Post safe separation reliability requirements for fuzing systems from surface risk criteria

Risk analysis of overflight scenarios for mortar and artillery projectils and fuzes: HE, smoke, illumination

56th Fuze Conference, Baltimore

Wednesday, 16 May 2012

Open Session IVA, 11:40AM

Funded by German Military Engineering and Procurement Agency BWB K 1.3

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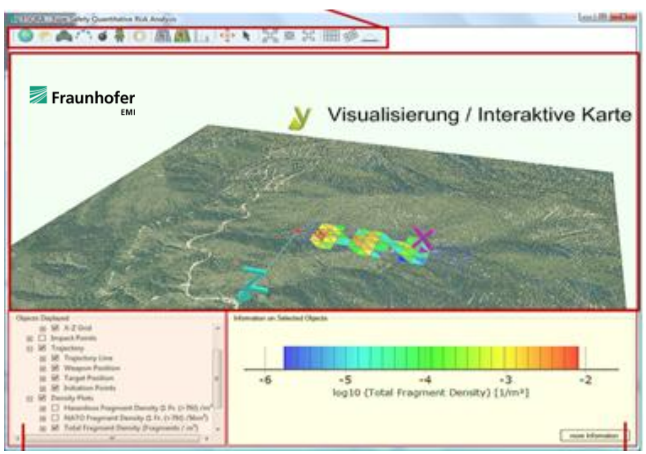
Content

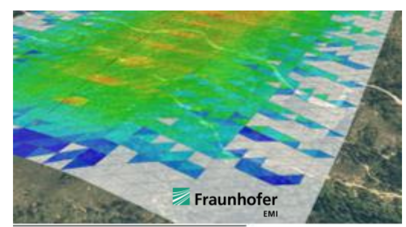
- Background, aim, input data
- Overview risk analysis methodology
- Hazard/Damage/Risk quantities
- Sample applications
- Implemented projectiles, fuzes
- Conclusions and outlook

Background

- Shooting over own troops, third party, settlements often unavoidable
- Scenarios: field camp protection, out-of-area missions close to settlements, test or training scenarios (if test ranges are too small)
- Assessment of scenario depending on threat level (e.g. shelling of camp)
- Very different scenarios
- Fast assessment taking specific information into account

