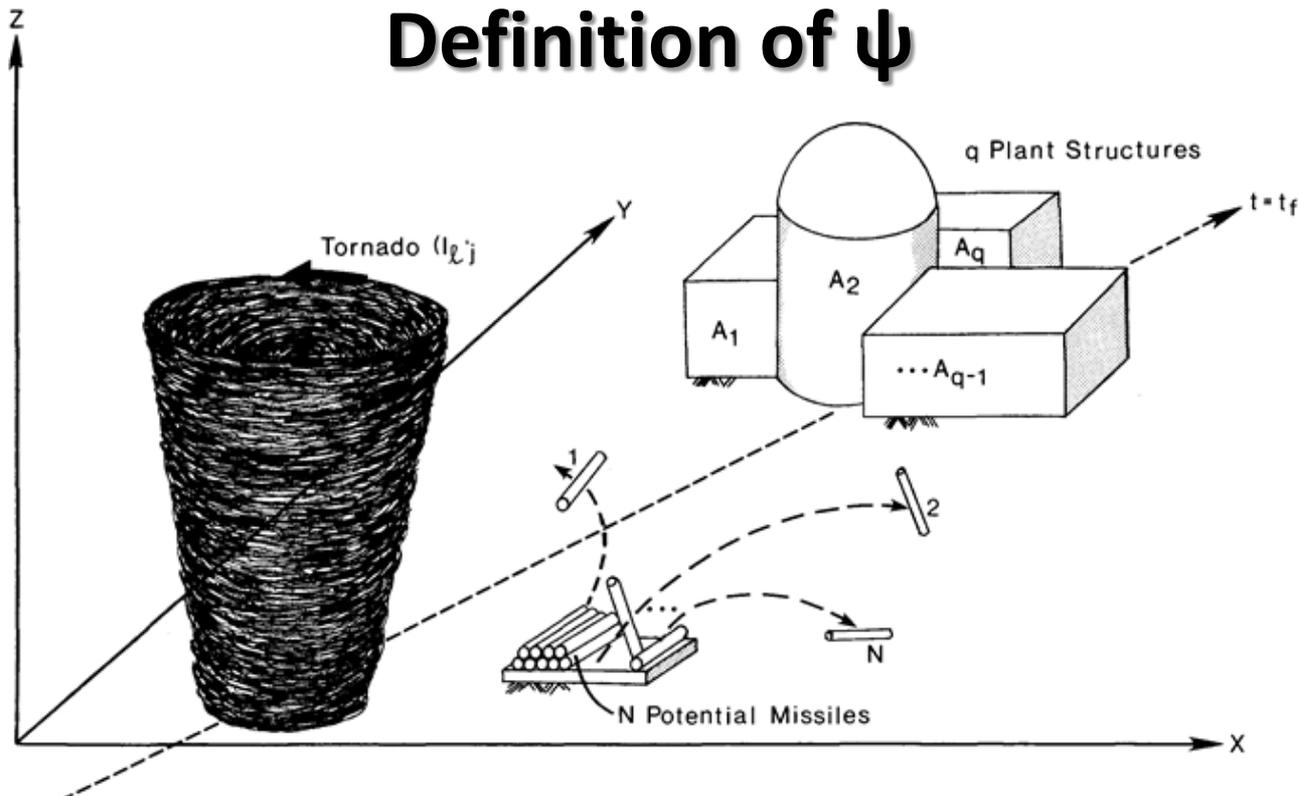# NUREG 4710 ψ [PSI] VALUES

Anil Julka

Definition of ψ

- **NUREG CR 4710: ψ** is the probability of an impact of a wind-driven missile for each missile from the entire population per unit area of the target of interest for ***the average*** ***tornado hazard interval at the site.***
- **ψ** = probability of missile impact/missile/unit area/tornado
- Using **ψ,** the conditional probability of a missile impact on a target during a given tornado can be estimated if the **number of available missiles** and the **exposed surface area of the target** are known.

