Industry Proposed Method to Address RIS-2015-006

- **Purpose**: Demonstrate a relatively simple method for evaluating tornado-missile risk of exposed SSCs.

- **Background** – NRC Regulatory Issue Summary (RIS) 2015-006 reminds licensees of the need to conform with a plant's current, site-specific licensing basis for tornado-generated missile protection. In addition to physical design methods, the NRC allows the use of probability analysis to evaluate the need for providing tornado missile protection.

  Even plants meeting their design basis for tornado missile protection operate with risk due to tornado missiles. This happens as a result of the assumed loss of offsite power and the possibility of post-trip component failures. These failures include both random failures of protected equipment and tornado-missile induced failures of non safety related components. For example, unprotected non-safety related water storage tanks and diesel generators may be credited in the PRA for accident mitigation.

  Considering the discussion above, the tornado-missile risk to be evaluated is the increase in risk that exists due to the exposed portions of safety related SSCs that are credited in the licensing basis as having tornado-missile protection. This is an incremental risk as opposed to the total tornado-missile risk at a site.

Analysis Overview

- This method uses a single tornado initiating event assumed to strike the entire site.

- A site walk down is used to identify exposed SSCs, both SR and NSR, credited in the PRA model for accident mitigation. An exception is those components that will be failed anyway by the tornado-induced loss of offsite power (for example, switchyard, main feed water, condensate, condenser vacuum. Etc.)

- Missile strike probabilities are calculated for the exposed SSCs identified above and modeled in the plant response model.

- The single tornado initiating event is quantified in the plant response model. The risk importance of each exposed component may then be obtained (from the resulting cutset file).

- The CDF contribution of each exposed component may then be evaluated to determine whether missile protection is needed.

- If the total CDF contribution of those exposed components assumed to have missile protection in the design basis is less than 1E-06 per year, then the risk is considered negligible and does not warrant tornado missile protection.

Regulatory Perspective

- Intended to be a qualitative application of risk information (screening approach)
    - RG 1.200, section 1.2.5: *"[S]creening can be performed by using a bounding or demonstrably conservative analysis with defined quantitative screening criteria to demonstrate that the risk from some external events is sufficiently low to eliminate them from additional consideration. Walkdowns of the plant site and plant buildings are used to confirm the assumptions used for the screening basis."*

- Not a traditional risk informed licensing application per RG 1.174

Qualitative Application of Risk Information

- Involves evaluation of a **single** initiating event, rather than probabilistic evaluation of a spectrum of events

- Does **not** involve using risk information to make changes to plant programs (e.g. tech specs)

- Use of risk information is **extremely limited** scope in this application, majority of approach is deterministic

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Assumptions

- The site is considered a point and a single tornado is assumed to strike the entire site.
- The tornado strike frequency for the site includes all strength tornados.
- Where there is a reasonable distance separating targets, strikes on targets are considered independent (no correlation)
- Where targets are adjacent to one another, complete correlation is assumed.
- The component failure probability given a missile strike is generally considered to be 1.0, unless justified otherwise.

Walkdown Guidance

- The site walkdown is used to identify SSCs (both SR and NSR) that are potentially vulnerable to missile strikes and credited in the PRA model for accident mitigation

- Prior to the walkdown, a Tornado Missile Equipment List (TMEL) should be developed to identify SSCs of potential interest.

- TMEL is typically based on the internal events PRA list of equipment, excluding:
  - Initiating events that are not considered coincident with tornado strike (e.g., SGTR)
  - SSCs dependent on offsite power, as a LOOP is assumed
  - SSCs inside Seismic Class I buildings, unless they are near openings vulnerable to missile penetration (e.g., louvers, roll-up doors)

- All SSCs on the TMEL should all be located and viewed during the walkdown

Walkdown Guidance (cont.)

- Field notes and pictures should be taken during the walkdown. Notes should include:
  - Location of the SSC with respect to buildings, walls and other structures (that may provide some shielding)
  - Exposed cables, piping, and tubing, that if struck by a missile could lead to SSC failure
  - Dimensions of exposed SSC, its supports, and associated equipment (cables, etc.)
- For SSCs located inside Class I structures, consider the following:
  - Openings in structures that may result in missile penetration inside the structure. Examples are louvers and doors (unless rated for tornado missiles)
  - Cables running outside the Class I structure
  - Exhaust piping or stacks outside the Class I structure
- During the walkdown, any exposed equipment credited for mitigation but not on the TMEL should be noted and added to the TMEL

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Method

In order to determine the core damage impact of tornado missiles to the plant, six key pieces of information are needed:

- <u>Tornado Point Strike Frequency</u> (P_s'): This is the frequency at which a tornado, of any magnitude, strikes any particular point. In this analysis, the site is considered a point and tornados are considered to strike the entire site.

