NEI Tornado Missile Risk Evaluator (TMRE)

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- Methodology Overview

AGENDA

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- Safe Shutdown Targets
- Missile Population
- Plant Walkdown
- Exposed Equipment Failure Probability
- Tornado Missile Risk
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- TMRE Conservatisms
- TMRE Comparisons
- Conclusion

Notional Plant Licensing Basis

Containment
Seismic Class I Structures
Service Water (SW) Pumphouse
Diesel Generator Building

Containments/Seismic Class I Structures

Licensing Basis:

- *"The containments and Seismic Class I portions of the Auxiliary Building, the turbine hall, the pumphouse, and the diesel generator building are designed to withstand the effects of a tornado."*
- *"The design criteria of the containment and the Class I portions of the auxiliary and turbine buildings to withstand the effects of a tornado, including wind force, pressure differential, and missile impingement are described in Bechtel Topical Report B-TOP-3, 'Design Criteria for Nuclear Power Plants Against Tornadoes."*

SW Pumphouse

Licensing Basis:

- *"The pumphouse structure has been designed to remain intact under a tornado wind having a tangential velocity of 300 mph plus a forward progress of 60 mph."*
- *"The structure is capable of remaining intact for a pressure drop of 1/2 psi. Before this pressure drop is realized, the building would be vented by the failure of the louvers and doors."*

Diesel Generator Building

Licensing Basis:

- *"A lateral force caused by a funnel of tornado wind having a peripheral tangential velocity of 300 mph and a forward progress of 60 mph was applied to the building."*

External Missiles Considered

External missiles equivalent to:

- An airborne 4-in x 12-in x 12-ft plank traveling end on at 300 mph or
- A 4000-lb automobile flying through the air at 50 mph and at not more than 25 ft above the ground

Design Assumption

- Objects of low cross sectional density – such as boards, metal siding, and similar items – may be picked up and carried at the maximum wind velocity of 300 mph

External Missiles Considered

SW Pumphouse

Licensing Basis:

- *"Interior missile shield walls and exterior walls protecting the service water pumps are constructed of reinforced concrete with a minimum thickness of 12". The internal missile shield walls have been located to preclude the possibility of damage from a missile passing through a louver or door. Reinforced concrete walls of 12" thickness cannot be penetrated by the design tornado missiles..."*

External Missiles Considered

- *Vertical missiles not considered per Bechtel Topical Report B-TOP-3, "Design Criteria for Nuclear Power Plants Against Tornadoes"*

Safe Shutdown Post-Tornado

Licensing Basis

- *"The design basis for tornado missile protection of systems and components is that it is possible to shut the plant down and keep it in hot shutdown during and after the passage of a tornado."*

TMRE Overview

- Site Tornado Climatology
- Safe Shutdown Vulnerable Targets
- Missile Population
- Plant Walkdown
- Exposed Equipment Failure Probability (EEFP)
- Tornado Missile Risk (TMR)

Tornado Climatology

Data Sources Available for Calculating Tornado Strike Probability

- **NUREG/CR-4461, Rev 2, "Tornado Climatology of the Contiguous United States"**
  Provides nuclear plant site specific data to develop hazard curve
- **NOAA Storm Prediction Center**
  http://www.spc.noaa.gov.

NUREG/CR-4461, Rev 2

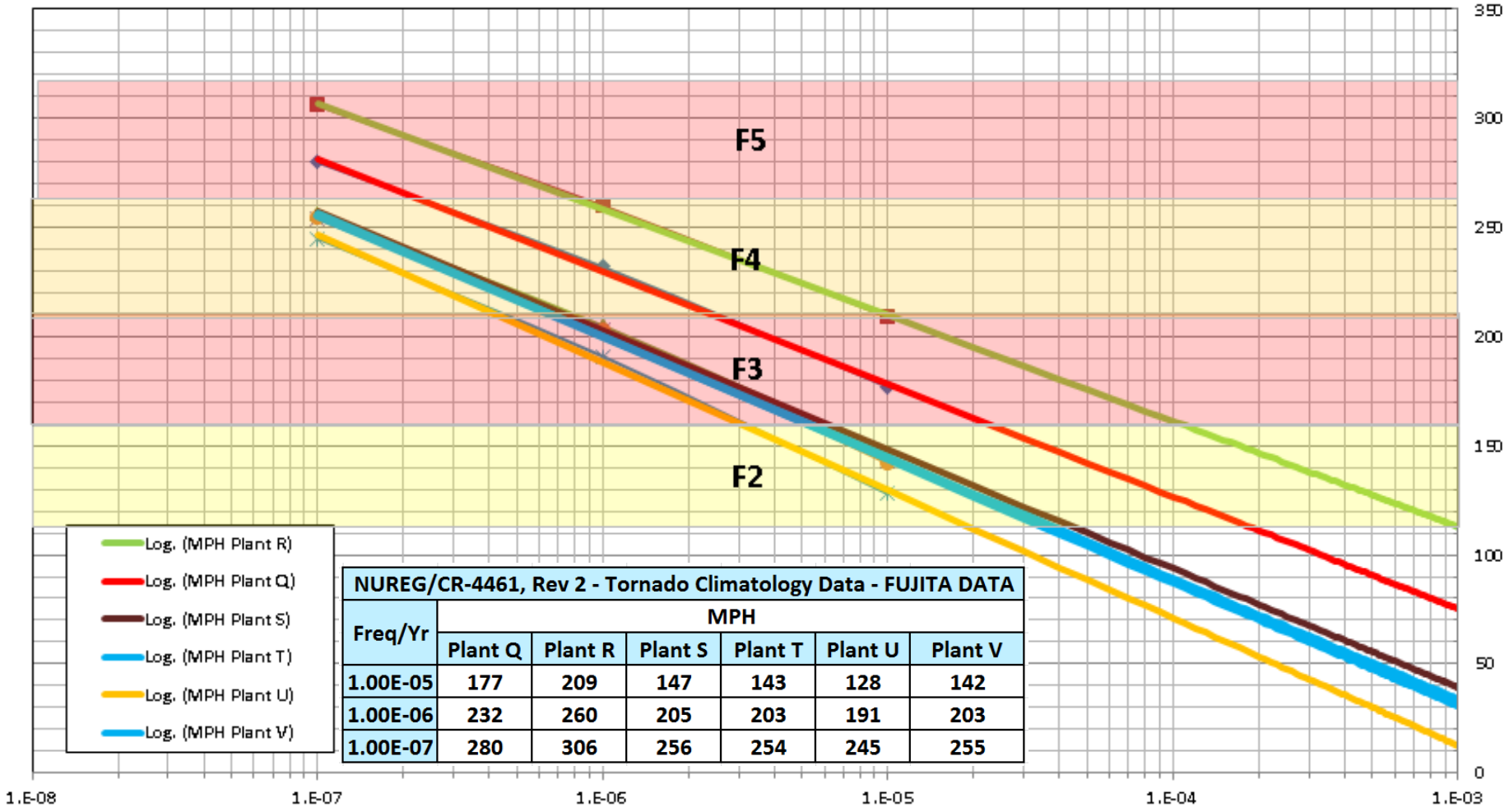
Tornado Climatology of the Contiguous United States

Table 6-1, *Tornado Wind Speed Estimates for United States Nuclear Power Plant Sites*

- Wind speeds for specific tornado frequencies
- Derived from plant-specific NOAA data

NUREG/CR-4461, Rev 2 - Tornado Climatology Data - FUJITA DATA						
Freq/Yr	MPH					
	Plant Q	Plant R	Plant S	Plant T	Plant U	Plant V
1.00E-05	177	209	147	143	128	142
1.00E-06	232	260	205	203	191	203
1.00E-07	280	306	256	254	245	255

