among aircraft types, of the enroute overflights in the vicinity of the facility of interest are comparable to the distributions in the historical data. If operations at a given location are much different than the overall distribution in the historical data, alternative estimates of crash frequencies, based on the appropriate mix of aircraft at the location, should be considered.

4.2.1 ESTIMATES OF CRASH FREQUENCIES BASED ON AN ANALYSIS OF IMPACT ACCIDENTS

Air Force mishap data solicited from the Air Force Safety Agency [Ref. 4.3-4.5] provides one basis for estimating crash frequencies for military aviation. Air Force classification of mishaps is based on the economic costs of damage to the aircraft and personnel costs and are defined as follows:

Flight Mishap - A mishap involving an Air Force aircraft when intent for flight exists.

Class A - A mishap in which the resulting total cost of property damage, injury and illness is $1,000,000 or greater; or an Air Force aircraft is destroyed; or a fatality occurs.

Class B - A mishap in which the resulting total cost of property damage, injury and illness is $200,000 or more, but less than $1,000,000.

Class C - A mishap in which the resulting total cost of property damage is $10,000 or more, but less than $200,000 or injury or occupational illness resulted in a lost workday case involving days away from work.

Destroyed - Destroyed means uneconomical to repair, defined by the number of man-hours estimated as needed to repair the aircraft. Repair time varies depending on the type of aircraft.

Mishap Rates - Rates are computed on basis of the number of mishaps per 100,000 flying hours.

Flight Related - When there is a mishap with little or no damage to the aircraft, the incident does not affect the mishap rate.

One set of data provided by the AFSA is based on the lifetime mishap history, up to the early 1994 time frame, of a large number of Air Force aircraft. A total of 5171 Class A, 2450 Class B, and 3598 Destroyed mishaps are included in this data set. A summary of these mishaps, by aircraft type, is given in Table 4.1. Related flight information included in the table is the total flight hours for each type of aircraft. Also included in the table are estimates of mishap rates, given as rates per 100,000 flight hours.

The various aircraft types were grouped by the three subcategories of military aviation, small aircraft, large aircraft, and helicopter.The mishap data for the three subcategories are summarized in Tables 4.2 to 4.4. Again, estimates of mishap rates are per 100,000 flight hours. Since T-33 aircraft have been out of the Air Force inventory for some time, mishap rates for small aircraft are estimated excluding the T-33 data as well.

The mishaps recorded in Tables 4.1 to 4.4 include a large number of mishaps not applicable to crashes into off airfield facilities, e.g., nonimpact mishaps, on airfield crashes, etc. Therefore, the mishap rates provided in these tables may be over estimates of crash rates into off airfield structures. In addition, takeoff and landing incidents are likely to be significant contributors to crashes into structures; thus, it is appropriate to develop crash rates per takeoff and landing. To do this it is necessary to have a more detailed description of the mishap.

A second set of data provided by the AFSA included summary information for mishaps in the 1979-1993 time period. Useable information was derived from 1426 mishaps. To develop crash frequency estimates, the 1426 mishaps were classified either as impact or non-impact mishaps. Impact mishaps included accidents involving ground, runway, water, midair, terrain, vehicle, and building impact. Non-impact mishaps included incidents involving foreign objects, birds, etc., and parked aircraft fires and other such incidents. Non-impact mishaps are considered not applicable. There were 1093 impact mishaps. Those mishaps included all classes of damage to the crashing aircraft. The mishaps were partitioned by aircraft "size" (large, small and helicopter) and by flight phase (takeoff, landing and inflight). Takeoff and landing were further partitioned into "on runway" and "off runway" mishaps. In-flight mishaps were partitioned into "normal" and "special", i.e., low altitude and maneuvering operation mishaps. A graphical description of the classification of the mishaps is shown in Figure 4.1. For this analysis, takeoff includes takeoff roll, abort/discontinue, and initial climb portions of a flight; landing includes the pattern, final approach, flare and rollout portions; normal in-flight includes climb to cruise, cruise between an originating airfield and an operations area, if applicable, and cruise descent portions; and special in-flight includes low level and maneuvering operations in restricted airspace.

The number of impacting mishaps for each subcategory of aircraft and flight phase, appropriate flight information and the resulting estimates of crash frequencies are summarized in Table 4.5.

Crash frequencies for takeoffs and landings are per takeoff/landing. Crash frequencies for "normal" inflight operation, are "per mile." The estimated mileage derived to estimate inflight rates is based on an analysis of the expected number of miles flown during "normal" flight. This analysis attempted to account for the time in the takeoff and landing phases of flight as well as the time in maneuvers and other special operations. This required a considerable amount of judgment by the analyst.

For some facilities, particularly hardened structures, a more appropriate estimate of a crash frequency may be one based on only considering impact mishaps in which the crashing aircraft was destroyed. Of the 1093 impact mishaps, a crashing aircraft was classified as "destroyed" in 819 mishaps. These impact destroyed mishaps were partitioned in the same way as impact mishaps as shown in Figure 4.1. A summary of this data and the resulting estimates of crash frequencies are given in Table 4.6.

Basic mishap data, flight information and partitioning of mishaps by aircraft subcategory and flight phase were developed by T. Lin at Sandia National Laboratory [Ref. 4.6]. Development of estimated miles flown during "normal" inflight operations is based on an analysis of aircraft operations by Logicon RDA [Ref. 4.7].

