RSAConference2018
San Francisco | April 16 – 20 | Moscone Center

SESSION ID: GRC-T07

SUPERFORECASTING: EVEN YOU CAN PERFORM HIGH-PRECISION RISK ASSESSMENTS

Rick Howard

CSO
Palo Alto Networks
@racebannon99

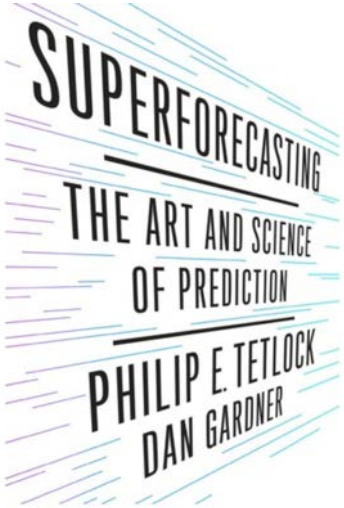
Richard Seiersen

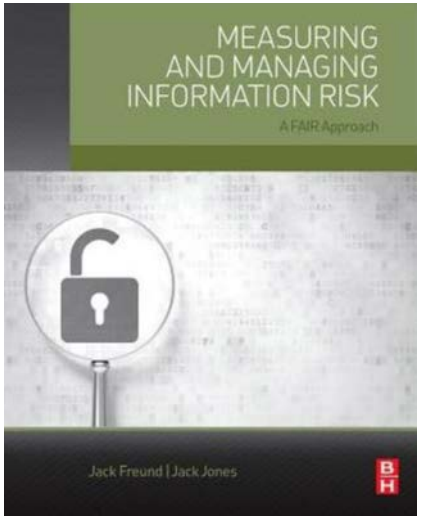
CISO
Lending Club
@RichardSeiersen

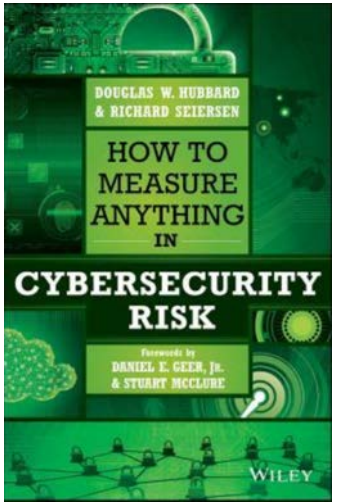
Why This Talk?

CYBERSECURITY CANON

https://cybercanon.paloaltonetworks.com/



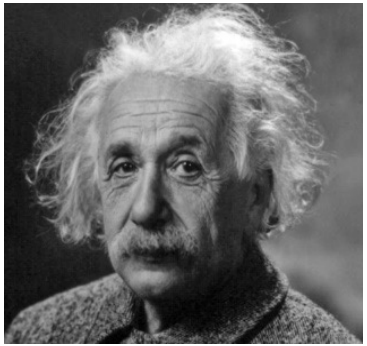




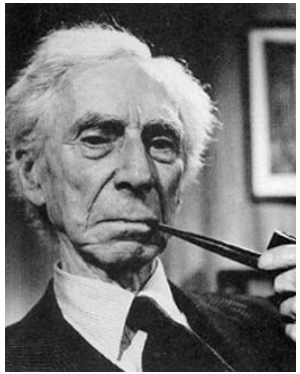
What Do These Four Things Have In Common

THE SUPERFORECASTER'S POINT OF VIEW

The Superforecaster's Point Of View



As far as the propositions of mathematics refer to reality, they are not certain; and as far as they are certain, they do not refer to reality. **—Albert Einstein**



Although this may seem a paradox, all exact ***science is based on the idea of approximation****. If a man tells you he knows a thing exactly, then you can be safe in inferring that you are speaking to an inexact man.* **—Bertrand Russell**

The Superforecaster's Point Of View

If you haven't measured something, you really don't know very much about it– **Karl Pearson**

The whole idea of probability is to be able to describe by numbers your ignorance or equivalently your knowledge.
– Prof Ronald Howard

The Superforecaster's Point Of View

Effective measurement **retains our uncertainty** as opposed to **obscuring** it.

Which of these *obscures*, and which of these *retains*, your uncertainty?

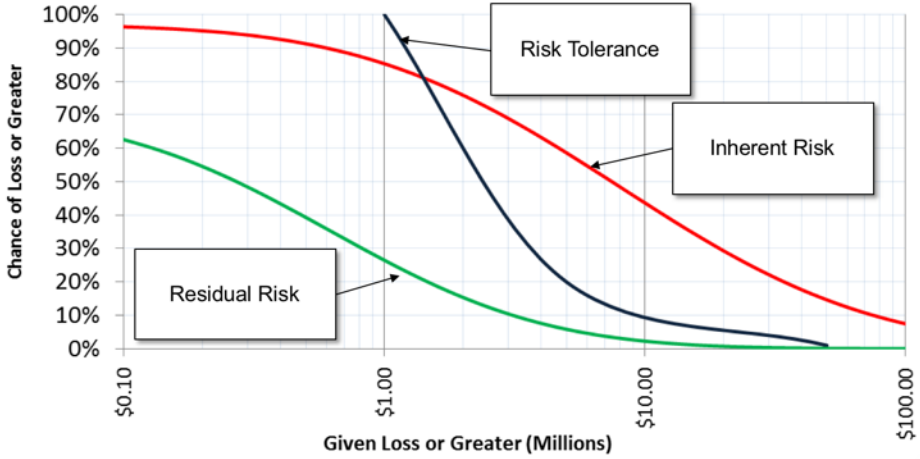
Impact →	1	2	3	4	5
Probability ↓	Negligible	Minor	Moderate	Significant	Severe
(81-100)%	Maximum Risk	Maximum Risk	Maximum Risk	Extreme Risk	Extreme Risk
(61-80)%	Maximum Risk	Maximum Risk	Moderate Risk	High Risk	Extreme Risk
(41-60)%	Minimum Risk	Low Risk	Moderate Risk	High Risk	High Risk
(21-40)%	Minimum Risk	Low Risk	Low Risk	Moderate Risk	High Risk
(1-20)%	Minimum Risk	Minimum Risk	Low Risk	Moderate Risk	High Risk

And Research Says……

"faux communication aka placebo effect…"

"proven to be worse than doing nothing."

OBSCURES



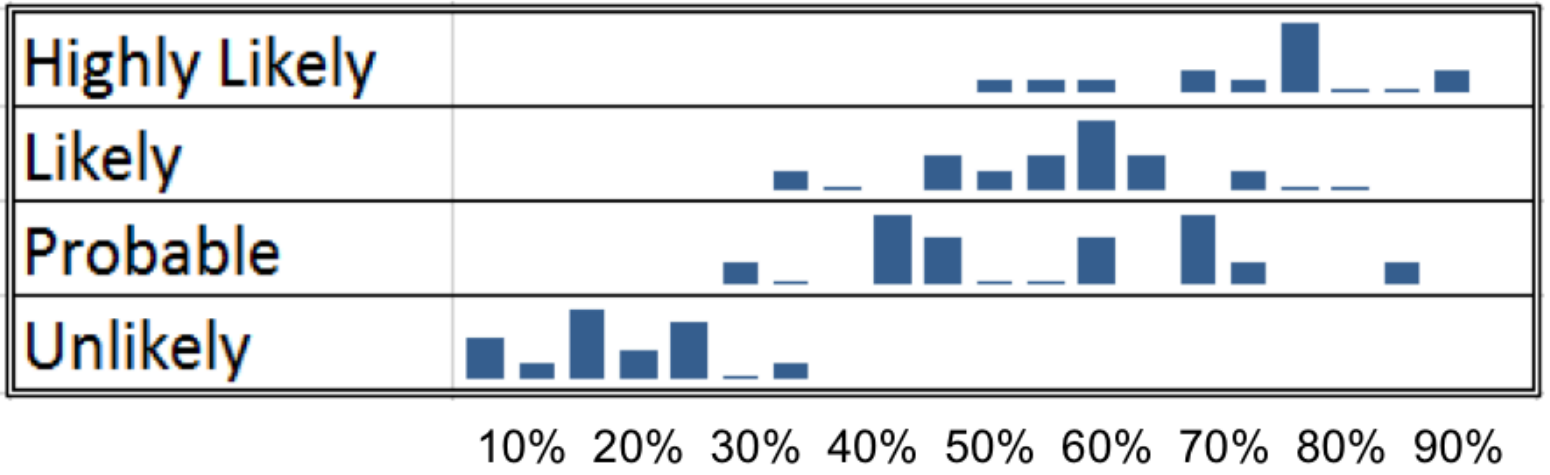
RETAINS

Superforecaster's Point Of View

Budescu et al. *Psychological Science*, 2009 for the use of verbal, qualitative scales for likelihoods:

23 NATO officers estimated probabilities for events described using combinations of 11 terms used in communicating likelihoods in intelligence reports (e.g. "War between X and Y is V.")

"[Verbal terms] induce an illusion of communication (aka "the placebo effect").



HISTORY OF BAYESIAN MEASUREMENT

History of Bayesian Measurement

Source: University of York, 2013

1740s

History of Bayesian Measurement


Source: University of York, 2013

1740s

Likelihood

How probable is the evidence given that our hypothesis is true?

Prior

How probable was our hypothesis before observing the evidence?

$$P(H \mid e) = \frac{P(e \mid H)\, P(H)}{P(e)}$$

Posterior

How probable is our hypothesis given the observed evidence?

Marginal

How probable is new evidence under all possible hypotheses?

History of Bayesian Measurement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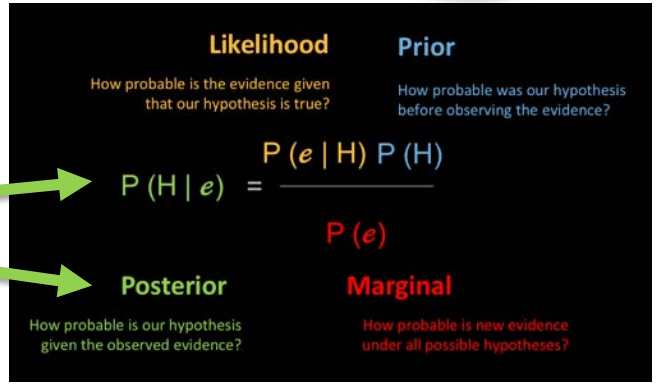

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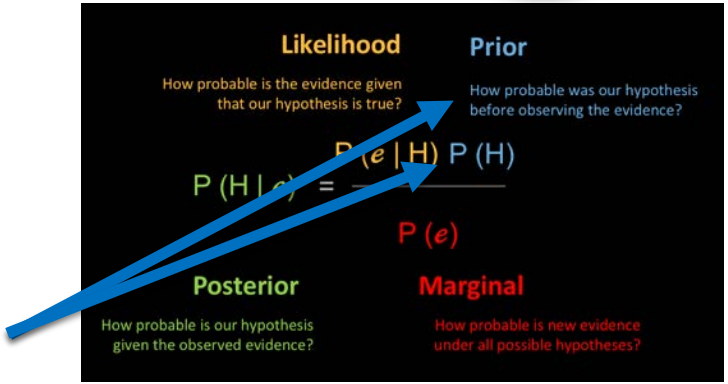

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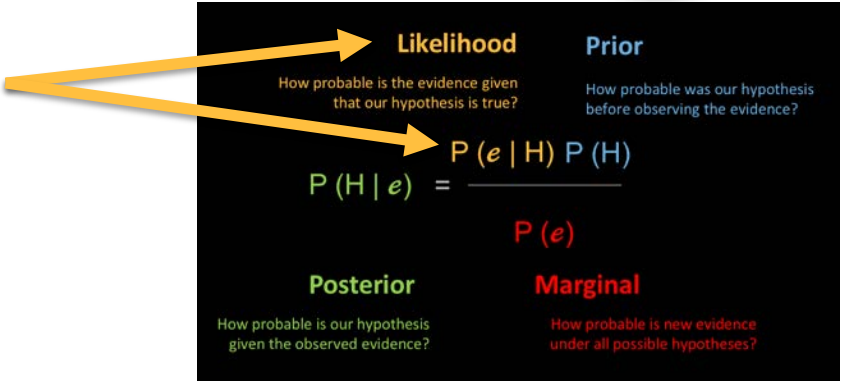

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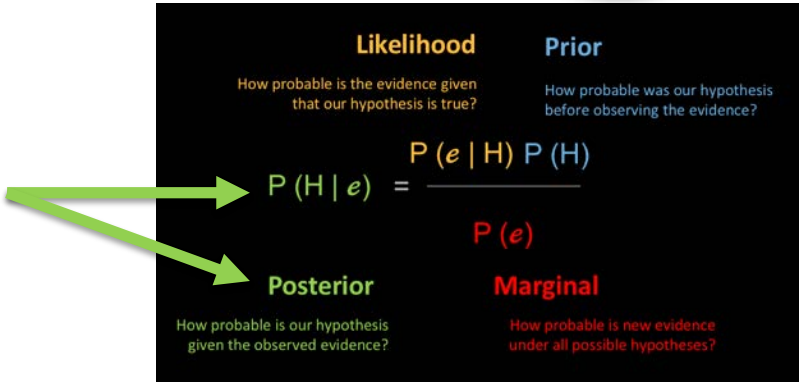

What is the Probability of a material breach in the next three years?

