ETH Eidgenössische Technische Hochschule Zürich Swiss Federal Institute of Technology Zurich

Laboratory for Safety Analysis INSTITUTE FOR ENERGY TECHNOLOGY

DMAVT Departement Maschinenbau & Verfahrenstechnik: Department of Mechanical & Process Engineering

Risk Analysis of Highly-integrated Systems

RB I: Result Representation (Expected Value, Frequency-Consequence-Diagram, Uncertainties), Visualisation (GIS)

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Frequency-Consequence-Diagram

- Coordinate system with event frequency and damage consequence (consequence assigned to frequency)
- No connection to a risk value
- Synonyms for the frequency-consequence-diagram
  - F-C-Diagram (Frequency-Consequence)
  - F-N-Diagram (Frequency- Number of Fatalities)
  - W-A-Diagram (Probability-Consequence) is misleading

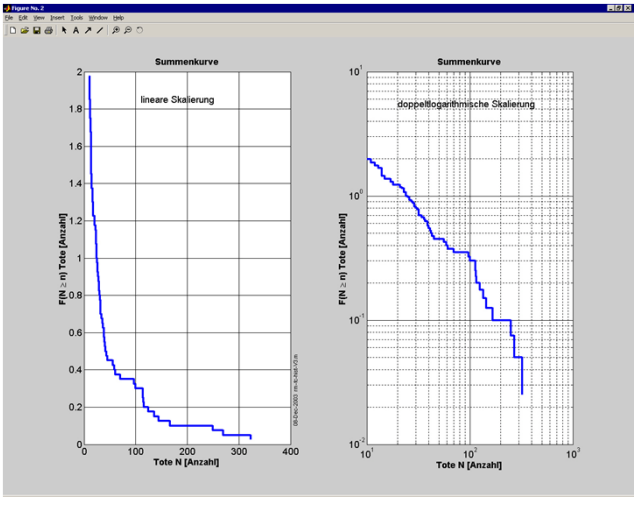
Example: Number of deaths from tornados in the US between 1938 and 1977

- Accumulated frequency as a base for the F-C-diagrams
- Procedure for the construction of a F-C-sum-diagram (CCDF)

$$F(N \geq n) = \sum_{i=1}^{k} F(N=n)$$

Number of deaths: n_i	Number of Tornados with i Deaths: $F(N=n)$	Accumulated frequency: $F(N \geq n_i)$	Accumulated frequency per year: $F(N \geq n_i)/40$
10	5	79	1.975
11	4	74	1.850
12	3	70	1.750
...	...	...	...
250	1	3	0.075
270	1	2	0.050
323	1	1	0.025

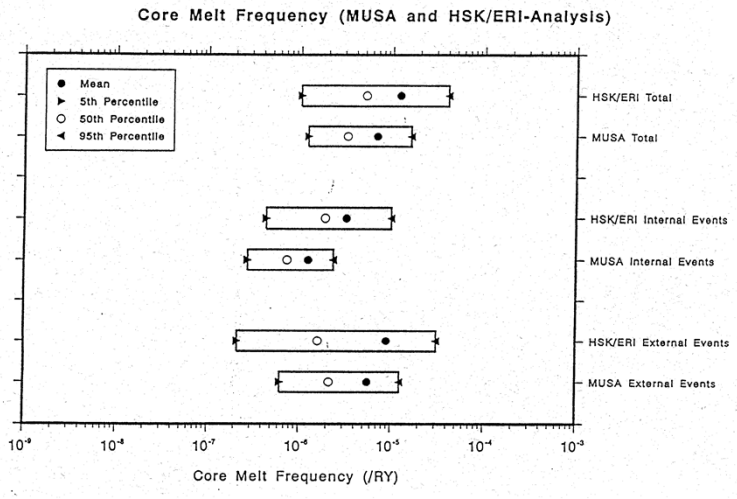
F-C-diagram



Probalistic Risk Analysis (PRA)

The analysis level in nuclear technology:

- **Level 1**
  Plant relevant analysis to identify dangerous or undesired scenarios and events. E.g. identification of scenarios, which lead to a core melt and determining their occurrence probability.
- **Level 2**
  Analysis of possible impact on the plant by undesired events, and determining the release of energy and substances into the environment. E.g. categorised releases (amount, conditions, frequency) from the containment.
- **Level 3**
  Analysis of transport mechanisms within the environment, assessment of the consequences from an accidental activity release, and their frequency. E.g. loss of human life, area contamination etc. including specific occurrence probability.



