Black Swans and Meteors

"Worst Case Scenarios" and Why We Need to Ignore Them

BLUEFIELD
PROCESS SAFETY

Mike Schmidt bio

- Principal of Bluefield Process Safety since 2008
- Joined Union Carbide in 1977
- Began work in process safety following tragedy in Bhopal in 1984
- Joined faculty at Missouri S&T in Rolla in 2009, teaching on safety and risk
- Work includes
  - Facilitating PHAs, LOPAs, RTC establishment
  - SIS conceptual design, SIL verification calcs
  - PSM compliance and audits

Maria Vega-Westhoff bio

- **BS in Chemical Engineering**
- **Safety Consultant at Bluefield Process Safety since 2015**
- **Work includes**
  - **Facilitating PHAs, LOPAs**
  - **Mechanical Integrity**
  - **PSM compliance and audits**
  - **SIS conceptual design, SIL verification calcs**

Black Swans and Meteors

“Worst Case Scenarios” and Why We Need to Ignore Them

BLUEFIELD
PROCESS SAFETY

Presented by

- **Michael S. Schmidt**
  - **Principal, Bluefield Process Safety, LLC**
    St. Louis, Missouri
  - **Adjunct Professor, Missouri S&T**
    Rolla, Missouri
- **Maria Vega-Westhoff**
  - **Safety Consultant,**
    Bluefield Process Safety, LLC
    St. Louis, Missouri

“Worst-Case” Scenarios

- **“Worst-Case” has no actionable meaning without a specified definition – you can always think of something worse.**
- **“Credible” has no actionable meaning without a specified likelihood – otherwise, you are simply left with “possible.”**
- **EPA worst-cases, although incredible, are well defined**

BLUEFIELD PROCESS SAFETY

Inconceivable *vs.* Improbable

- **“Black Swans”**
  - **Not simply rare, but inconceivable**
  - **Inconceivable, so not predictable**
  - **Not predictable; explainable only in hindsight**
- **“Meteors”**
  - **Rare**
  - **Evidence convincingly points to their possibility**
  - **Conceivable, predictable, and calculable**

Improbable but not impossible

- By their very nature, "black swans" cannot be addressed in a risk assessment
- "Meteors" are sometimes suggested, but without likelihood, judgments about "credible" are based on feelings

BLUEFIELD PROCESS SAFETY

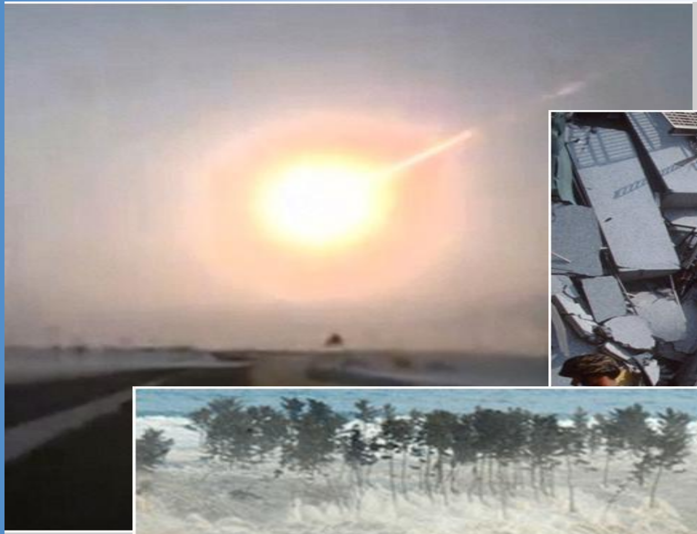
Some "meteors"