- <u>Tornado Missile Impact Parameter</u> (ψ): This is the frequency of impact of a missile on a structure or component, expressed as the frequency of impact per missile per unit target area per tornado.

- <u>Number of Missiles on Site</u> (N): This is the number of candidate missiles on site that could cause damage to the components of interest. The number of missiles on site may be on the order of 30,000 to 100,000 and may be estimated based on comparisons to tornado analyses done for other sites.

- <u>Missile Strike Probability</u> (P_{ms}): This is the probability of a tornado generated missile impacting a target, given a tornado strikes the site. P_{ms} is based on the missile impact parameter (ψ), the target area and the number of missiles available.

- <u>Component Failure Probability</u> (P_F): Given a tornado, a component can fail due to direct forces from tornado winds or from being struck by a tornado generated missile. The probability of these events occurring is discussed further below.

- <u>Target Area (A):</u> The likelihood of a tornado missile striking a target is directly related to the area of the target. Generally, the target area is taken as the cross sectional area of the target, in square feet.

Tornado Point Strike Frequency:

- The tornado point strike frequency is based on NUREG/CR-4661, Rev 2.
- This NUREG/CR uses data on tornados reported from January 1950 to August, 2003, 50.67 years of data.
- Appendix A of this NUREG/CR contains tornado results for each 2-degree box. Therefore, the tornado frequency for a sites particular location may be used.
- The information includes the expected point strike probability for a point structure anywhere within the box.
- The point strike frequency includes tornados of <u>all strengths</u> that occurred in the associated box.

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Tornado Missile Impact Parameter, Psi (ψ) :

- The missile impact parameter, Ψ (Greek capital letter Psi), is defined as the probability of impact/missile/unit target area/tornado strike frequency.

- NUREG/CR-4710 presents values of Ψ developed from past tornado missile impact studies that used the TORMIS computer code.

- The Ψ values were developed based on Tornado <u>point</u> strike frequencies.

- NUREG/CR-4710 provides Ψ values for:

  -Large structures (>1000 square feet) and,

  -Small targets (approximately 100 to 1000 square feet)

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Psi (ψ) Value Selection

- Mean value for large structures (buildings, tanks):

  Ψ = 1.23E-10   [NUREG/CR-4710, Table 4-1a]

- Three mean values for smaller targets (exhaust stacks, pumps, valves and piping) are provided in NUREG/CR-4710, Table 4-1b.

  Ψ = 2.42E-9   [High Exposure]

  Ψ = 8.64E-11   [Medium Exposure]

  Ψ = 1.54E-11   [Low Exposure]

- 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.

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

Psi (ψ) Value: weighted average for small targets

- Alternatively, a weighted average may be used for small targets judged to have some protection.

- The NUREG 4710 methodology (p G-37) weights the three psi exposure level values using a distribution on exposure with values of 0.1, 0.4, and 0.5 for the high, medium and low exposures respectively.
  This gives a Ψ value of:
  (0.1 x 2.42E-09 + 0.4 x 8.64E-11 + 0.5 x 1.54E-11) = 2.85E-10.

- This Ψ value is judged to be appropriate for structures with some missile protection; for example, SSCs that would benefit from shielding affects of adjacent buildings.

Number of Missiles on Site (Nm):

The number of missiles on site may be calculated based on walk downs or by using data from existing analysis done for other sites. Previously calculated missile populations are shown below.

Site	Number of missiles	Reference	Comments
Oconee	75,000	NSAC-60 Oconee PRA	3-Unit PWR on reservoir in Seneca SC. Considers missiles within 1 mile
Turkey Point	100,000	Turkey Point IPEEE value	2-Unit PWR adjacent to Biscayne Bay, near Homestead, FL. Considers missiles within 1 mile
Fort Calhoun	30,000	FCS IPEEE value	Single-Unit PWR adjacent to Missouri River near Fort Calhoun, NE
Fermi	75,000	SER, NRC-2014-0109	Single-unit BWR adjacent to Lake Erie in Newport, MI. Considers missiles within 2500 feet, surveyed prior to refueling outage.
Seabrook	66,800	1984 Tornado Missile Risk Analysis	Single-unit PWR located on a salt marsh in Seabrook, NH.
Average	69,000		Note that except for Fort Calhoun, the missile populations are similar.

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Missile Strike Probability (P_{ms}):

This is the probability of a missile strike on a particular component or system given a tornado point strike on the site.