Tornado Frequencies



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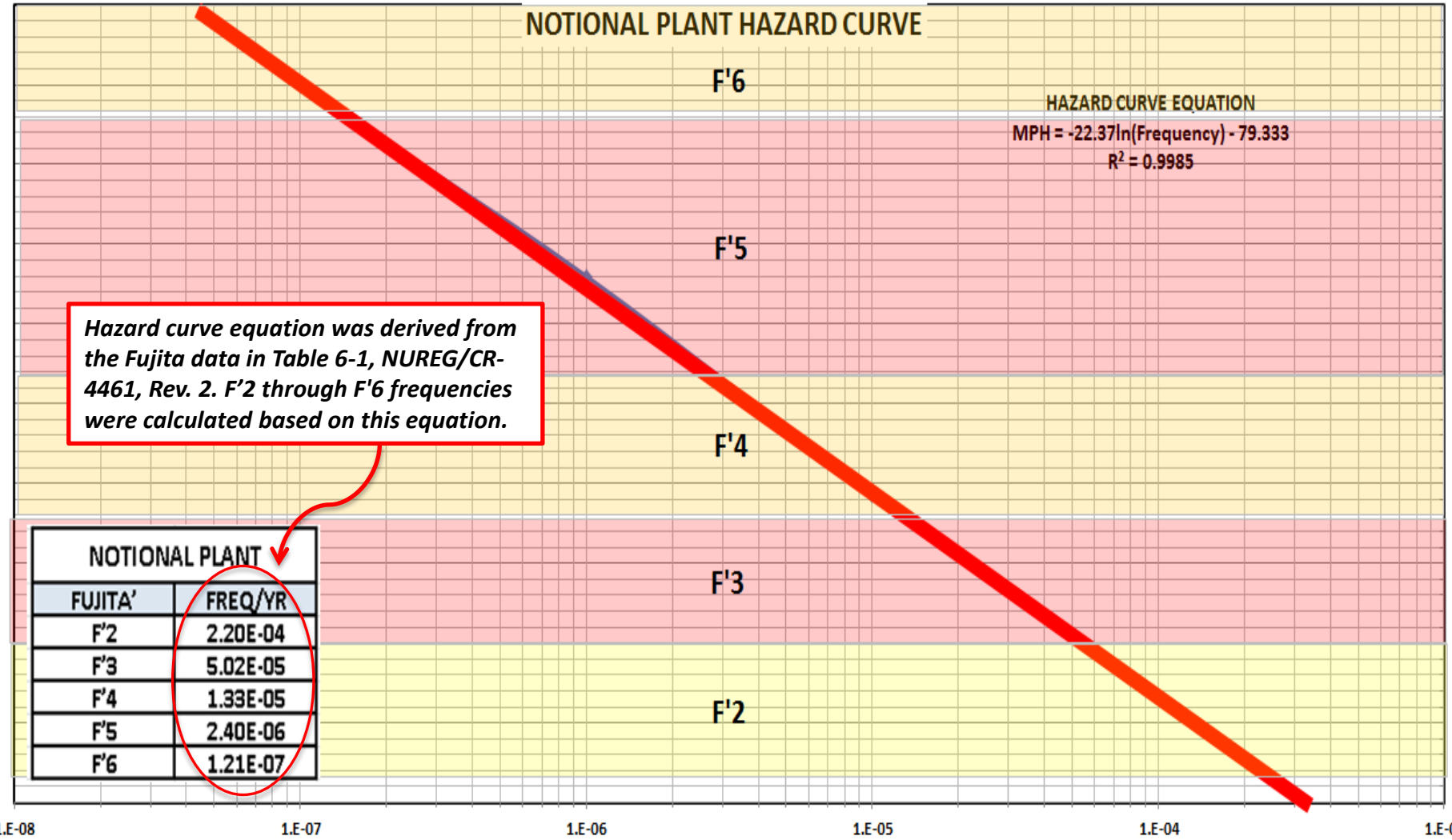
F’ Wind Scale

Tornado Intensity	Wind I
F'0	40-73
F'1	73-103
F'2	103-135
F'3	135-168
F'4	168-209
F'5	209-277
F'6	277-300

F’ is the wind scale used in NP-768 studies.

This wind scale was used to “back out” the missile impact parameter values that will be presented later.

Determination of Tornado Strike Frequency



Hazard curve equation was derived from the Fujita data in Table 6-1, NUREG/CR-4461, Rev. 2. F'2 through F'6 frequencies were calculated based on this equation.

NOTIONAL PLANT	
FUJITA'	FREQ/YR
F'2	2.20E-04
F'3	5.02E-05
F'4	1.33E-05
F'5	2.40E-06
F'6	1.21E-07

Selected Safe Shutdown Vulnerable Targets

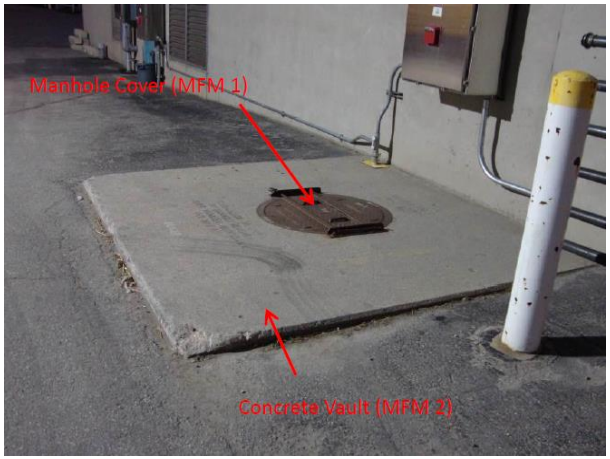
Notional Plant

Targets Selected for Evaluation

- Identified based on design evaluation & walkdown
- Selected for TMRE demonstration
  - Emergency Diesel Generator (EDG) Exhaust Stacks
  - Outside Cable Vault
  - Condensate Storage Tanks (CSTs)
  - Service Water (SW) Components
  - EDG & Auxiliaries

Example Targets

EDG Stack Support Bracket



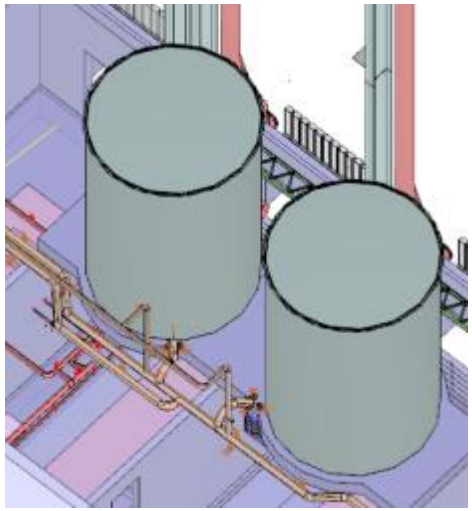
Cable Vault

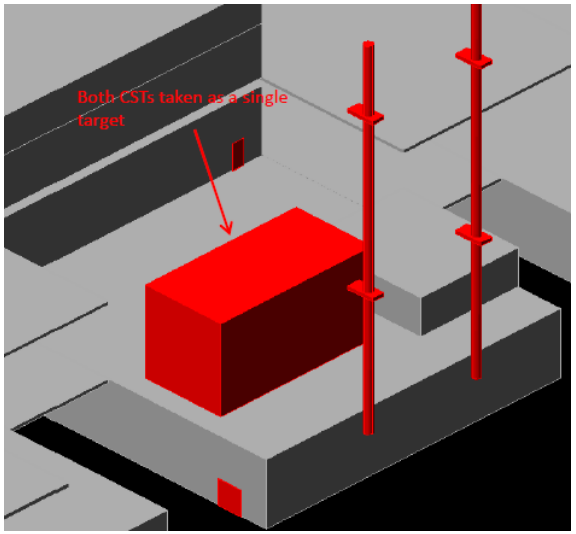
EDG Stacks are protected on one side by metal siding which is peeled off above F'2 scale winds.

EDG stack support brackets prevent stacks from collapsing during high winds, a significant issue above F'2 winds when siding begins to fail and act as a sail that increases wind pressure against the stacks.

Cable vault contains one division of safety related cables from diesels to safety related service water pumps.

Correlation Considerations - CSTs





Photos and diagram show two CSTs that are considered a single target due to proximity and vulnerable instrumentation located between tanks. CSTs were modeled as a single rectangular box containing the tanks, instrumentation and piping – see 3D view.

Exposure Considerations – SW Pumphouse

Access door and louvers allow missile entry.

Rollup Doors are made of light sheet metal and will allow missile entry into pumphouse containing service water pumps.

In addition to identifying and characterizing targets and their vulnerabilities, the walkdown identifies missiles and potentially simple remedies to minimizing missile risk.

