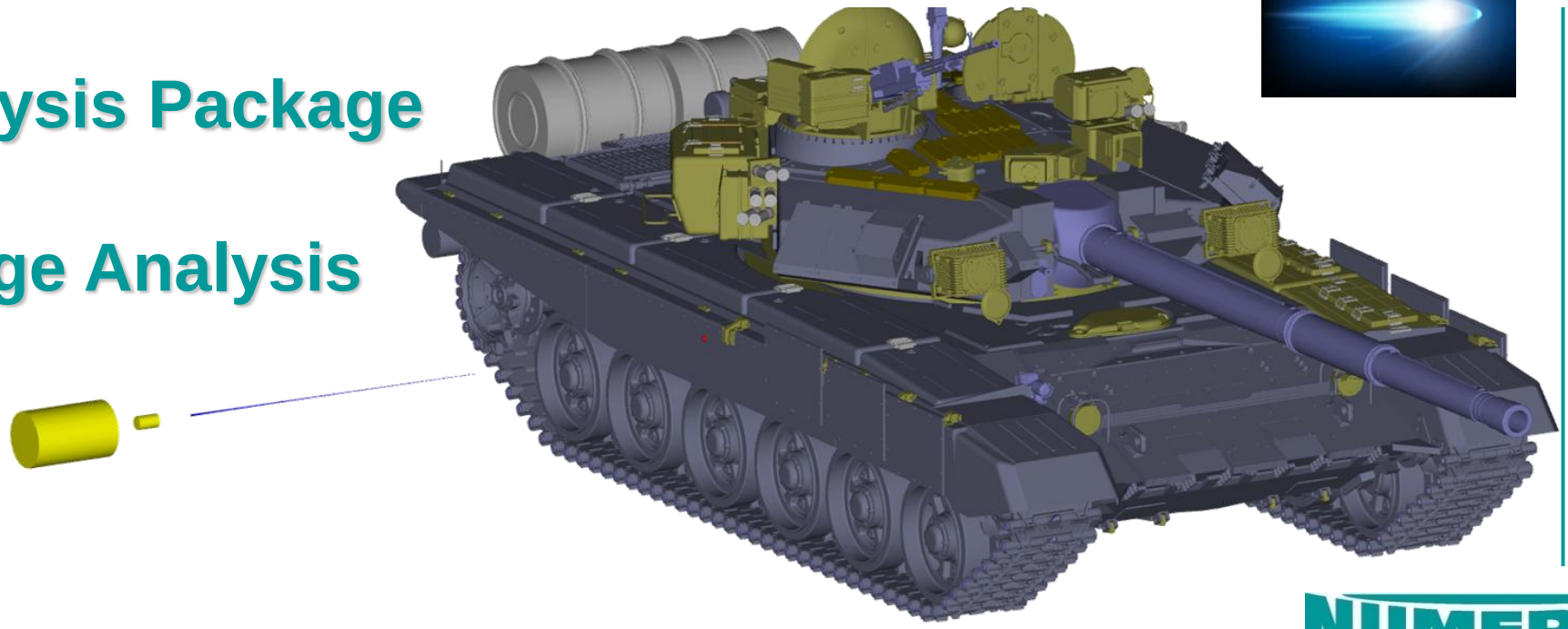
NUMERICS

Uniquely Specialized in
Simulation Software and Engineering Services

MAP-SC

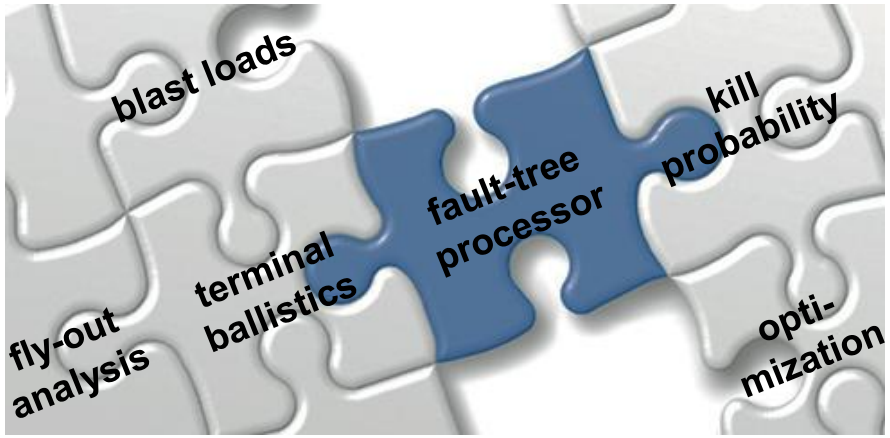
Modular Analysis Package for Shaped Charge Analysis



NUMERICS

What is MAP?

MAP (Modular Analysis Package) is a „unit assembly system“ for customized weapons effects (WE) and lethality / vulnerability (L/V) codes.



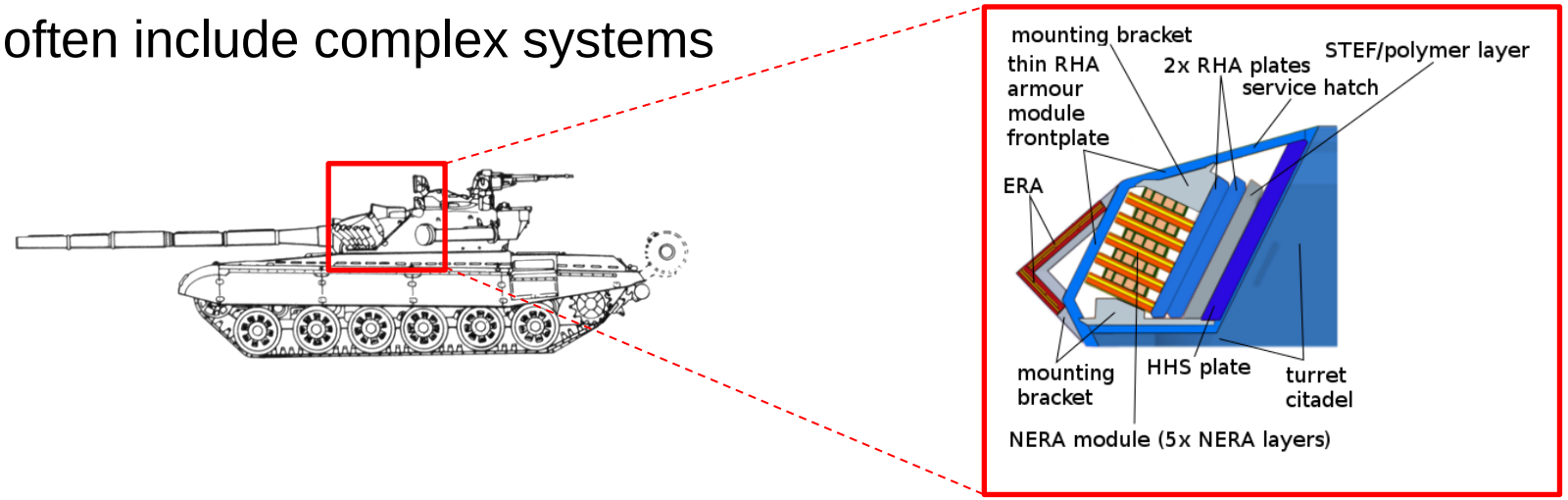
- Tailored software solutions are assembled from existing functional modules and adaped to customers‘ specific requirements
  → relatively short project time
  → tested and proven models
- Further modules can be added if the functional requirements change
  → high flexibility and adaptivity for future demands

Motivation for MAP-SC

Analyze terminal ballistics effects of several SC warheads into armor systems

Modern armor consists of different materials

and often include complex systems



Motivation for MAP-SC

Analyze terminal ballistics effects of several SC warheads into armor systems

Combine available models for different aspects into one complete software program

1. Threat modeling of the shaped charges including the stochastic effects (e.g. jet stretching, jet breakup, particle drift and rotation),

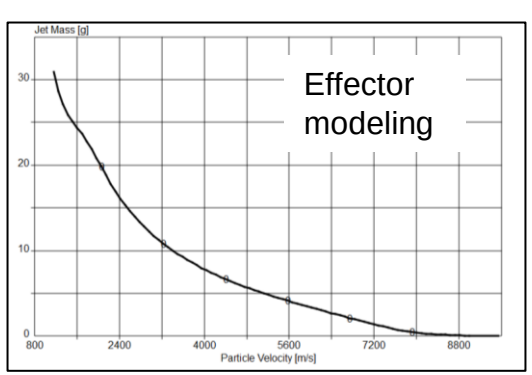
2. Terminal ballistics modeling of the SC jet with the main armor evaluating the penetration depth and the crater geometry caused by the jet particles,

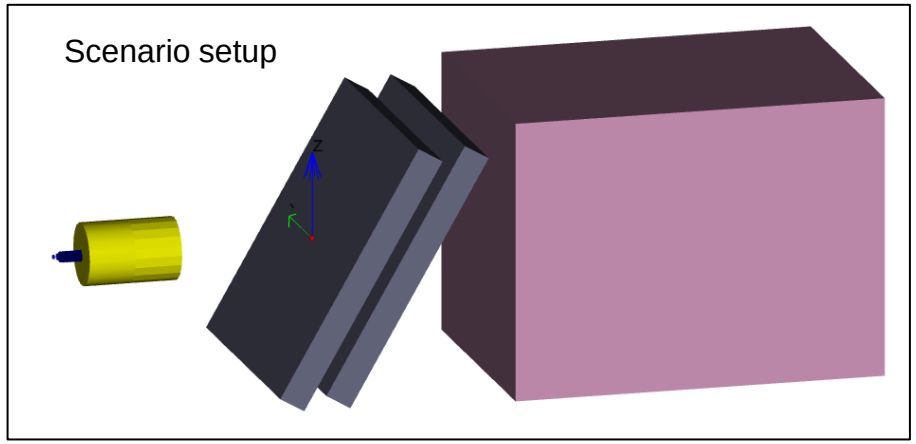
3. Terminal ballistics modeling with ERA plates including ERA initiation, ERA plate acceleration and interaction of the ERA plates with the SC jet,

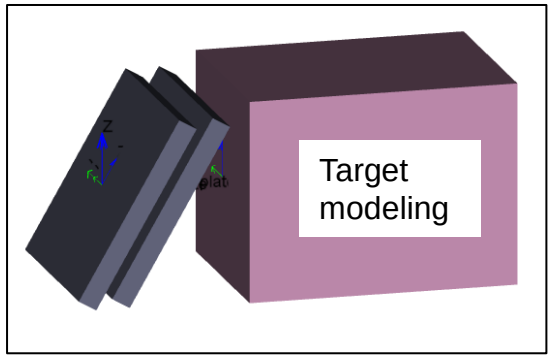
4. Behind armor debris modeling considering the exit of the jet particles and the detaching of the armor material at the rear surface.