History of Bayesian Measurement

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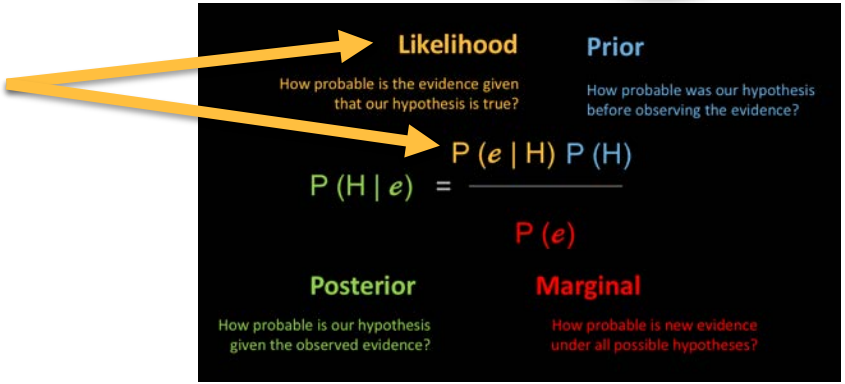

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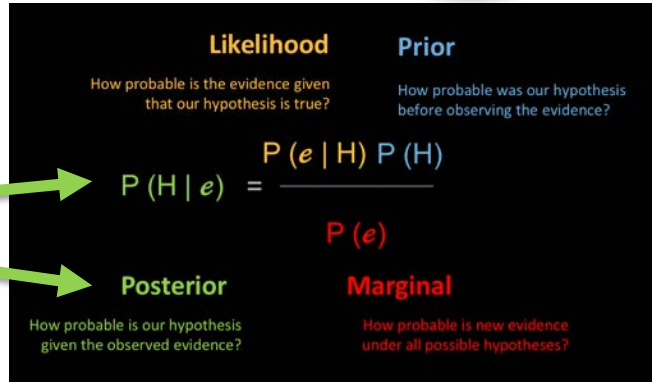
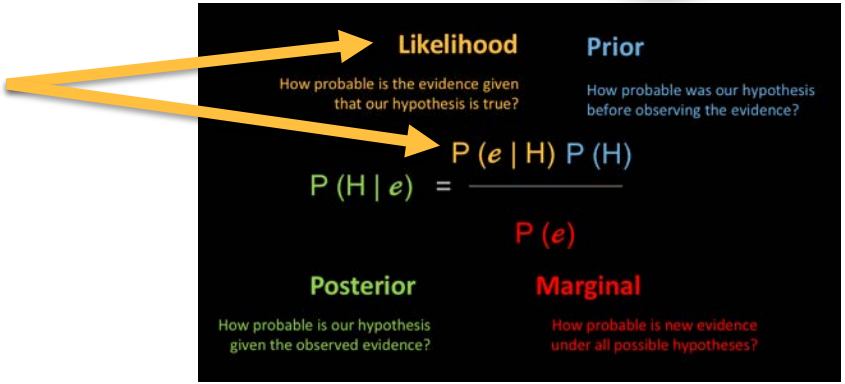


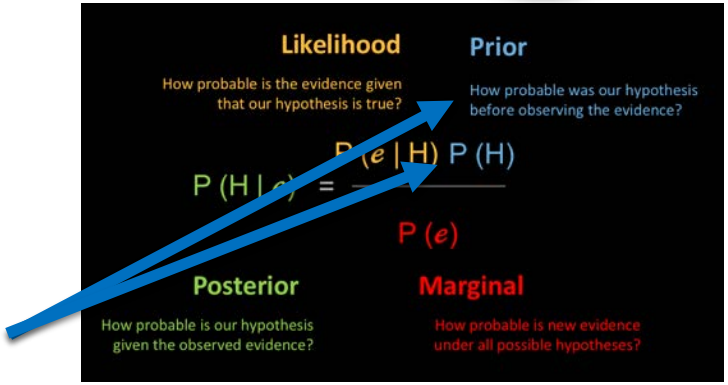
P (SPAM | “Viagra”)

History of Bayesian Measurement



$$P(\text{SPAM} \mid \text{“Viagra”}) = \frac{P(\text{“Viagra”}) \mid \text{SPAM})}{}$$

History of Bayesian Measurement



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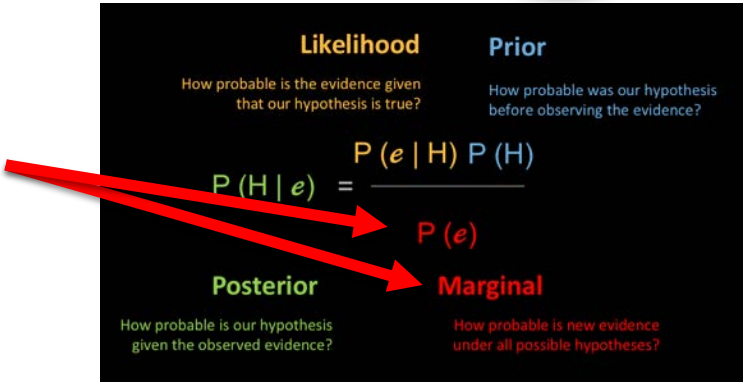
History of Bayesian Measurement



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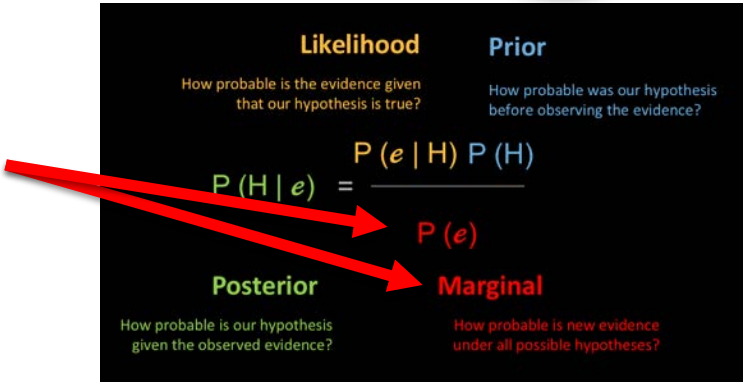
History of Bayesian Measurement



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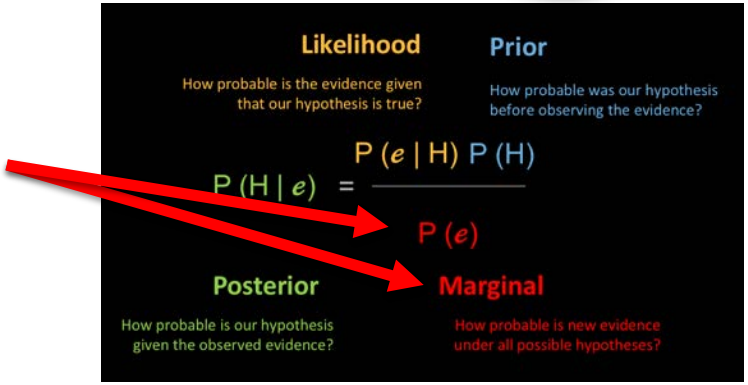

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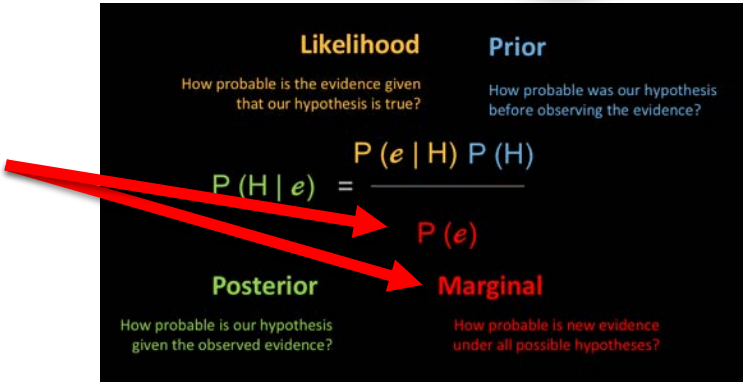

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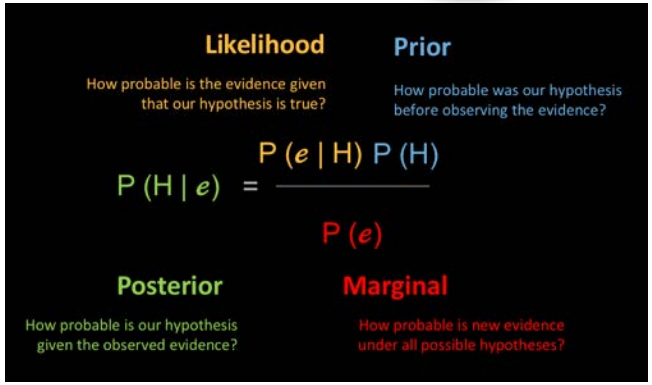
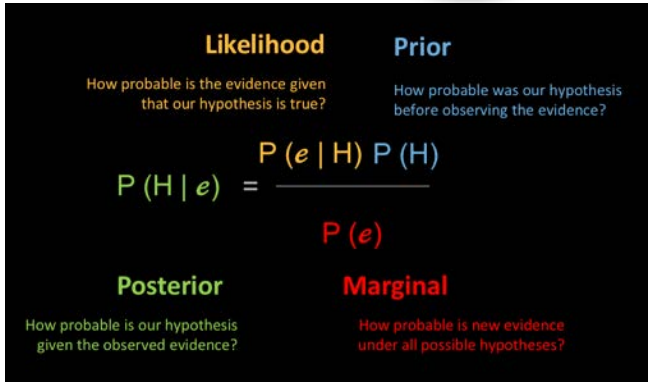


30%

$$P(\text{SPAM} \mid \text{“Viagra”}) = \frac{P(\text{“Viagra”} \mid \text{SPAM}) * P(\text{SPAM})}{P(\text{“Viagra”} \mid \text{SPAM}) * P(\text{SPAM}) + P(\text{“Viagra”} \mid P(\text{HAM}) * P(\text{HAM})}$$

History of Bayesian Measurement



87%

$$P(\text{SPAM} \mid \text{“Viagra”}) = \frac{P(\text{“Viagra”} \mid \text{SPAM}) * P(\text{SPAM})}{P(\text{“Viagra”} \mid \text{SPAM}) * P(\text{SPAM}) + P(\text{“Viagra”} \mid P(\text{HAM}) * P(\text{HAM})}$$

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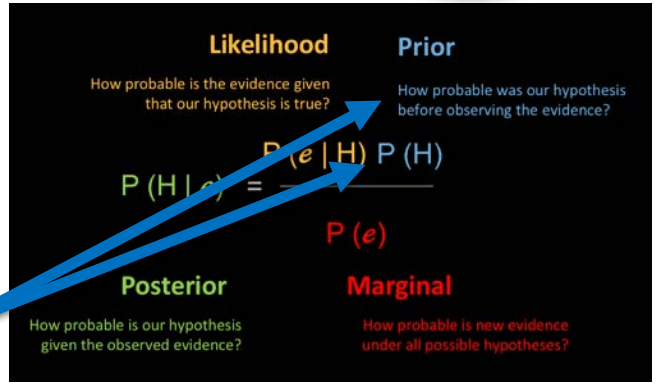
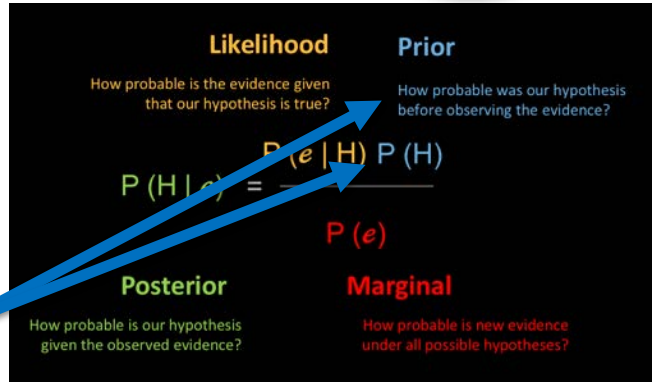


What is the Probability of a material breach in the next three years?

History of Bayesian Measurement

Upper Bound:

Lower Bound:



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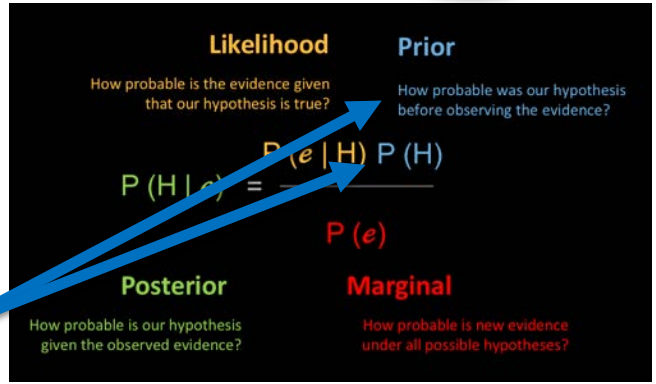

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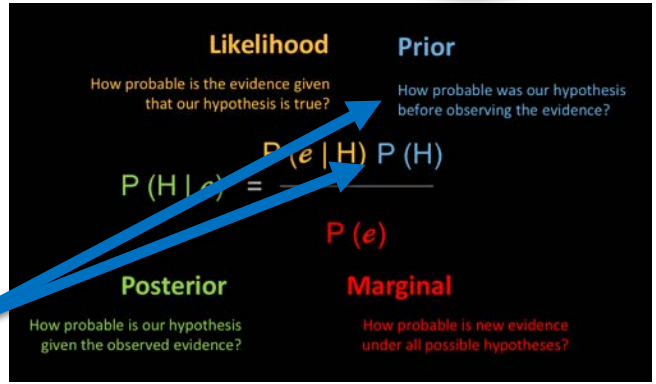

Confidence Interval

What is the Probability of a material breach in the next three years?

History of Bayesian Measurement

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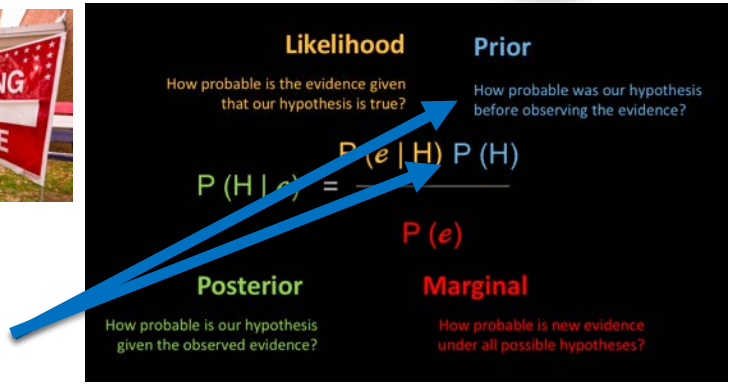


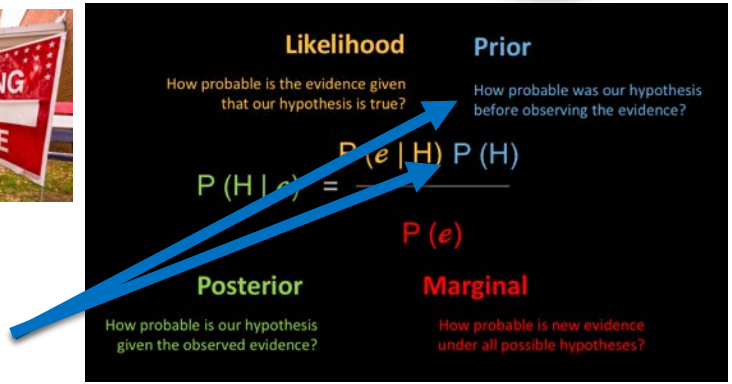
Confidence Interval

What is the Probability of a material breach in the next three years?

History of Bayesian Measurement

Upper Bound: 12%

Lower Bound:



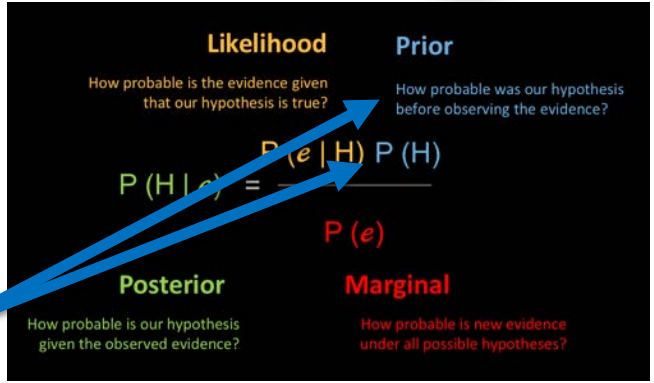
Confidence Interval

What is the Probability of a material breach in the next three years?

