



GRADING QUANTITATIVE RISK ASSESSMENTS FOR MULTIPLE-STAGE OPERATIONS

International Explosives Safety Summit and Exposition 2025

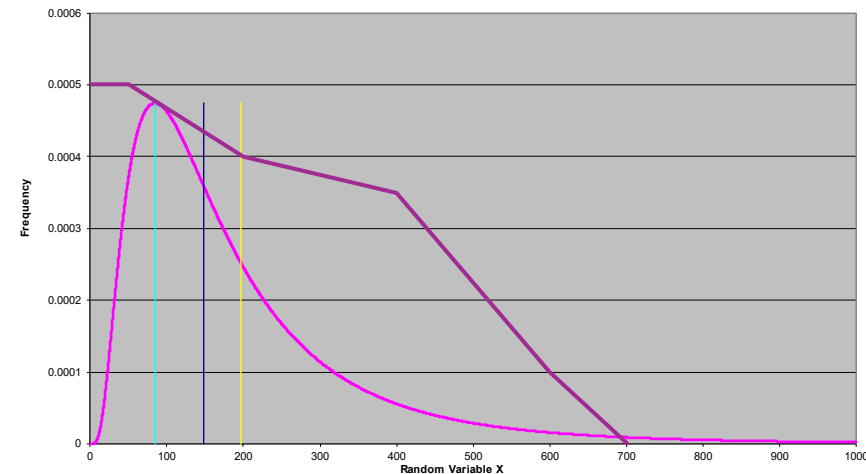
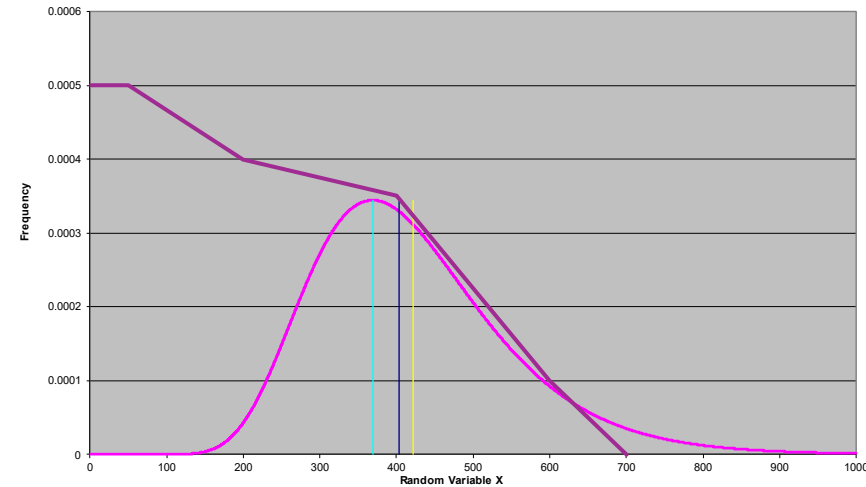
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OUTLINE

- Background
- Basic concepts
- Grading risk
- Multi-stage activities
- Grading risk for multi-stage activities
- Practical application
- Summary
- Questions



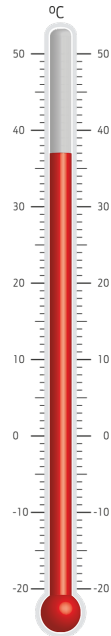
BACKGROUND

- Project
 - ▶ The effort that was considering this topic ended before the subject was studied, either in general or for the particular operation in question
 - ▶ Decision made to publish a presentation anyway, to begin to socialize the concepts involved
 - ▶ No recommendations are made herein -- only presenting discussion points
- Quantitative Risk Assessment (QRA) for Explosives Safety
 - ▶ More information required to generate risk results (as compared to determining QD compliance)
 - ▶ More information generated by QRA – have to decide what to do with the results
 - Single Phase Operation – need some sort of criteria set to grade results
 - Multiphase Operation??

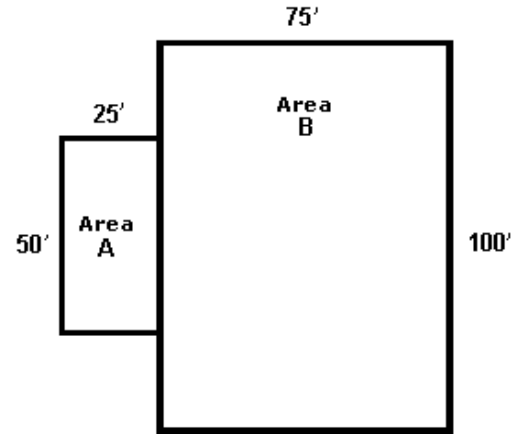
BASIC CONCEPTS: DIMENSIONS

- 1D
- 2D
- 3D
 - ▶ True 3D
 - ▶ “Time River” of 2D
- Contours
 - ▶ 2D + Contours = 3D
 - ▶ 3D + Contours = 4D

