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A Graded Approach to the Selection of Minimum Subcritical Margin

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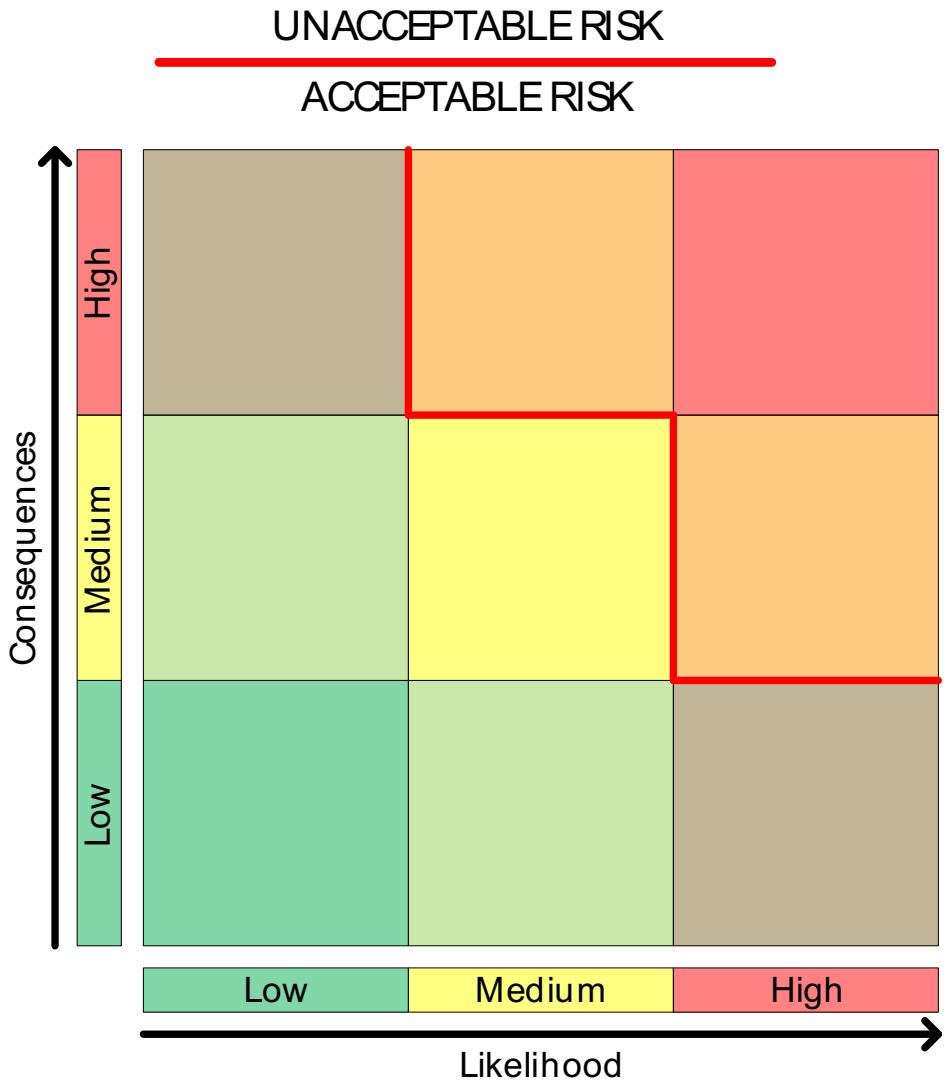
The Graded Approach

- The IAEA Safety Glossary defines the graded approach as:

1. *"For a system of control, such as a regulatory system or a safety system, a process or method in which the stringency of the control measures and conditions to be applied is commensurate, to the extent practicable, with the likelihood and possible consequences of, and the level of risk associated with, a loss of control."*
2. *"An application of safety requirements that is commensurate with the characteristics of the facilities and activities or the source and with the magnitude and likelihood of the exposures."*

Risk Evaluation Matrix

- The typical risk evaluation matrix looks something like this.
- Usually, evaluation guidelines are established to set the bar on “acceptable risk” (red line)
- Sometimes, numerical values are assigned to each of these categorizations