History of Bayesian Measurement

Upper Bound: 12%

Lower Bound: 2%



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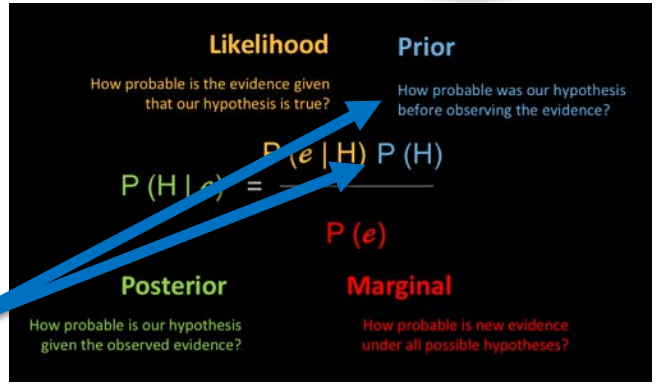
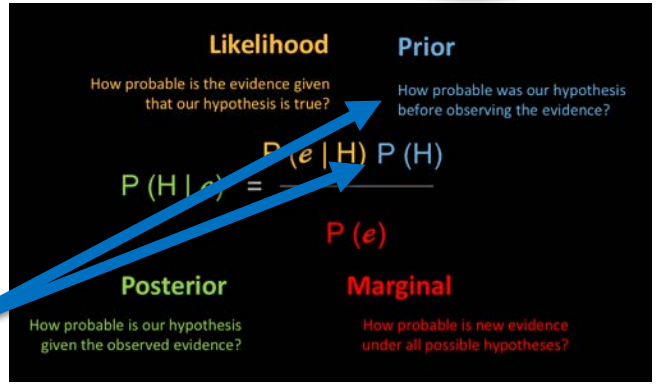


Material:

What is the Probability of a material breach in the next three years?

History of Bayesian Measurement



Material: > $1M

What is the Probability of a material breach in the next three years?

History of Bayesian Measurement

Upper Bound: 12%

Lower Bound: 2%

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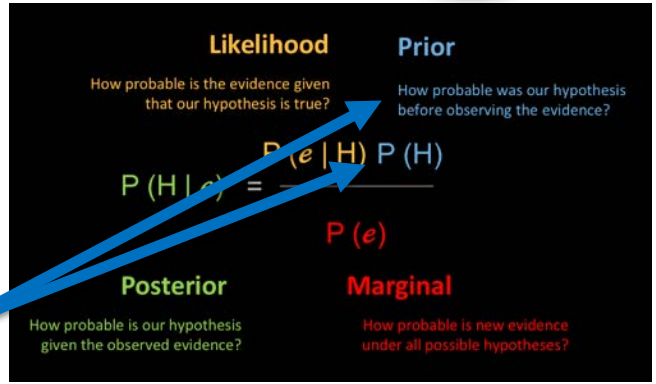

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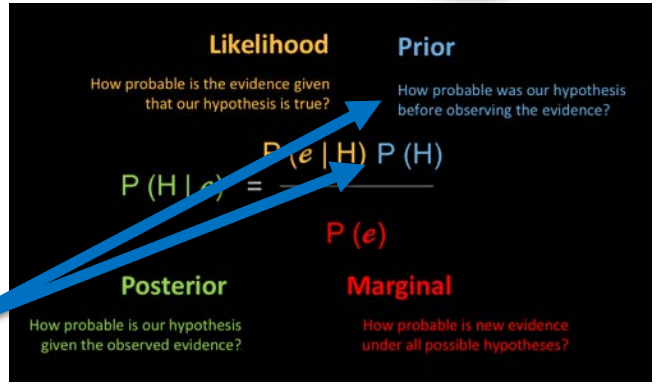

What is the Probability of a material breach in the next three years?

History of Bayesian Measurement

Source: University of York, 2013

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Frequentists Viewpoint

History of Bayesian Measurement

Source: University of York, 2013

Complex Problems

Frequentists Viewpoint

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IMAGE URL (FOR HOTLINKING/EMBEDDING): HTTPS://IMGS.XKCD.COM/COMICS/CONDITIONAL_RISK.PNG

History of Bayesian Measurement


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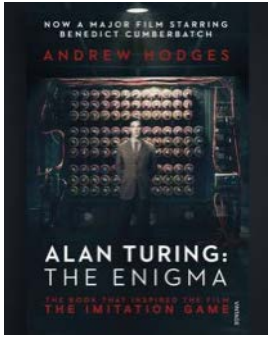

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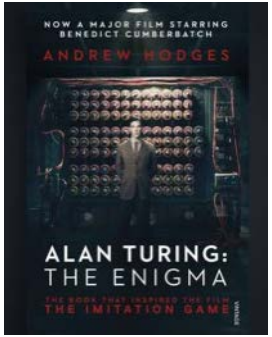

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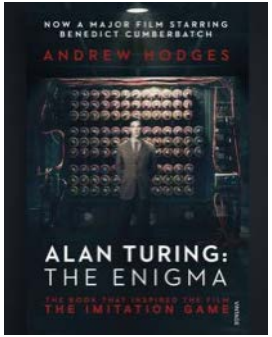
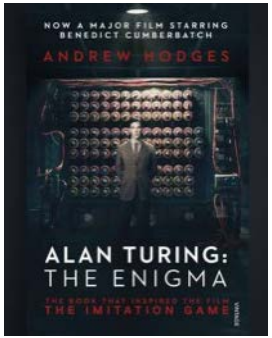


MONTE CARLO
MONACO

Frequentists Viewpoint

History of Bayesian Measurement



Frequentists Viewpoint

SUPERFORECASTER'S HITS AND MISSES:

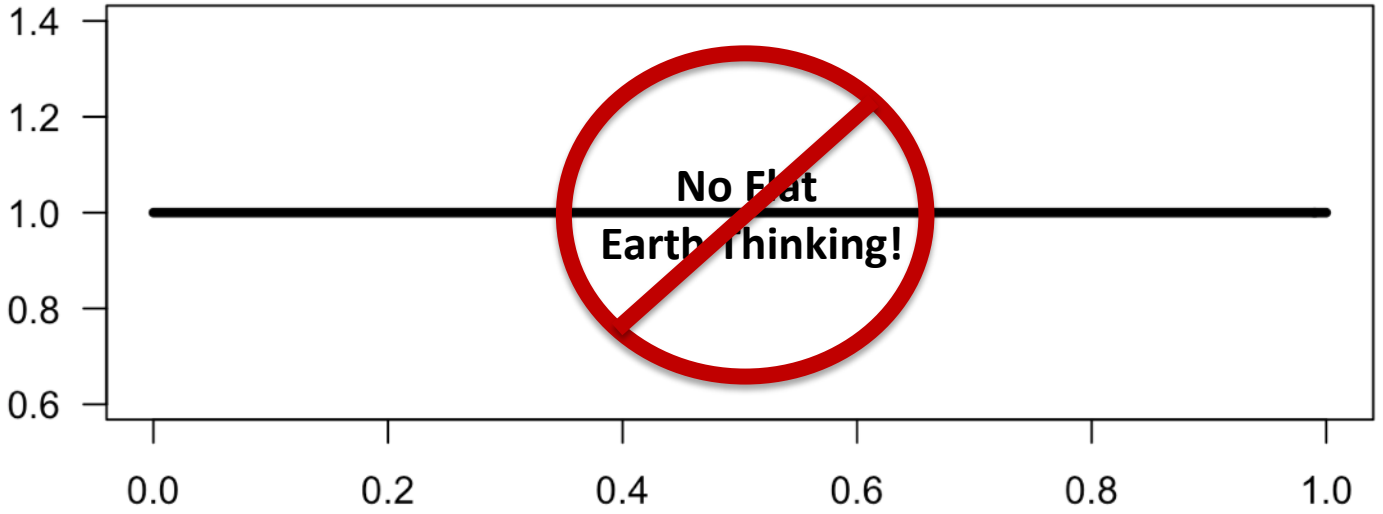
No Flat Earths

Super Forecaster's Methods: Hits & Misses
No Flat Earths!

Imagine a batter getting ready to swing at his first pro ball game. You know nothing about him, and you know absolutely nothing about baseball. You are in fact from a different planet and know little about our physics. How likely is he to hit his first pitch?

Super Forecaster's Methods : Hits & Misses
No Flat Earths!

You are completely uncertain! For you, all possibilities are equally plausible. From a measurement perspective, that idea in shape form looks like this:

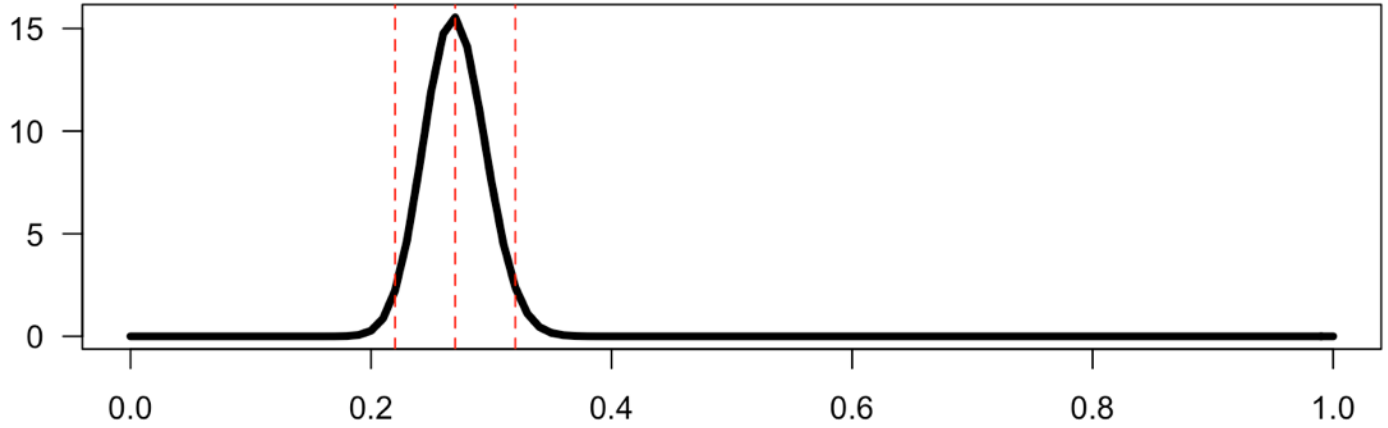


Super Forecaster's Methods : Hits & Misses Embracing Uncertainty

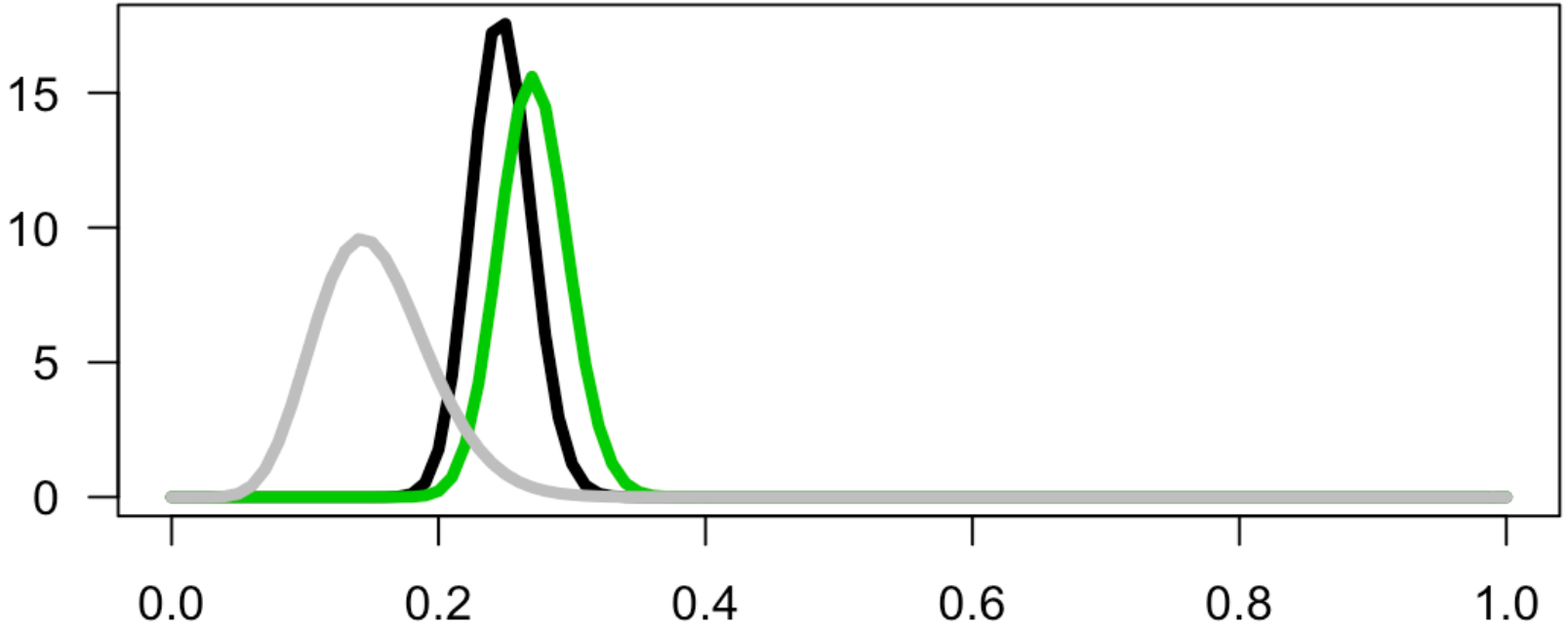
Now we turn to a serious fan. She knows all about the realities of physics on the planet earth, and in fact knows a lot about baseball. But, she knows nothing about this player. How likely is he to hit his first pitch?

Super Forecaster's Methods : Hits & Misses Embracing Uncertainty

You are uncertain, but not entirely uncertain: You know that the current batting average is .270. Being a good Bayesian you retain your uncertainty by building a shape around the "central tendency." That's because you know that the "true average" is fuzzy (uncertain). The fuzzy area is called the "credible interval." It's a function of how much data you have in terms of hits and misses. BTW: We used 81 hits and 219 misses to make our .270.