Exposure Considerations – SW Pumphouse

Access door and louvers allow missile entry

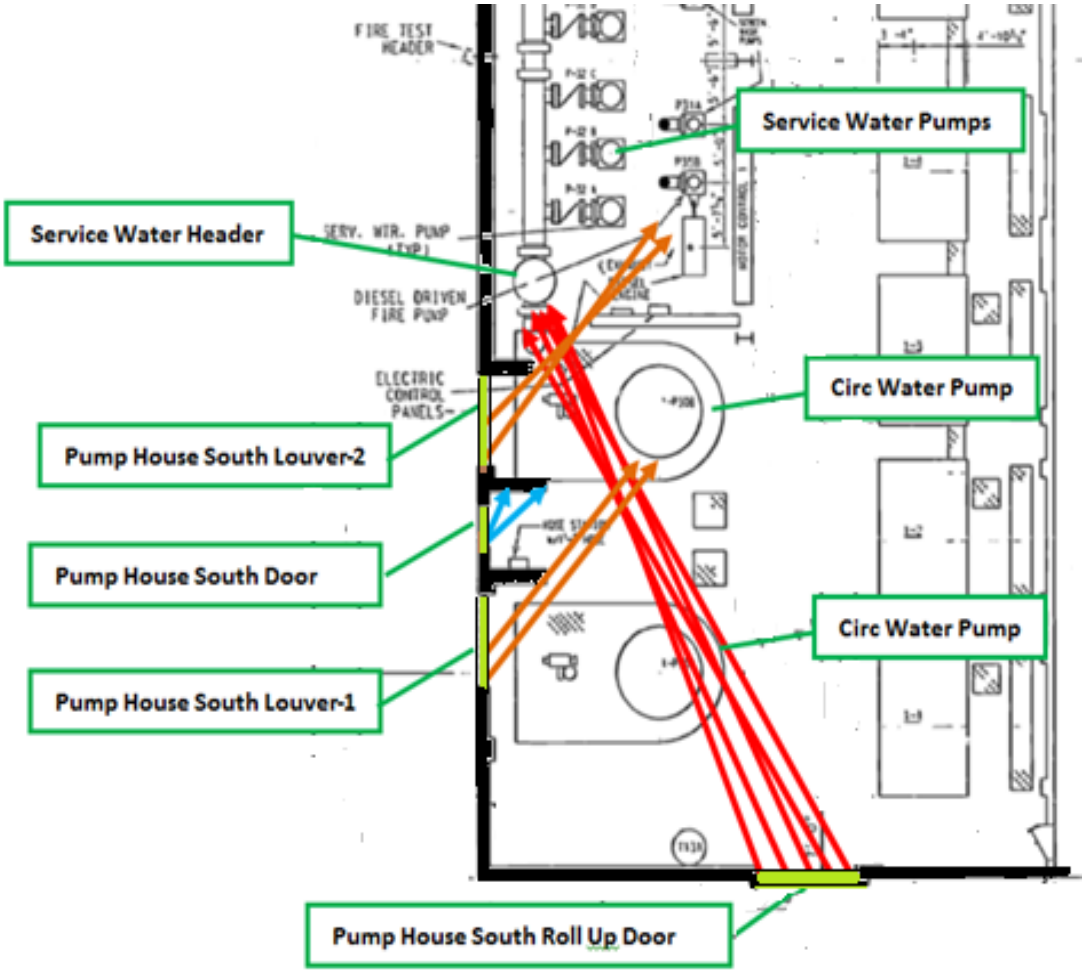
“Missiles” (large heavy metal frames) with favorable aerodynamics stored in front of targets. Material was removed and area designated as a missile free zone.

Exposure Considerations – SW Pumphouse

Photo shows missile's "view" of barriers protecting service water pumps and headers as seen from the rollup door. The large pump is circulating water pump.

Metal siding and grating that was previously installed to protect against missiles was not credited. View shown is just past the circulating water pump.

Exposure Considerations – SW Pumphouse

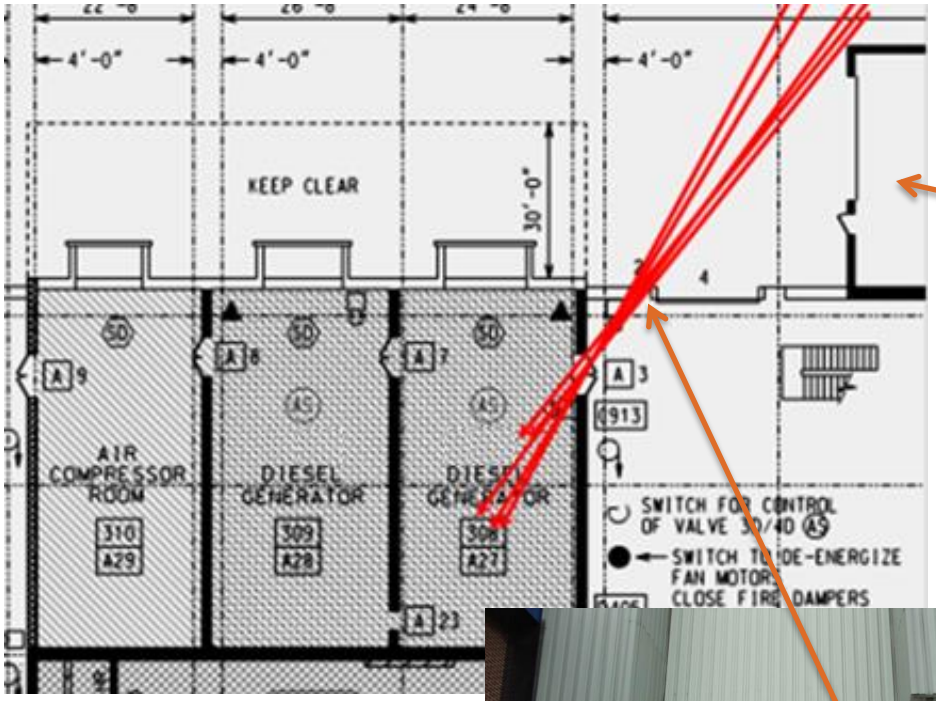


Pumphouse Missile Path Through Louvers, Doors, and Roll-Up Doors

Potential missile paths to risk important targets can be evaluated by assessing missile tracks through vulnerable openings. Robust barriers blocking missile path to target should also be considered; circulating water pumps in this example.

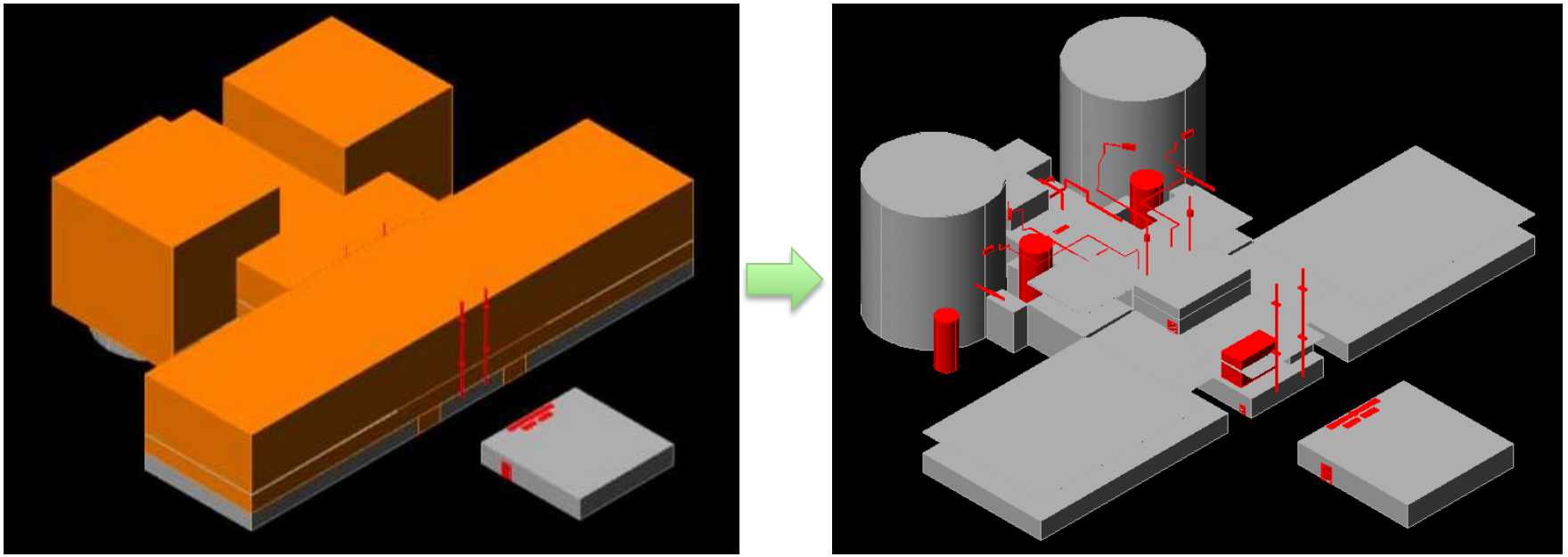
Target exposure area would be assessed based on missile window size based on the direct path of a missile to the target.