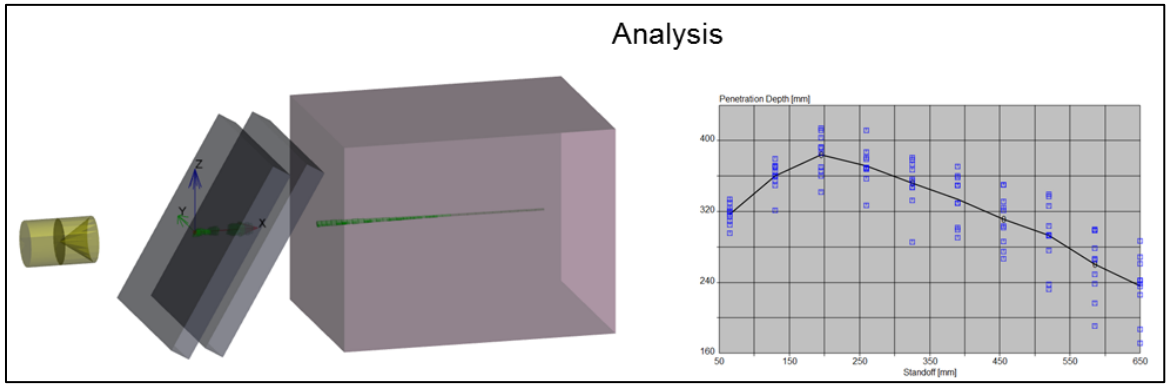
General Approach

Target and threat model are set up independently and combined in a scenario that is analysed in a calculation module.



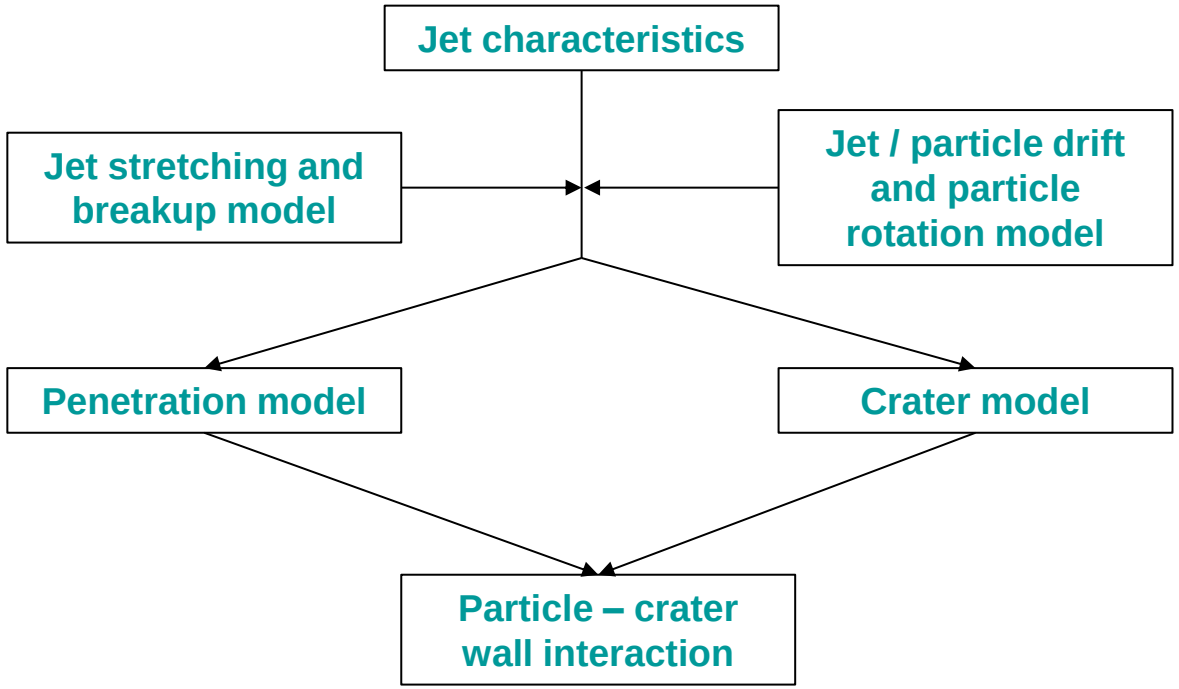


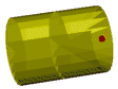


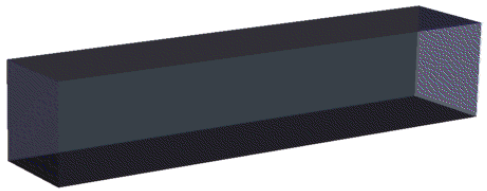


General Approach

Combination of (semi-)analytical models for individual shaped charge and terminal ballistics processes.

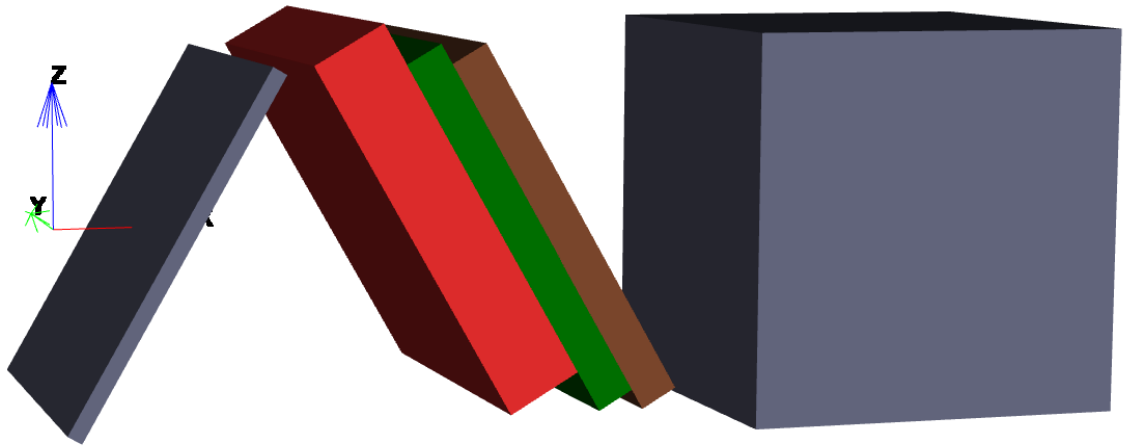






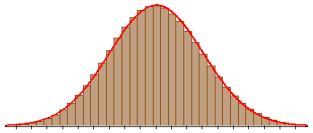
Target Model

In the MAP-SC basic version, target structures are modeled as an array of plates or blocks.

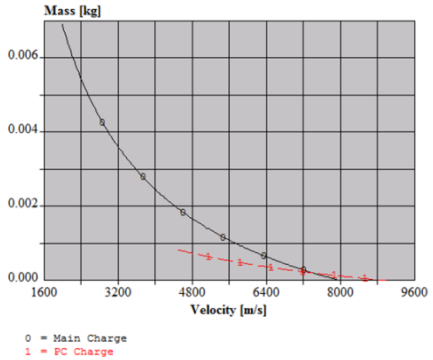


Shaped Charge Model

Different types of SC modeling are available



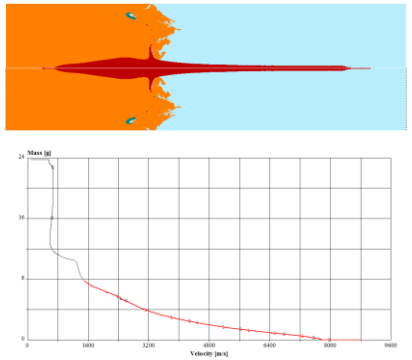
uncertainties



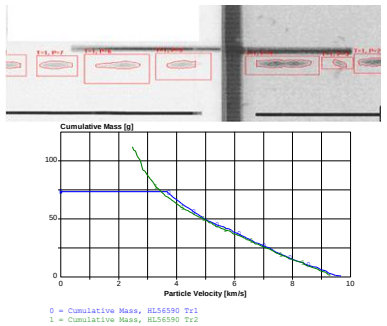
$$\frac{dM}{dv} = -a\frac{M_L}{v_{scale}} \cdot \left(\frac{v_{scale}}{v}\right)^q$$

from analytical function

Threat Model



from hydrocode (SPEED interface with multi-jet capability)



