Engineering Risk Benefit Analysis

1.155, 2.943, 3.577, 6.938, 10.816, 13.621, 16.862, 22.82, ESD.72

RPRA 7. Risk Management

George E. Apostolakis
Massachusetts Institute of Technology

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The Risks We "Accept"

Annual Individual Occupational Risks

• All industries	7×10^{-5}
• Coal Mining:	24×10^{-5}
• Fire fighting:	40×10^{-5}
• Police:	32×10^{-5}
• US President	$1{,}900 \times 10^{-5}$

Annual Public Risks

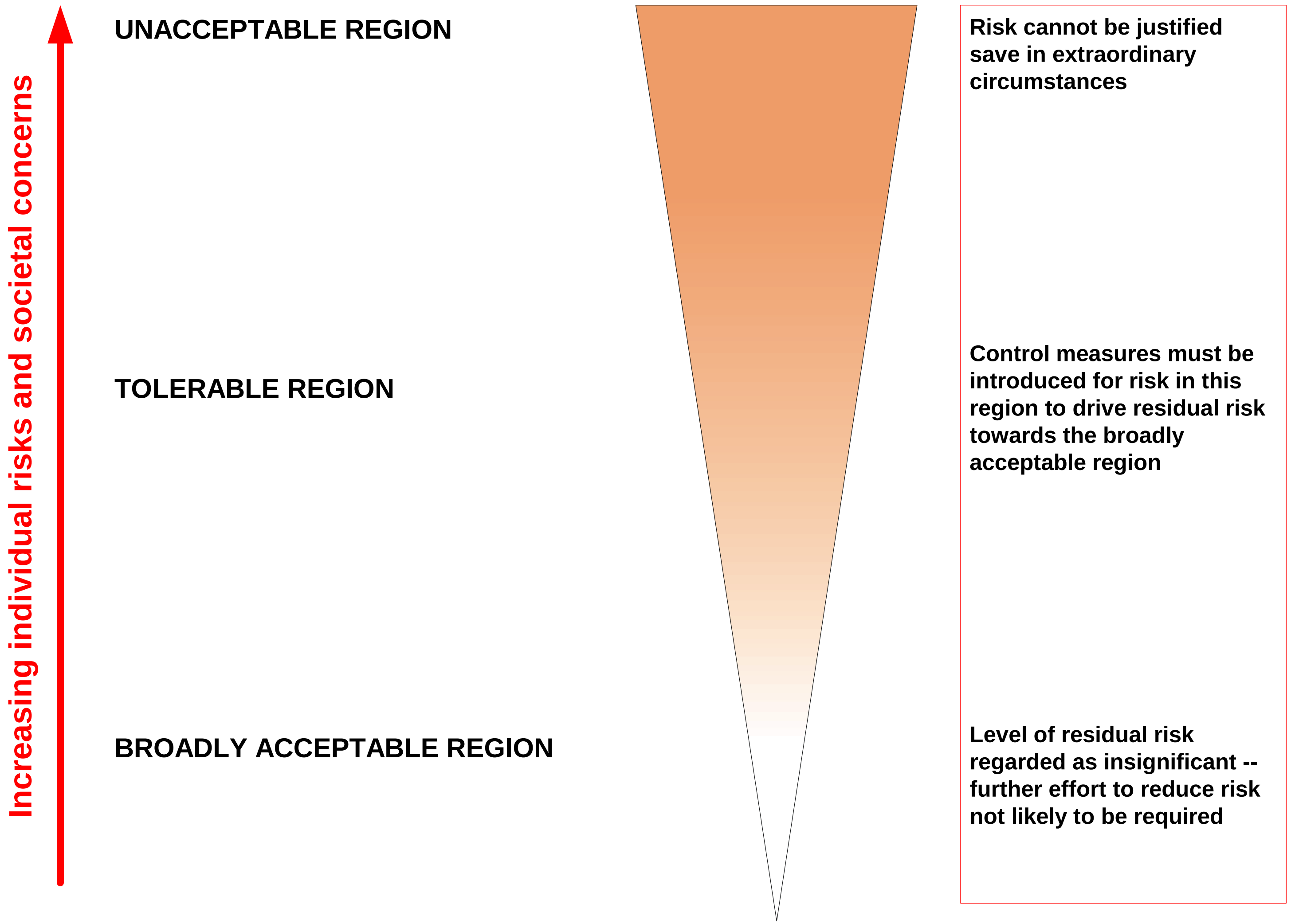
• Total	870×10^{-5}
• Heart Disease	271×10^{-5}
• All cancers	200×10^{-5}
• Motor vehicles:	15×10^{-5}

Source: Wilson & Crouch, *Risk/Benefit Analysis*, Harvard University Press, 2001.

Risk Acceptance

- **Voluntary vs. involuntary risks.**
- **Adequate protection of public health and safety.**
- **Unacceptable vs. tolerable risks.**

"Acceptable" vs. "Tolerable" Risks (UK Health and Safety Executive)



NASA Integrated Action Team Definition

<u>Acceptable Risk</u> is the risk that is understood and agreed to by the program/project, Governing Program Management Council (GPMC), and customer sufficient to achieve defined success criteria within the approved level of resources.