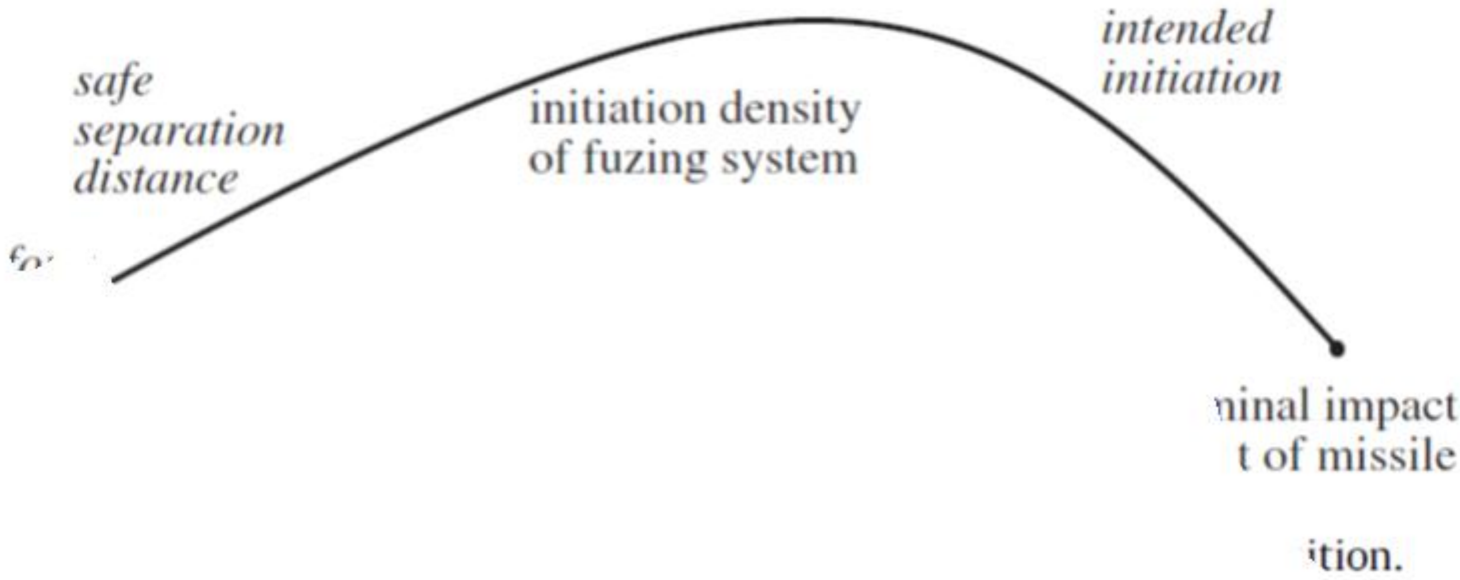


Fuze Safety Quantitative Risk Analyis tool: FSQRA



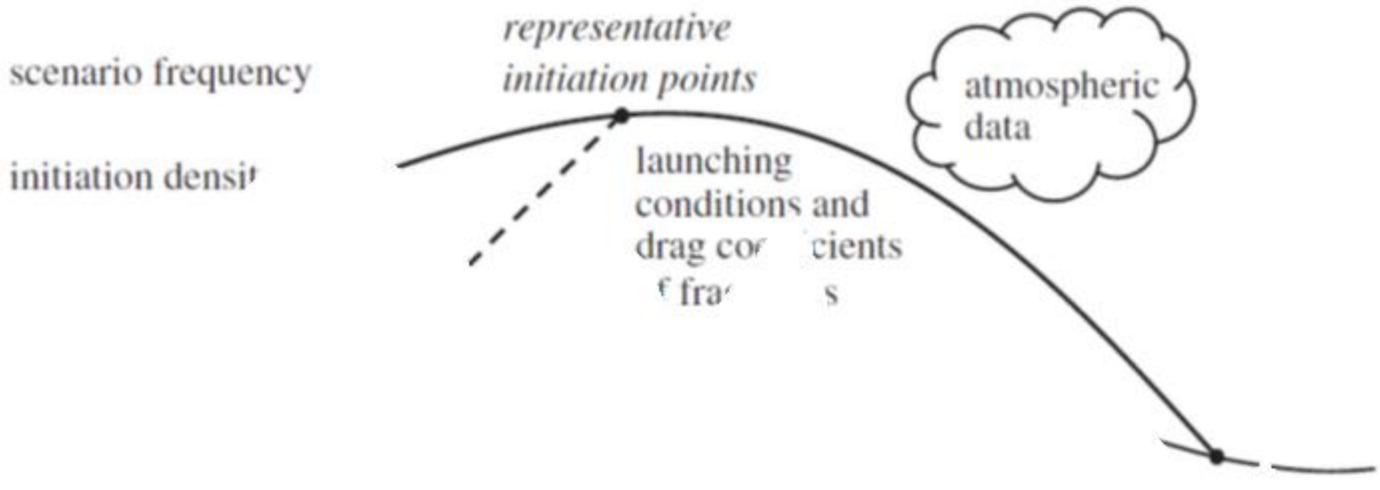
Example for average fragment density per round taking fuze failure rate on trajectory into account

Idea: Determine connection between technical safety of fuzing system on trajectory with risks for personnel on ground and vice versa



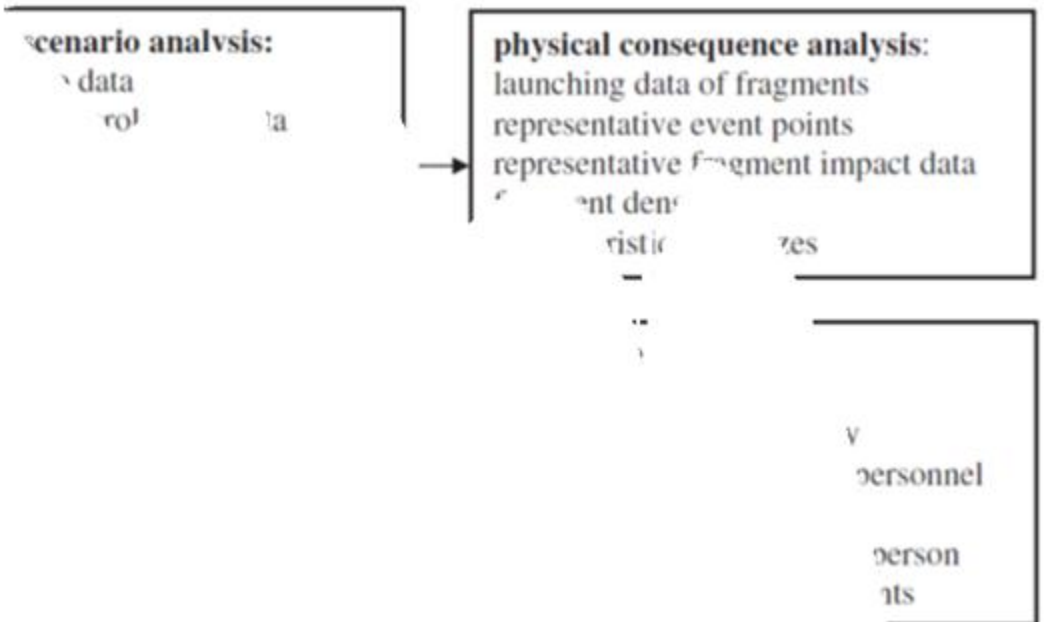
→ Fuzing system is safe, if risks for persons on ground are acceptable.