Exposure Considerations – EDG & Auxiliaries



Missile tracks are limited to paths that avoid the concrete building in the upper right of the plan view and travels through both the outside personnel and EDG room entry doors.

Clad Buildings



- Cladding and some structural members from cladded buildings will become missiles and need to be added to missile population.
- New targets exposed to tornado missiles when cladding is removed by high winds.
- Engineered buildings assumed to lose most cladding above F2 tornado.

Missile Population

Number of Missiles Onsite

- N_m onsite may be estimated based on walkdowns
- Missile populations utilized in published analyses are shown below
  - Proximity to target
  - Missile energy & characteristics
  - Target fragility

Site	Number of missiles	Reference	Comments
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.

Actual Missile Count Data

Final Missile Set	Description	Missile Origin Zone																			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
1	Rebar				100				700		100	500			1,000	1,000	200			2,000	500	6,100
2	Gas Cylinder		25	72	15		5	10	160			20	8		20	50	20		6	100	25	536
3	Drum, Tank	20	25			10	5	10	40	20	20	50	10	10		30	15		22	1,010	120	1,417
4	Utility Pole					10			10								10	10	8	10	10	68
5	Cable Reel								10			400			50	20			5			485
6	3-in Pipe	25						100	300		27	200			500			10		4,100	1,600	6,862
7	6-in Pipe											100			500		150			800	20	1,570
8	12-in Pipe				10				50				20		100		50	30	14	400	38	712
9	Eqpt., Bin			1	3			10	28			44		11	36	54	4	16	10	320	22	559
10	Dumpster	2				2				11	35	4	20		4	2	4		6	24	8	122
11	Wood Tie								30				8			40		60	251	2,400	4,500	7,289
12	Wood Beam				20	80		200	220	10	500	150	300	40	580	40	380	220	380	400	2,110	5,930
13	Wood Plank				10	40			30				60	10	240		160	110	170	200	450	1,480
14	Metal Siding								300								300	5	230		100	635
15	Plywood Sheet				10	40			50		20		73	10	240		185	110	210	200	1,600	2,748
16	Wide Flange	80			4				150			100		15	230	10	160	22	131	200	70	1,172
17	Angle Section	100							150			200				80		8	5	6,000	3,000	9,543
18	Channel Section				10	40		30	100		15	250	60	10	240		10	150	170	1,200	2,850	5,135
19	Small Eqpt.			4			5	10		5				10	20						20	74
20	Large Eqpt.	77							10													87
21	Pipe Frame								30			200				20				5,000	1	5,251
22	Grating	6										100		8	16					320		450
23	Rect. Frame								10			5							30	200	1,200	1,445
24	Crane Sections																					0
25	Wood Frame												10		100			1			1,000	1,111
26	Vehicle	5	1	1	3	2	1	5	10	5	2	1	1	1	10	10	200	35	2,514	90	183	3,080
	Totals	315	51	78	185	224	16	375	2,388	51	719	2,324	570	125	3,886	1,356	1,848	787	4,162	24,974	19,427	63,861

Damaging Missiles

- TMRE assumes any missile strike fails the target
  - 1.0 failure probability per missile strike
- Based on this assumption, missile population input to TMRE should be limited to missiles of sufficient energy to damage a specific target
  - Some targets may be very fragile, as such the population may include lower energy missiles (e.g., metal siding, branches, small pipe, etc.)
  - Some targets are relatively robust; the relevant population would include only high energy missiles (e.g., large pipe, automobiles, utility poles, etc.)

Damaging Missiles - Actual Operating Site

IPEEE Analysis

Missile Category	Counted Number of Missiles	Calculated Number of Missiles
55 Gallon Drum	135	405
Containers	18	900
Wood	170	510
Wood Structures	74	148
Structural Steel	27	27
Gas Bottles	200	250
Scaffolding	400	600
Vehicles	255[1]	319
Utility Poles	30[1]	90
TOTAL	1,309	3,249

Damaging Missiles – NP-768 Study

- Plant A
  - Single unit
  - Uniform distribution of 6000 missiles
- Plant B1
  - 1 unit operational, 2nd under construction
  - Zone-based distribution of 5000 missiles
- Plant B2
  - 2-unit operational site
  - Zone-based distribution of 5000 missiles

TMRE Missile Population

- Assume conservative value of 10,000 damaging missiles for robust targets
- All missiles are within the damage proximity of each target
- Damaging missile count will be confirmed to be conservative during the plant walkdown – if not conservative the missile count will be adjusted.

Plant Walkdown

Plant Walkdown Process

- Develop walkdown plan
  Identify:
  - Potential vulnerabilities
  - SSCs vulnerable to high winds
- Conduct walkdown
- Prepare walkdown documentation

PLANT WALKDOWN OBJECTIVES

CONFIRM:

- Validity of safe shutdown targets
- Damaging missile population is conservative
- Target correlation
- Adjustments to Internal Events PRA due to tornado effects

IDENTIFY:

- Specific tornado missile hazards that can be eliminated
- Additional vulnerabilities and targets that need to be considered

Typical Missiles Identified During Walkdowns Inside and Outside

Missiles Inside Metal Clad Building

Outside Missiles

Exposed Equipment Failure Probability (EEFP)

- Derive Missile Impact Parameter
- Set-up Plant Internal Events PRA
- Perform Risk Calculation Using EEFP
- Compare Results to Acceptance Criteria

Missile Impact Parameter (MIP) Derivation

MIP

Definition:

- Missile Impact Parameter (**MIP**)
  - Missile hit probability per missile per target exposed area (ft^2) per tornado intensity (F'2 through F'6)

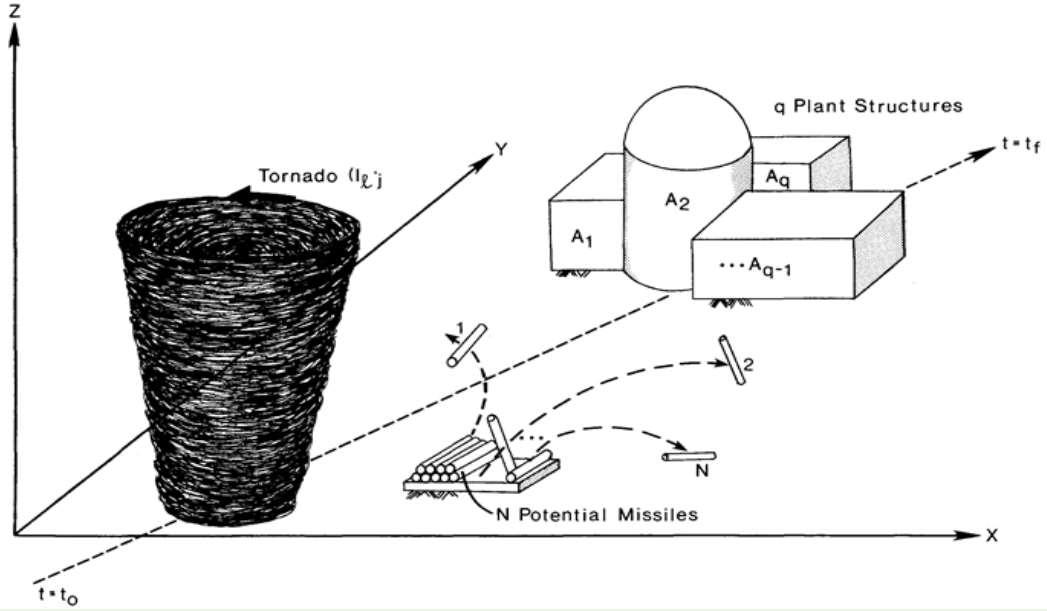
Use:

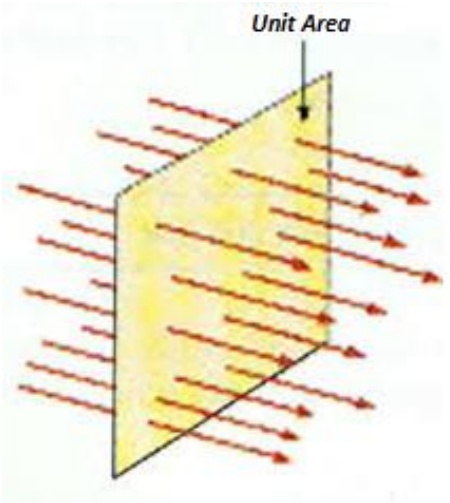
- **MIP** is used in calculating an exposed target failure probability for input into the adjusted Internal Events PRA:

Exposed Target Failure Probability =

MIP x # of Missiles x Exposed Target Area x Fragility

Definition of MIP





- **MIP** is the probability of a wind-driven missile impact per unit area of the plant structures for each missile from the entire population of missiles for a specific tornado hazard frequency (F'2 – F'6)
- Using **MIP,** the conditional probability of a missile impact on a vulnerable target during a given tornado can be estimated if the **number of available missiles** and the **exposed surface area of the target** are known

Missile Impact Parameter (MIP)

MIP = H Value / Tornado Frequency /Area of Plant Structures

Where Units are:

H-Value ⇨ Missile Hit Probability $(missile*year)^{-1}$

Tornado Frequency ⇨ $year^{-1}$

Area of Plant Structures ⇨ ft^2

All data is from NP-768, Section 3. H-Value is the direct output from the analysis in NP-768.