- Geophysical events
- Climate-related events
- Transportation events



BLUEFIELD PROCESS SAFETY

Geophysical Events

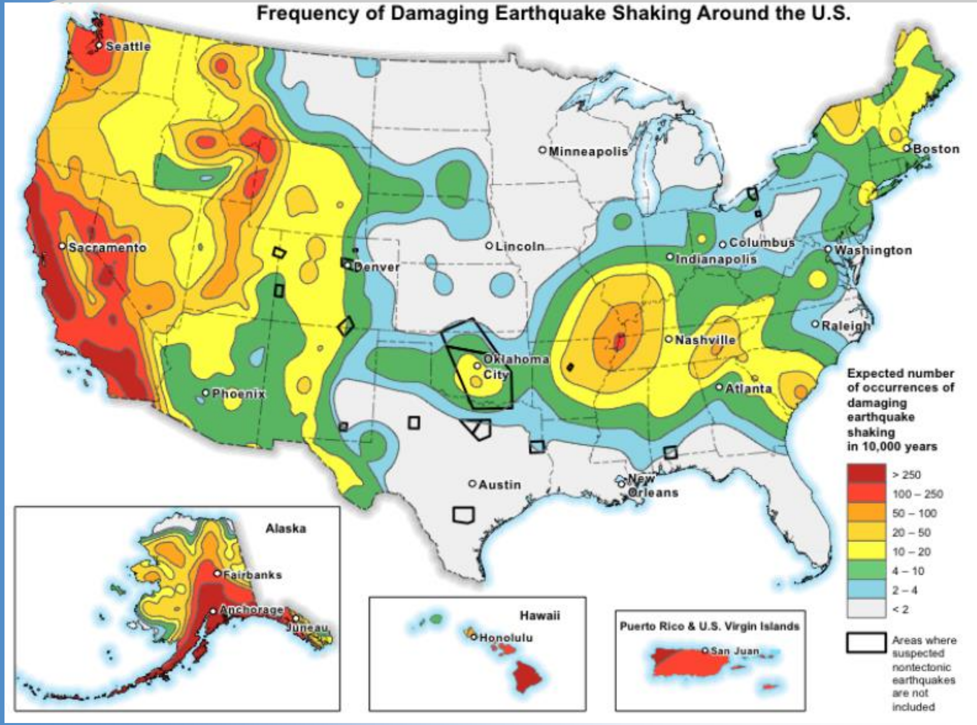


Meteors

1 event / 40 years **(damaging meteors)**
x 250 km² **(damage zone)**
/ 5.2·10⁸ km² **(Earth's surface)**
= 1.2·10⁻⁸ events per year

BLUEFIELD PROCESS SAFETY

Earthquakes



2×10^{-2}/yr

1×10^{-2}/yr

5×10^{-3}/yr

2×10^{-3}/yr

1×10^{-3}/yr

5×10^{-4}/yr

2×10^{-4}/yr

1×10^{-4}/yr

Tsunamis

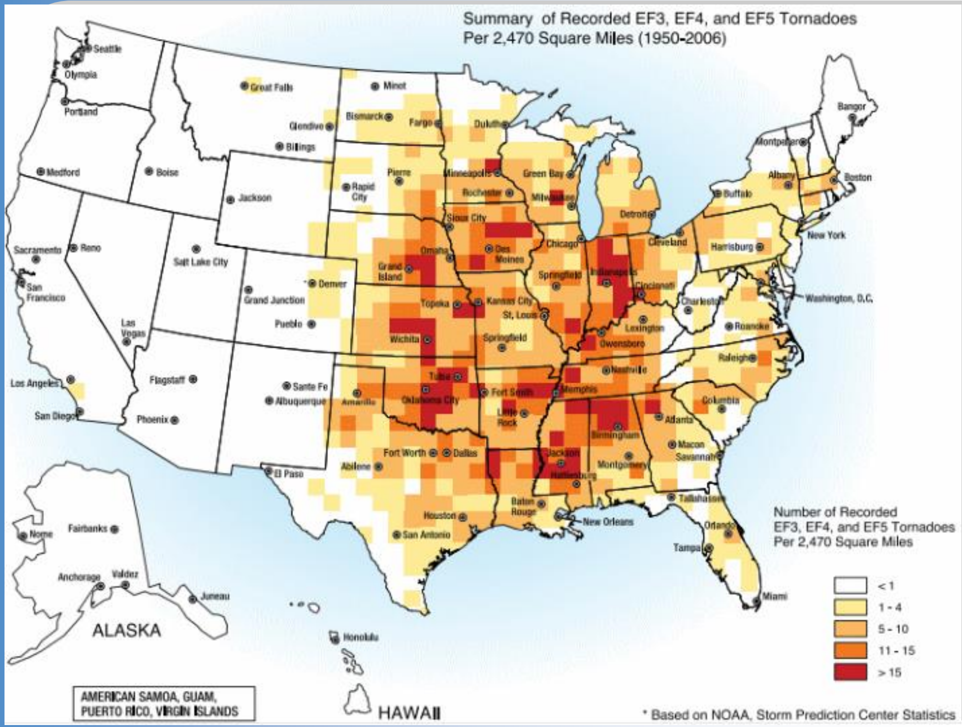
5 events / year (damaging tsunamis)
x 20 km (damage zone)
x *f* (fraction of tsunami in body of water)
/ L (coastline length in body of water)
= 100 event·km/yr · *f*/L