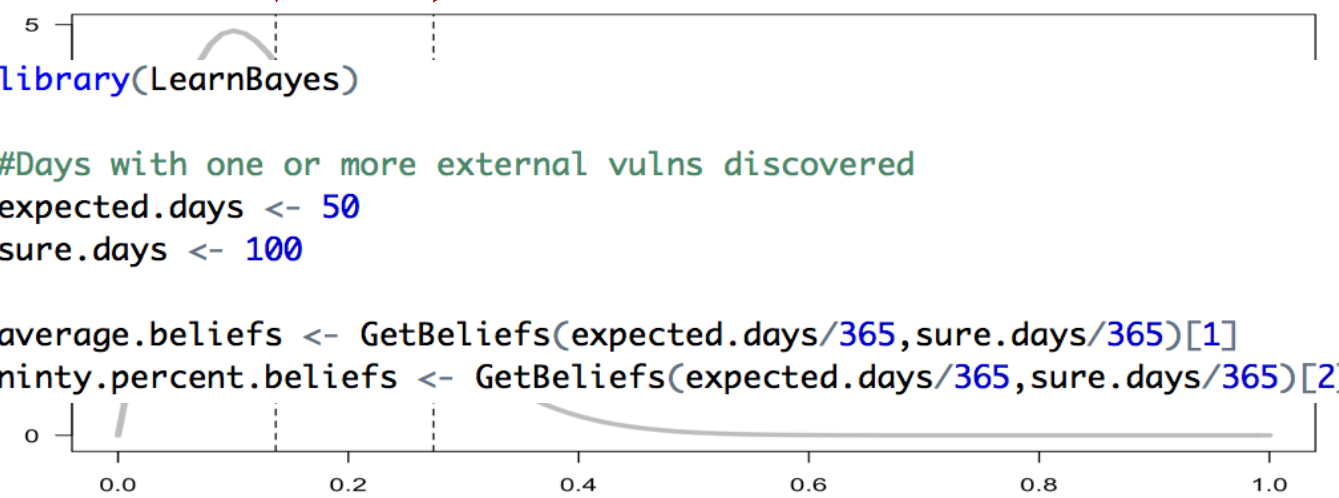
Super Forecaster's Methods : Hits & Misses
Updating Beliefs With Data



Super Forecaster's Methods : Hits & Misses Encoding Beliefs On Bug Bounty

How many days a year, on average, do you believe bug bounty discovers one or more external vulnerabilities, and what's your 90% boundary?

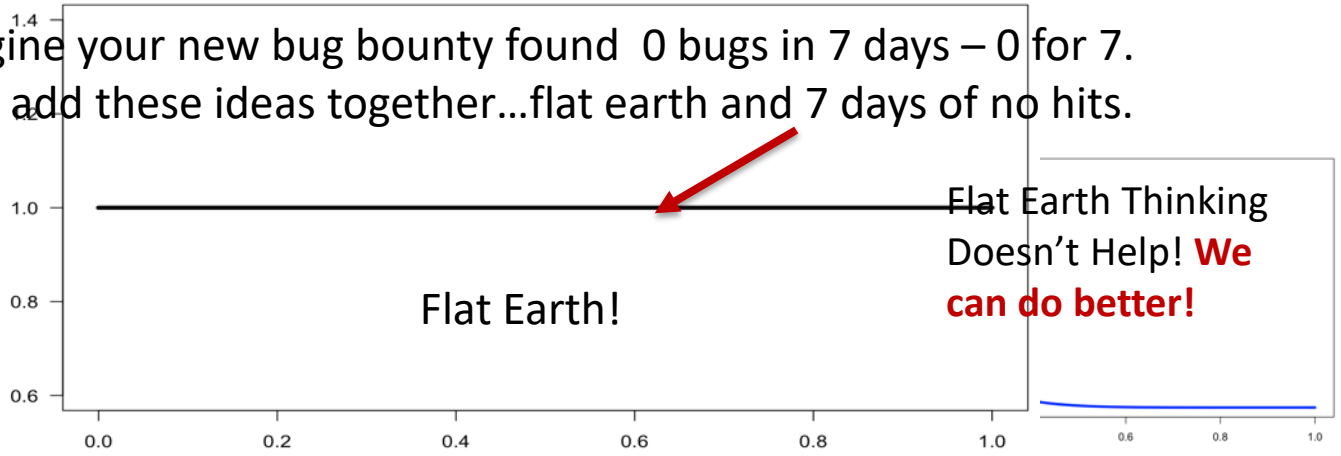

```
library(LearnBayes)

#Days with one or more external vulns discovered
expected.days <- 50
sure.days <- 100

average.beliefs <- GetBeliefs(expected.days/365,sure.days/365)[1]
ninty.percent.beliefs <- GetBeliefs(expected.days/365,sure.days/365)[2]
```



Super Forecaster's Methods : Hits & Misses Encoding Beliefs On Bug Bounty

What does your graph looks like if you guess you average 182 vulnerability days *a year, and* your 90% limit is 328 *(i.e. 90% of 365)*?

Imagine your new bug bounty found 0 bugs in 7 days – 0 for 7.
Let's add these ideas together…flat earth and 7 days of no hits.

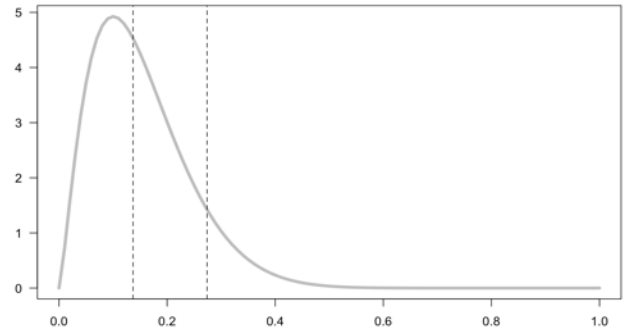


Super Forecaster's Methods : Hits & Misses Encoding Beliefs On Bug Bounty

```
average.beliefs <- GetBeliefs(expected.days/365,sure.days/365)[1]
ninty.percent.beliefs <- GetBeliefs(expected.days/365,sure.days/365)[2]

#Plot our beliefs about reality + one week
total <- 7
hits <- 0
misses <- total - hits
curve( dbeta( x, average.beliefs + hits, ninty.percent.beliefs + misses),
       from = 0, to = 1,
       las = 1, lwd = 4, col = 2)
```

Expected = 50 Days
Sure = 100 Days

Let's add you prior beliefs of an average of 50 vulnerability days with a likely maximum of 100 days (i.e. 90% boundary) to 1 weeks worth of actual bug bounty data.



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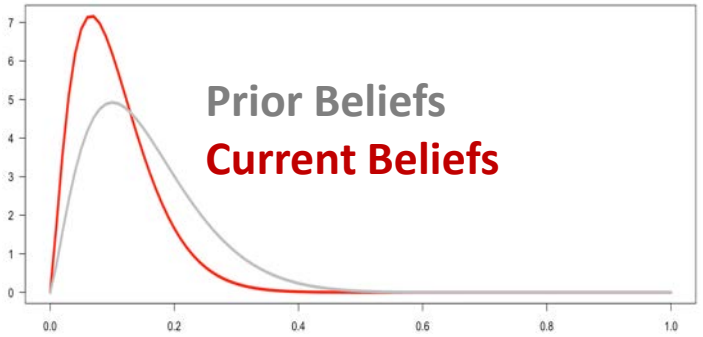
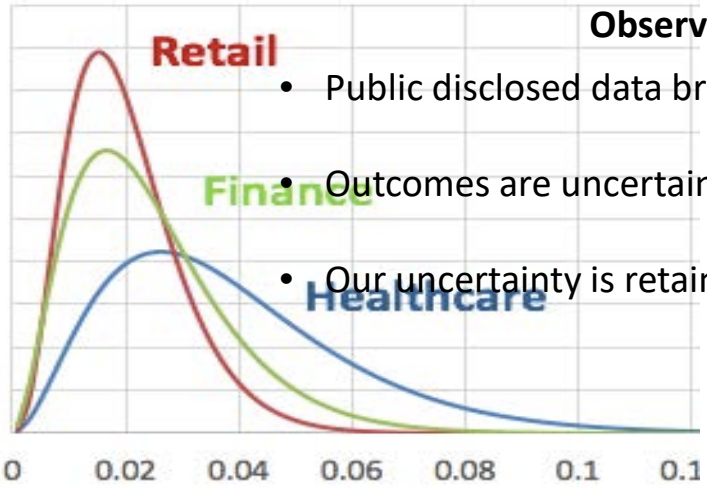


Super Forecaster's Methods : Hits & Misses
What Is My Probability Of Breach?

Fortune 500 Healthcare
- Yearly Avg Rate: 3.85%
- 3 Year Avg Rate: 11%

Fortune 500 Finance
- Yearly Avg Rate: 2.46%
- 3 Year Avg Rate: 7.2%

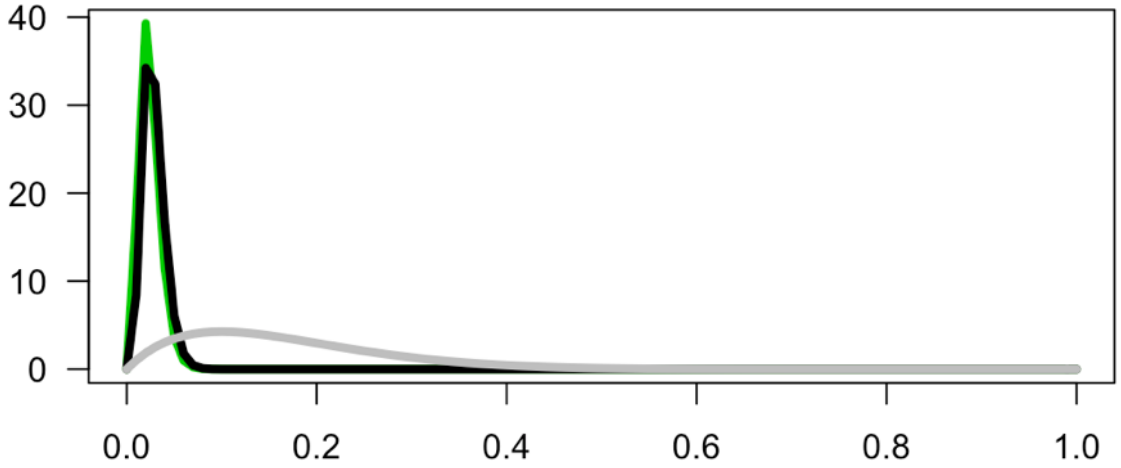
Fortune 500 Retail
- Yearly Avg Rate: 2.02%
- 3 Year Avg Rate: 5.9%



Observations
- Public disclosed data breaches from 2014-2015
- Outcomes are uncertain, but update our beliefs
- Our uncertainty is retained as opposed to obscured!

Super Forecaster's Methods : Hits & Misses
Updating Beliefs With Data

You're a fortune 10,000 retailer, what's your likelihood of breach? You had one breach in the last 10 years. We're going to combine the retail data from the last page with this data to get an answer.



11%

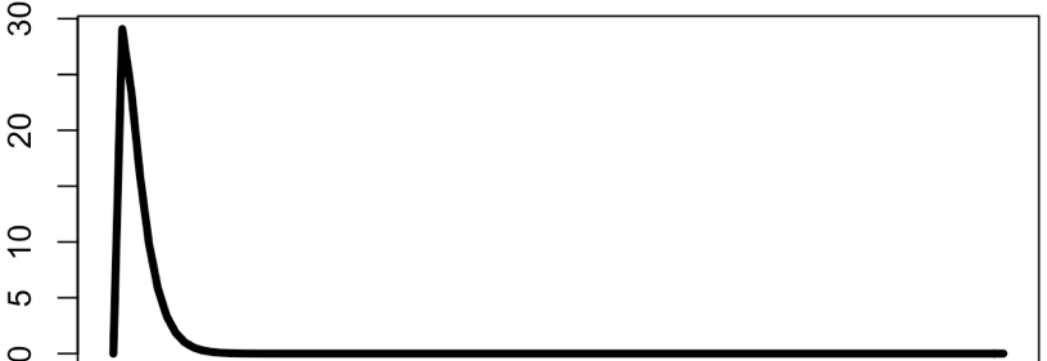
Super Forecaster's Methods : Simulations
Monte Carlo Explained….in code

So, how do we (faux scientists) get numbers like 11% or other such "forecasts"?

We simulate, fake it, make it up, we gamble…..we use Monte Carlo Simulations!

Beliefs <- GetBeliefs(.02 , .05)
Simulations <- 10000
Probabilities <-
Years <- 5
Hits <- r
ProbOr

```
probs
 [1] 0
 [7] 0
> hits
  [1]
 [44]
 [87]
[130]
[173]
[216]
```




```
7250488
0330673
      .7
0 0 0.9
0 0 0.9
0 0 0.8
0 0 0.4
1 0 0
0 0 0
```

WHAT TO PRESENT TO THE BOARD

What To Present to the Board

Impact →	1	2	3	4	5
Probability ↓	Negligible	Minor	Moderate	Significant	Severe
(81-100)%	Low Risk	Moderate Risk	High Risk	Extreme Risk	Extreme Risk
(61-80)%	Minimum Risk	Low Risk	Moderate Risk	High Risk	Extreme Risk
(41-60)%	Minimum Risk	Low Risk	Moderate Risk	High Risk	High Risk
(21-40)%	Minimum Risk	Low Risk	Low Risk	Moderate Risk	High Risk
(1-20)%	Minimum Risk	Minimum Risk	Low Risk	Moderate Risk	High Risk

What is the likelihood that a certain cyber event will happen?

What To Present to the Board

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What is the likelihood that a certain cyber event will happen?

Heat Maps are Poor Vehicles for Conveying Risk

2005: Surveyed NATO Officers believe that Highly Likely could mean anywhere between 40% and 100% likely. - Heuer

2006: Studies find that experts choose "1" more often in a scale of say "1" to "10" regardless of the subject matter the number is supposed to represent. - Rottenstreich

2008: Ordinal scales inadvertently create range compression; a kind of extreme rounding error. - Cox

2009: Surveyed students and faculty believe that “Very Likely” could mean anywhere between 43% and 99% likely. - Budescu

2016: Cybersecurity scoring systems like OWASP (Open Web Access Security Project), CVSS (Common Vulnerability Scoring System), CWSS (Common Weakness Scoring System), and the CCSS (Common Configuration Scoring System) perform improper math on non-mathematical objects to aggregate a risk score. - Hubbard/Seirsen

2016: The idea of “Risk Tolerance” is not presented. Just because risk officers rate an event as highly likely does not mean that leadership is not willing to accept that risk. - Hubbard/Seirsen

2016: Heat maps convey no information about when the event might happen (next year, next three years, next decade.) - Hubbard/Seirsen

2016: Some risk officers rate events as more likely just because they could be more impactful. - Hubbard/Seirsen

2016: When percentages were explicitly defined, highly likely is between 90% and 99% for example, survey participants violated the rules over half the time. - Hubbard/Seirsen

2016: Most surveyed experts using ordinal scales from "1" to "5" chose the values of "3" or "4" reducing the 5X5 matrix to a 2X2 matrix. - Hubbard/Seirsen

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“Cyber”

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What is the likelihood that a certain cyber event will happen?

NO

"Cyber"

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NO

"Cyber"

What To Present to the Board

What To Present to the Board

What is the likelihood that a certain cyber event will happen?

What To Present to the Board

Think Differently

What is the Probability of one or more material breaches in the next three years?