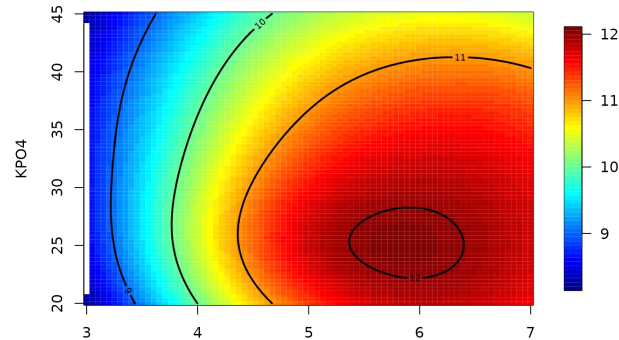
1D



2D



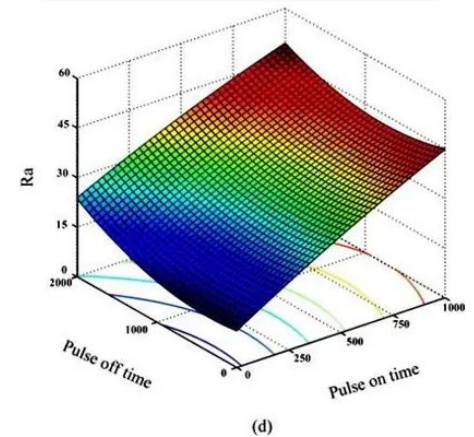
2D with Contour



3D



3D with Contour



BASIC CONCEPTS: GRADING N DIMENSIONS WITH LESS THAN N

- Grading 2D (i.e., an area) with a parameter
 - ▶ Area is single point measurement of 2D
 - ▶ Knowing the area does not provide length and width
- Grading 3D with 2D
 - ▶ Cross-sections
 - ▶ Using footprint (area) to represent volume

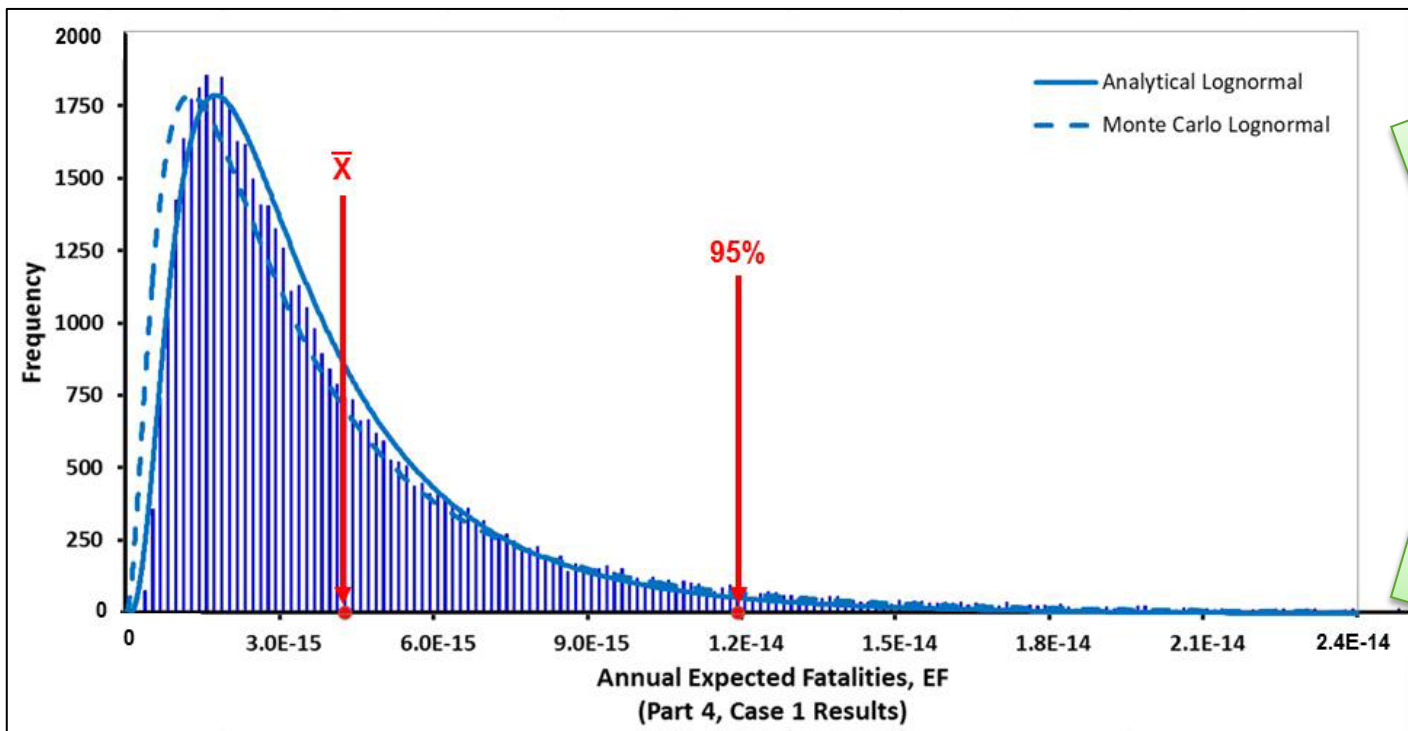
- Grading 3D with a parameter?