–Each program/project is unique.

–Acceptable risk is a result of a knowledge-based review and decision process.

–Management and stakeholders must concur in the risk acceptance process.

–Effective communication is essential to the understanding of risk.

–Assessment of acceptable risk must be a continuing process.

The Importance of Risk Communication

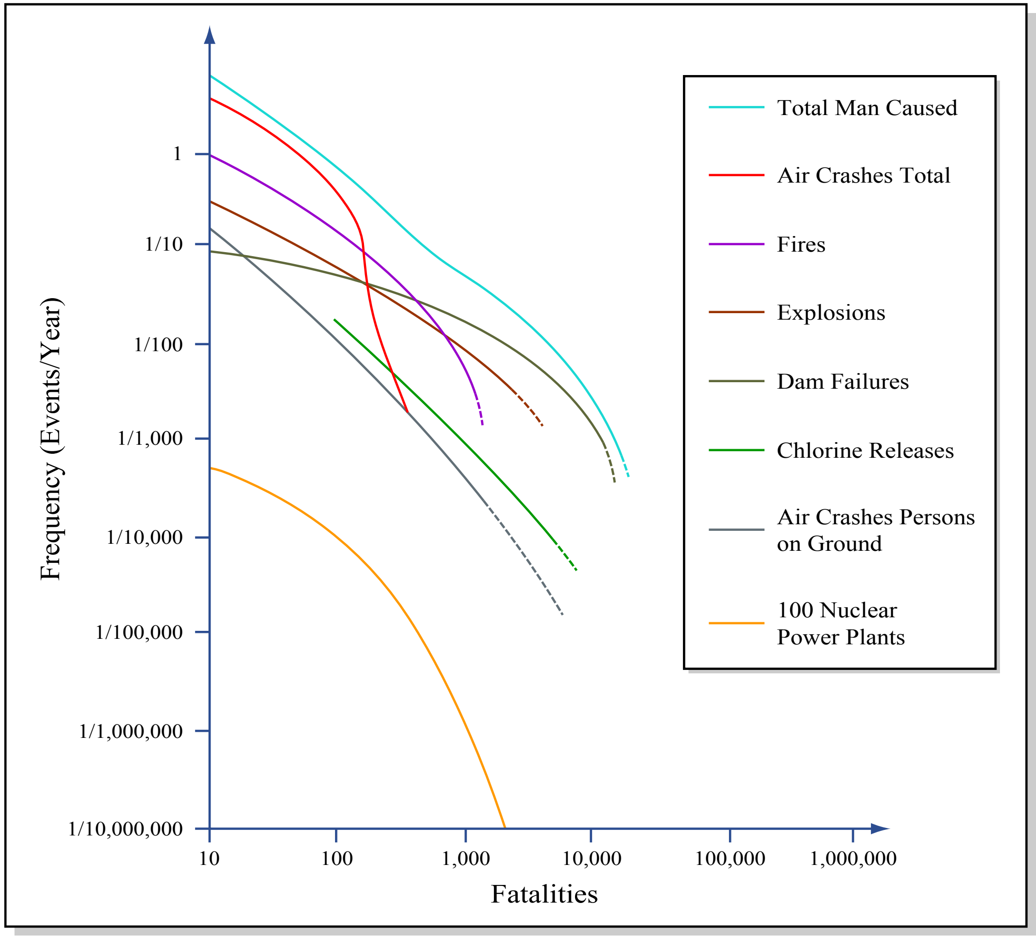


Figure by MIT OCW.
Adapted from Rasmussen, et al. "The Reactor Safety Study." WASH-1400, US Nuclear Regulatory Commission, 1975.

Safety Goals

- **A lifetime cancer risk of less than 10^{-4} for the most exposed person is acceptable.** ***(US EPA)***
- **A lifetime cancer risk of less than 10^{-6} for the average person is acceptable.** ***(US EPA)***
- **Individual probability of death greater than 10^{-3} per year for workers and 10^{-4} per year for the public is unacceptable.** ***(UK Health and Safety Executive)***
- **Individual probability of death less than 10^{-6} per year is "broadly acceptable."** ***(UK Health and Safety Executive)***

Quantitative Health Objectives for Nuclear Power Plants (NRC)

- The individual early fatality risk in the region between the site boundary and 1 mile beyond this boundary will be less than 5×10^{-7} per year (one thousandth of the risk due to all other causes).

- The individual latent cancer fatality risk in the region between the site boundary and 10 miles beyond this boundary will be less than 2×10^{-6} per year (one thousandth of the risk due to all other causes).

Involving the Stakeholders

Risk assessment can and should be used to involve stakeholders and provide a mechanism for the consideration of their cultural, socioeconomic, historical, and religious values, in addition to the risks to human health and the environment associated with the contamination of DOE facilities and their remediation.