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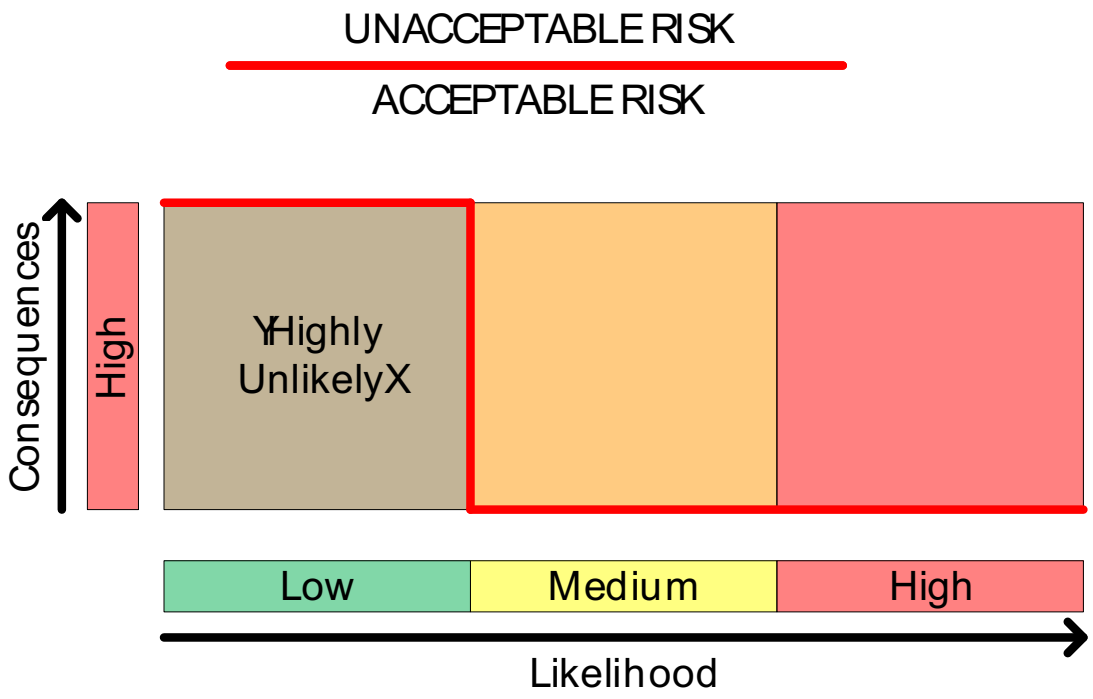
Criticality Accident Risk Evaluations

- Without the ability to grade the consequences of an event, the risk evaluation matrix collapses to a modified Heaviside function
- This philosophical approach creates a lack of flexibility in evaluating the risks



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Minimum Subcritical Margin

- Minimum subcritical margin (MSM) is mandated as “margin of subcriticality,” but has been identified using many different terms: subcritical margin, arbitrary margin, and administrative margin, et al.
- The MSM is designed to account for “unknown-unknowns” present in calculated k_{eff} values
- Competing interests drive the selection of the appropriate value of the MSM.

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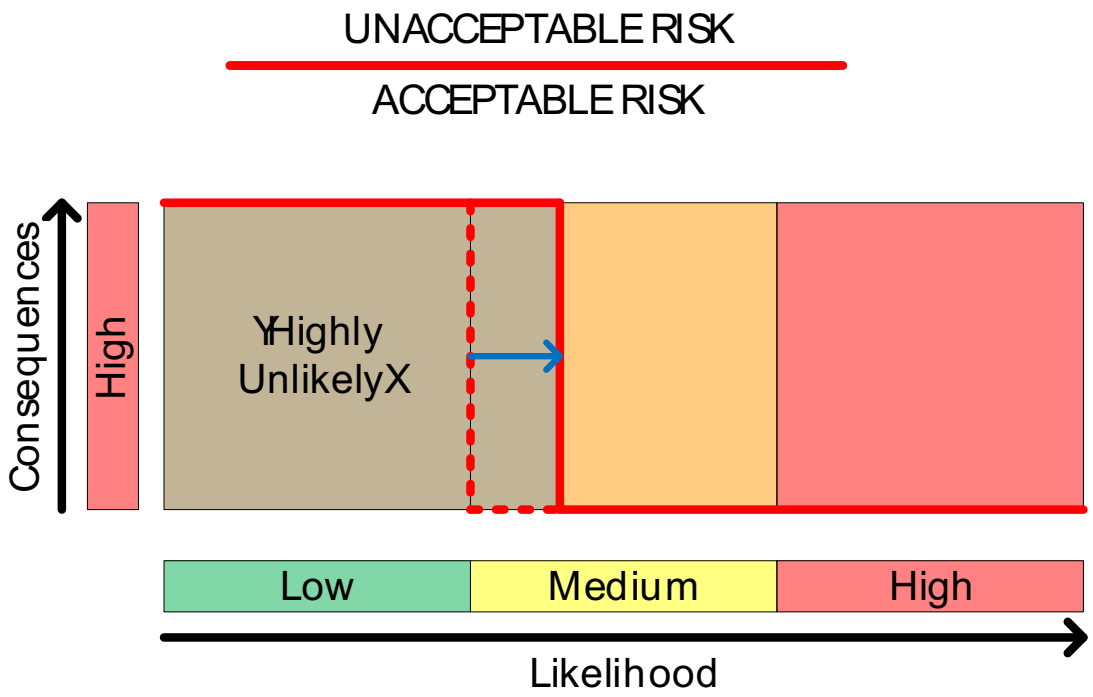
Minimum Subcritical Margin