Input data: launching/target position, aeroballistic data, fuze initiation density, person densities



Multiple representative initiation points and fragment/component points are used to compute the hazard potential, damage and risk for personnel due to unintended initiations of the fuze on the trajectory.

Quantitative risk analysis steps: scenario, physical consequence, damage, probability and risk analysis



Important input

Initiation density
Frequency of rounds

Person density, omitting the target area

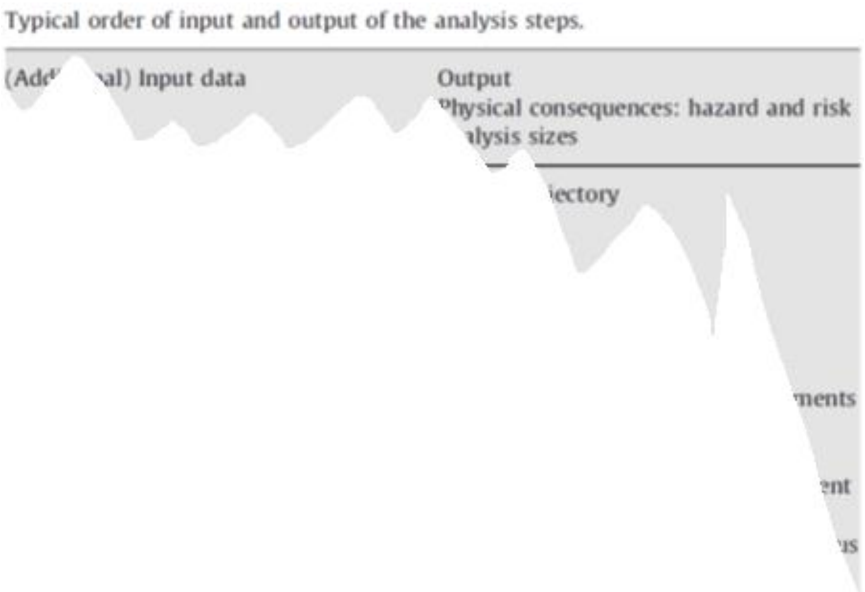
Output for Assessment:

Nato fragment density (E>79J)

Lokal fatal individual risk

Expected fatalities
F-N curve

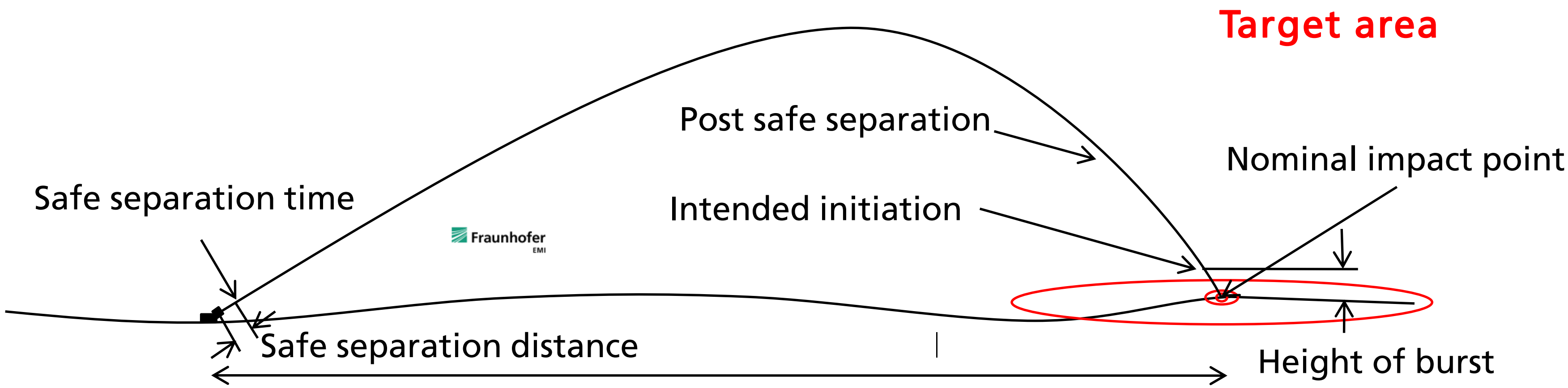
Details and order of acccessible risk analysis quantities