Example MIP Calculation

Based on NP-768 Data

"H-Value" (missile hit probability)
Reference - EPRI NP-768, Table 3-15, page 3-22

Tornado Intensity (F-Scale)	NRC Region	Lower Limit	Mean	Upper Limit
	I	4.04×10^{-9}	1.62×10^{-8}	2.84×10^{-8}
2	II	3.44×10^{-10}	1.38×10^{-9}	2.42×10^{-9}
	III	7.38×10^{-11}	2.96×10^{-10}	5.19×10^{-10}
	I	8.16×10^{-9}	2.53×10^{-8}	4.23×10^{-8}
3	II	6.27×10^{-10}	1.94×10^{-9}	3.25×10^{-9}
	III	1.19×10^{-10}	3.68×10^{-10}	6.18×10^{-10}
	I	4.54×10^{-9}	9.12×10^{-9}	1.37×10^{-8}
4	II	3.02×10^{-10}	6.06×10^{-10}	9.11×10^{-10}
	III	0.0	2.19×10^{-10}	4.40×10^{-10}
	I	3.60×10^{-9}	1.14×10^{-8}	1.93×10^{-8}
5	II	4.11×10^{-10}	7.49×10^{-10}	1.09×10^{-9}
6	I	8.68×10^{-10}	3.99×10^{-9}	7.11×10^{-9}

- Example MIP is based on Plant A tornado missile hit probability data (EPRI NP-768, Section 3).
- NP-768 does not calculate MIP directly.
- Derive example MIP from Plant A "H-Value," tornado frequency, and total exposed area of plant structures from NP-768 data.

Example MIP Calculation
Plant A Mean H-Value Data

F'-Scale	H-Value 1/(missile*year) *Table 3-15*	Tornado Mean Frequency *Table 3-4*	Area of Plant Structures *Table 3-1*	MIP

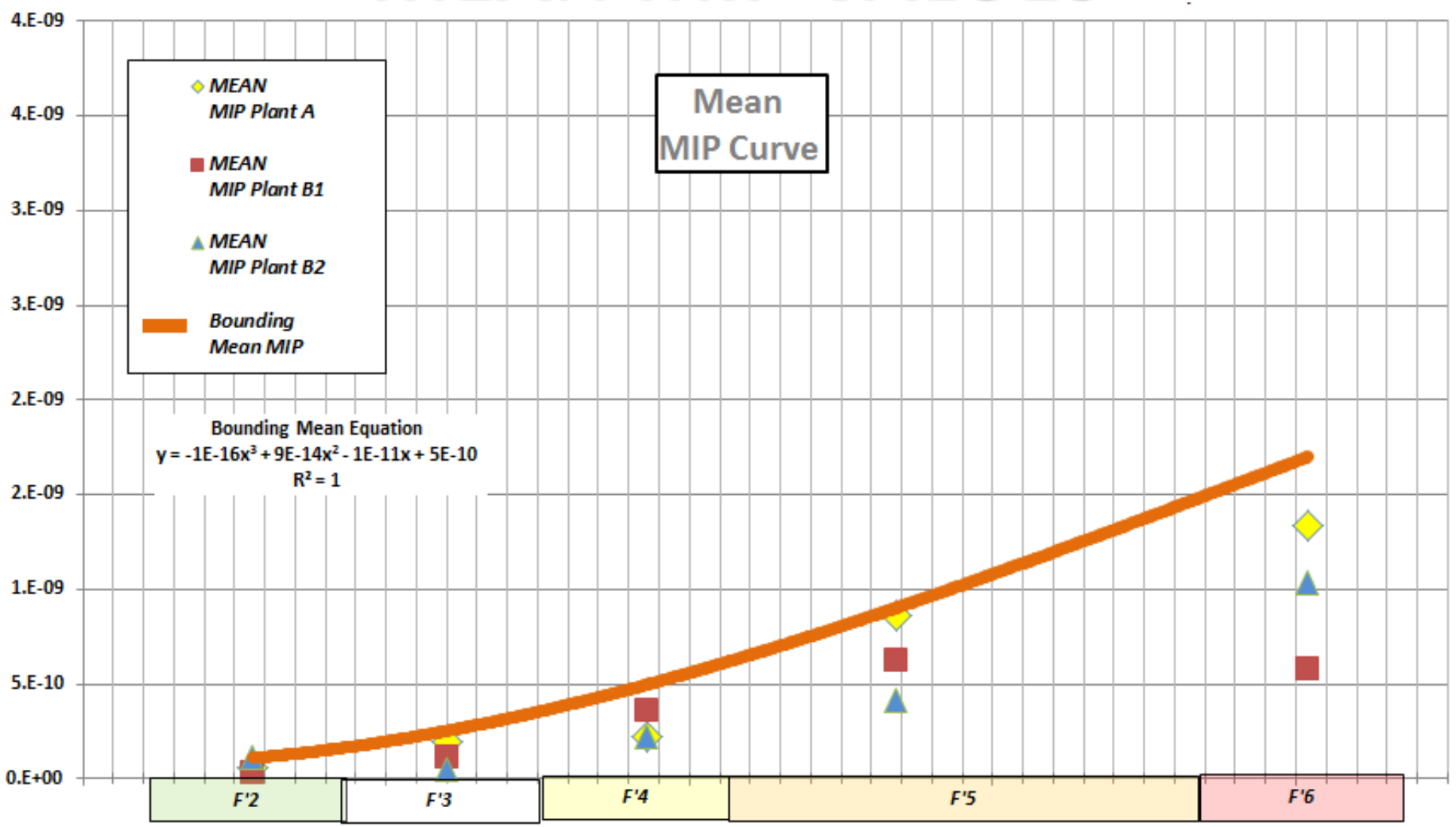
[H-Value] / [Tornado Frequency] / [Unit Area of Plant Structures] = MIP

MEAN MIP VALUES

- MIP mean values for the three plants modeled in NP -768, (Plant A, B1, B2) are shown in the table below.
- A set of MIP values developed that bound all three sets of mean values.

	MEAN MIP Plant A	***MEAN MIP Plant B1***	***MEAN MIP Plant B2***	***Bounding Mean MIP***
F'2	5.81E-11	2.7E-11	1.1E-10	***1.1E-10***
F'3	1.97E-10	1.2E-10	5.2E-11	***2.5E-10***
F'4	2.27E-10	3.6E-10	2.2E-10	***5.0E-10***
F'5	8.66E-10	6.2E-10	4.1E-10	***9.0E-10***
F'6	1.33E-09	5.7E-10	1.0E-09	***1.7E-09***