$P_{ms} = AN_m\Psi$

Where,

- A = target Area in square feet
- N_m = the number of missiles on site
- Ψ = Missile Impact Parameter = probability of impact/missile/sq-ft target area/tornado point strike frequency
- The missile strike probability is explicitly modeled and appears as a basic event in the model for each component vulnerable to a tornado missile strike.

Component Failure Probability

- This is the probability of a component failing given that it is hit by a tornado missile. Since this number is difficult to determine, it is generally conservatively assumed to be 100%. Generally this simplifying assumption does not produce unreasonable results. However, there may be components where a probability other than 100% is appropriate. For example, the Main Steam Safety Valves (MSSV) and the Atmospheric Dump Valves (ADVs) Vent stacks.

- In the tornado missile analysis offsite power is assumed to be lost if a tornado strikes the site. Therefore, condenser vacuum and normal heat removal is lost and decay heat removal with the steam generators requires the ability to pump AFW into the Steam Generators and vent steam to atmosphere using the MSSVs or an ADV.

- The MSSVs and the ADVs themselves are well protected but the vent stacks come up through the Auxiliary Building Roof and are not protected from tornado missiles. The run considered vulnerable includes the exposed stack height above the roof as well as a portion inside the non-tornado proof building. A tornado missile could conceivably hit and bend over one or more pipes and crimp them, restricting the flow of steam.

- The stacks are an array of rugged steel pipes that would need to be bent over significantly to prevent the flow of steam. Since they are arranged close to one another, they would tend to support one another as one stack started to hit the other. It would take a very large missile or multiple missiles to bend and crimp all of the vent stacks. However, we conservatively assume that 10 % of the time a tornado missile hits the MSSV/ADV vent stacks that they will be crimped sufficiently to render the Steam Generators unable to vent steam adequately for heat removal using AFW. This then is the conditional probability of failure given a missile hits the MSSV/ADV vent stacks.

Target Area (A):

- Target areas are needed to calculate the probability of a missile strike for each component. The target area is taken to be the cross sectional area (in square feet) of the exposed portion of a component.   In the case of unprotected tanks, the top portion was not included since a strike to the top would not drain the tank.

- For components adjacent to one another, for example two AFW pump turbine vent stacks, each supporting an AFW Pump, the vent stacks may be considered a single target with a combined target area. Therefore, a single missile that hits the combined area is conservatively assumed to fail both pumps.

- The degree of exposure is accounted for in the selection of the missile impact parameter, Ψ.   See the section on missile impact parameter above for more information.

Direct Wind Affects:

- Some systems and/or components are not designed to withstand tornado strength winds. These may include the Control Room HVAC condenser Units (roof top), Switchgear Room HVAC condenser Units (roof top), Fire Pump House, Station Blackout Diesel Generator Building and the Switchyard. These components are assumed failed for all tornados in this simplified, single-tornado analysis.

- However, many non-safety related components are rugged enough to withstand tornado strength winds. For example, outside tanks , which are generally maintained full, have been shown to be unaffected by tornado strength winds.

- Exposed piping that is well supported is assumed to withstand tornado strength winds but vulnerable to failure from a missile strike.

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Calculation

- Examples of missile strike probability calculations:

| Component	Area (Sq-ft) (A)	Number of Missiles (B)	Point Strike Missile Impact Parameter (C)	Conditional Probability of Missile Strike (Point Strike) A x B x C	Basic Event	Component Failure Prob
Condensate Storage Tank	3,000	70,000	1.23E-10	2.6E-02	TOR-CST	1.0
Combined A & B AFW Turb Pump Exhaust	100	70,000	2.85E-10	2.0E-03	TOR-AFWTDPUMP	1.0

Fault Tree Modeling

Note in this example that the missile strike probability of the AFW Turbine exhaust calculated in the previous slide is the basic event probability for TOR-AFWTDPUMP shown below.
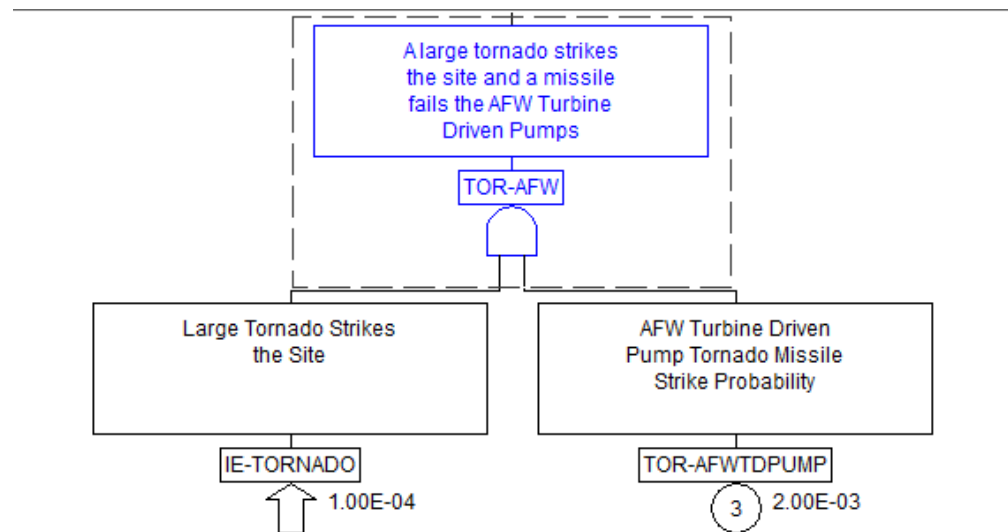
Fault Tree Modeling