4.2.2 ESTIMATES OF CRASH FREQUENCIES BASED ON AN ANALYSIS OF THE MISHAP DATABASE DEVELOPED FOR THE MINUTEMAN III WSSA

Another source of mishap information is the mishap database developed for the DNA-supported Minuteman III WSSA [Ref. 4.2]. This database was developed from data extracted from individual mishap reports, also available from the AFSA. Its primary use was as a resource for crash location and crash kinematic information, but it is also useful as a basis for estimating crash frequencies. Development of crash frequency estimates using this database is based on identifying mishaps involving a "crash" which is defined as "An aircraft mishap associated with flight that prevents the aircraft from coming to a full stop landing on its gear." In addition, for this analysis, flight phases are defined as:

> Takeoff: The phase of flight from the application of takeoff power on the runway to the point where the aircraft altitude is not affected by its proximity from the departure runway.
>
> Landing: The phase of flight from the point where the aircraft altitude is affected by its proximity from the approach runway to its departure from the runway under a controlled taxi.
>
> In-flight: The phase of flight where the aircraft altitude is not affected by its proximity to the runway.

A summary of the crash data, estimated crash frequencies and applicable flight information for individual aircraft types and groups of aircraft types, as well as for the three subcategories of aircraft, is presented in Tables 4.7 and 4.8.

The basic crash data and flight information were developed by M. Fuentes at Sandia National Laboratories [Ref. 4.6]. The estimated miles used for estimating crash frequencies during the inflight phase of flight is based on analysis of military aircraft operations by Logicon RDA.

Table 4.8

Crash Data and Estimates of Crash Frequencies Based on the Minuteman III Mishap Database

						Normal Flight			Special Operations		
				Number of Sorties	Flight Hours	Estimated Miles	No. of Crashes	Crash Rate/ Mile	Estimated Miles	No. of Crashes	Crash Rate/ Mile
Large	Bombers (Bs)		B1, B52, B57	343,000	2,177,000	5.00E+08	2	4.00E-09	5.00E+08	6	1.20E-08
	Cargo (Cs)		C130	2,669,000	6,343,000	1.50E+09	4	2.67E-09	1.50E+09	10	6.67E-09
			KC135	1,123,000	4,728,000	1.10E+09	1	9.09E-10	1.10E+09	0	<9.09E-10
			Other Large Cs	2,333,000	7,738,000	1.80E+09	2	1.11E-09	1.80E+09	1	5.56E-10
			Small Cs	821,000	1,535,000	3.50E+08	1	2.86E-09	3.50E+08	1	2.86E-09
			All Cargo	6,946,000	20,344,000	4.75E+09	8	1.68E-09	4.75E+09	12	2.53E-09
			All Large (Bs, Cs)	7,289,000	22,521,000	5.25E+09	10	1.90E-09	5.25E+09	18	3.43E-09
Small	Attack (As) Fighters (Fs)	Single Engine	A7	925,000	1,387,000	2.40E+08	9	3.75E-08	2.60E+08	43	1.65E-07
			F16	2,675,000	3,730,000	8.30E+08	32	3.86E-08	9.30E+08	104	1.12E-07
			All Single-engine	3,600,000	5,117,000	1.07E+09	41	3.83E-08	1.19E+09	147	1.24E-07
		Multiple Engine	A10	1,740,000	2,962,000	5.10E+08	16	3.14E-08	5.60E+08	47	8.39E-08
			F4	3,882,000	5,162,000	1.20E+09	20	1.67E-08	1.30E+09	139	1.07E-07
			F15	2,082,000	2,864,000	6.40E+08	4	6.25E-09	7.10E+08	60	8.45E-08
			F111, FB111	658,000	1,648,000	3.70E+08	9	2.43E-08	4.10E+08	40	9.76E-08
			All Multiple-engine	8,362,000	12,636,000	2.72E+09	49	1.80E-08	2.98E+09	286	9.60E-08
			Other As, Fs	1,530,000	2,079,000	4.50E+08	12	2.67E-08	5.00E+09	73	1.46E-08
			All As, Fs	13,492,000	19,832,000	4.24E+09	102	2.41E-08	9.17E+09	506	5.52E-08
	Trainers (Ts)		Subsonic: T37	4,154,000	5,212,000	7.00E+08	4	5.71E-09	7.80E+08	11	1.41E-08
			Supersonic: T38	5,109,000	6,036,000	1.20E+09	11	9.17E-09	1.40E+09	27	1.93E-08
			Other Ts	1,347,000	2,254,000	3.90E+08	3	7.69E-09	4.30E+08	7	1.63E-08
			All Ts	10,610,000	13,504,000	2.29E+09	18	7.86E-09	2.61E+09	45	1.72E-08
			All Small (As, Fs, Ts)	24,102,000	33,336,000	6.53E+09	120	1.84E-08	1.18E+10	551	4.68E-08
Helicopter				1,028,000	1,449,000	8.30E+07	17	2.05E-07	9.30E+07	9	9.68E-08
All Military Aircraft				32,419,000	57,306,000	1.19E+10	147	1.24E-08	1.71E+10	578	3.38E-08

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DATE 4/12/02 Witness ______

Clerk [illegible]