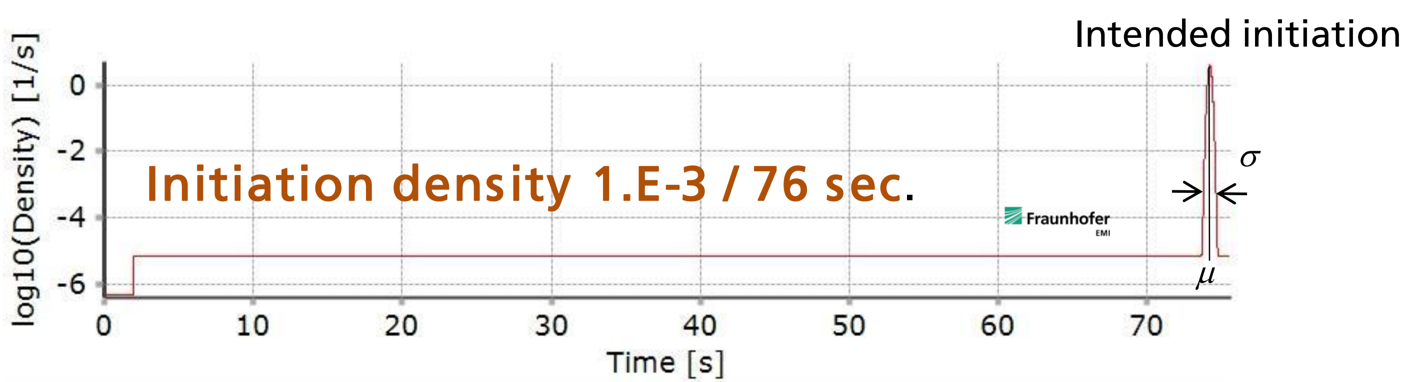

Typical order of input and output of the analysis steps.

(Add... al) Input data	Output Physical consequences: hazard and risk ... alysis sizes
	...jectory
	...ments
	...ent
	...s