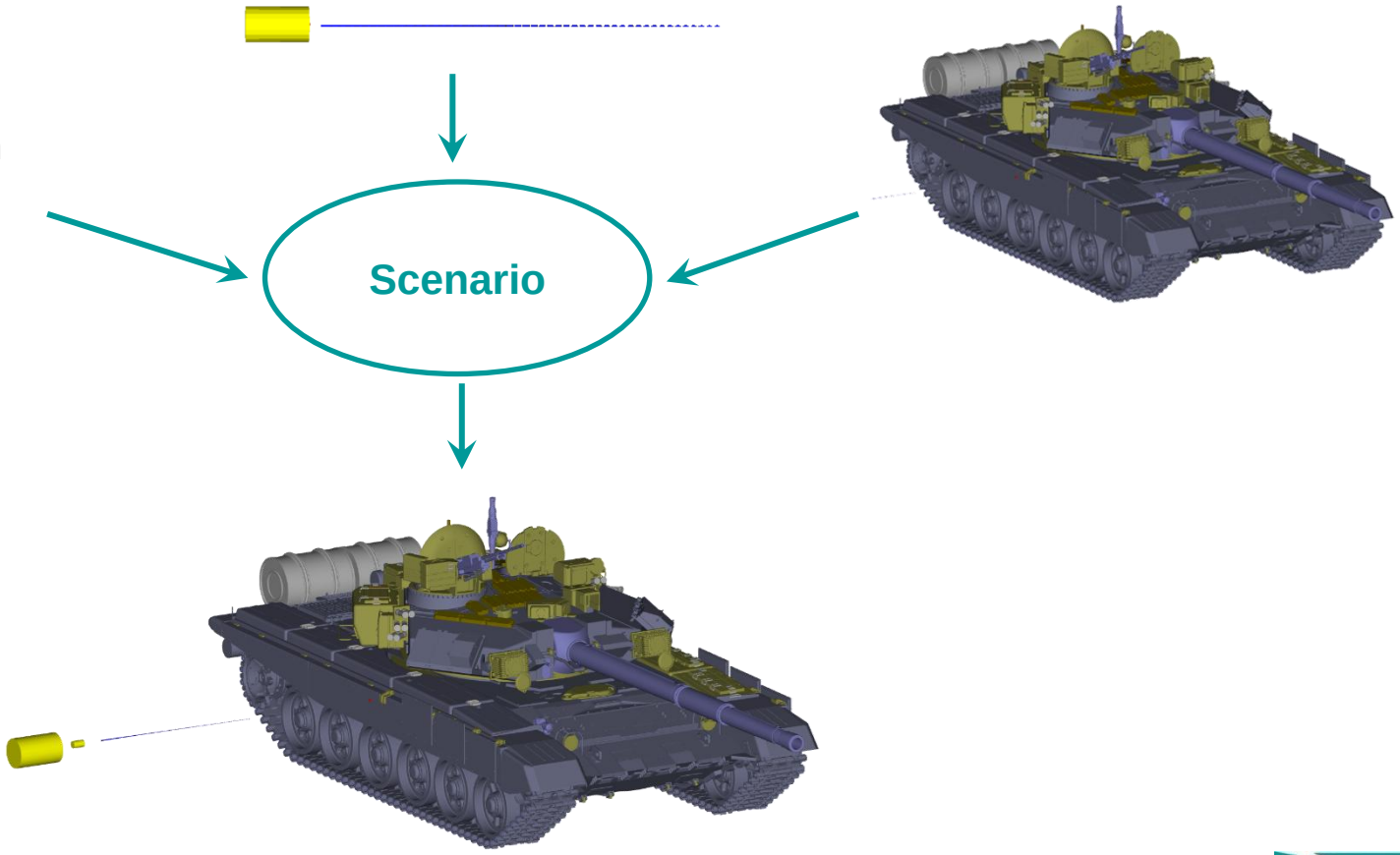
from experiments (optional)

Scenario

The encounter / endgame situation is defined separately in a scenario.

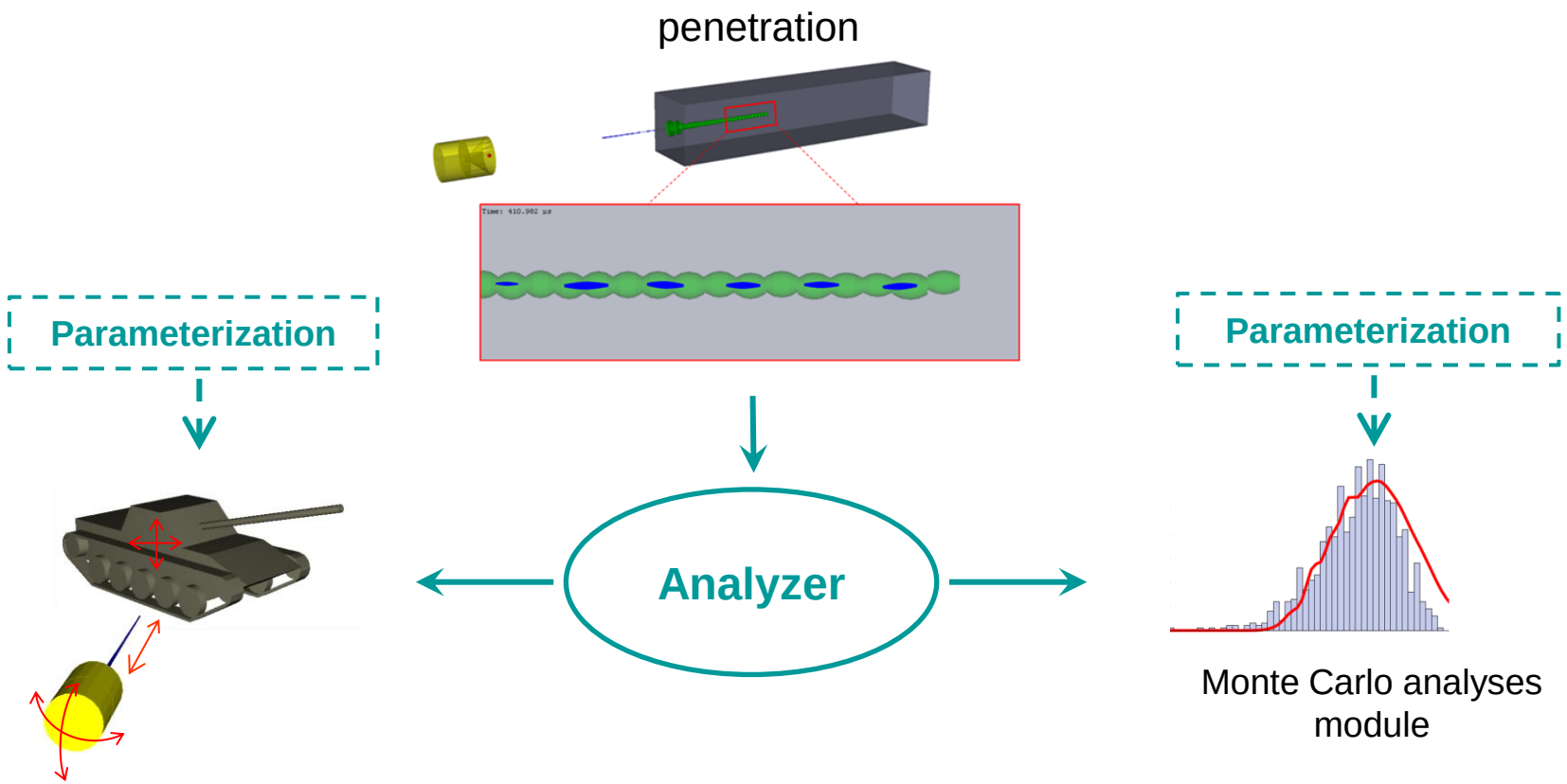
Parameters

- threat / target position
- threat / target velocity
- pitch, yaw, roll
- analysis settings
- …



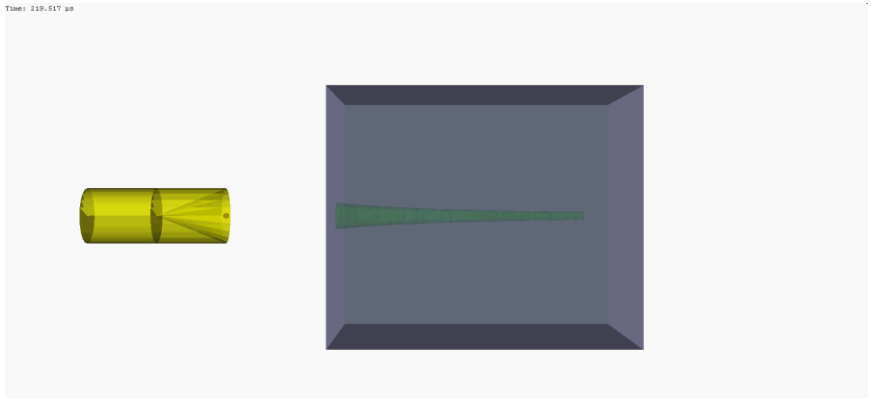
Analyzer

The analyzer can handle M/C simulations that can be parameterized if required.

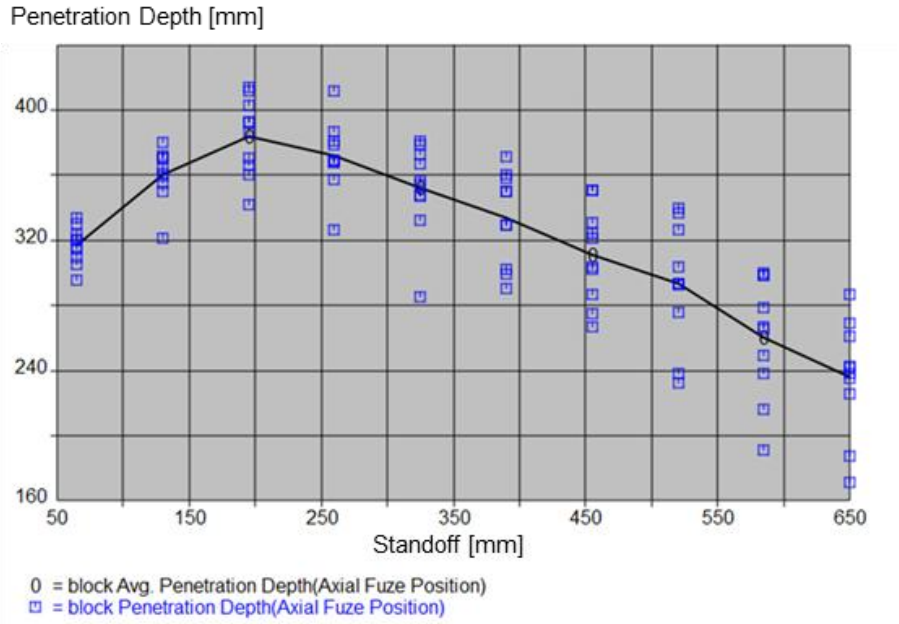


Output

- (animated) 3D graphics



- diagrams



Output

- text

Output

Effect Summary:

