2013 International Nuclear Atlantic Conference - INAC 2013
Recife, PE, Brazil, November 24-29, 2013
ASSOCIAÇÃO BRASILEIRA DE ENERGIA NUCLEAR - ABEN
***ISBN:* 978-85-99141-05-2**

Evaluation of Aircraft Crash at Laboratório de Geração Nucleo-Elétrica (LABGENE) Located at Centro Experimental ARAMAR

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ABSTRACT

One of the human-induced external hazards to be considered in a Level 1 Probabilistic Safety Assessment for a nuclear plant is the aircraft crash, so it's necessary to have the estimative of the frequency of this hazard. In this paper is obtained the annual frequency of aircraft crash at the Laboratório de Geração Núcleo-Elétrica (LABGENE) located at the Centro Experimental Aramar (CEA).The calculation of this frequency was based on the method recommended in the Standard Review Plan Section 3.5.1.6 considering the airports, training camps and airways located in CEA's region. The estimated value for the aircraft crash frequency obtained is in accordance with the acceptance criteria established in the Standard Review plan Section 3.5.1.6.

1. INTRODUCTION

One of the human-induced external hazards to be considered in a Level 1 Probabilistic Safety Assessment for a nuclear plant is the aircraft crash [1], so it's necessary to have the estimative of the frequency of this hazard. In this paper is obtained the annual frequency of aircraft crash at the Laboratório de Geração Núcleo-Elétrica (LABGENE) located at the Centro Experimental Aramar (CEA). The calculation of this frequency was based on the method recommended in the Standard Review Plan Section 3.5.1.6 [2] considering the airports, training camps and airways located in CEA's region.

2. ESTIMATION OF AIRCRAFT CRASH FREQUENCY

2.1. Movement of the Airspace in the Region of Interest

According to informations obtained with the Segundo Centro Integrado de Defesa Aérea e Controle de Tráfego Aéreo – Comando da Aeronáutica [3] there are eight airways passing

ISBN: 978-85-99141-05-2

through the vicinity of CEA. The airways are: UM656, UZ21, UM415, UW50, UW49, W16, W24 e A428.

There is one airport, Aeroporto Estadual de Sorocaba and two airfields located in Boituva and in Fazenda Ipanema.

Additionally, according to [4], CEA is a restricted area (SBR 404) for flights below 700 m (2000 ft), therefore, in this case, the entrance through the vicinity of CEA must be authorized by the Director of Centro Tecnológico da Marinha.

2.2. Criteria Adopted

According to the acceptance criteria of the method recommended in the Standard Review Plan Section 3.5.1.6 [2], the frequency of aircraft accidents resulting in radiological consequences above to the limits of exposure established must be less than an order of magnitude of $1.0x10^{-7}$ per year. The frequency is considered to be less than an order of magnitude of $1.0x10^{-7}$ per year by inspection if the distances from the plant meet all of the criteria listed below:

a) The plant-to-airport distance D is between 5 and 10 statute miles, and the projected annual number of operations is less than 500 D^2, or the plant-to-airport distance is greater than 10 statute miles, and the projected annual number of operations is less than 1000 D^2;

b) The plant is at least 5 statute miles from the nearest edge of military training routes, including low-level training routes, except for those associated with usage greater than 1000 flights per year, or where activities may create an unusual stress situation;

c) The plant is at least 2 statute miles beyond the nearest edge of a Federal airway.

If above proximity criteria are not met, a detailed review of aircraft hazards must be performed by analyzing the movement of the airways, airports and heliports and calculating their frequency of occurrence.

Boituva's airfield is used with most frequency by the parachuting school, so these operations will be held near the airfield with no flying over the CEA's area.

For the air operations at Fazenda Ipanema, according to the information given by the Superintendência Federal de Agricultura de São Paulo [5], the aerodrome is used for practicing, training of pilots, coordinators and aviation executors as well as to demonstration and aeroagricultural equipments testing. However, it hasn't been used/operated in a systematical way. The numbers show only 4 (four) events of landing and taking off in the last 5 (five) years. It's emphasized that every flight plan in Fazenda Ipanema's area excludes, obligatorily, the CEA's airspace.