Linear Dimension
 $\leq 158 \text{ cm} / 62 \text{ in}$
 =
Length + Width + Height
 $\leq 158 \text{ cm} / 62 \text{ in}$



GRADING RISK: EXAMPLES

- TP-14/IMESA[®]FR[®]
- A (2D) distribution graded by one or more (1D) parameters



Grading

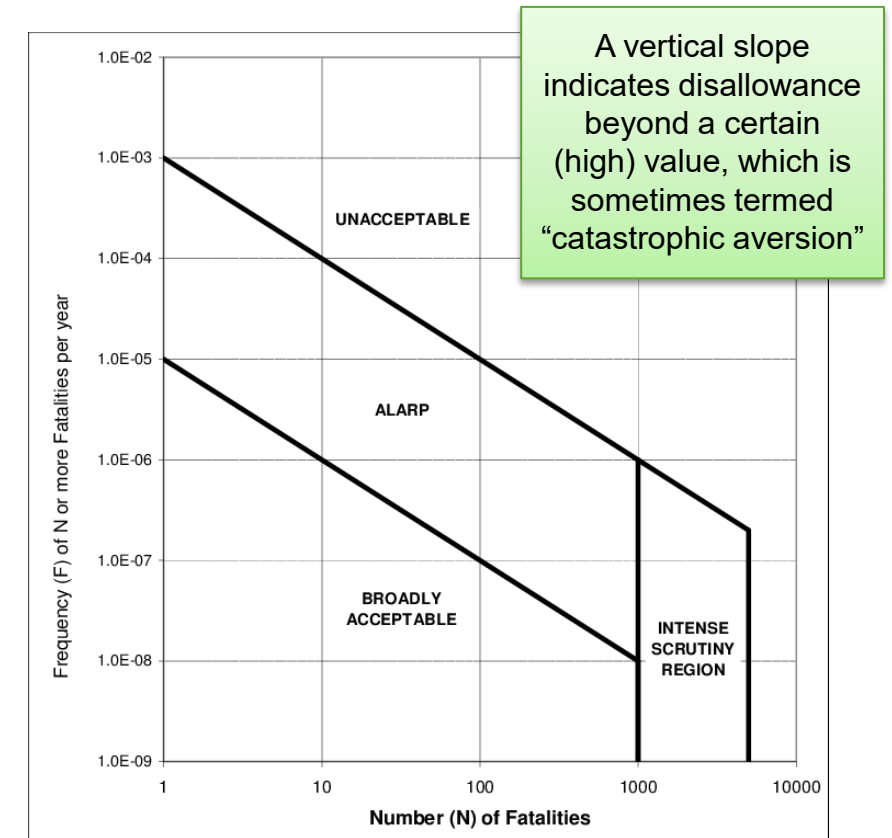
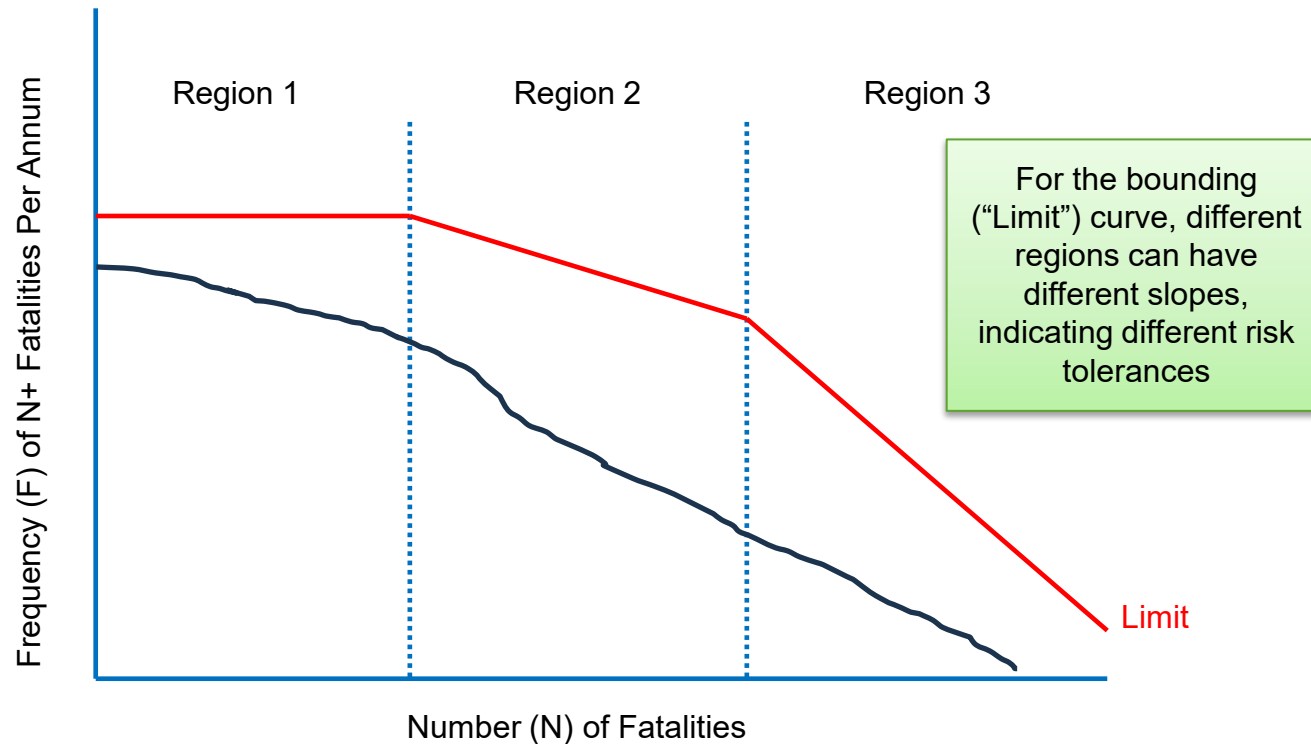
Or