Component Name	Shots	Standoff [mm]	Pen.Depth [mm]	Min.Pen.Depth [mm]	Max.Pen.Depth [mm]	Std. Dev. [mm]	Cutoff Vel. [m/s]	Energy [J]	Momentum [m*kg/s]
block	10	150	435.602	357.967	515.656	60.5282	2365.99	197507	94.8675

Single Shots Effect Summary:

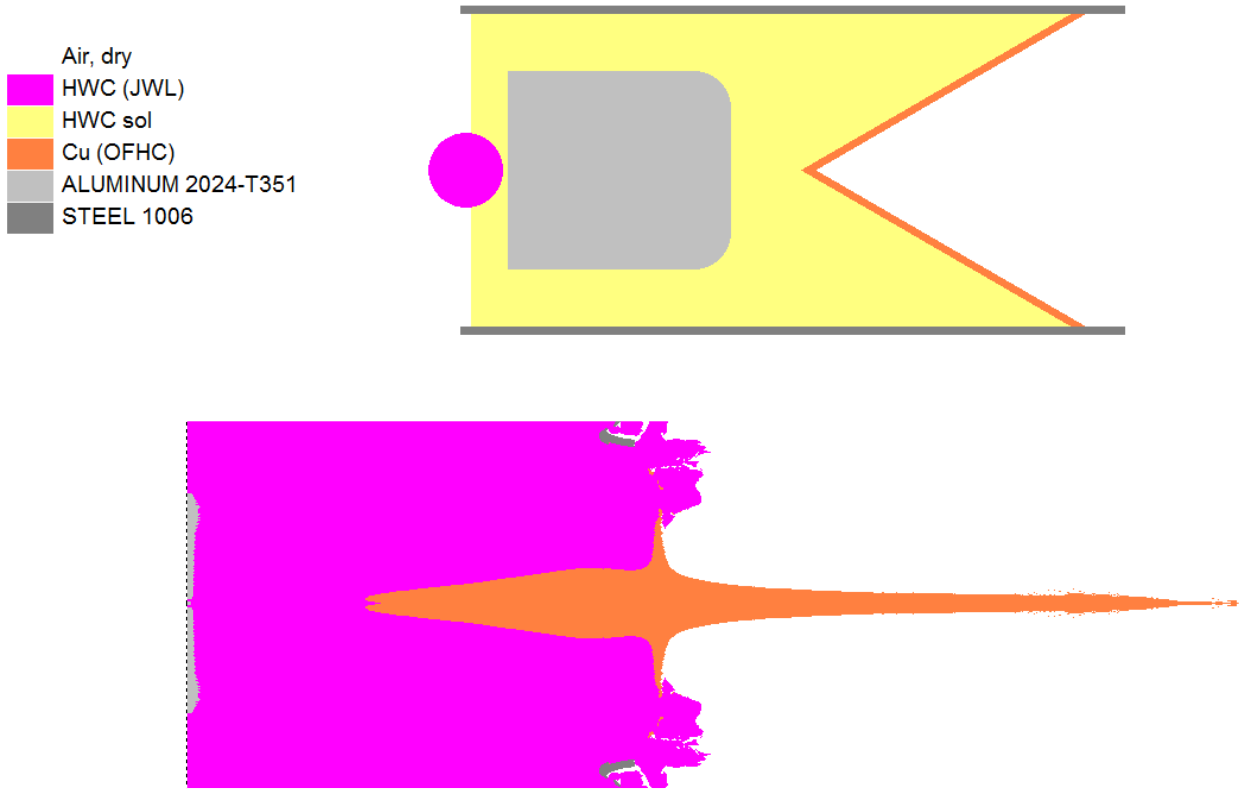
Component Name	Pen.Depth [mm]	Cutoff Vel. [m/s]	U0Y [m/s]	U1Y [m/s]	U2Y [m/s]	U0Z [m/s]	U1Z [m/s]	U2Z [m/s]	Energy [J]	Momentum [m*kg/s]
block	369.406	2689.99	-14.0151	1.57098	5.69626	21.6858	-1.72562	27.5913	195700	93.9101
block	357.967	2779.99	-23.0318	-1.12413	16.6447	17.1067	-1.14154	0.529425	195700	93.9094
block	478.193	2149.99	-1.8934	0.548647	-2.11605	7.5996	3.48871	8.64984	197959	95.1092
block	515.656	1789.99	-0.262454	-6.11364	-14.0202	3.2993	-2.01136	4.07122	197959	95.1093
block	456.514	2329.99	6.11409	0.609671	-18.6513	7.80673	1.79008	6.31612	197959	95.1091
block	400.793	2689.99	0.843835	-6.212	-10.5311	-19.2914	1.70067	17.229	197959	95.1086
block	515.542	1699.99	-1.03505	-2.29024	-8.72244	2.94274	-5.44694	-15.4092	197959	95.1093
block	445.741	2419.99	9.6531	-1.10593	-16.5766	9.77887	-2.56413	-6.95988	197959	95.109
block	359.696	2779.99	-19.9302	4.87876	-7.41903	-20.274	-11.7123	-20.0173	197959	95.1079
block	456.512	2329.99	-0.603476	-3.70054	11.768	-11.3607	-0.202691	2.41555	197959	95.1091

Main Charge Craters:

Time [ms]	X [mm]	Y [mm]	Z [mm]	Crater_L [mm]	Crater_D [mm]	Vel [m/s]	X0 [mm]	T0 [ms]
0.0294273	0	-0.118039	0.0945739	3.71655	6.5833	9529.99	-29.0346	0.0106409
0.0311548	3.7165	-0.0750436	0.0829347	1.99219	9.19978	8989.99	-29.0346	0.0108265
0.0316651	5.70868	-0.0672443	0.078709	2.03168	7.512	8899.99	-29.0346	0.0109074
0.0322035	7.74035	-0.0597206	0.0741363	2.07918	9.24665	8809.99	-29.0346	0.0110031
0.0326952	9.81952	-0.0530367	0.0699305	2.11608	6.70656	8719.99	-29.0346	0.0110376
0.0330283	11.9356	-0.0478923	0.0671806	2.16151	6.70986	8629.99	-29.0346	0.0108997
0.0337734	14.0971	-0.0297611	0.0608385	6.22207	5.36134	8539.99	-29.0346	0.0111584
0.0348641	20.3191	-0.0313935	0.0501173	2.30915	8.4599	8449.99	-29.0346	0.0112719
0.0354019	22.6283	-0.0264228	0.0451413	2.3631	9.6654	8359.99	-29.0346	0.0112795
0.0361279	24.9914	-0.0208646	0.0382373	2.41643	9.52187	8269.99	-29.0346	0.0114573

Example – Standoff Curve

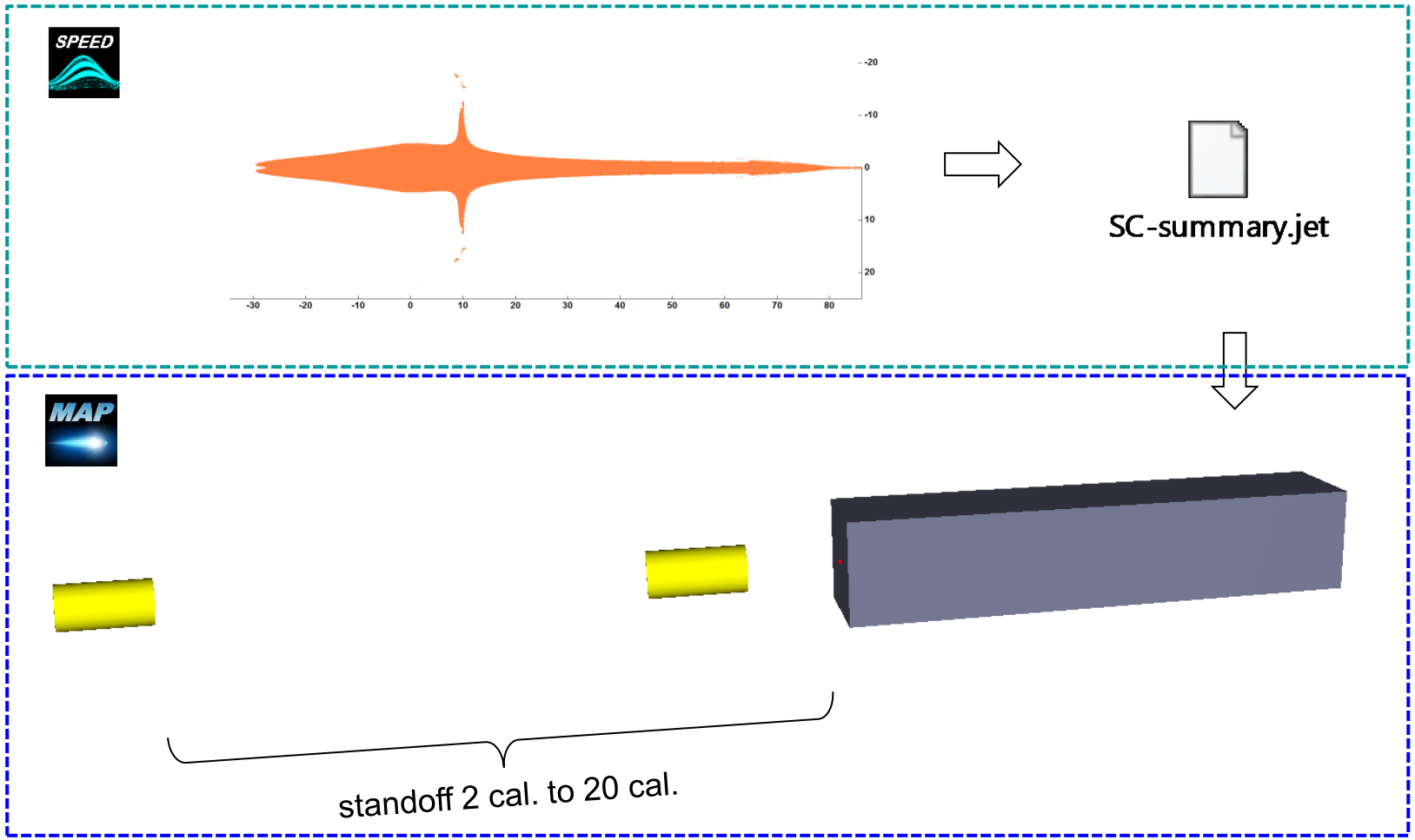
Determination of a standoff curve for the SC KB44