~~What is the likelihood that a certain cyber event will happen?~~

What To Present to the Board

~~What is the likelihood that a certain cyber event will happen?~~

What is the Probability of one or more material breaches in the next three years?

I am 90% sure that within the next three years, the probability of a material impact to the company due to a computer breach is between 2% and 12%.

What To Present to the Board

~~What is the **likelihood** that a certain cyber event will happen?~~

What is the **Probability** of a material breach in the next three years?

I am 90% sure that within the next three years, the **probability** of a material impact to the company due to a computer breach is between 2% and 12%.

What To Present to the Board

~~What is the likelihood that a certain cyber event will happen?~~

What is the Probability of a material breach **in the next three years**?

I am 90% sure that within the **next three years**, the probability of a material impact to the company due to a computer breach is between 2% and 12%.

What To Present to the Board

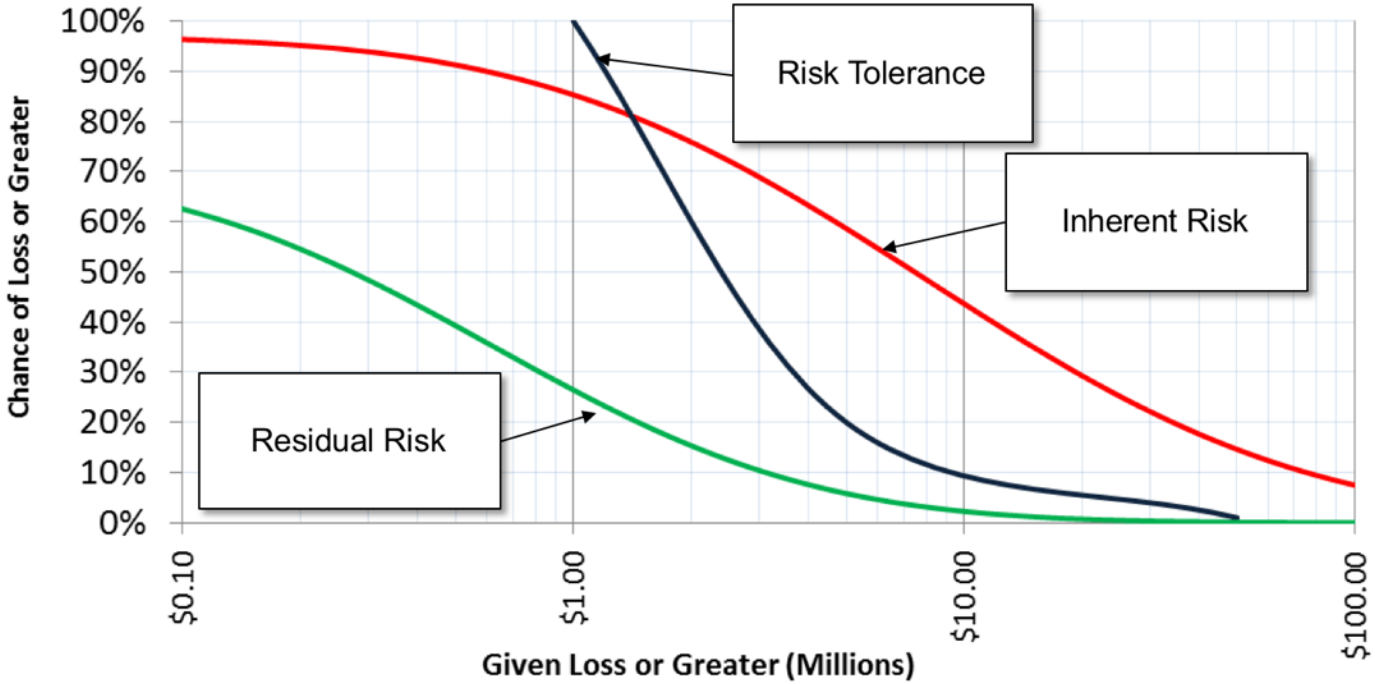
What is the Probability of a material breach in the next three years?

~~What is the likelihood that a certain cyber event will happen?~~

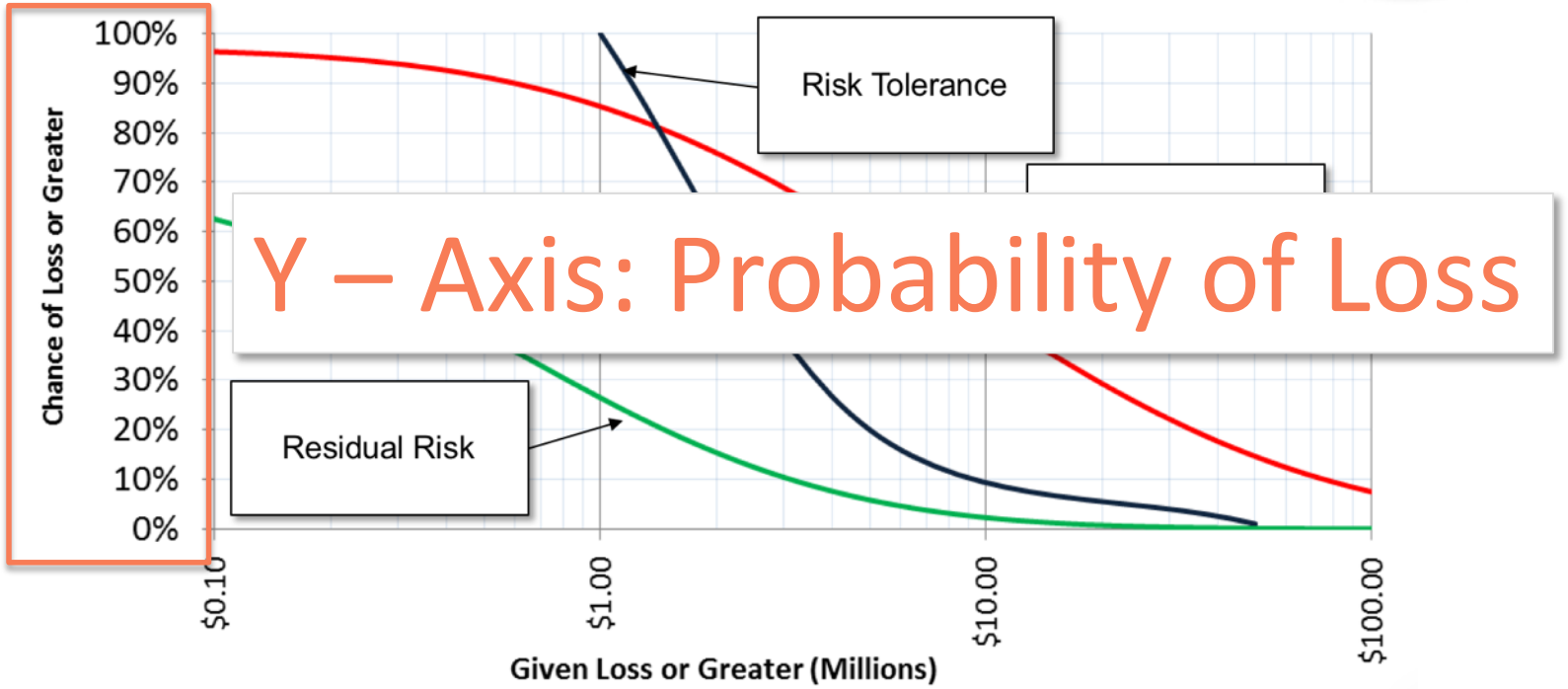
I am 90% sure that within the next three years, the probability of a material impact to the company due to a computer breach is between 2% and 12%.