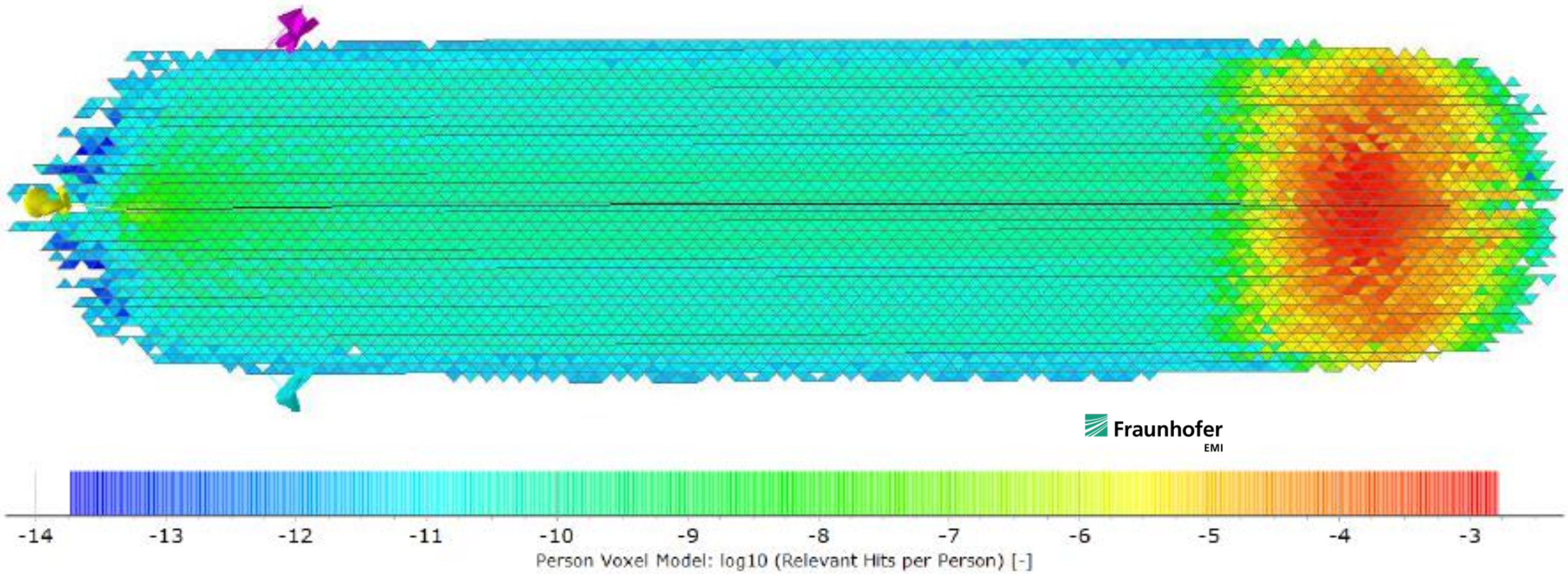
Use of FSQRA 3-D software tool:
(1) Input of data/ using standard input
(2) Computation of risk quantities
(3) Visualisation of results
(4) Assessment of acceptance of scenario

Example for szenario and initiation density





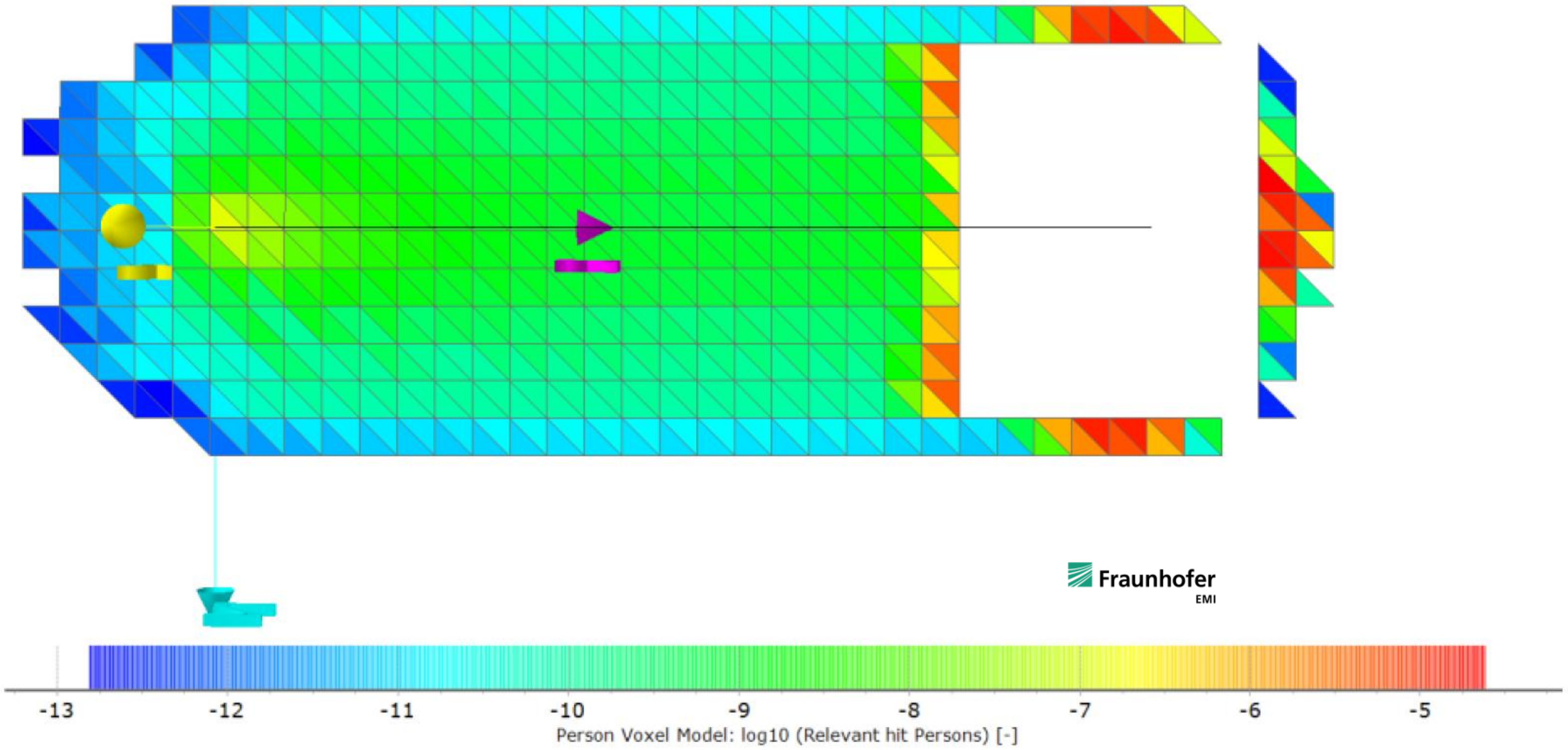
Example: Individual local fatal risk due to fragments for a single round for mortar (independent of person density)