Hydrocode simulation (SPEED) of jet formation

Example – Standoff Curve

Determination of a standoff curve for the SC KB44



Example – Standoff Curve

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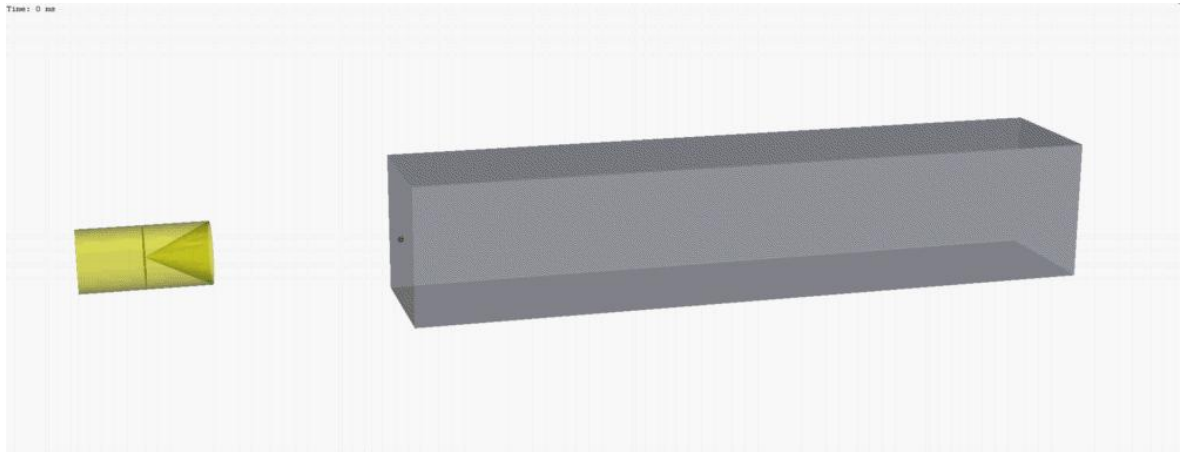
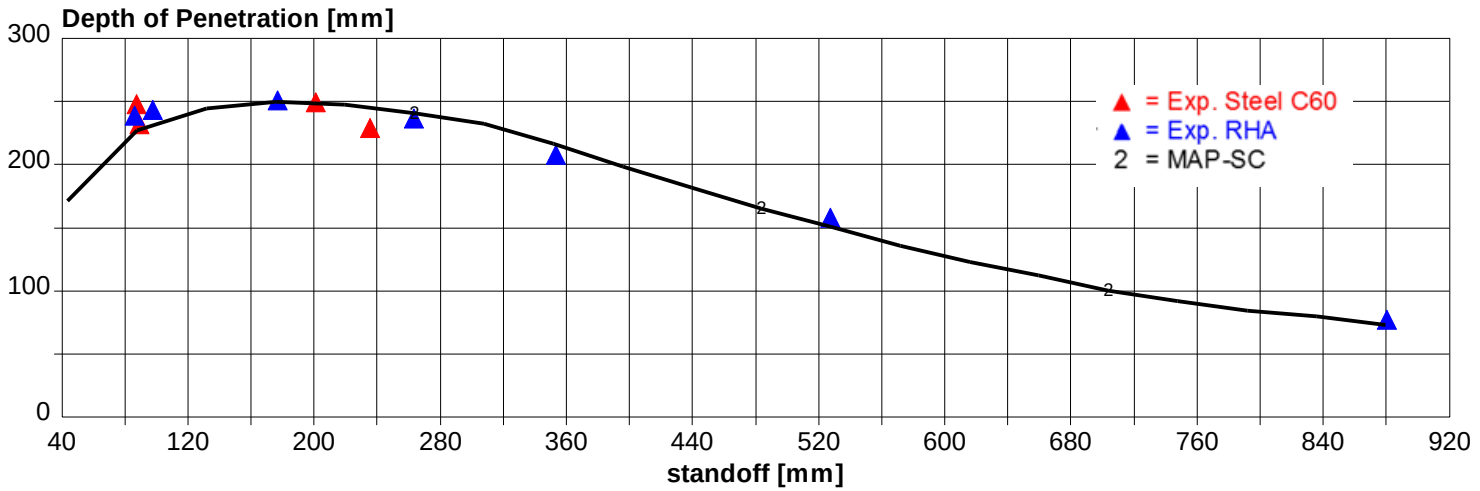
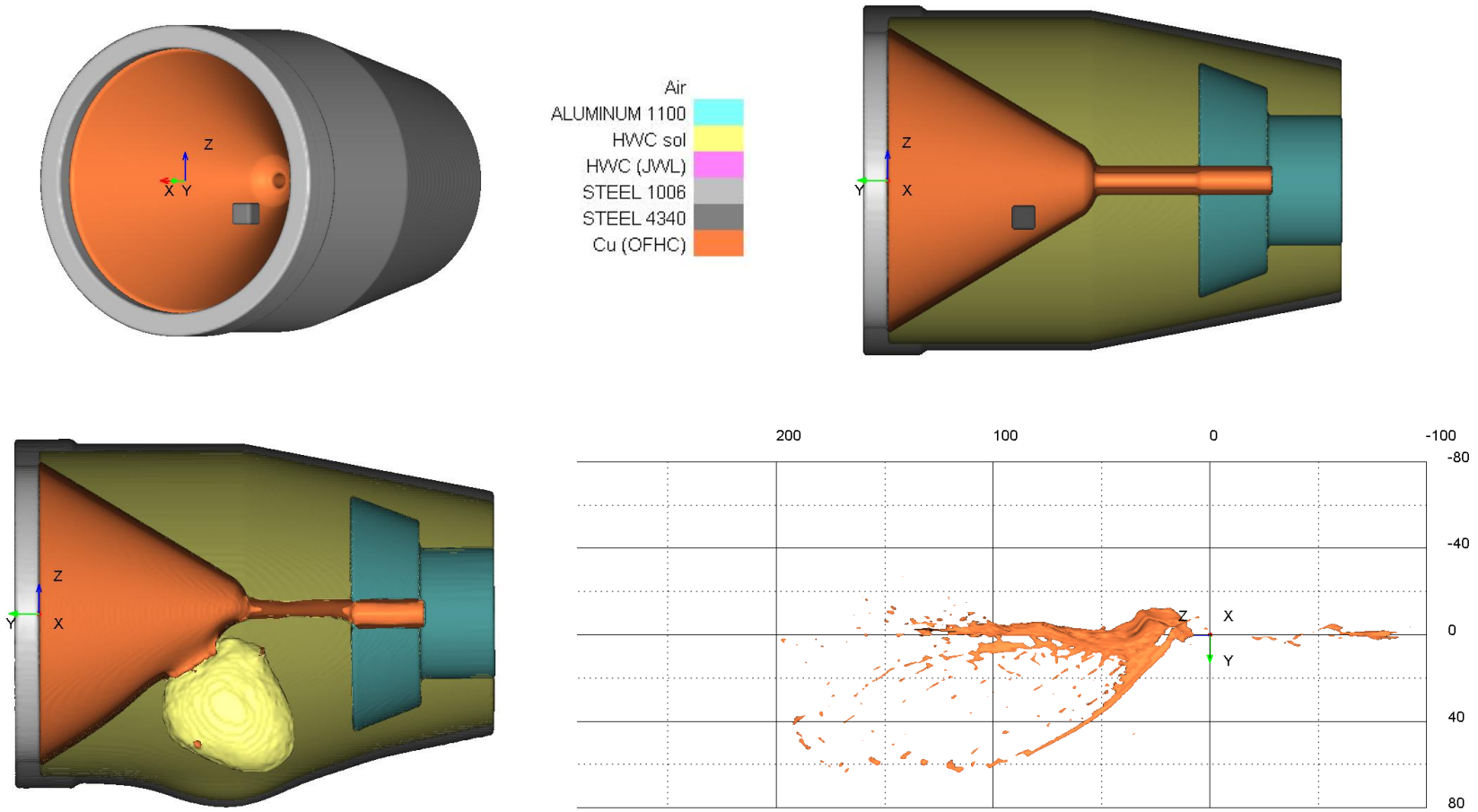




Example – Disturbed Jet (Multi-Jet)