Body of Water	*f*, Fraction of Tsunamis	L, Coastline	Event Frequency
Pacific Ocean	0.71	135,000 km	5×10^{-4} events/yr
Mediterranean	0.15	17,000 km	9×10^{-4} events/yr
Atlantic/Carib	0.07	110,000 km	6×10^{-5} events/yr
Indian Ocean	0.06	89,000 km	7×10^{-5} events/yr
Black Sea	0.01	7,000 km	1×10^{-4} events/yr

Climate-related Events

BLUEFIELD PROCESS SAFETY

Tornadoes



Average impact zone of a tornado is 13 km² (5 mi²)

Tornadoes

State	Tornado Rate	State	Tornado Rate	State	Tornado Rate
KS	6×10^{-3}	AR	4×10^{-3}	GA	2×10^{-3}
OK	5×10^{-3}	NE	4×10^{-3}	MN	2×10^{-3}
IL	5×10^{-3}	LA	4×10^{-3}	CO	2×10^{-3}
MS	5×10^{-3}	TN	3×10^{-3}	ND	2×10^{-3}
AL	4×10^{-3}	IN	3×10^{-3}	OH	2×10^{-3}
IA	4×10^{-3}	MO	3×10^{-3}	SD	2×10^{-3}
FL	4×10^{-3}	KY	3×10^{-3}	VA	2×10^{-3}
MD	4×10^{-3}	TX	3×10^{-3}	DE	2×10^{-3}
SC	4×10^{-3}	NC	3×10^{-3}	WI	2×10^{-3}

Tornado rate:

Tornadoes per year per 13 km^2

BLUEFIELD PROCESS SAFETY

Hurricanes

State	Hurricane Rate	State	Hurricane Rate
TX	8	MD	4
LA	8	DE	4
MS	16	NJ	4
AL	16	NY	4
FL	8	CT	4
GA	8	RI	4
SC	8	MA	2
NC	8	NH	2
VA	4	ME	1

Hurricane rate:
Hurricanes per century per 160 km of coastline

BLUEFIELD PROCESS SAFETY

Transportation Events

Truck crashes

- **1.24 serious crashes per 100 million miles travelled**

Highway Volume	Crash Rate
High volume highway (8500 trucks per day)	2×10^{-3}
Medium volume highway (850 trucks per day)	2×10^{-4}
Low volume highway (85 trucks per day	2×10^{-5}

Crash rate:

Crashes per year per 100 m of highway

BLUEFIELD PROCESS SAFETY

Train derailments

20,000 accidents/10 years
x 0.71 **(derailment fraction)**
/ 225,000 km **(total railroad)**
= $6 \cdot 10^{-4}$ derailments per yr per 100 m