MUSA: Mühleberg Safety Analysis
HSK: Hauptabteilung für Sicherheit von Kernanlagen
ERI: Energy Research, Inc.

The Source-Term

- The amount and the isotope composition, combined with physical and chemical properties, the heat quantity in a contaminant plume resp. –cloud, the time profile and the height of release describe the Source-Term.
- The Source-Term is depending on the accident sequence.

- Examples of different Source-Terms:

Quellterm	Zeit vor Freisetzung [h]	Dauer der Freisetzung [h]	Freisetzungsrate [MW]	Freisetzungshöhe [m]	Zeit zur Alarmierung [h]	Freigesetzter Anteil						
						Xe-Kr	Org-I	I	Cs-Rb	Te-Sb	Ba-Sr, Ru	La
QT1	2.0 3.0	1.0 5.0	2.0 0.2	10 10	1.0 -	1.0 -	0.001 -	0.1 -	0.1 -	0.05 0.05	0 0.01	0 0.001
QT2	2.0	1.0	0	10	1.0	1.0	0.001	0.1	0.1	0.1	0.01	0.001
QT3	2.0	1.0	0	10	1.0	0.1	0.00001	0.001	0.001	0.001	0.0001	0.00001
QT4	2.0 3.0 5.0	1.0 1.0 1.0	0 0 0	10 10 10	1.0 - -	1.0 - -	0.00033 0.00033 0.00033	0.033 0.033 0.033	0.033 0.033 0.033	0.033 0.033 0.033	0.0033 0.0033 0.0033	0.00033 0.00033 0.00033
QT5	2.0	24.0	0	10	1.0	1.0	0.001	0.1	0.1	0.1	0.01	0.001

Uncertainty: Percentiles

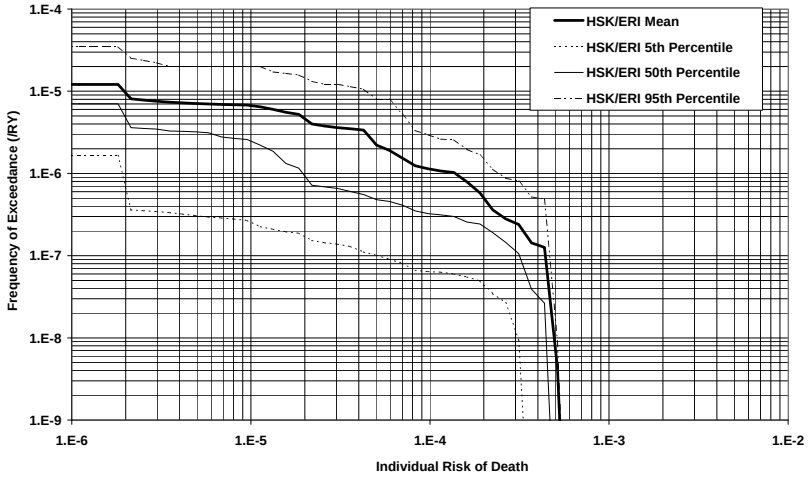
- A percentile is the value of a variable below which a certain percent of observations fall.
- So the 95th (5th) percentile is the value below which 95% (5%) of the observations may be found.
- The 50th percentile is the value where half of the values will be below and half will be above. It is called the median.
- The 50th percentile and the average are different meassures.