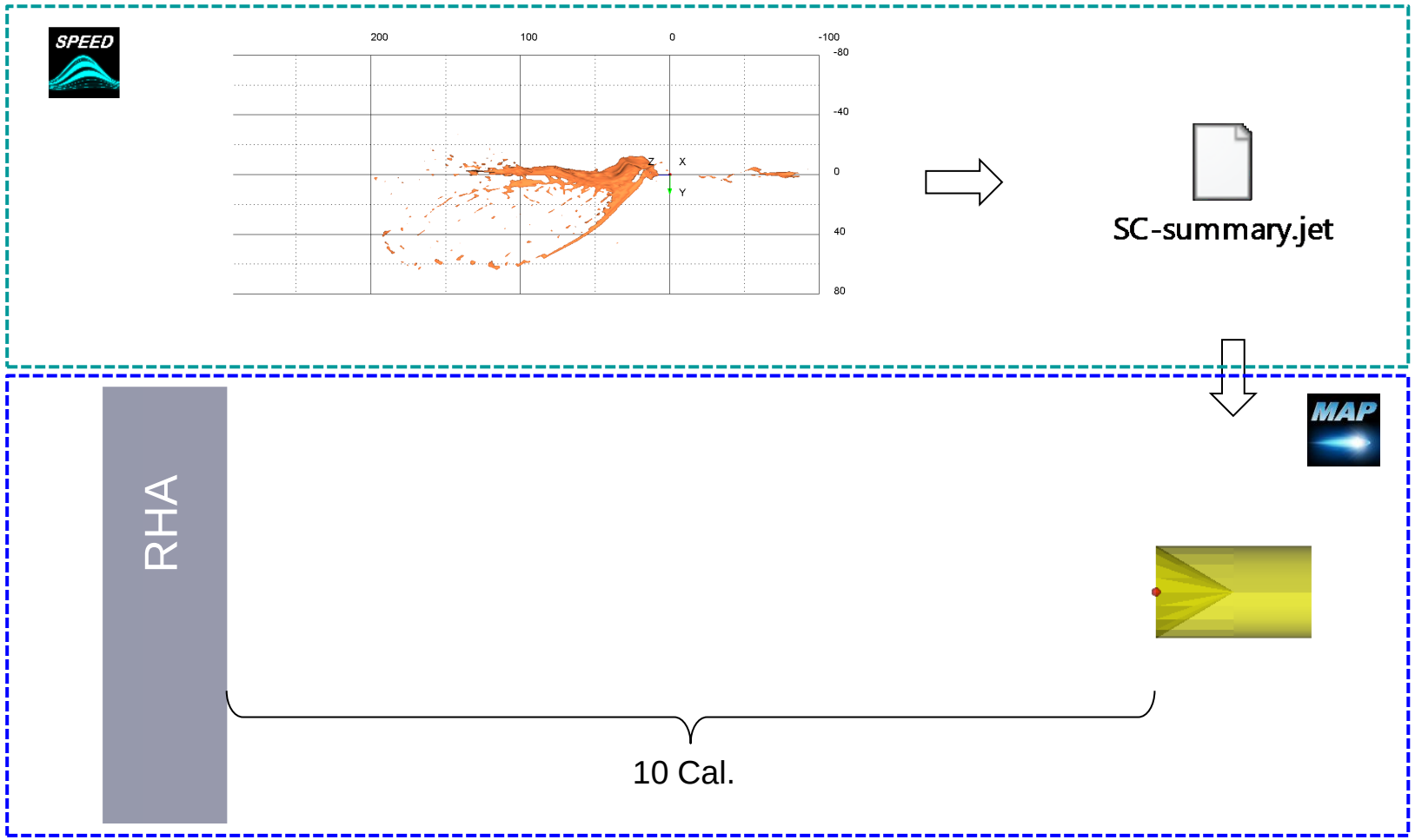
Residual penetration performance of SC after fragment impact



Hydrocode simulation (SPEED) of fragment impact and disturbed jet formation

Example – Disturbed Jet (Multi-Jet)

Residual penetration performance of SC after fragment impact

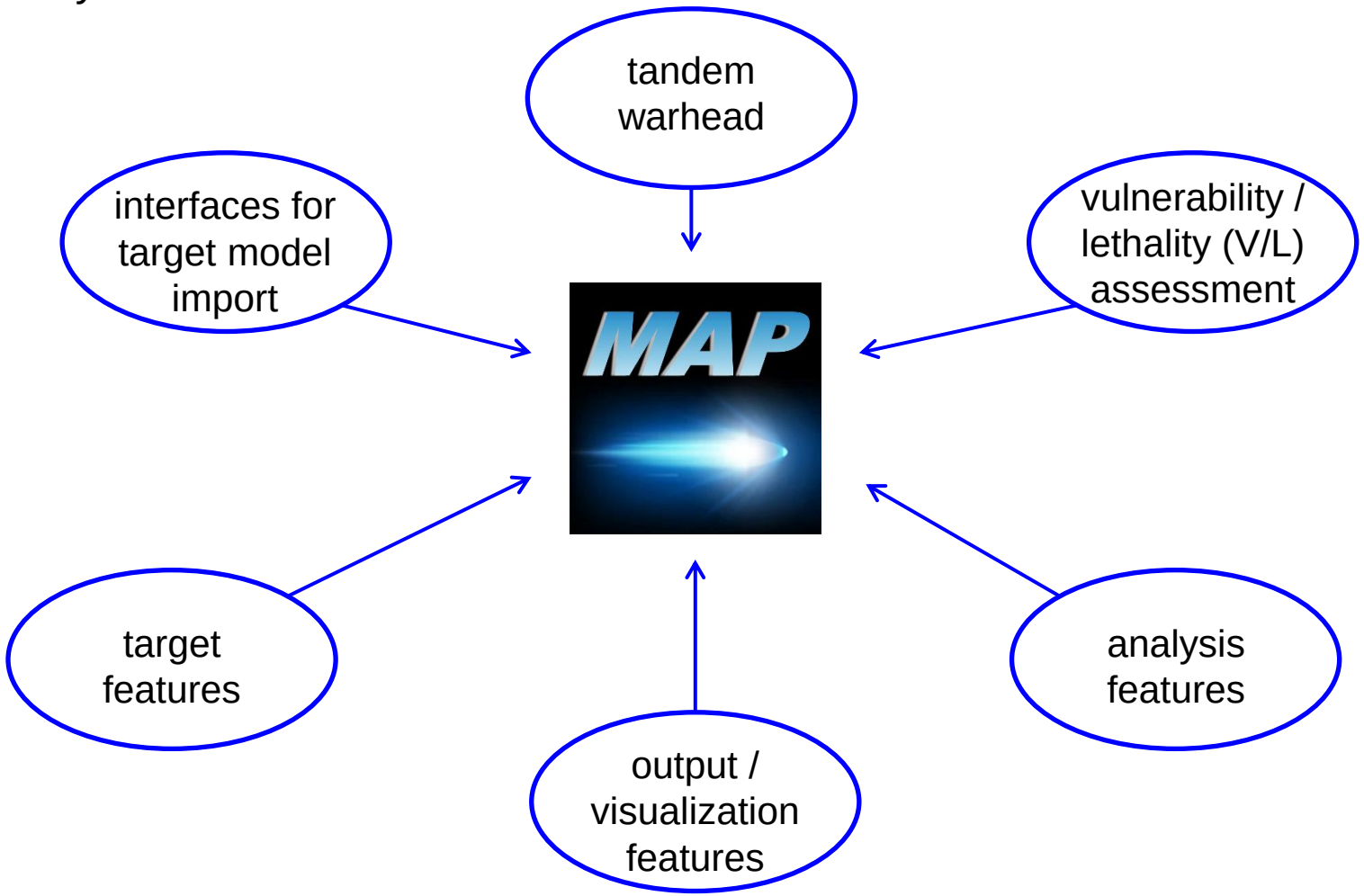


Example – Disturbed Jet (Multi-Jet)

Residual penetration performance of SC after fragment impact

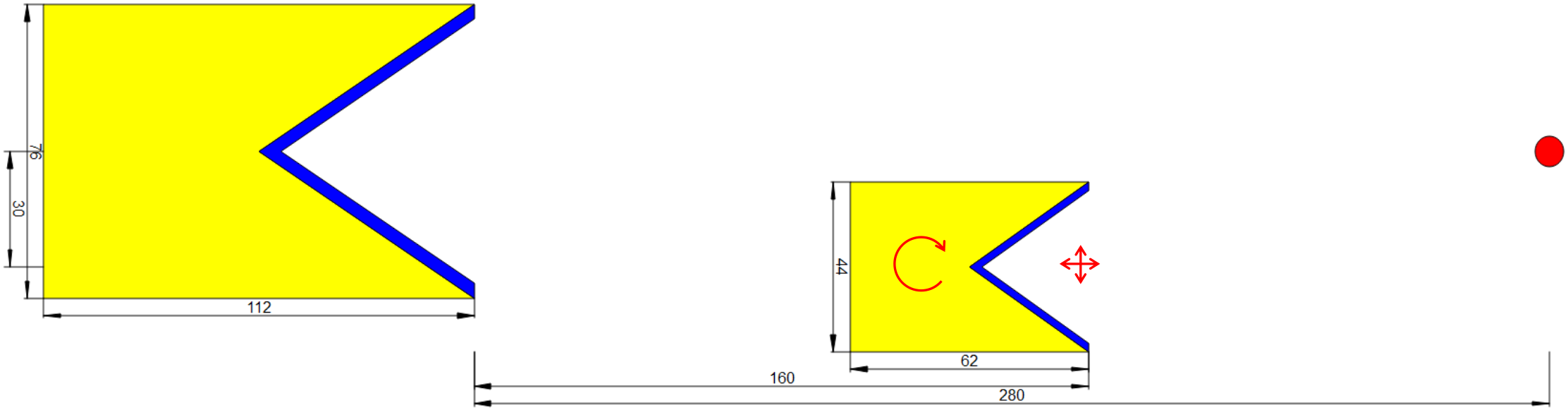
Optional Modules for Customization

The described basic version is readily available. However, it can be further enhanced / customized by additional modules.



Tandem SC Module

Tandem warheads can be considered with a tandem module.

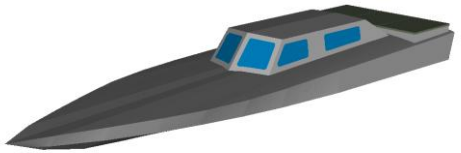


- radial offset
- inclination
- user-defined delay time

Target Modeling Modules

Target modeling can be enhanced by interfaces for geometry import in different formats or by an increased functionality of the integrated modeler.