Ψ VALUES

- Calvert assessment applies four ψ values from Appendix G, section 4.1, of NUREG/CR-4710

- **Large Target ψ = 1.23E-10**

- Small Target ψ is a weighted sum of Small Target High Medium and Low Exposure ψ values:

    High Exposure ψ   **= 2.42E-09**

    Medium Exposure ψ = 8.64E-11

    Low Exposure ψ   **= 1.54E-11**

    Small Target Weighted ψ = *0.1 x 2.42E-09 + 0.4 x 8.64E-11 + 0.5 x 1.54E-11=* **2.85E-10**

- Exposure classification based on location of target with respect to concentration of missiles, shielding from buildings or other structures. Additionally, relative height can be considered as a factor.

LARGE TARGET Ψ

From page G-36 of NUREG 4710:

*"Table 4-1a gives the resulting normalized tornado missile impact parameter values for **large structures** in USNRC Regions I and II for 5 equal probabilities. The values range over an order of magnitude with a mean value equal to 1.23-10/missile/ft^2 of target area/tornado point strike frequency. The values of **ψ** are normalized with respect to a **point strike frequency** since this is the basis that the USNRC hazard analysis used. The values in Table 4-1a are applicable for large structures and tanks."*

a) Large Structures in USNRC Regions I and II

Value	Probability	Normalized Parameter, Ψ*
1	0.20	1.49-11
2	0.20	3.49-11
3	0.20	7.16-11
4	0.20	1.61-10
5	0.20	3.31-10
Mean		1.23-10

LARGE TARGET Ψ Basis

- **Definition of LARGE TARGETS**: *Targets larger than 1000 sq. ft. are assumed to be LARGE TARGETS based on the definition for SMALL TARGETS noted in Appendix G section 4.1: "… small targets approximately 100 to 1000 ft^2….".*

- **ψ Values**. *No description is provided or source is cited for the five ψ values. Assumed to correlate to tornado intensities F2, F3, F4, F5, and F6.*

- **Probability.** *The basis for the "0.20" probability and its uniform application to all ψ values in addition to the mean of the total is not explained.*

- **Reconstitution of Large Target ψ**. ψ values are likely derived from NP-768 which is referenced in Appendix G. NP-768 provides the target hit probabilities calculated by various TORMIS analyses.

Reconstitution of Large Target ψ Basis

- The TORMIS studies documented in NP-768 do not directly calculate ψ values but ψ can be calculated by dividing the hit probability, "H", by the associated tornado frequency and total site area considered in the TORMIS analysis.

- NP-768 evaluated several plant types; A, B1, B2. Hit probabilities for plant A in NP-768 were selected because it provides highest values

NP-768 Large Target ψ Results

ψ values are calculated for each tornado intensity using NP-768 data

The ψ values were calculated using this formula:

H Value x Tornado Frequency x Total Target Area = ψ

TABLE 1	EPRI NP-768 Data - Plant A				Table 4-1a App G NUREG/CR-4710
H Value = 1/(missile*year) Table 3-15	**Tornado Frequency** *(tornado/year)*	*Approximate* **Total Target Area** *(ft²)*	ψ **(PSI)** *=1/(missile*ft² *tornado))*	**NP-768 PSI Value x 0.2**	
1.62E-08	8.17E-04	3E+05	6.61E-11	1.32E-11	1.49E-11
2.53E-08	3.77E-04	3E+05	2.24E-10	4.47E-11	3.49E-11
9.12E-09	1.18E-04	3E+05	2.58E-10	5.15E-11	7.16E-11
1.14E-08	3.86E-05	3E+05	9.84E-10	1.97E-10	1.61E-10
3.99E-09	8.78E-06	3E+05	1.51E-09	3.03E-10	3.31E-10
			Mean =	**1.22E-10**	**1.23E-10**

The resultant value approximates the TORMIS results for plant A in NP-768 when the same adjustments are made; applying a probability of 0.2 and taking the mean of the 5 values.

Other Large Target ψ Issues

- Can Large Target **ψ** value be applied to all types of plants, all tornado regions, and without considering the plant specific missile population? NP-768 provided different missile fluxes for different plants and for different regions.