- Making changes in the MSM results in a shift in the risk acceptance profile toward “more likely”
- Small changes in the MSM can result in significant changes in process throughput
- Note that changes in the MSM do not change the risk category!



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Systematic Grading Methodology

- In order to apply a systematic grading methodology, the factors which influence the risk of a criticality accident need to be *classified*.
- Remember that risk is a nexus of likelihood and consequences.
- Historically, and generally, criticality accidents are automatically assigned high consequences, regardless of circumstance. This thinking is reflected in applicable regulations for non-reactor facilities. 10 C.F.R. §70.61(d), 10 C.F.R. §830 Subpart B §§ 204(6)(i)

Grading

- When determining appropriate grading criterion, consider the objectives and activities involved in each process:
  - The objective of the minimum subcritical margin is to account for “unknown-unknowns” associated with the calculations used.
  - The process objectives can generally be quantified as “throughput” of one sort or another.
  - Note the competing interests. Generally, more margins will result in lower throughput, and vice versa.

- Step 1: Identify the areas of significant impact within each process

Grading

- Examples of areas of significant impact for the minimum subcritical margin (ISG-10(draft)):
  - Benchmark Similarity
  - System Sensitivity
  - Neutron Physics of the System
  - Rigor of the validation methodology
  - Margin in system parameters (Minimum subcritical margin vs. margin of safety)
  - Normal vs. Abnormal Conditions
  - Statistical Arguments

Grading (cont.)

- Step 2: Within each area, develop criteria to determine the significance of each item relative to the objective.
- For example: Benchmark Similarity

Reliability of Benchmark Sources	Benchmark Source Independence	Range of benchmark parameters	Number of relevant benchmarks	Selection of benchmark parameters
□ 1 – No available benchmarks Ÿ □ 3 – Directly-applicable critical experiments	□ 1 – Single source of benchmarks Ÿ □ 3 – Multiple independent benchmarks	□ 1 – No parameters in range Ÿ □ 3 – All parameters in range	□ 1 – No available benchmarks Ÿ □ 3 – Many available benchmarks	□ 1 – No relevant parameters selected Ÿ □ 3 – All relevant parameters selected

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Grading (cont.)

- Step 3: Once the criteria are determined and weighted, a scorecard approach can be used.
- The results of the scoring give a comparative basis for selection of margin
- Many different schemes exist to assist in this step

Areas of Impact – Minimum Subcritical Margin

Benchmark Similarity	0.335	Area 2	1.823	Area 3	0.643	Area 4	0.111	Area 5	0.235
Weighting Factor	0.5	Weighting Factor	2	Weighting Factor	4	Weighting Factor	1	Weighting Factor	2
Aggregate Score	0.67	Aggregate Score	??	Aggregate Score	??	Aggregate Score	??	Aggregate Score	??
Reliability	2	Criteria 1	n	Criteria 1	n	Criteria 1	n	Criteria 1	n
Independence	1	Criteria 2	n	Criteria 2	n	Criteria 2	n	Criteria 2	n
Range	3	Criteria 3	n	Criteria 3	n	Criteria 3	n	Criteria 3	n
Quantity	2	Criteria 4	n	Criteria 4	n	Criteria 4	n	Criteria 4	n
Selection	2	Criteria 5	n	Criteria 5	n	Criteria 5	n	Criteria 5	n
Normalized Score 0.095		Normalized Score 0.516		Normalized Score 0.182		Normalized Score 0.031		Normalized Score 0.066	