LOSS EXCEEDANCE CURVES

Loss Exceedance Curves

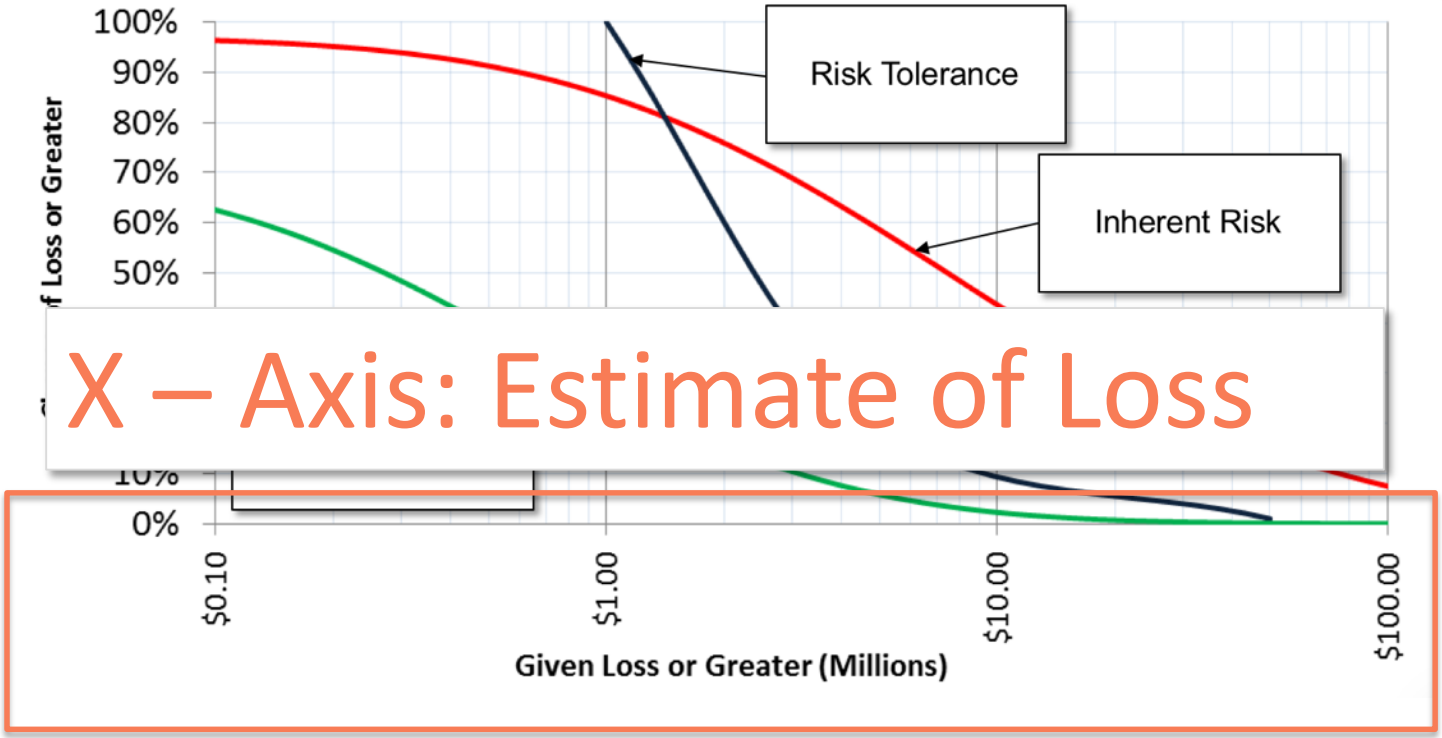


Loss Exceedance Curves



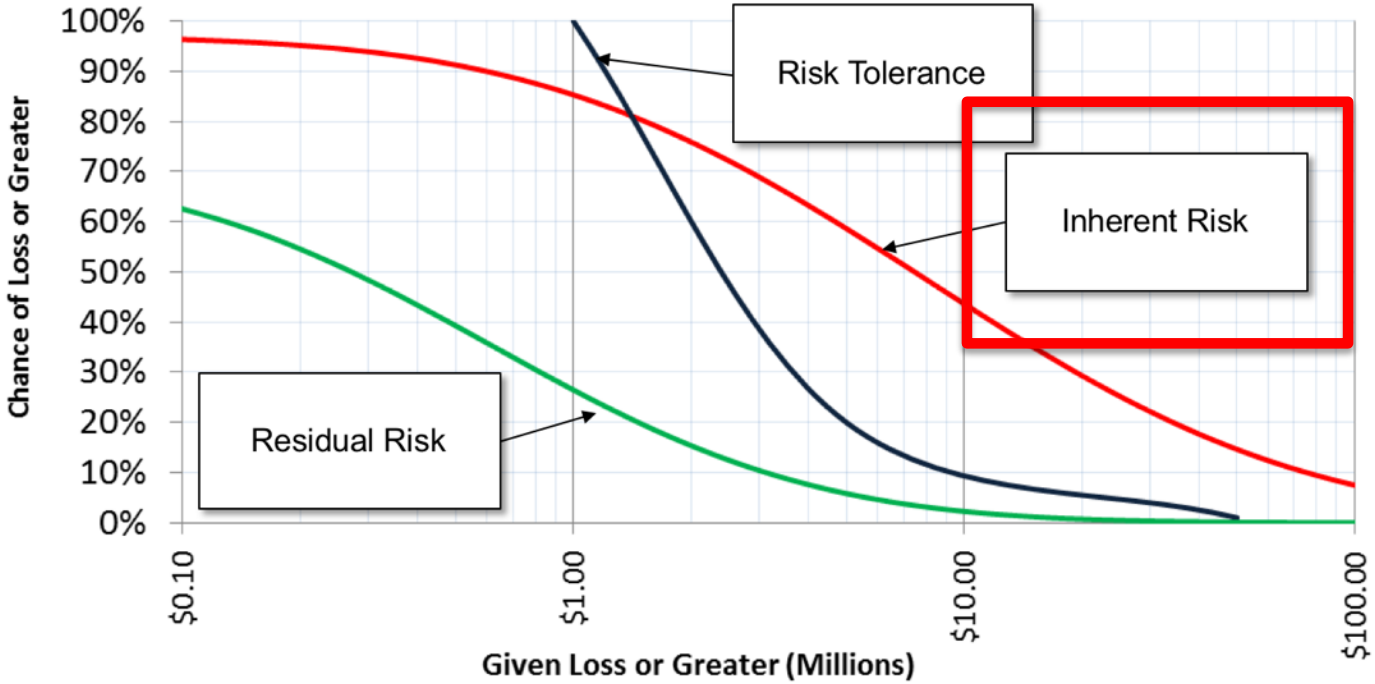
Y – Axis: Probability of Loss

Loss Exceedance Curves

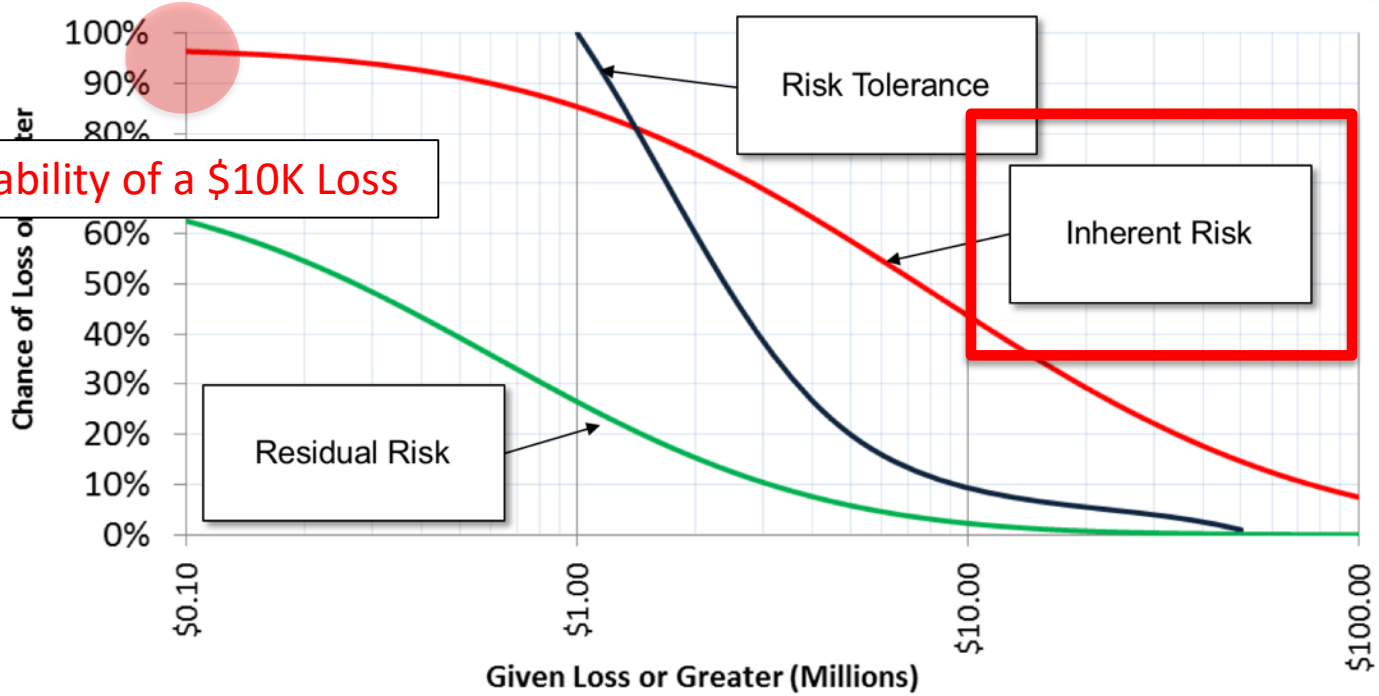


X – Axis: Estimate of Loss

Loss Exceedance Curves



Loss Exceedance Curves



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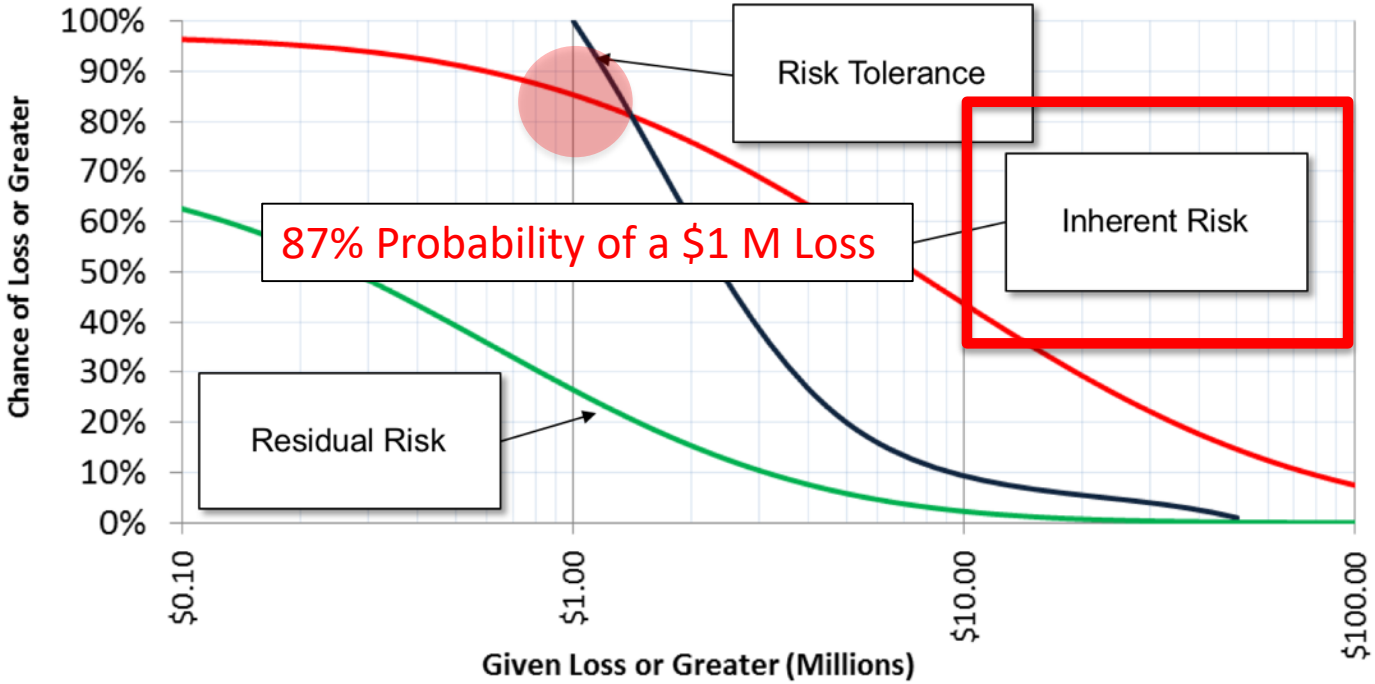

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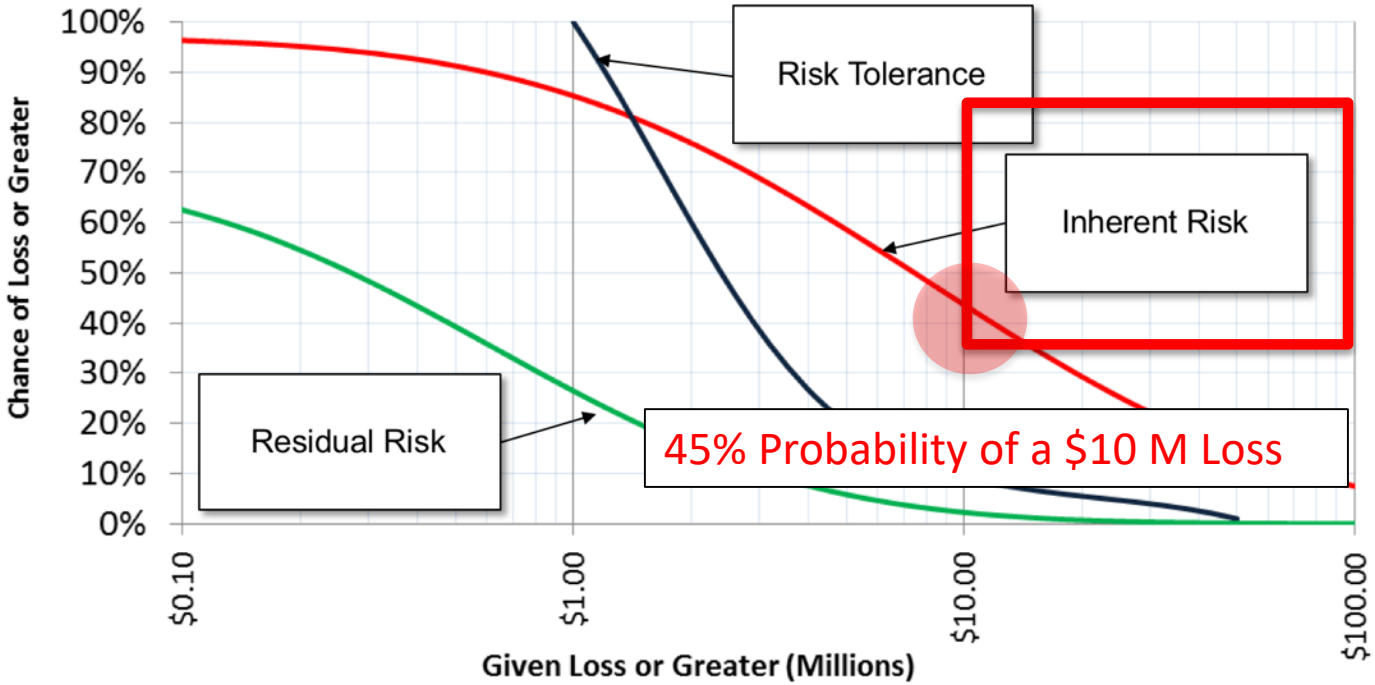

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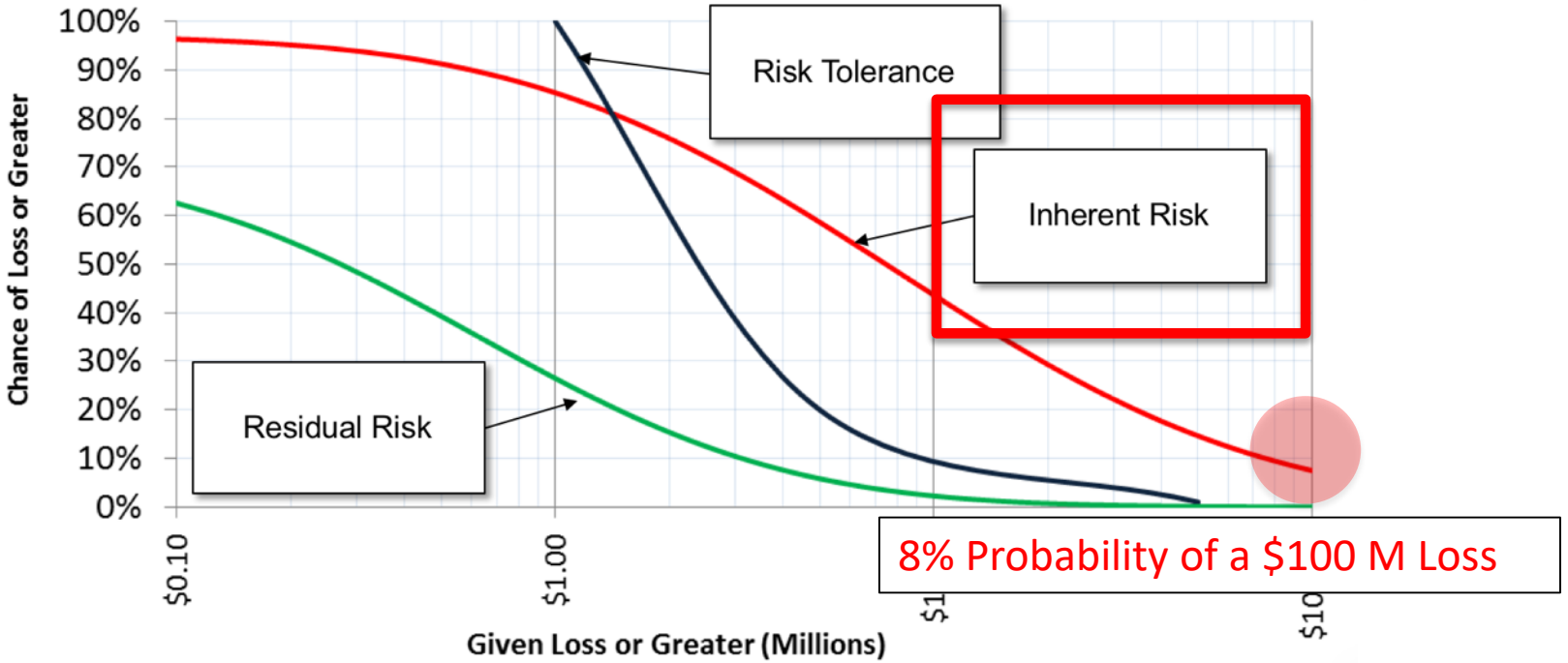

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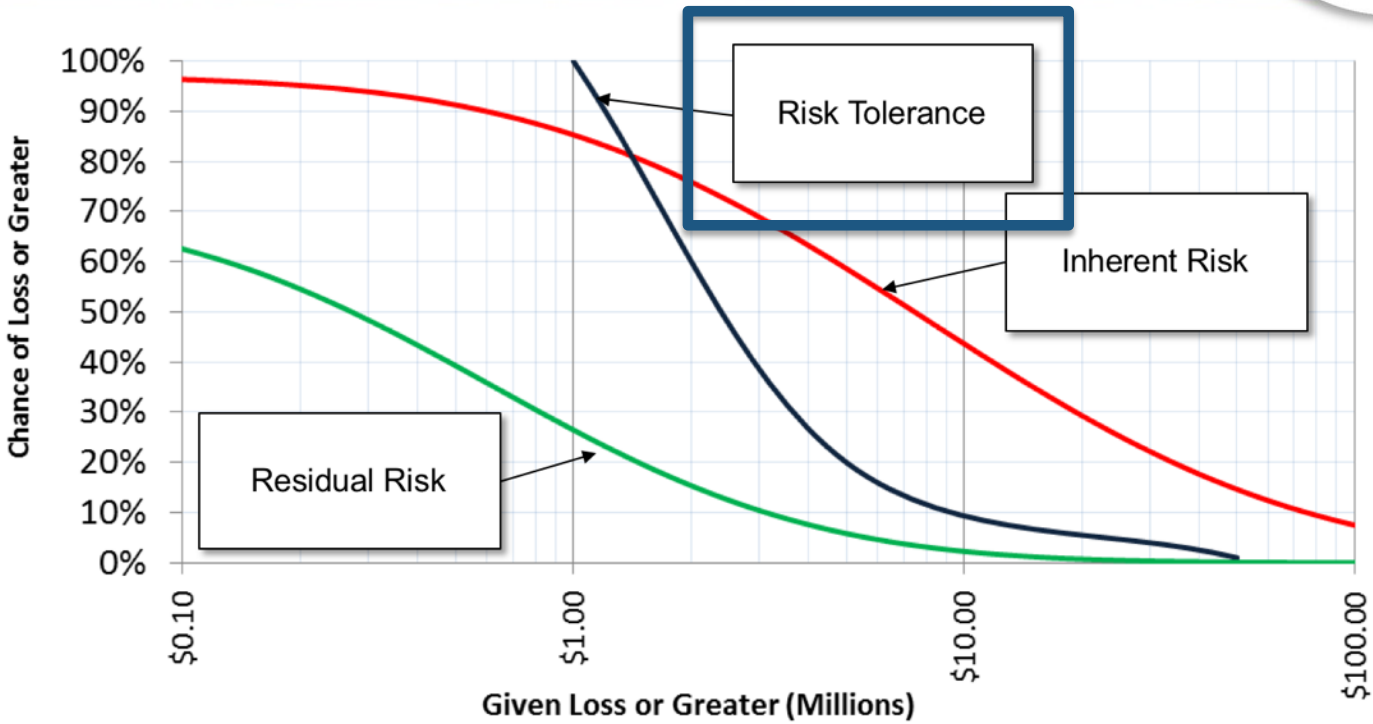