BLUEFIELD PROCESS SAFETY

Pipeline ruptures

Piping Size	Pipeline Failure Type	Failure rate
> 150 mm dia.	Full breach (Guillotine failure)	1×10^{-5}
> 150 mm dia.	Partial breach-10% (Leak)	1×10^{-4}
≤ 150 mm dia.	Full breach (Guillotine failure)	1×10^{-4}
≤ 150 mm dia.	Partial breach-10% (Leak)	1×10^{-3}

Failure rate:

Failures per year per 100 m of pipeline

BLUEFIELD PROCESS SAFETY

Airplane crashes

- More than 10 km from airport

  $$H = h \cdot f \cdot A_{FACILITY} / (2\pi R \cdot d_{AVG})$$

  - H is frequency of airplane crashes into facility (crashes/yr)
  - h is global crash rate ($4 \cdot 10^{-7}$ crashes/flight)
  - f is frequency of flights from airport (flights/yr)
  - $A_{FACILITY}$ is area of concern for facility (L^2)
  - R is distance of facility from airport (L)
  - d_{AVG} is the average flight distance (L)

BLUEFIELD PROCESS SAFETY

Airplane crashes

- **Less than 10 km from airport**

  $$H = h \cdot e^{(-0.5/km \cdot R)} \cdot f \cdot A_{FACILITY} / (2\pi\ km \cdot R)$$

  - **H is frequency of airplane crashes into facility (crashes/yr)**
  - **h is global landing/takeoff crash rate ($1.3 \cdot 10^{-7}$ crashes/flight)**
  - **R is distance of facility from airport (L)**
  - **f is frequency of flights from airport (flights/yr)**
  - **$A_{FACILITY}$ is area of concern for facility (L^2)**

BLUEFIELD PROCESS SAFETY

Example Event Frequencies

Facility Event Description	**Frequency**
> 20 m meteor strike	$1 \cdot 10^{-8}$ per year
Damaging earthquake in upper Midwest	$1 \cdot 10^{-4}$ per year
Damaging earthquake on California coast	$1 \cdot 10^{-2}$ per year
Damaging tsunami on Pacific coast	$1 \cdot 10^{-3}$ per year
Damaging tsunami on Atlantic coast	$1 \cdot 10^{-4}$ per year
Hurricane on Gulf of Mexico coast	$1 \cdot 10^{-1}$ per year
Hurricane on New England coast	$1 \cdot 10^{-2}$ per year
Tornado in Tornado Alley	$1 \cdot 10^{-2}$ per year
Tornado in Rocky Mountains	$1 \cdot 10^{-4}$ per year
Rupture of large pipeline (> 150 mm, > 6 inches)	$1 \cdot 10^{-5}$ events per 100 m per year
Significant train derailment	$1 \cdot 10^{-3}$ events per 100 m per year
Significant truck crash on high volume highway	$1 \cdot 10^{-3}$ events per 100 m per year
Significant truck crash on medium volume highway	$1 \cdot 10^{-4}$ events per 100 m per year
Significant truck crash on low volume highway	$1 \cdot 10^{-5}$ events per 100 m per year
Plane crash on plant 50 km from medium-sized airport (STL)	$1 \cdot 10^{-7}$ per year
Plane crash on plant 5 km from medium-sized airport (STL)	$1 \cdot 10^{-4}$ per year

Justice J.P.Stevens

- **“Some risks are plainly acceptable and others are plainly unacceptable,”**
- **Adding: The odds of fatality of one in a billion could not be considered significant but that for odds of a fatality of one in a thousand “a reasonable person might well consider the risk significant.”**

BLUEFIELD PROCESS SAFETY

Risk, not consequences

- **Decisions based on "Worst-Case" Scenarios are not driven by risk, but consequences, and are poorly defined at that.**
- **"It is in that gap between once every thousand years and once every billion years that the definition of 'credible' will be found…With that definition in hand, we can eliminate scenarios that are not credible."**

BLUEFIELD PROCESS SAFETY

Questions?

- **Contact us:**

Mike Schmidt –

(314)420-9350

bluefieldsafety@gmail.com

Maria Vega-Westhoff –

(573)999-4791

m.vegawesthoff.bluefieldsafety@gmail.com