Individual		
	Current	Proposed
1E-06	Fail	Fail
1E-07	Pass	Pass & Warning
	Pass	Pass

- X no greater than X_{\max}
- 95% confidence no greater than $X_{\max} + \Delta_{\max}$

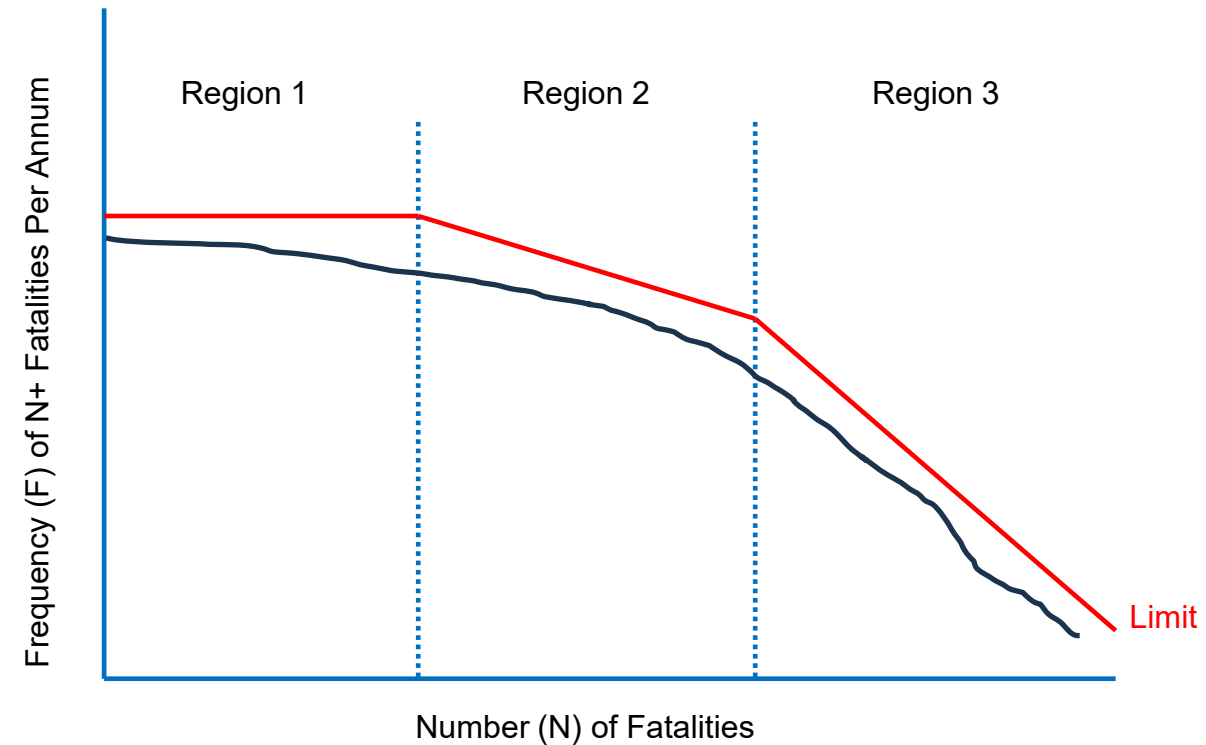