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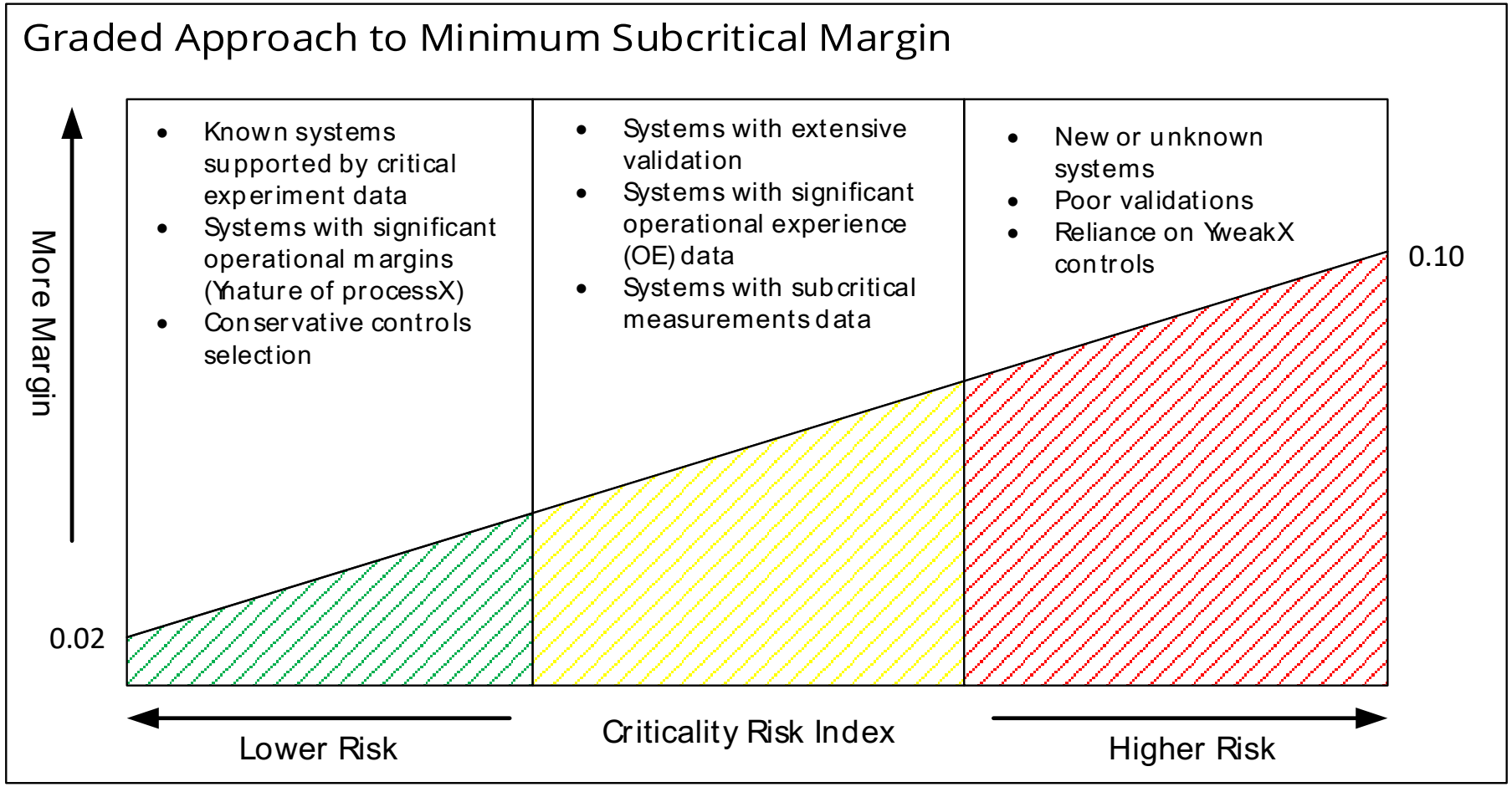
Grading (cont.)

- Once the grading criteria are established and grades assigned, a quantitative estimate of the minimum subcritical margin can be made
- An established process makes assessments of the selected margin much less complicated for all stakeholders.
- Another approach is to remove the use of k_{eff} as a measure of safety altogether. Instead of setting margins on k_{eff}, set safety margins on process parameters. This approach has been discussed in the literature.

Grading (cont.)



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Minimum Subcritical Margin

- When overall facility risk is considered in aggregate, it is possible that increased subcritical margin results in *higher* risks to workers or the public.
- If conservative criticality safety margins extend the mission time of a facility, all the related operational risks to workers and the public for that facility are increased.
- Facility stakeholders and safety professionals should consider the *overall* facility risk associated with (potentially) unneeded analytical conservatism.

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Conclusions

- Overly conservative application of the minimum subcritical margin can lead to an increase in the overall risk to workers in a facility.
- Determination and application of the minimum subcritical margin should use the graded approach
- The graded approach should use a method that quantitatively determines the appropriate minimum subcritical margin and can be demonstrated to stakeholders to ensure buy-in.
- Application of safety margins to process parameters may be a preferred approach.

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