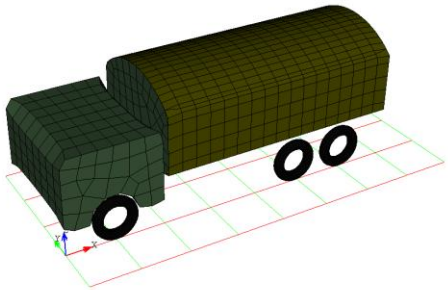
BRL-CAD interface



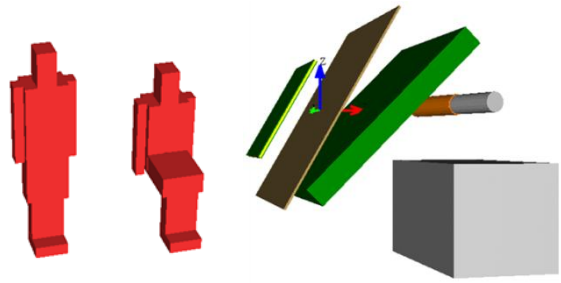
STEP interface

Target Model

k-file interface



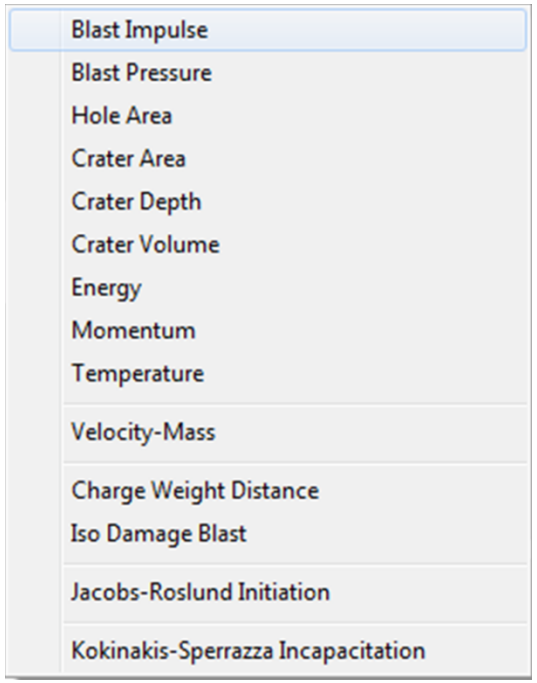
enhanced integrated modeler

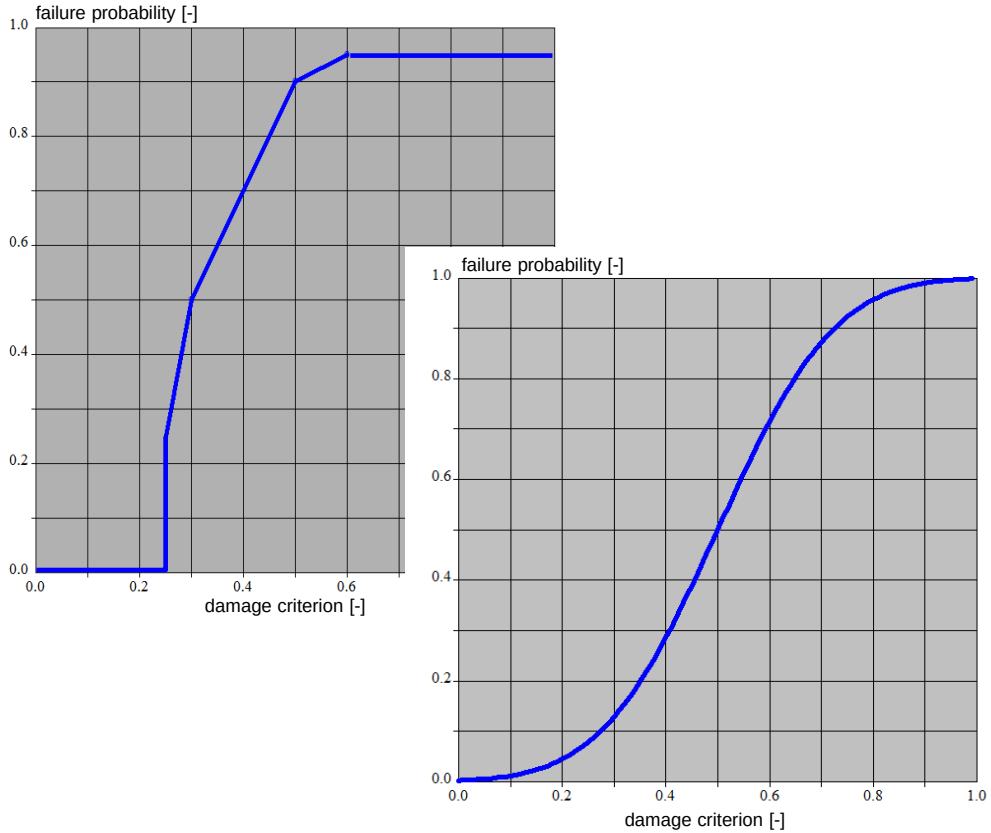


L/V-Module – Target Functional Modeling

The functional model of the L/V module consists of two parts:

1. Damage criteria definition (Type + Failure Probablilities)

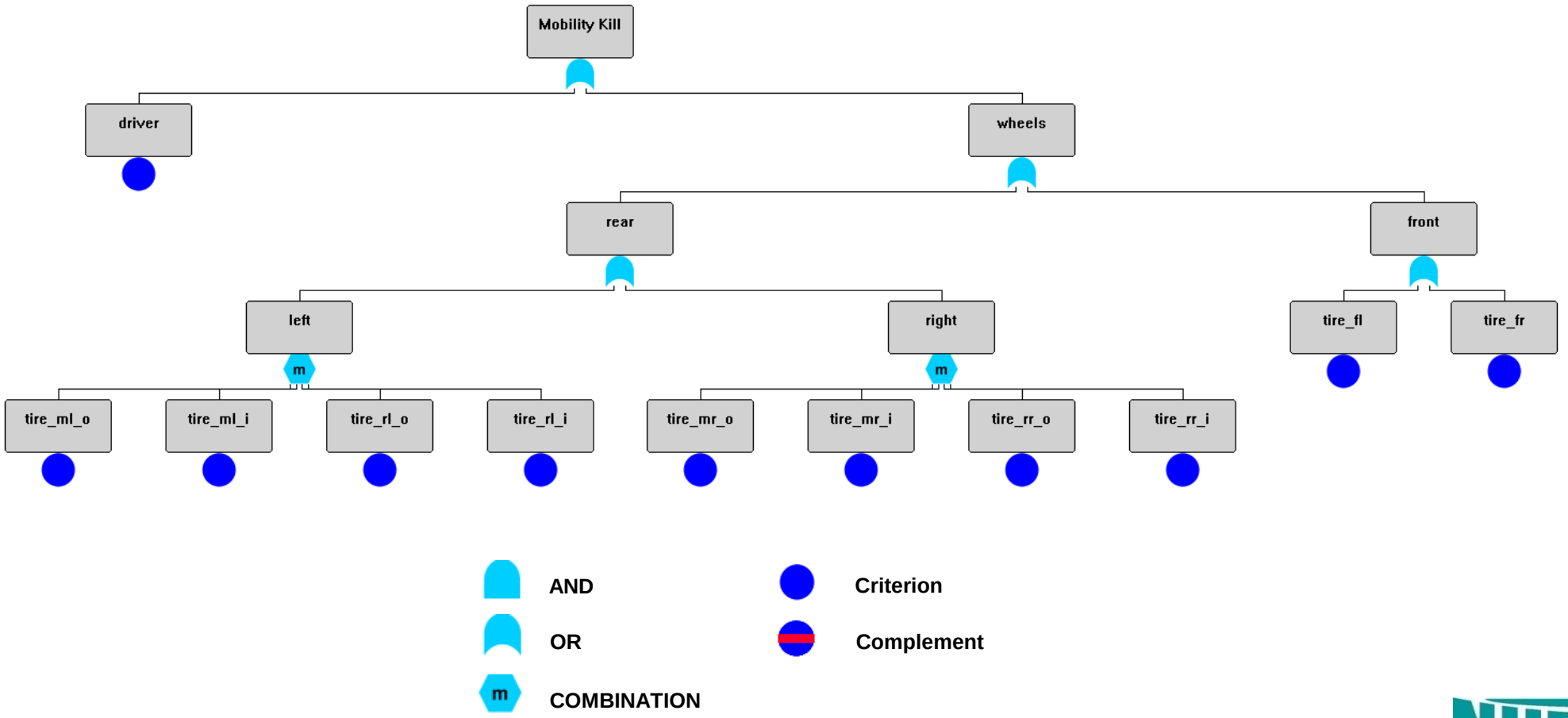




L/V-Module – Target Functional Modeling

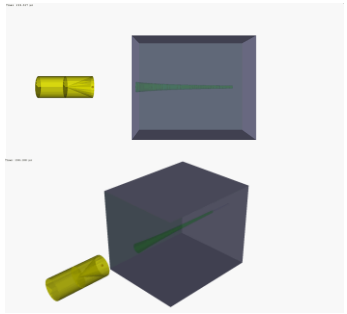
The functional model of the L/V module consists of two parts:

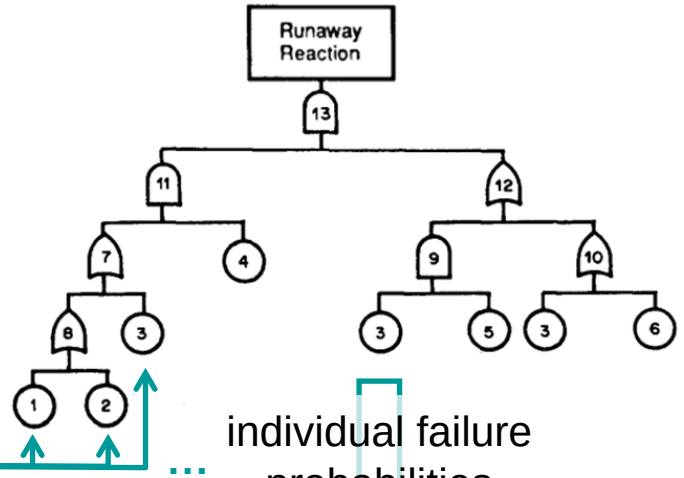
2. Fault Tree



L/V-Module – Fault Tree Processor

The single failure probabilities are combined according to their relationship defined in the fault tree.