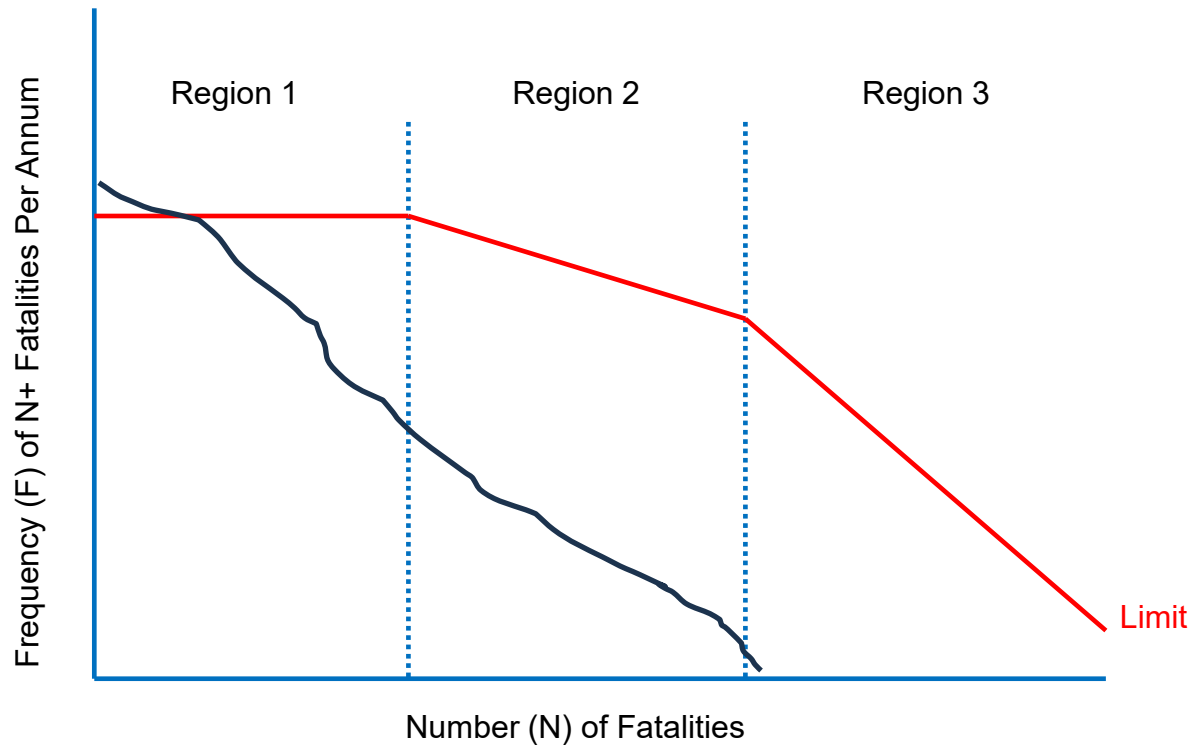
GRADING RISK: EXAMPLES

- F-N curve (cumulative risk)
- A (2D) Bounding “Curve” to grade a (2D) cumulative distribution of risk results