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Sorocaba's airport, located 12 km from the LABGENE, composes its general movement by the following types of usage:

- Regular Aviation: aero transport is executed with determined weekly difference, with previously established days. Generally, air companies of people/cargo public transport flights;
- General Aviation: flights that are rarely done, with no regularity e.g: aero taxi, private transport, government's aircrafts, etc;
- Others: flights that are not considered either general aviation or regular aviation, e.g: experimental aviation.

According to information obtained at Segundo Centro Integrado de Defesa Aérea e Controle de Tráfego Aéreo – Comando da Aeronáutica [3] concerning Sorocaba's airport, the annual average of operations from 2009 to 2011, considering the whole movement of the airport (general, regular and military aviation and others) that intervene in the CEA's region was of 22104. According to [2], as the distance between Sorocaba's airport and CEA is of 12 km (7.5 miles) and the annual number of operations is inferior to the established limit ($500D^2$ = 28125 operations), this airport can be excluded from the study.

Concerning the helicopter's movement over LABGENE, as mentioned before, there is a restricted area (SBR 404) to flight at inferior altitudes at 700m (2000 ft).

Therefore, considering the criteria established in a, b and c for the annual frequency of aircraft crash over the LABGENE, there will be only considered the contribution of aircrafts that used the airways UM656, UZ21, UM415, UW50, UW49, W16, W24 e A428.

2.3. Calculation Method of F

According to [2], the annual frequency of aircraft crash for airways can be obtained by the equation:

$$F_i = \frac{P * N_i * A}{W_i} \tag{1}$$

where:

F_i = annual frequency of aircraft crash for airway i;
P = in-flight crash rate for aircraft using airway i (per km);
N_i = number of flights per year along the airway i;
W_i = width of airway i;
A = effective plant area (km^2).

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The effective plant area can be obtained by:

$$A = A_{sb} + A_{sk} + A_{ex} \quad (2)$$

where:

A_{sb} = shadow area;
A_{sk} = skid area;
A_{ex} = expanded area.

The shadow area is the elevation of the plant's area over the horizontal plane considering the drop angle for different types of aircrafts and fail modes. This area, according to [6] can be obtained by:

$$A_{sb} = \frac{(C + ws) * H}{tg(\theta)} \quad (3)$$

where:

C = length of the plant;
ws = length of the wing (considering the type of aircraft);
H = height of the plant;
θ = drop angle = 15^o [6].

The building's largest horizontal dimension is artificially increased to account for aircraft dimensions by adding the aircraft wing span to the building dimension.

The skid area around the plant is determined by the characteristics of the aircraft being considered and layout of the facility. Again, the building's largest horizontal dimension is artificially increased to account for aircraft dimensions by adding the aircraft wing span to the building dimension. Barriers, such as the presence of trees and relative location of nearby buildings can decrease the skid length. According to [6] this area is given by:

$$A_{sk} = (C + ws) * sd \quad (4)$$

where:
sd= skid length.

The expanded area is the area around the top of a facility that accounts for an aircraft's wing span. From [7], this area is given by:

$$A_{ex} = (C + ws) * L \quad (5)$$

where:
L= width of the plant.

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2.4. Calculation of F

The number of flights for each airway is the annual average obtained from the annual movement in 2010 and 2011. The data are obtained in a management and control system of air traffic called SETA Millennium, implemented in November 2010 and it adds new functions and more reliable data collecting and processing [8]. The annual number of flights for each airway in 2010 and 2011 is shown in Table 1.