National Research Council, *Building Consensus*, 1994

The Analytic-Deliberative Process

- ***Analysis*** **uses rigorous, replicable methods, evaluated under the agreed protocols of an expert community - such as those of disciplines in the natural, social, or decision sciences, as well as mathematics, logic, and law - to arrive at answers to factual questions.**

- ***Deliberation*** **is any formal or informal process for communication and collective consideration of issues.**

National Research Council, *Understanding Risk*, 1996.

PRA Provides the Analysis

- The “dominant” accident scenarios are the basis for risk management.
- The objectives are to meet the safety goals and to optimize the design and operations.

Risk management options from the scenarios: Fire risk

$$\lambda_x = \sum_j \lambda_j Q_{d|j} Q_{x|d,j}$$

λ_x = contribution to consequence x from fires

λ_j = Fire frequency in location j

$Q_{d|j}$ = Pr[cable damage given fire in j]

$Q_{x|d,j}$ = Pr[occurrence of x given cable damage]

Case study

Zone designator/ Scenario		Frequency, Events Per Year λ_x	λ_y	λ_j	$Q_{d/j}$	$Q_{x/d,j}$	$Q_{y/x,d,j}$
1. Fire Under Cable Trays Damaging Power Cables to System A		4.6-8	4.6-8	1.1-7	0.32		
		7.9-6	7.9-6	1.3-5	0.62		
		4.2-4	4.2-4	3.7-4	0.90		
		7.1-5	7.1-5	1.2-4	0.62	1.0	1.0
2. Fire in the Aisle Damaging Power Cables to System A		5.5-8	5.5-8	1.2-7	0.20		
		4.7-6	4.7.6	8.4-6	0.55		
		1.0-4	1.0-4	1.6-4	0.87		
		2.4-5	2.4-5	4.2-5	1.0	0.57	1.0
3. Fire on Floor Damaging Control Cable 10 Feet Above the Floor and Failing All Control Instrumentation Capability		3.0-10	<1.0-10	5.3-7	0.12	2.5-4	0.02
		7.3-8	7.3-9	3.3-5	0.45	5.0-3	0.1
		3.3-6	5.9-7	5.0-4	0.80	1.0-1	0.5
		1.9-6	3.0-7	1.5-4	0.48	2.6-2	0.16

NOTE: Exponential notation is indicated in abbreviated form; i.e., 4.6-8 = 4.6×10^{-8}

$\lambda_x = \lambda_j Q_{d/j}\, Q_{x/d,j}$

$\lambda_y = \lambda_j Q_{d/j}\, Q_{x/d,j}\, Q_{y/x,d,j}$.

Controlling fire frequency λ_j

1.2E-4; 4.2E-5; 1.5E-4 per year

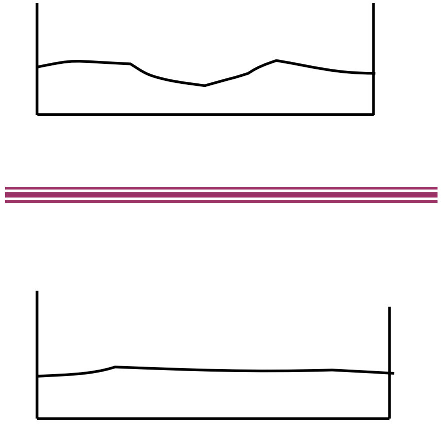
They are the result of transient fuels.

Option: Stringent administrative controls

Not a credible option. Controls are already supposed to be stringent.

Controlling cable damage $Q_{d/j}$

Construct a fire barrier between redundant cable trays.



Controlling system response $Q_{x|d,j}$ and $Q_{y|x,d,j}$

Install a self-contained charging pump (System A).

Connect power cable independent of fire zones (System A).

Analytical results

Option	Description	Percentile	λ_x Events per year	Reduction Factor	λ_y Events per year	Reduction Factor
0	Base Case	5th 50th 95th Mean	2.2×10^{-6} 3.0×10^{-5} 1.1×10^{-3} 1.0×10^{-4}	1.0	1.5×10^{-6} 2.6×10^{-5} 9.7×10^{-4} 9.6×10^{-5}	1.0
1	Fire Barriers	5th 50th 95th Mean	5.9×10^{-7} 9.1×10^{-6} 2.3×10^{-4} $3.9 \times$ 10-5	2.6	2.1×10^{-7} 7.4×10^{-6} 2.1×10^{-4} 3.3×10^{-5}	2.9
2	Self Contained Charging Pump	5th 50th 95th Mean	1.6×10^{-6} 8.8×10^{-6} 9.9×10^{-5} 1.9×10^{-5}	5.3	3.6×10^{-7} 3.4×10^{-6} 9.2×10^{-5} 1.2×10^{-5}	8.0
3	Alternate Power Source	5th 50th 95th Mean	1.7×10^{-6} 7.1×10^{-6} 4.8×10^{-5} 1.4×10^{-5}	7.1	5.6×10^{-7} 3.0×10^{-6} 2.6×10^{-5} 6.9×10^{-6}	14.0

Deliberation

Management sought crew's views.

Other issues were considered.

"Alternate power source" was the chosen option.

- **model acts of "unbelievable intelligence" either.**