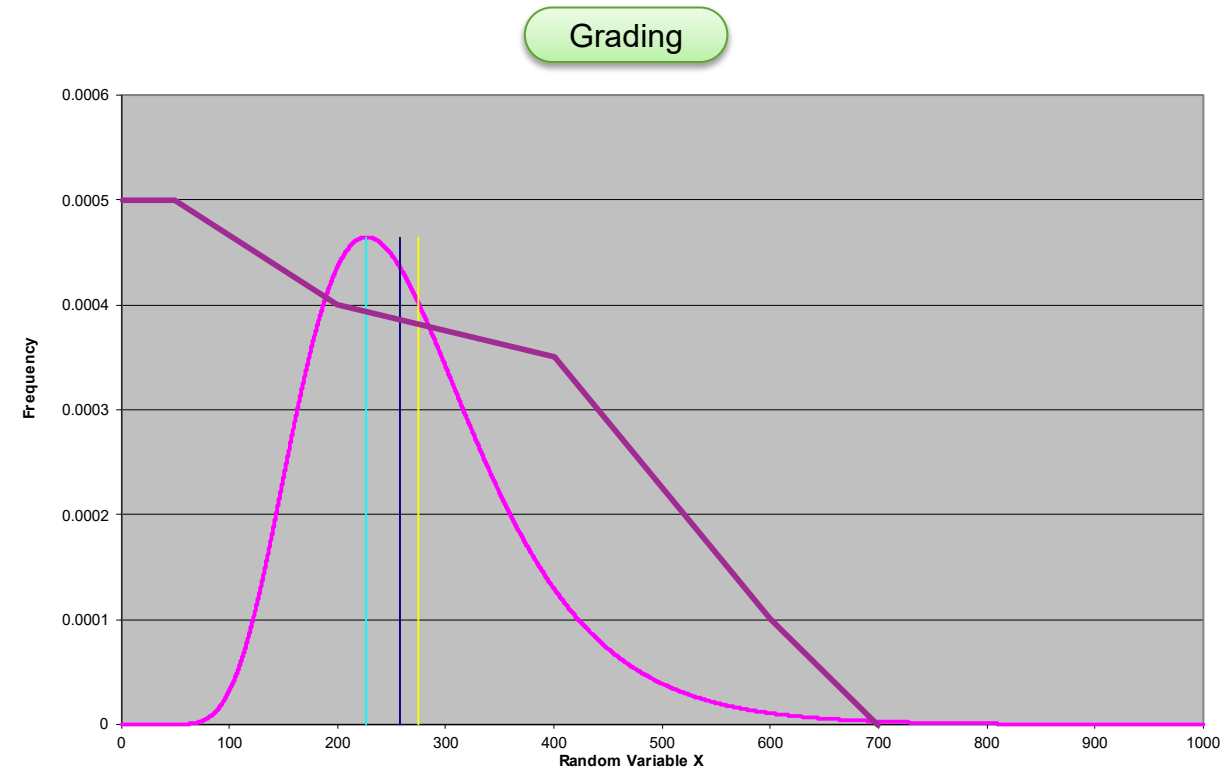
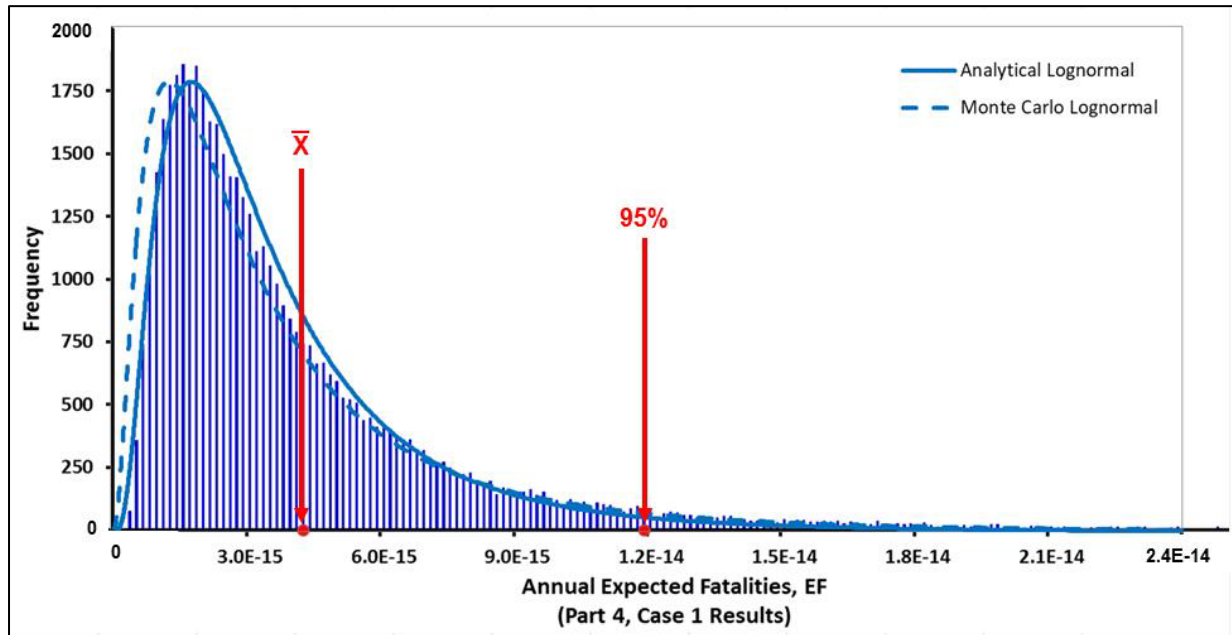
GRADING RISK