Note in this case the tornado directly fails offsite power (given the tornado occurs, offsite power is guaranteed lost). The same modeling would be used for SSCs assumed failed by tornado strength winds. For simplicity, the loss of offsite power is considered non-recoverable.
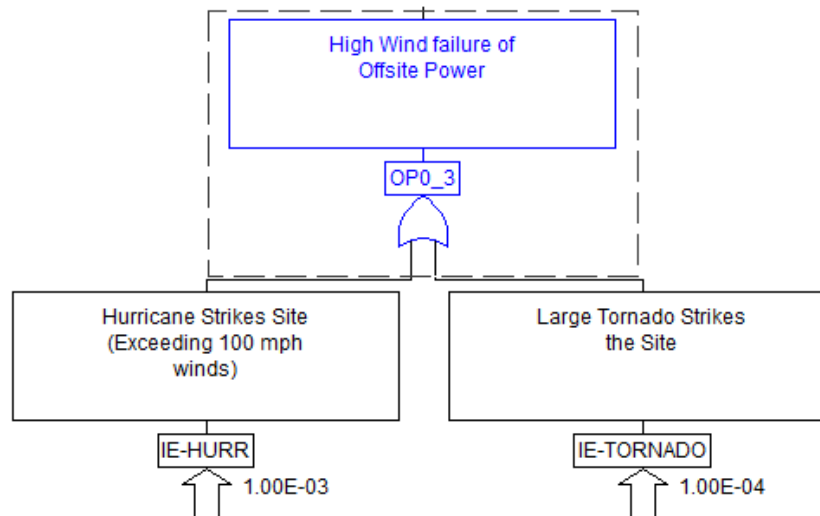
Quantification

- Add tornado initiator and impacts into the fault tree of the sites average maintenance model.
- The tornado impacts should include all those items identified in the walkdown, including those not required to be protected but credited in the PRA.
- Quantify the tornado initiator
- The resulting cutset file will show the risk importance measures of each exposed component.
- The risk contribution of the exposed components may be calculated by multiplying the Fussell Vesely risk importance measure by the total tornado CDF.
- Note that although all of the exposed components contribute to the plants quantified tornado missile risk, we are primarily interested in the risk contribution of the components assumed to have missile protection in the plants design basis. If the risk contribution of those components is less than 1E-06, then missile protection is not warranted.

Sensitivities

- Sensitivities may be performed on influential parameters such as the number of tornado missiles on site and the missile impact parameter, Ψ. The conditional probability of a missile strike, P_{ms}, for each component is directly proportional to the components area, A, the number of missiles on site, N_m, and Ψ, as shown in the equation: $P_{ms} = AN_m\Psi$ (from slide 14)

- The impact on CDF would be roughly proportional to these parameters.

- The tornado point strike frequency may similarly be evaluated, although that is probably not necessary as NUREG/CR-4661, Rev2 provides point strike frequencies for all areas where nuclear power plants are located.

Conservative Assumptions

- Components hit by a missile are assumed failed unless justified otherwise.
- An unrecoverable LOOP is assumed for all tornados.
- Ψ values are based on NRC Region I tornado experience, which has the highest incidence of high F-scale tornadoes among the three regions.
- The entire site is assumed to be a point. Therefore, all components are assumed to receive a point strike by the tornado. In reality, it is very unlikely for a tornado path to cover the entire site.
- The point strike frequency includes tornados of all intensities including EF0 and EF1 tornados. These tornados have the highest frequency and yet are not capable of generating damaging missiles.
- PRA credited structures not designed for tornado winds are assumed failed for all tornados, (e.g. SBO DG Building, Fire Pump House)

Conclusions

- If the sum of the risk contributions of the SSCs assumed missile proof in the design bases is < 1E-06/yr, the tornado missile risk contribution is considered negligible and providing physical protection is not warranted.

- The analysis may indicate that missile protection is warranted for certain SSCs but not others.