MEAN MIP VALUES

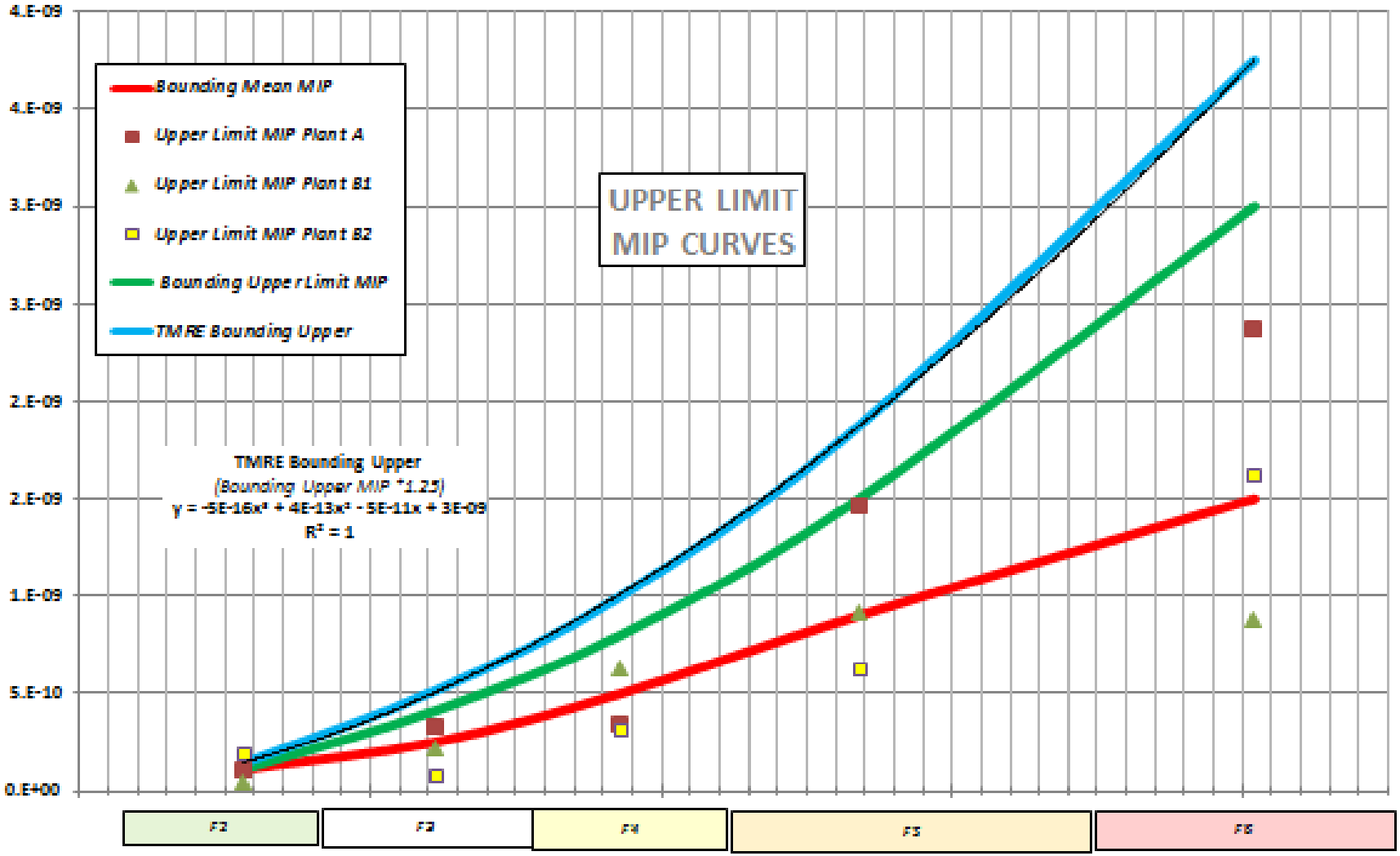


UPPER MIP VALUES

- Upper limit MIP values for the three NP-768 plants are provided in the table below.
- A set of MIP values were developed that bound all three sets of upper limit values.
- The set of MIP values that will be used in the TMRE is based on the bounding upper limit MIP values increased by a factor of 1.25.

	Bounding Mean MIP	*Upper Limit MIP Plant A*	*Upper Limit MIP Plant B1*	*Upper Limit MIP Plant B2*	*Bounding Upper Limit MIP*	*TMRE MIP*
F'2	***1.1E-10***	1.0E-10	4.9E-11	1.9E-10	**1.9E-10**	**2.4E-10**
F'3	***2.5E-10***	3.3E-10	2.2E-10	8.4E-11	**4.1E-10**	**5.1E-10**
F'4	***5.0E-10***	3.4E-10	6.3E-10	3.2E-10	**8.0E-10**	**1.0E-09**
F'5	***9.0E-10***	1.5E-09	9.1E-10	6.3E-10	**1.5E-09**	**1.9E-09**
F'6	***1.5E-09***	2.4E-09	8.8E-10	1.6E-09	**3.0E-09**	**3.8E-09**

TMRE BOUNDING MIP VALUES



Target Characteristics

- Surface Area
- Exposure
- Correlation

Target Surface Area

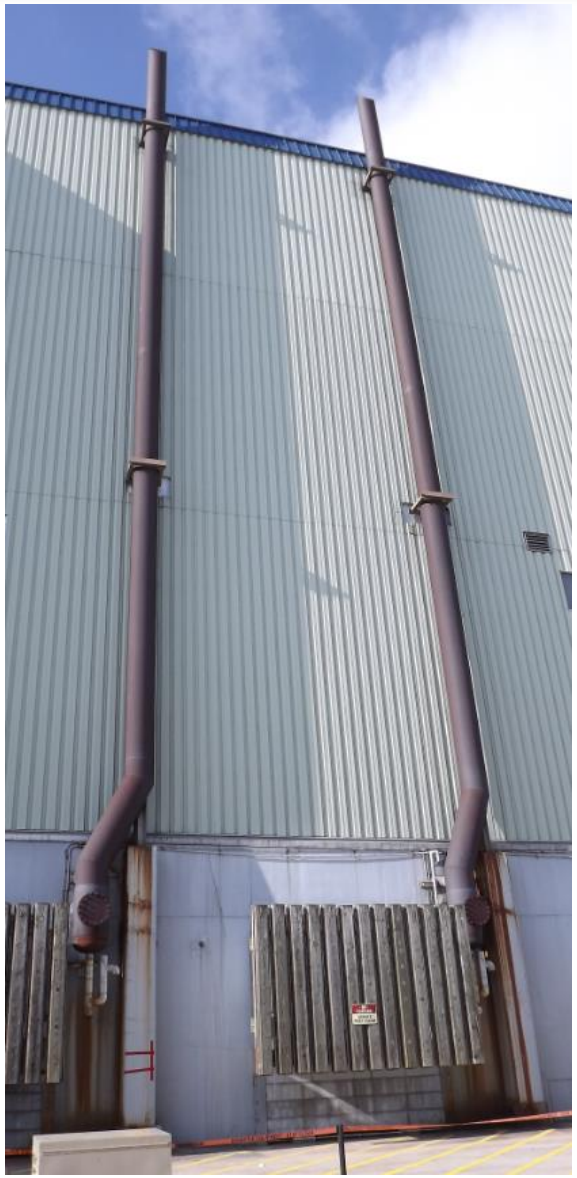
- EDG Exhaust Stacks
- Outside Cable Vault
- CSTs
- SW Components

Definition of Correlation

- Exposed targets are correlated if the targets can be struck by the same tornado missile, considering the set of missiles defined in the licensing basis.

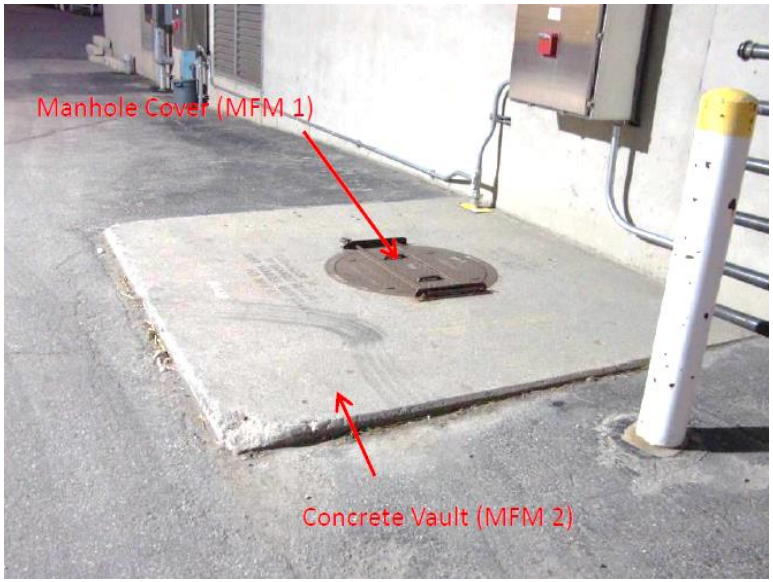
EDG Exhaust Stacks

- Two separate targets, not correlated
- Exposed cylindrical surface (870 ft^2 each)