Table 1: Airways Movement in 2010 and 2011

Airway	2010	2011	Total	Average
UM656	114	3721	3835	1917.5
UZ21	644	9089	9733	4866.5
UM415	1365	2740	4105	2052.5
UW50	1985	3428	5413	2706.5
UW49	1492	3067	4559	2279.5
W16	248	515	763	381.5
W24	1967	2232	4199	2099.5
A428	697	919	1616	808

The annual frequency of aircraft crash over the LABGENE, concerning the airways, is given by:

$$F = F_{UM656} + F_{UZ21} + F_{UM415} + F_{UW50} + F_{UW49} + F_{W16} + F_{W24} + F_{A428} \quad (6)$$

where:

F_{UM656} = annual frequency of aircraft crash over the LABGENE for UM656;

F_{UZ21} = annual frequency of aircraft crash over the LABGENE for UZ21;

F_{UM415} = annual frequency of aircraft crash over the LABGENE for UM415;

F_{UW50} = annual frequency of aircraft crash over the LABGENE for UW50;

F_{UW49} = annual frequency of aircraft crash over the LABGENE for UW49;

F_{W16} = annual frequency of aircraft crash over the LABGENE for W16;

F_{W24} = annual frequency of aircraft crash over the LABGENE for W24;

F_{A428} = annual frequency of aircraft crash over the LABGENE for A428.

ISBN: **978-85-99141-05-2**

For the effective area calculation, will be considered only the buildings, that in the case of aircraft crash, results in radiological consequences above to the limits of exposure established. To LABGENE, the buildings considered were the Prédio do Reator, Prédio do Combustível and Prédio Auxiliar Controlado, as they are buildings that in the case of aircraft impact with severe damages to their structures can represent meaningful liberations.

Being:

C = 70.2 m;
L = 60.1 m;
H = 31.4 m (height of Prédio do Reator);
ws = 60 m [7];
sd = 500 m [7];
$\theta = 15°$ [6].

From the equations (3), (4) and (5) are obtained:

$A_{sb} = 15257.67\ m^2$;
$A_{sk} = 65100\ m^2$;
$A_{ex} = 7825.02\ m^2$.

$$A = A_{sb} + A_{sk} + A_{ex} = 88182.7\ m^2 = 0.0882\ km^2$$

By equation (1), we can obtain the annual frequency of aircraft crash for each airway. By the equation (6) we can obtain an estimation for the annual frequency of aircraft crash over the LABGENE. Table 2 shows the obtained values.

Table 2: Annual Frequency of Aircraft Crash

Airway i	N	W	P	A	Fi
UM656	1918	40 km	$2.5x10^{-10}$/ km	0.0882 km^2	$1.06x10^{-9}$ /year
UZ21	4867	40 km	$2.5x10^{-10}$/ km	0.0882 km^2	$2.68x10^{-9}$ /year
UM415	2053	40 km	$2.5x10^{-10}$/ km	0.0882 km^2	$1.13x10^{-9}$ /year
UW50	2707	40 km	$2.5x10^{-10}$/ km	0.0882 km^2	$1.49x10^{-9}$ /year
UW49	2280	40 km	$2.5x10^{-10}$/ km	0.0882 km^2	$1.26x10^{-9}$ /year
W16	382	15 km	$2.5x10^{-10}$/ km	0.0882 km^2	$5.61x10^{-10}$/year
W24	2100	15 km	$2.5x10^{-10}$/ km	0.0882 km^2	$3.09x10^{-9}$ /year
A428	808	15 km	$2.5x10^{-10}$/ km	0.0882 km^2	$1.19x10^{-9}$ /year
Annual frequency of aircraft crash over the LABGENE					$1.25x10^{-8}$ /year

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3. CONCLUSIONS

The value of the annual frequency of aircraft crash obtained was 1.25×10^{-8}. Therefore, the annual frequency of aircraft crash is below 1.0×10^{-7}/year what obeys the acceptance criteria described in Section 3.5.1.6 of the Standard Review Plan [2].

The projection of the annual frequency of aircraft crash over the LABGENE, for a period of 40 years, considering an air traffic increasing of 36% [9] is 1.7×10^{-8}, that is below the value determined in the established acceptance criteria [2].

An evaluation of the air traffic increase in the vicinity of CEA must be accomplished in a way to verify if the value of 36% considered in this study is still valid and, therefore, confirm if the projection of the annual frequency of aircraft crash over LABGENE, for a period of 40 years also obeys the acceptance criteria established in [2].

ACKNOWLEDGMENTS

Thanks to CTMSP for the material and financial support.

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