- Point estimate
- Bounding curve
- Area under bounding curve



GRADING RISK: EXAMPLES

- SAFER/IMESA FR
- A (2D) distribution graded by a bounding curve with multiple regions (different slopes)

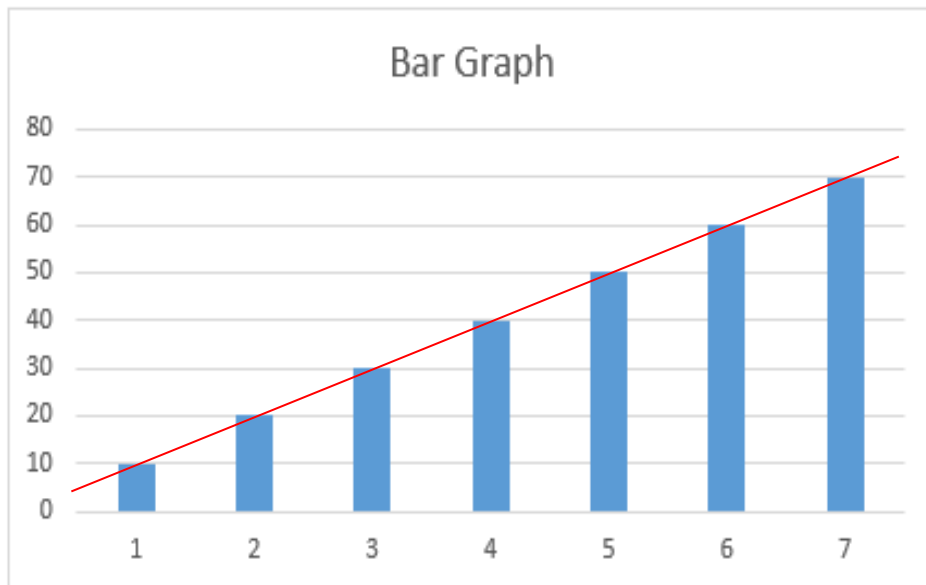


MULTI-STAGE ACTIVITIES

- Some explosives safety operations may have multiple stages/phases, perhaps each with stage having a separate grading approach (and possibly a different regulatory authority), or even multiple countries involved (e.g., a port in Canada bringing in explosives to be sent by rail/river/road to the U.S. for use in the mining industry)
- Example (think ground safety before a launch):
 - ▶ Storage 1
 - ▶ Transportation
 - ▶ Storage 2
 - ▶ Setup
 - ▶ Operation
- How to use QRA to grade each stage and/or the total operation?

MULTI-STAGE ACTIVITIES -- CONSIDERATIONS

- Discrete
- Continuous



Can we add a trendline?

Can we establish the value of the function between Bar 3 and Bar 4?

- Dimensions
- Are the phases in the activity discrete?

Sampling a continuous function:

1. Value at Sample 1
2. Value at Sample 2
3. Value at Sample 3
4. Value at Sample 4
5. Value at Sample 5
6. Value at Sample 6
7. Value at Sample 7