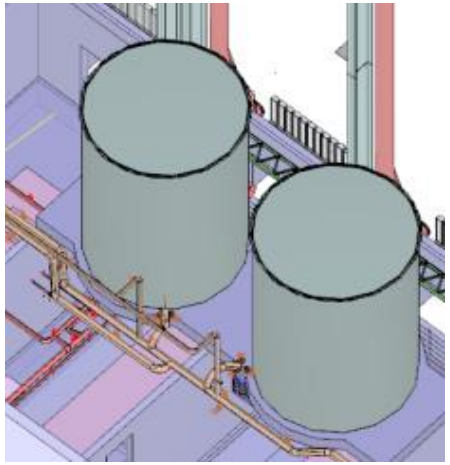
Outside Cable Vault

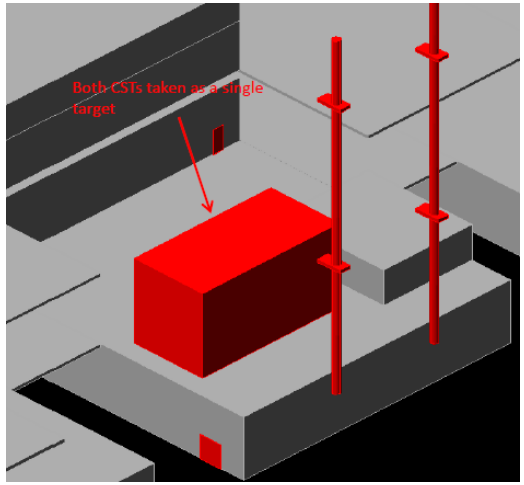
- Two targets, one vault for each division that are not correlated – separated by ~ 120ft.
- Area of concrete pad vault cover (58 ft^2)



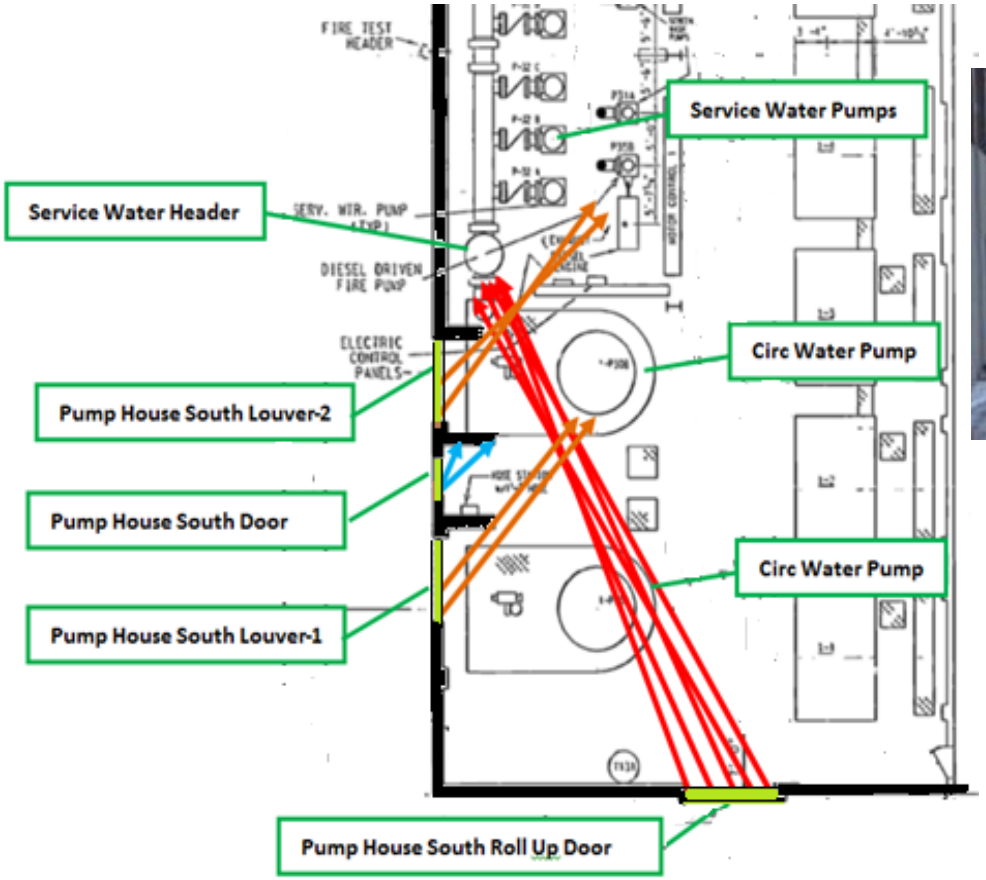
Condensate Storage Tanks

- Two tanks, correlated, representing one target
- Exposed area calculated from exposed five-sided rectangular box (3200 ft^2)





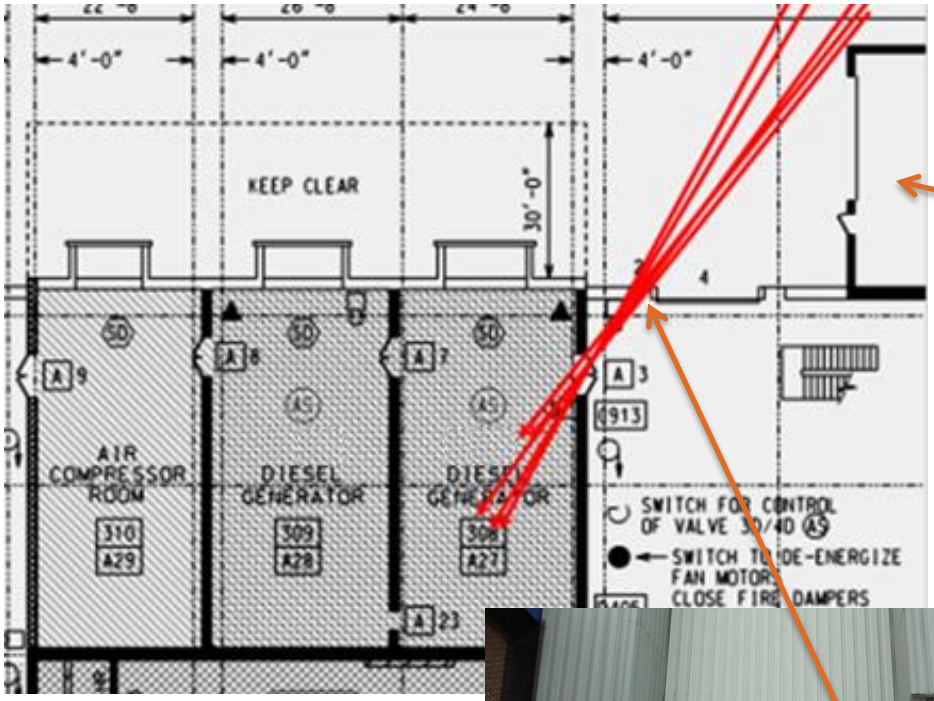
Service Water Components



Pumphouse Missile Path Through Louvers, Doors, and Roll-Up Doors

- Two targets per unit – service water header isolation valve, not correlated
- Only rollup door provides a path to target. However target is shielded by circ water pumps which a robust barrier to missile progress. **Target screened out.**

Exposure Considerations – EDG & Auxiliaries



Missile tracks are limited to paths that avoid the concrete building in the upper right of the plan view and travels through both the outside personnel and EDG room entry doors.

Target Screened Out.

Calculating Tornado Missile Risk (TMR)

- Exposed Equipment Failure Probability
- PRA Model Modifications
- Risk Calculation
- Comparison to Acceptance Criterion

Exposed Equipment Failure Probability CST Example

Target	F'-Scale	MIP	# of Missiles	Target Area	Conditional Probability (Fragility)	Probability of Failure from Missile Strike
CSTs	2	2.41E-10	10000	3200	1.0E+00	**7.7E-03**
	3	5.13E-10	10000		1.0E+00	**1.6E-02**
	4	1.00E-09	10000		1.0E+00	**3.2E-02**
	5	1.88E-09	10000		1.0E+00	**6.0E-02**
	6	3.75E-09	10000		1.0E+00	**1.2E-01**