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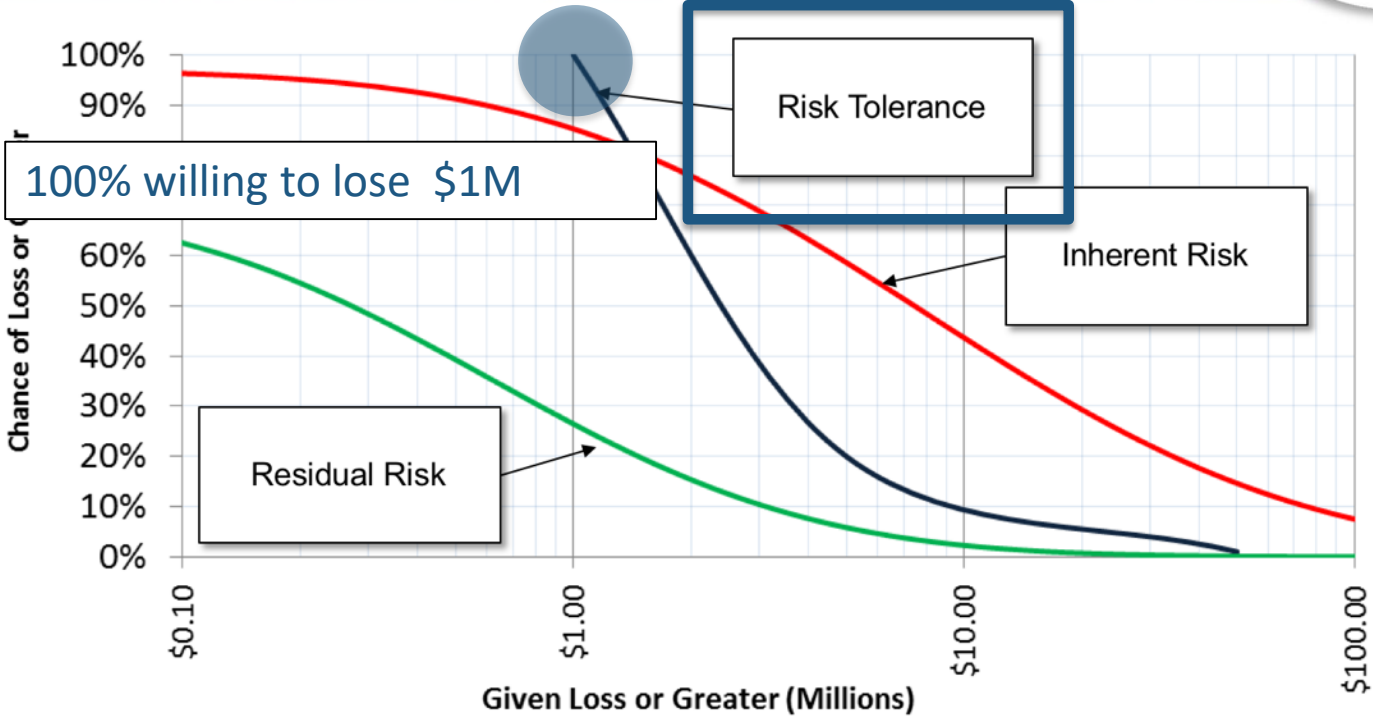

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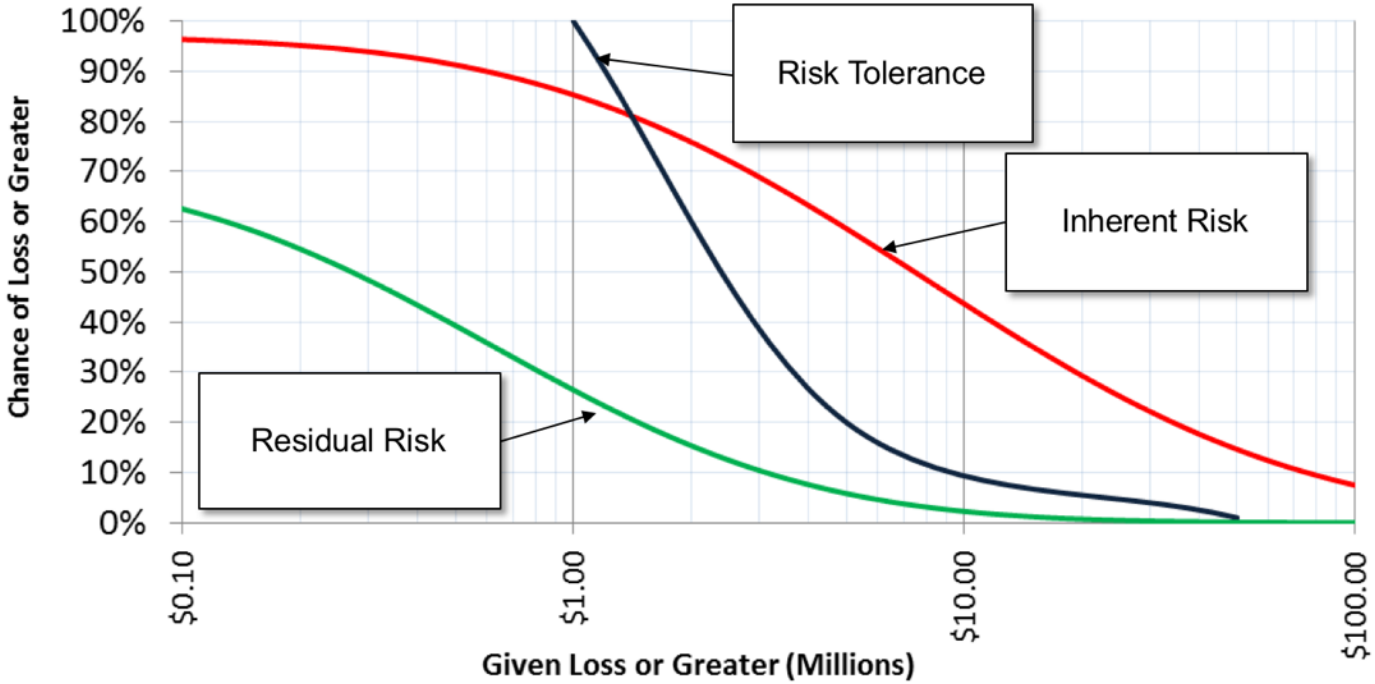

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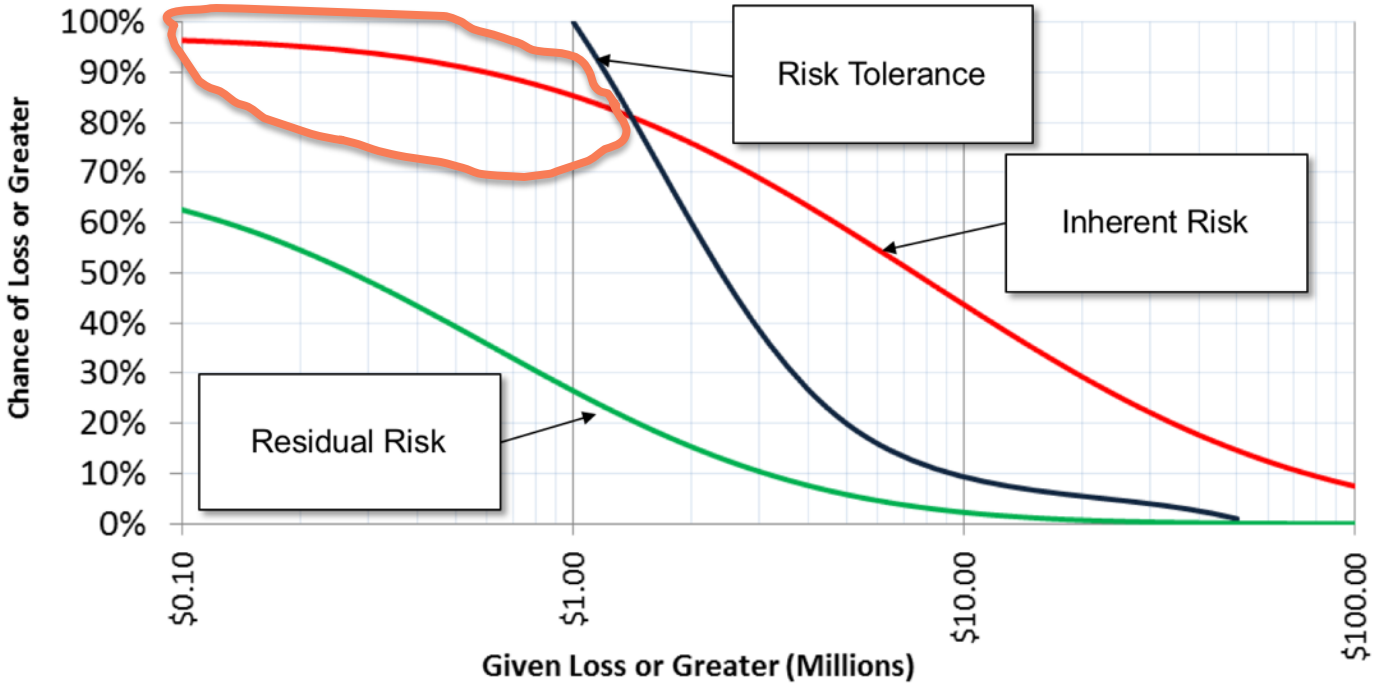

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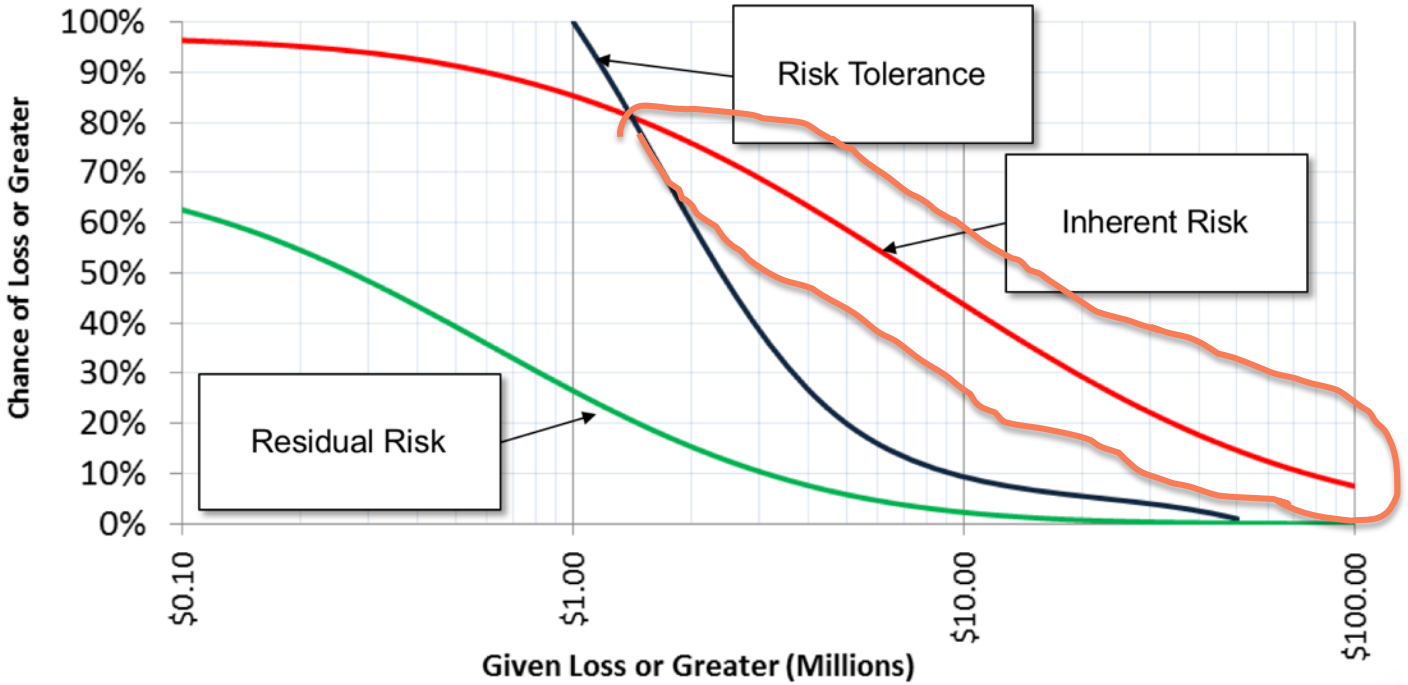

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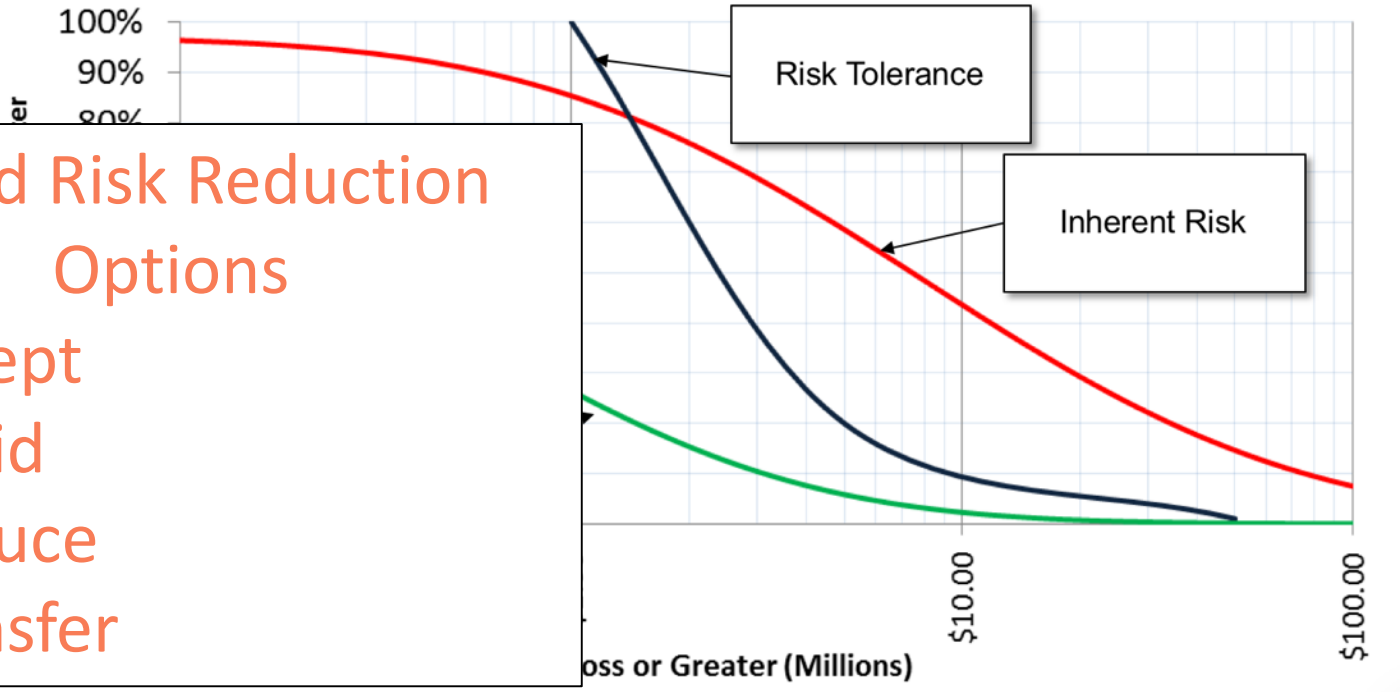