- Should the NP-768 TORMIS analyses used in NP-768 be updated to reflect latest knowledge and insights related to tornado climatology and the behavior of tornados? Appendix G states: *The values of* **ψ** *are normalized with respect to a* **point strike frequency** *since this is the basis that the USNRC hazard analysis used*; however NUREG/CR-4461 rev 2 notes that *The total probability of a structure being struck by a tornado with winds exceeding some value u is the sum of the* **point structure** *and* **life-line** *probabilities*.

SMALL TARGET ψ

- **SMALL TARGET Definition.** The definition for SMALL TARGETS noted in Appendix G section 4.1: "... *small targets approximately 100 to 1000 ft²....".* However, none of the targets cited in the Seabrook study are over 1000 ft² and 20 of the 30 targets are under 100 ft².

- **High, Medium, Low Exposure Grouping.** Contrary to the statement from Appendix G, the Seabrook study did not segregate the target areas into high, medium and low exposure areas. The grouping noted was as follows:

  The probabilities for the 30 identified target areas are summarized in Tables V-1 through V-3. The targets have been grouped in 3 categories, as specified by United Engineers:

  - *Those targets for which missile shields have been provided (Table V-1).*
  - *Those targets for which the primary problem is protection of safety related areas against the effects of sudden depressurization (Table V-2).*
  - *Other targets identified during the design review process (Table V-3).*

  There are no other groupings in the Seabrook evaluation.

Small Target ψ Weighting Factors

- The Calvert evaluation consolidates the ψ high, medium, low small target values into one value by applying unique weighting factors to each exposure category and summing them. The weighting factors are obtained from NUREG 4710 Appendix G, page G-37:

  "For each of the targets a conservative distribution on exposure was assumed to be 0.1, 0.4 and 0.5 for large, medium and small exposures."

- Appendix G does not provide a basis for these weighting factors.

- Weighting factors are different in other related NUREGs:

NUREG/CR #	Plant	WEIGHTING FACTORS			Large Target ψ
		High	Medium	Low	
4710	St. Lucie	0.1	0.4	0.5	2.84E-10
4488	Quad Cities	0.1	0.8	0.1	3.11E-10
4762	Turkey Point	0.1	0.8	0.1	3.11E-10
4458	Point Beach	0.0	0.5	0.5	5.00E-11
4713	*Document unavailable*				?
4767	Cooper	*No ψ calculated. NUREG states plant is adequately protected against tornado missiles*			*N/A*

RECONSTITUTION OF SMALL TARGET Ψ VALUES

- Data from Seabrook tables V-1, V-2, V-3 was used to calculate High, Medium and Low exposure ψ values by grouping the targets based on size.
    - Outliers in the High and Low categories were identified and removed from the calculation.
    - The mean value of each group's ψ values was multiplied by a "probability" of 0.2 [as per NUREG 4710 App G] and then the
    - factors from App G were applied to each group's ψ values and then totaled.

- Applying this method approximated the result Calvert used for SMALL TARGET ψ, calculated = **3.03E-10** as compared to the Calvert value of **2.84E-10**.

- This method for calculating ψ could be considered as replicating the method applied in Appendix G.

PROPOSED PSI (Ψ) VALUE SELECTION CRITERIA FOR SMALL TARGETS

- **High Exposure:**
  - Unsheltered, exposed on 3 or more sides to missiles
  - Relatively large number of missiles within 300 feet
  - Less than 40 feet above height of most potential missiles
- **Medium Exposure:**
  - Criteria for High or Low Exposures not met
- **Low Exposure**
  - Sheltered, such that missiles may only approach from one direction, or via a limited flight path (e.g., through an opening such as a door)
  - Relatively low to moderate number of missiles within 300 feet
  - Greater than 40 feet above the height of most potential missiles

CONCLUSION

The ψ values for LARGE and SMALL targets can reconstituted based on applying reasonable assumptions that could be considered similar to those applied in the original analysis.