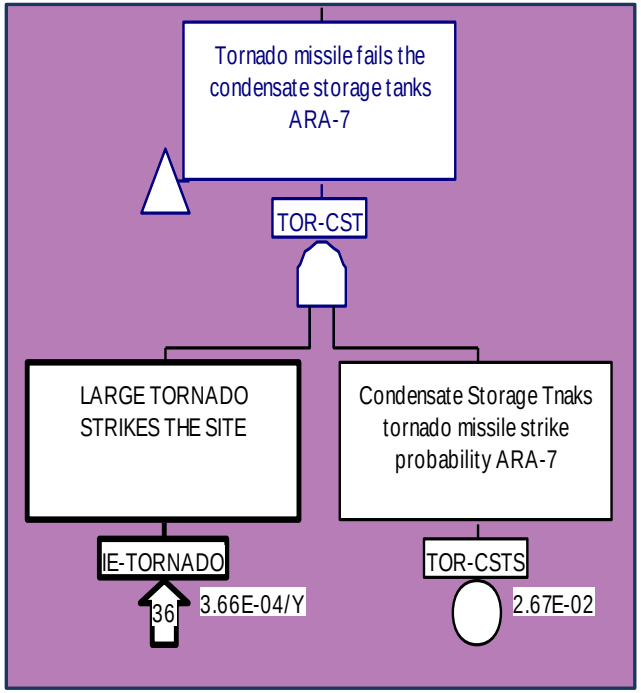
PRA Model Modifications - Overview

PRA logic modeling of TMRE discussed per ASME/ANS PRA Standard Technical Elements:

- Initiating Event/Hazard Analysis (IE)
- Accident Sequence Analysis (AS)
- Success Criteria (SC)
- Systems Analysis (SY)
- Human Reliability Analysis (HR)
- Data Analysis (DA)
- Quantification (QU)

PRA Model Modifications – IE

- Site tornado hazard
  (e.g., based on NUREG/CR-4461, Rev. 2)
- Hazard implemented in PRA as separate initiating event per F'-Scale hazard interval
  - F'0 and F'1 non-significant risk contributors, not specifically modeled
  - F'2, F'3, F'4, F'5 and F'6 hazard intervals specifically modeled
- Hazard interval frequency = [Hazard Exceedance Frequency at Beginning of Interval] - [Hazard Exceedance Frequency at End of Interval]



Logic Model Implementation - AS

- Loss of Offsite Power Accident (LOOP) accident sequence model used
- LOOP initiators replaced by F'2 thru F'6 tornado hazard interval initiating events

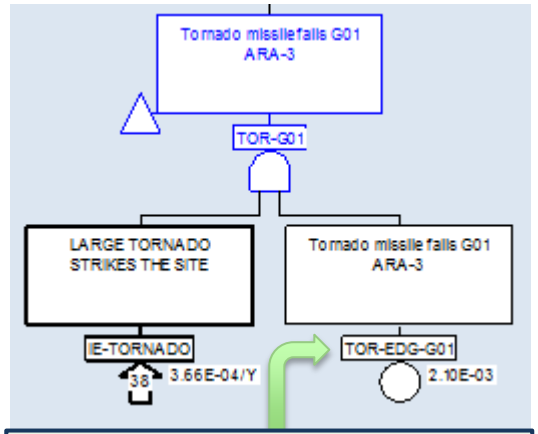
PRA Model Modifications - SC

- No changes to systemic or thermal hydraulic success criteria bases
- Tornado events do not change these bases

Logic Model Implementation

System fault tree logic supporting LOOP accident sequence logic maintained, but modified for tornado as described below:

- Tornado hazard interval initiators inserted in system logic in same locations the LOOP initiators exist
- Equipment/Functions in logic models assumed directly failed (set to TRUE in flag file, or tornado hazard interval initiating events inserted directly under these functions to fail them):
  - Gas Turbine
  - Fire Pumps
  - Instrument Air
- Tornado missile impact failure probabilities for each target modeled with AND gate as shown
- Target fragility assumed 1.0 given damaging missile hit



EDG failure given missile strike modeled as 1.0 probability

Logic Model Implementation - HR

- **Pre-Initiator Human Error Probabilities**: no changes
  - Tornado events do not change the probabilities of latent errors
- **Post-Initiator Human Error Probabilities (HEPs)**
  - In Main Control Room (MCR) actions
    - HEPs for LOOP scenarios used
  - Outside MCR actions
    - In safety-related buildings: used HEPs for LOOP scenarios
    - Actions exposed to wind effects:
      - HEPs set to 1.0 for actions required at $t \leq 60$ minutes
      - HEPs for LOOP scenarios used for action required at $t > 60$ minutes
- **Recovery Actions**
  - No recovery credit for wind-induced failures, including loss of offsite power (i.e., offsite AC recovery probabilities set to 1.0 or deleted from logic)

Logic Model Implementation - DA

- No changes to random failure probabilities, common cause failure (CCF) probabilities, or maintenance unavailabilities
- Tornado events do not change these probabilities (refer to previous slides regarding implementation of wind-induced failures in the system fault tree logic and human reliability analysis)

Logic Model Implementation - QU

- Model quantified in the same manner as base PRA
- Risk metric quantified: Core Damage Frequency (CDF)

Relevance of Notional Plant F&Os

- Reviewed and determined to have no impact on RG 1.200 Internal Events PRA use for TMRE methodology
- Licensee will cover F&Os in addition to defense-in-depth and safety margin in LAR submittal

Acceptance Criterion

- SRP 3.5.1.4, Revision 4 (March 2015) Section II, SRP Acceptance Criterion 3:

  "The method of identifying appropriate design-basis missiles generated by natural phenomena should be consistent with the acceptance criteria defined for the evaluation of potential accidents from external sources in **SRP Section 2.2.3**, 'Evaluation of Potential Accidents.' A licensee or applicant may justify the acceptability of the use of another methodology."

Acceptance Criterion

- SRP 2.2.3, Revision 3 (March 2007)
  Section II, SRP Acceptance Criterion 2:

  "If data are not available to make an accurate estimate of the event probability (see Technical Rationale 2) , an expected rate of occurrence of potential exposures resulting radiological dose in excess of the 10 CFR 50.34(a)(1) as relates to the requirements of 10 CFR Part 100, by an **order of magnitude of 10^{-6} per year is acceptable if, when combined with reasonable qualitative arguments, the realistic probability can be shown to be lower**."

Technical Rationale 2

- SRP 2.2.3, Revision 3 (March 2007) Section II, Technical Rationale 2:

  "Data are often not available to enable the accurate calculation of probabilities because of the low probabilities associated with the events under consideration. Accordingly, the expected rate of occurrence of potential exposures in excess of the 10 CFR 50.34 (a)(1) requirements as they relate to the requirements of 10 CFR Part 100 guidelines by an order of magnitude of 10^{-6} per year is acceptable if, when combined with reasonable qualitative arguments, the realistic probability can be shown to be lower."

TMRE Conservatisms

EPRI NP-768 conservatisms (basis for MIP values):

Plant Model Orientation

- Oriented in compass direction that maximizes missile impact probabilities on modeled targets

Missile Injection

- Methodologies conservative to favor missile injection and transport

  Examples:
  - Each missile positioned to wind to maximize lift probability
  - Each missile sample is independent of other missiles; thus, each missile transport not hindered by possible collision with other missiles

TMRE Conservatisms

- **MIP**
  - Upper limit
  - Additional 25% added for conservatism
- **Target Hit Probability**
  - Target elevation
    - High & low targets have same probability of being hit
- **Target Failure Given Hit (Fragility)**
  - Base approach directly fails target function with 1.0 failure probability given a missile hit

TMRE Conservatisms

PRA Model

- **No Recoveries**
  - No recoveries of wind-induced failures (including offsite AC) during the PRA mission time.

TMRE COMPARISON TO RG 1.200

- TMRE CDF: 2.32E-07
- RG 1.200 CDF: 1.76E-07

TMRE MISSILE SENSITIVITY

F'-Scale	TMRE CDF			
	10,000 MISSILES	20,000 MISSILES	50,000 MISSILES	100,000 MISSILES
F'6 (>277 mph)	6.27E-10	1.66E-09	7.10E-09	2.58E-08
F'5 (209-277 mph)	6.77E-09	1.48E-08	4.98E-08	1.47E-07
F'4 (168-209)	2.21E-08	4.27E-08	1.22E-07	3.08E-07
F'3 (135-168 mph)	5.05E-08	8.84E-08	2.13E-07	4.65E-07
F'2 (103-135 mph)	1.52E-07	2.20E-07	4.49E-07	8.86E-07
TOTAL	**2.32E-07**	**3.68E-07**	**8.40E-07**	**1.83E-06**

- The sensitivities all assume uniform distribution of missiles across the site; this is conservative since missiles are typically concentrated away from targets.
- Missile count will be verified during the plant walkdown – if 10,000 is not conservative the missile count will be adjusted.

Conclusion

The NEI Tornado Missile Risk Evaluator provides a simple and demonstrably conservative tool that can be broadly used by nuclear power plant licensees to assess the need to provide additional physical protection for plant components.