Board Risk Reduction Options

- Accept
- Avoid
- Reduce
- Transfer

PREPARING FOR THE BOARD

Step by Step

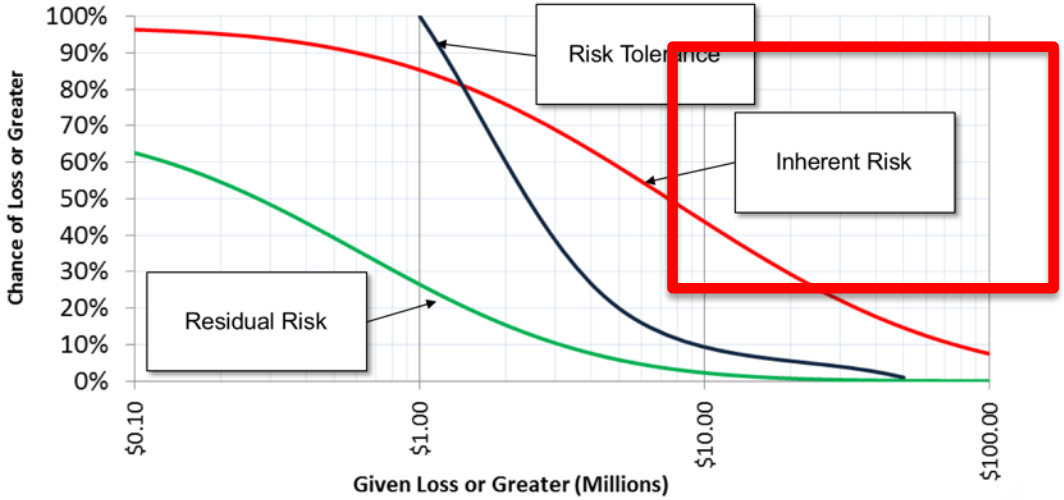
Preparing for the Board Step by Step

Preparing for the Board Step by Step

1: Determine the cost for all deployed security defenses: **people**, **process** and **technology**.

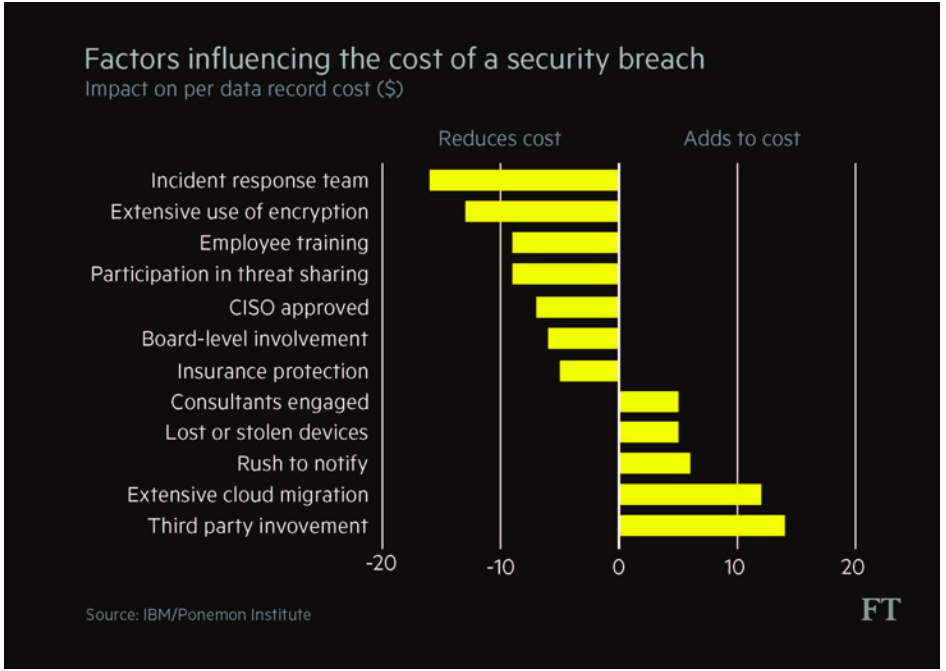
Preparing for the Board Step by Step

2: Build the loss exceedance curve of the current deployed defenses (Inherent Risk).



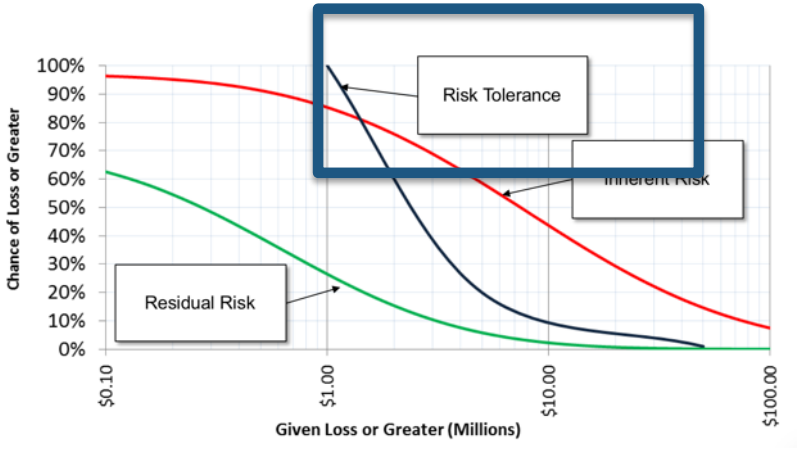
Preparing for the Board Step by Step

3: Calculate the cost for all incident response.



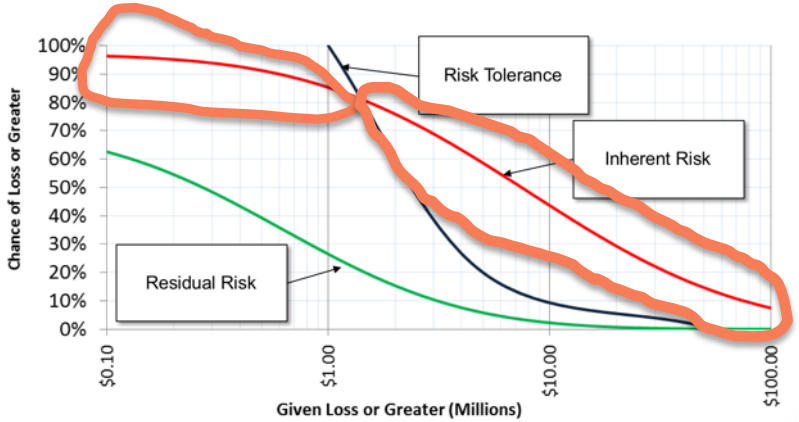
Preparing for the Board Step by Step

4: Build the loss exceedance curve of the leadership's risk appetite (Risk Tolerance).



Preparing for the Board Step by Step

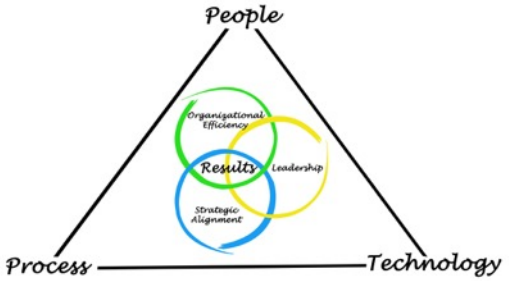
5: Overlay the two loss exceedance curves: Inherent vs risk tolerance.



Preparing for the Board Step by Step

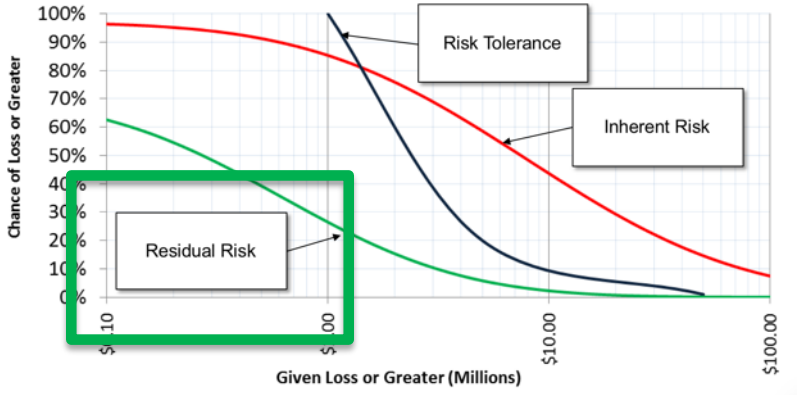
6: If the risk tolerance is larger than the inherent risk, do nothing.

Preparing for the Board Step by Step



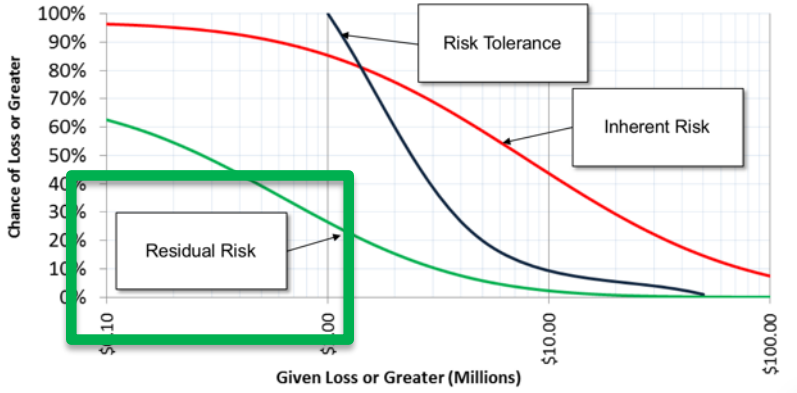
7: If the risk tolerance is smaller than the inherent risk, reduce the risk.

Preparing for the Board Step by Step



8: Build a new loss exceedance curve that includes the additional security controls.

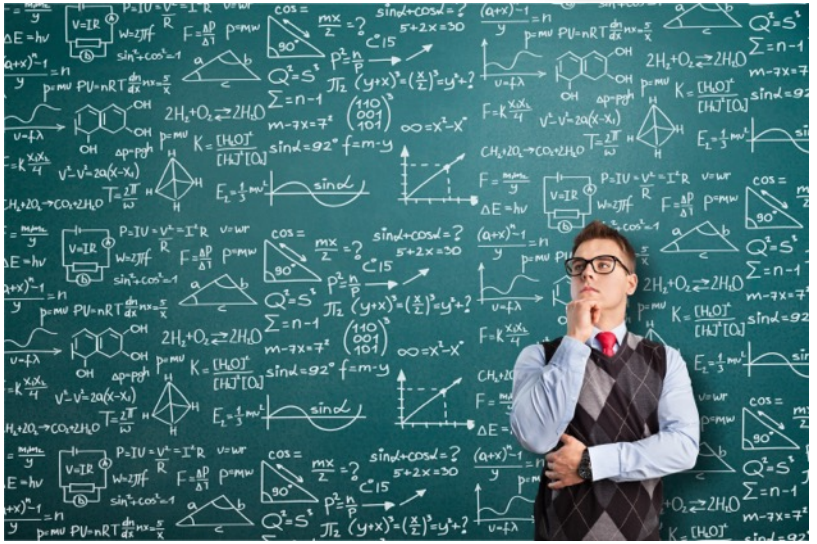
Preparing for the Board Step by Step



9: Calculate the cost of the risk reduction measures.

Preparing for the Board Step by Step

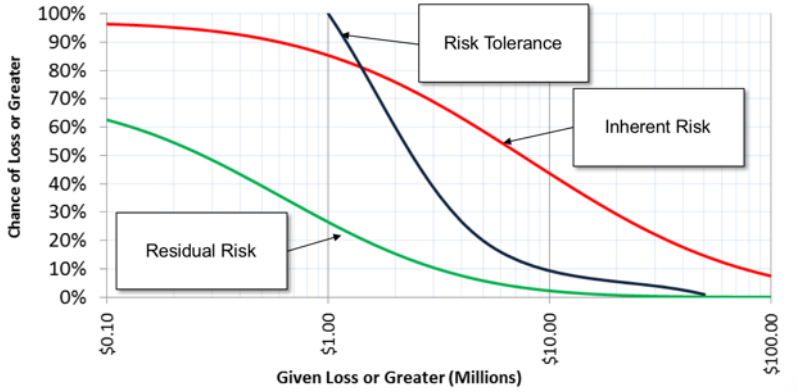
3: Calculate the cost for all incident response.



9: Calculate the cost of the risk reduction measures.

10: If the costs #9 > costs #3, think of something else to do or maybe accept the risk.

Preparing for the Board Step by Step



11: If you accept the risk, adjust the risk tolerance loss exceedance curve.

Preparing for the Board Step by Step

12: GOTO #1 and start over.

We Talked about ...

We Talked about ...

Why ....

We Talked about ...

Why ....

The Superforecaster's Point of View

We Talked about ...

Why ....

The Superforecaster's Point of View

History of Bayes

We Talked about ...

Why ....

The Superforecaster's Point of View

History of Bayes

Hits and Misses

We Talked about ...

Why ....

The Superforecaster's Point of View

History of Bayes

Hits and Misses

What to Present to the Board

Take Aways

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- There exists a large body of research that says that Qualitative Risk Matrices are inefficient tools to convey risk.

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- Risk is a measure of uncertainty where if you bet wrong could lead to catastrophe.

Take Aways

- There exists a large body of research that says that Qualitative Risk Matrices are inefficient tools to convey risk.
- Risk is a measure of uncertainty where if you bet wrong could lead to catastrophe.
- Bayes Algorithm and Monte Carlo simulations helps us estimate uncertainty for difficult problems.

Take Aways

- There exists a large body of research that says that Qualitative Risk Matrices are inefficient tools to convey risk.
- Risk is a measure of uncertainty where if you bet wrong could lead to catastrophe.
- Bayes Algorithm and Monte Carlo simulations helps us estimate uncertainty for difficult problems.
- Bayesian methods are the future of the network defender community.

Homework

Homework

Next Week

Download the White Paper, Slides: https://goo.gl/cgjqgE

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Super Forecasting: Even You Can Perform High Precision Risk Assessments

Next Quarter

Build Your own model in Excel and start playing with Bayesian Concepts.

Homework

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This Year

How to Measure Anything in Cybersecurity

Measuring and Managing Information Risk: A FAIR Approach

Superforecasting: The Art and Science of Prediction

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Draft White Paper / Slides: https://goo.gl/cgjqgE

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