Example Assessment of single type of scenario:
(local fatal risk) * (rounds per year) < (individual annual risk criterium)
1.E-7 *500/a =< 5.E-5/a

In practice a scenario mix is considered, e.g. medium and far shots.

For group risk assessment the person density in the target area is set to zero



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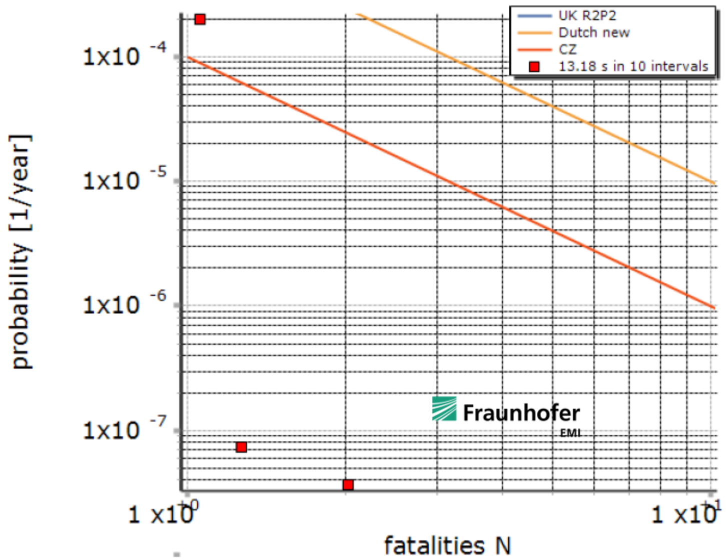
Annual frequency of N or more fatalities over number of fatalities: F-N curves



Person density assumed:
2.E-4 persons per square meter
corresponding to medium populated area

Example for single scenario:
(Probability of one or more fatalities per round) * (rounds per year) < (FN risk criterium)
2.E-4 * 5/a =< 1.E-3/a

Allows to foresee high casualty numbers
Collective risk criterion considers person density!

Implemented Projectiles/ Modified Point Mass Trajectory Models (STANAG 4355)

(Some of the Flight Control Input Data are ballistically identical)

155 mm Horwitzer, high explosive: 3 types

- 155mm, Panzerhaubitze 2000 – L15A1, HE / DM21, HE / DM111, HE

155 mm Horwitzer, smoke:

- 155mm, Panzerhaubitze 2000 – DM115, smoke

155 mm Horwitzer, illumination:

- 155mm, Panzerhaubitze 2000 – DM116, illumination

120 mm Wiesel, high explosive:

- 120mm, Wiesel II – IHE, HE

120 mm Wiesel, smoke:

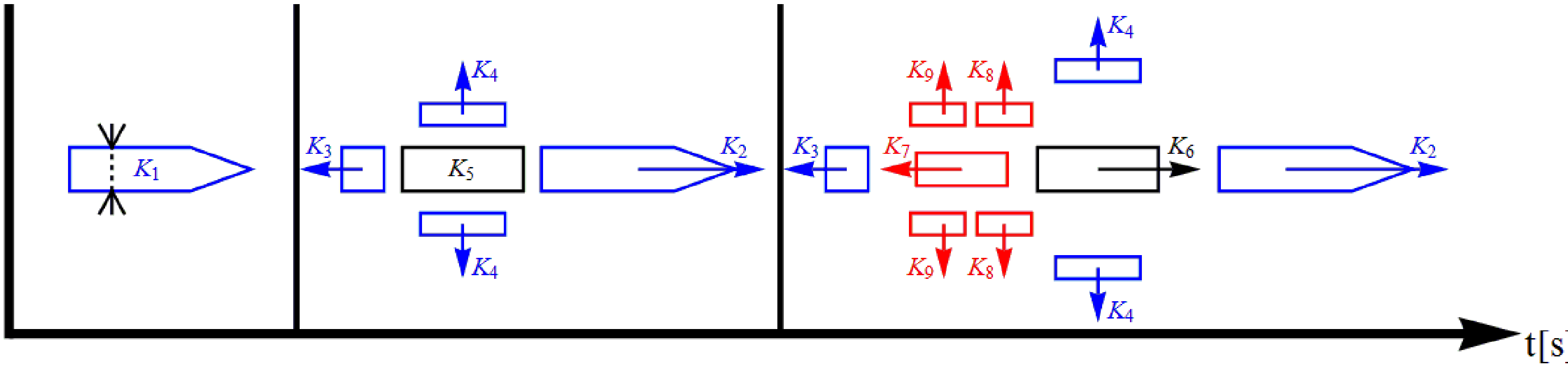
- 120mm, Wiesel II – DM16, smoke

120 mm Wiesel, illumination:

- 120mm, Wiesel II – DM35, illumination

Modelling of disintegration of illumination round

Multiple temporally and spatially separated initializations

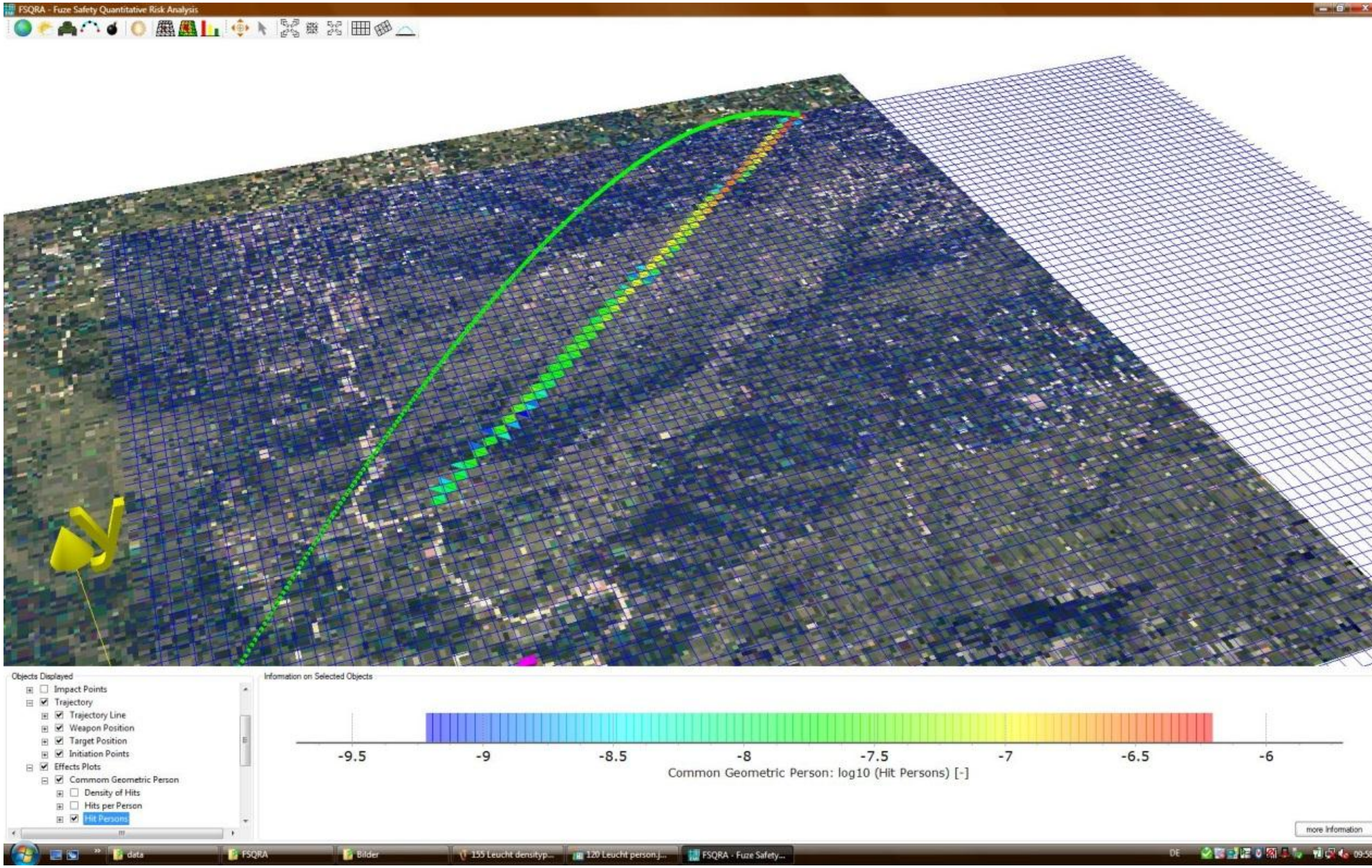


Phase 0 at t_0
First initiation of projectile

Phase 1 at t_1
Disintegration of outer shells

Phase 2 at t_2
Disintegration of inner shells

Example of local individual risks of illumination 155 mm projectile



Dangerous hits per person

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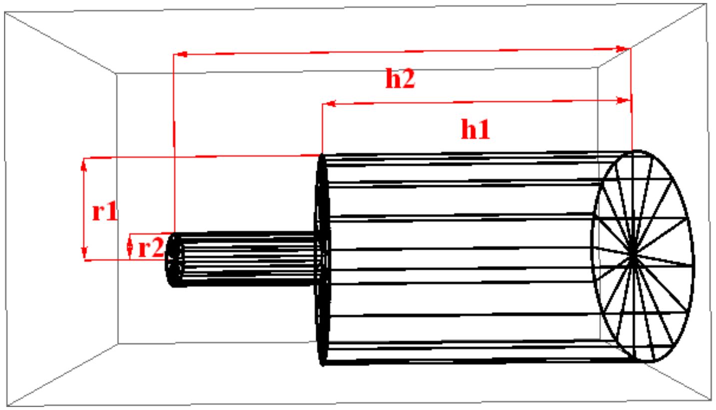
Implemented fragment matrices (as generated from arena tests) and component distributions matrices

- **155 MM:** DM 21; L15A1
- **120 MM:** DM 51; DM 21; DM 12;
  IHE; DM11 A4
- Component distribution matrices for all smoke and illumination 120 MM/155 MM projectiles

Arena test (WTD 91), radius: 5m



Example of hull geometry for component

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Implemented fuze models

- Can be defined by the user according to the results of technical reliability/safety analysis or according to specification of novel fuzing systems, or be derived from empirical data
- 4 Options:
  - Single point initiation
  - Gaussian/Normal distribution of initiation frequency on trajectory
  - Combination of rectangular distributions
  - Combination of rectangular distribution and a single Gaussian distribution
- A sample of a rectangular and normal combination was given in the sample case
- Fuze models for specific fuzes are not yet implemented. They will be defined in expert rounds and using reliability analysis results if available.

Conclusions

The quantitative risk analysis connects the failure rate of fuzes (existing or under development) on the projectile trajectory with risks of personnel on the ground.

Hazard, damage and risk quantities can be used for the flexible assessment of the acceptance of scenarios. Risk acceptance criteria are available for individual and collective risks.

For the assessment of scenarios it suffices to use (1) the fragment NATO density, (2) the local fatal individual risk and (3) the collective risk for generic scenarios using person distribution estimates.

For minimum safety requirements of persons on the ground, the technical overhead safety of fuzes can be defined in a rigorous way.

See article "Quantitative hazard and risk analysis for fragments of high-explosive shells in air", Journal for Reliability Engineering & System Safety, 94(9), p.1461-1470

Outlook

For the flexible analysis of overflight scenarios the FSQRA 3D tool will be further developed, possibly using NABK input.

Fuze models of all used German mortar and artillery fuzes will be provided.

The aim is to build up a military/procurement user community.

The software can be used to determine overflight safety requirements for fuzes.

Methodology could be also used also for ground-air, air-ground and air-air scenarios, e.g. for active field protection systems.

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