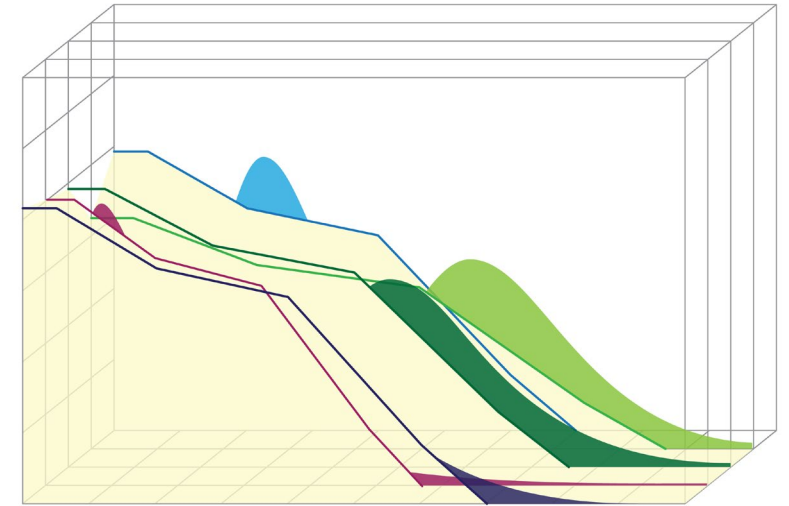
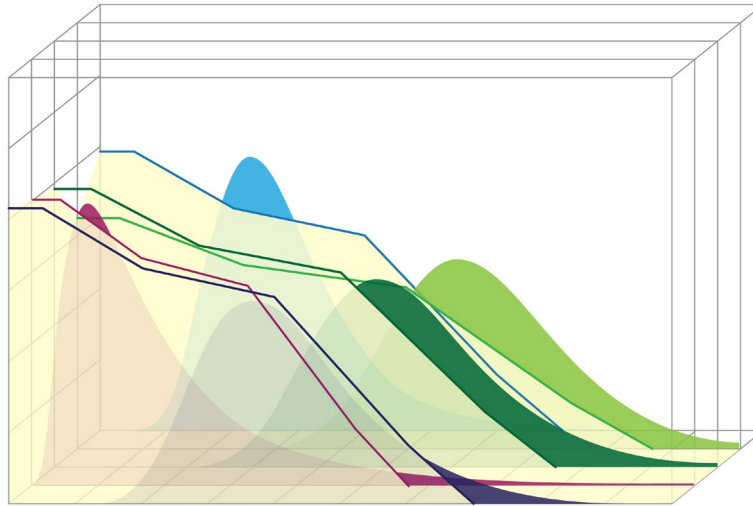
Number of people at the conference with the name:

1. Linda
2. Stephen
3. James
4. Karen
5. Doug
6. Knut
7. Jennifer

GRADING RISK FOR MULTI-STAGE ACTIVITIES

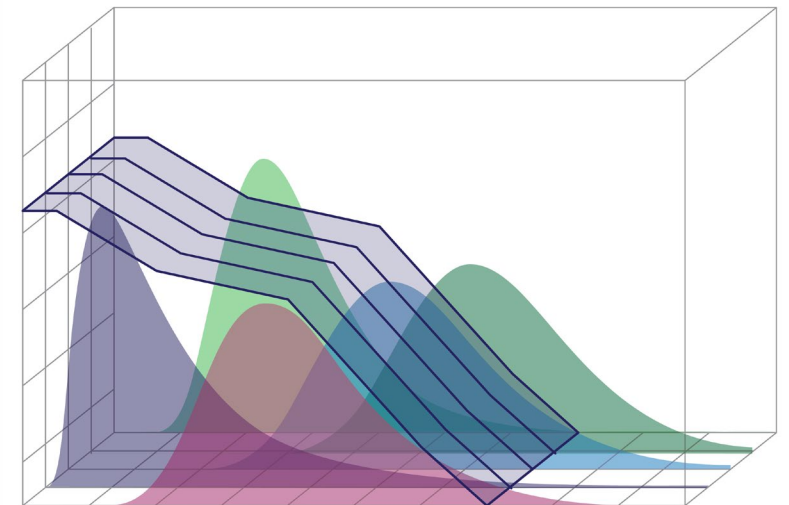
■ By phase

- ▶ Point estimate
- ▶ Bounding curve
- ▶ Area under bounding curve



■ Total

- ▶ Point estimate (n/a) [or airline baggage example]
- ▶ Bounding
 - Multiple bounding curves
 - Bounding surface
- ▶ Volume under bounding surface [dimension warning]



PRACTICAL APPLICATION

- Stage-by-stage
 - ▶ If any stage fails, the operation fails, regardless of “total score”?
 - ▶ If all stages pass, the operation passes, regardless of “total score”?
- Total
 - ▶ Is the total the sum of the individual stage results (graded in whichever manner chosen)?
 - ▶ Is a volume answer applicable?
- Both
 - ▶ The operation has to pass all stages
 - ▶ The “total score” also has to pass some measure

SUMMARY

- There are different approaches to grading QRA results, even for a single-stage operation.
- Simple approaches sometimes lack fidelity or miss some conditions.
- More complex approaches may capture more information, but may be harder to visualize and communicate.

- Multiple-stage operations can be judged stage-by-stage (in whichever manner deemed appropriate)
 - ▶ There may be a need to aggregate the risk across the entire operation.
 - ▶ Information may not exist between stages, so the grading criteria/approach must be chosen carefully if aggregating.

QUESTIONS