Example:

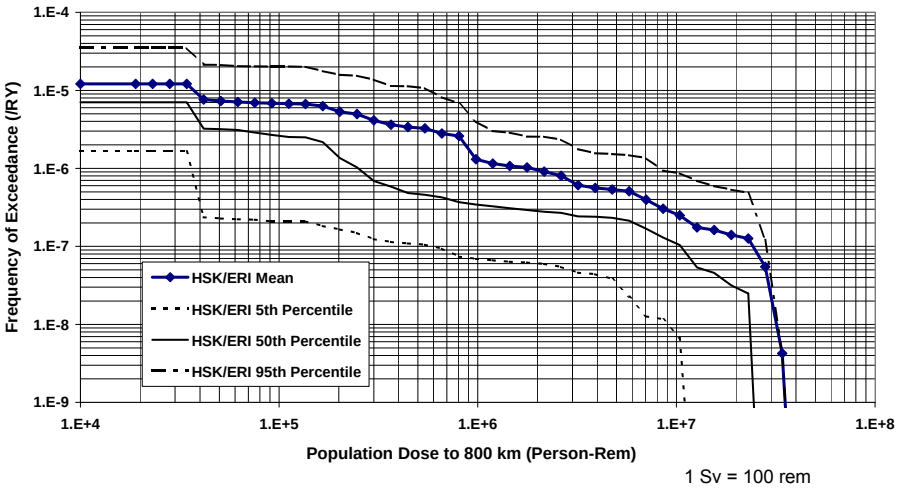
2, 3, 5, 9, 11

50th percentile=5 Average=6

Further Damage Parameters - Individual Death Risk

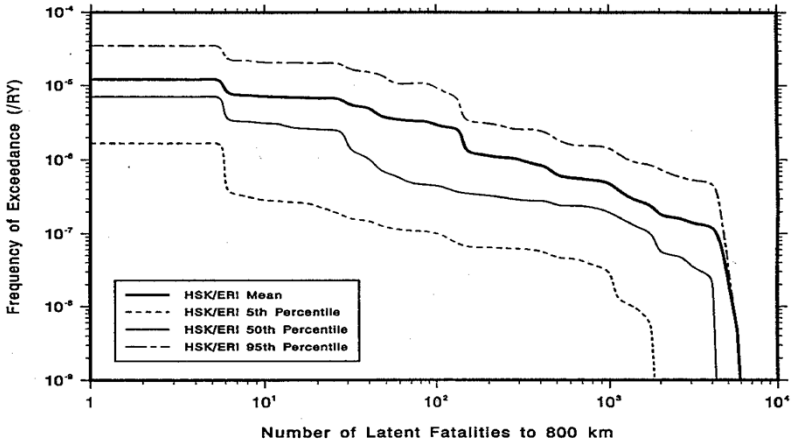


CCDF Form with Confidence Intervals

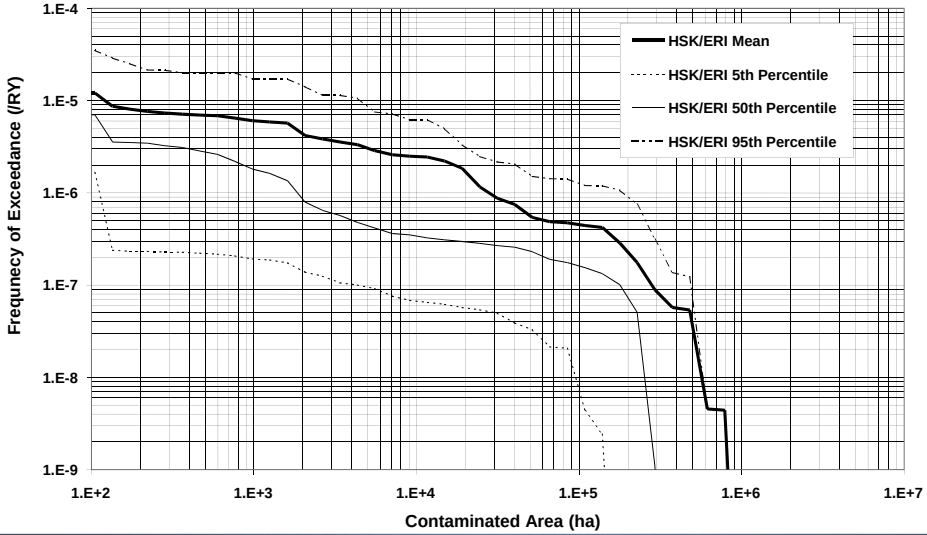


1 Sv = 100 rem

Cumulative frequencies of carcinogenic death of long term damage
(study of nuclear power plant Mühleberg)



Contaminated Area



Cs-137 contamination in the Ukraine, Belarus and Russia
(during the first months after the Chernobyl release)