Analysis result

…

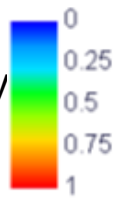
individual failure probabilities

Fault Tree Processor

statistically independent events
→ direct calculation

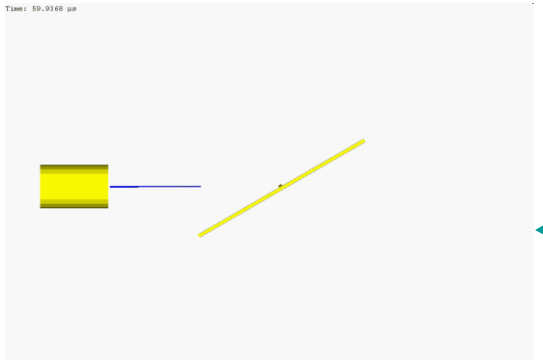
statistically dependent events
→ recursive algorithm (Page & Perry)

Kill Probability P_k

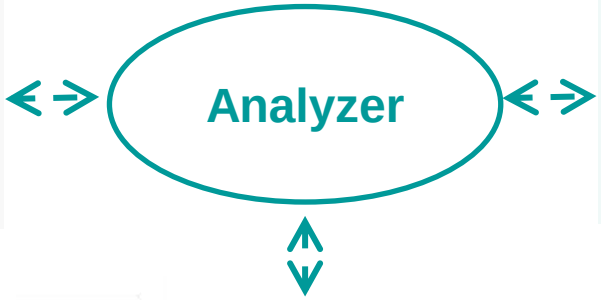


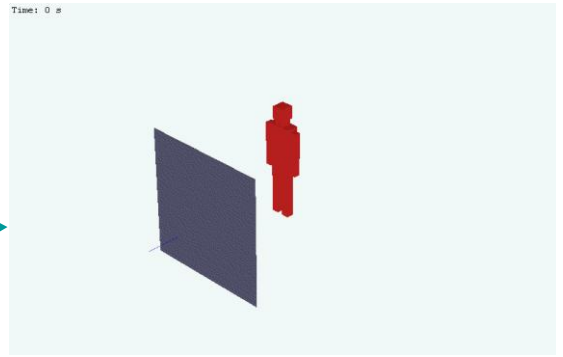
Analyzer Modules

The analyzer can be enhanced to conduct gridded simulations that can be parameterized if required. Add-ons for BAD and ERA are also available.

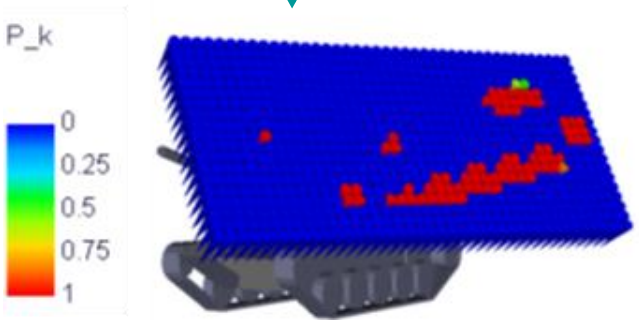


ERA module





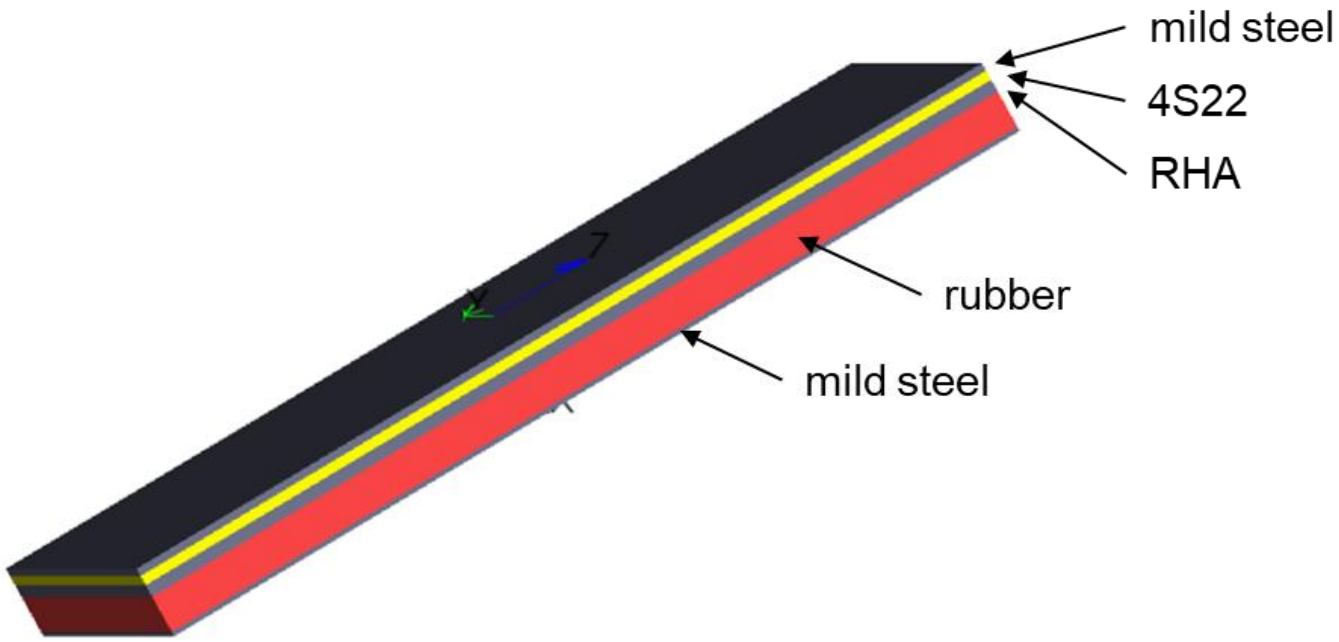
BAD module



gridded analyses module
(vulnerability)

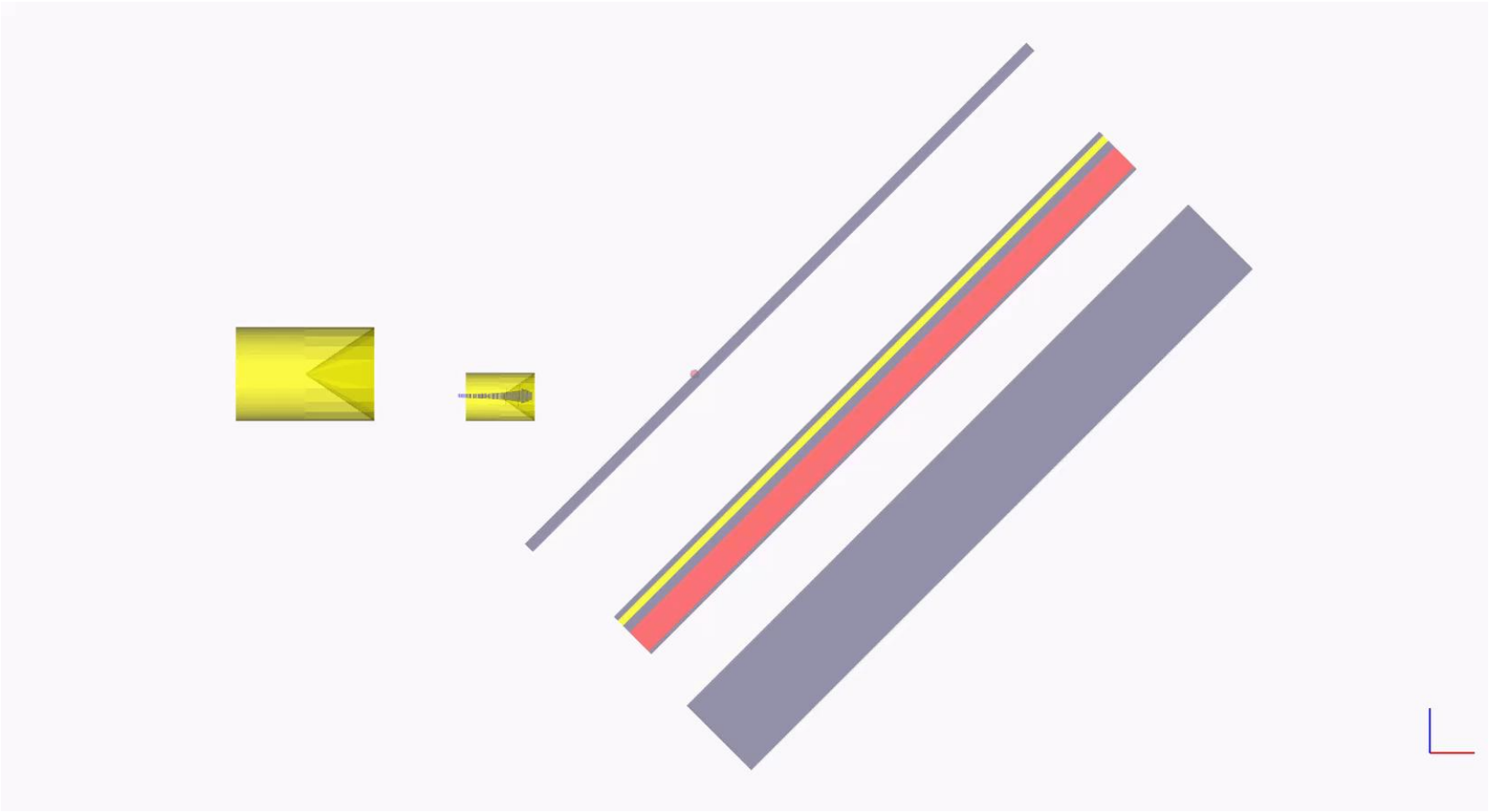
ERA Module

The ERA module allows to model sandwich structures with one explosive layer and an arbitrary number of flyer plate layers.



ERA Module

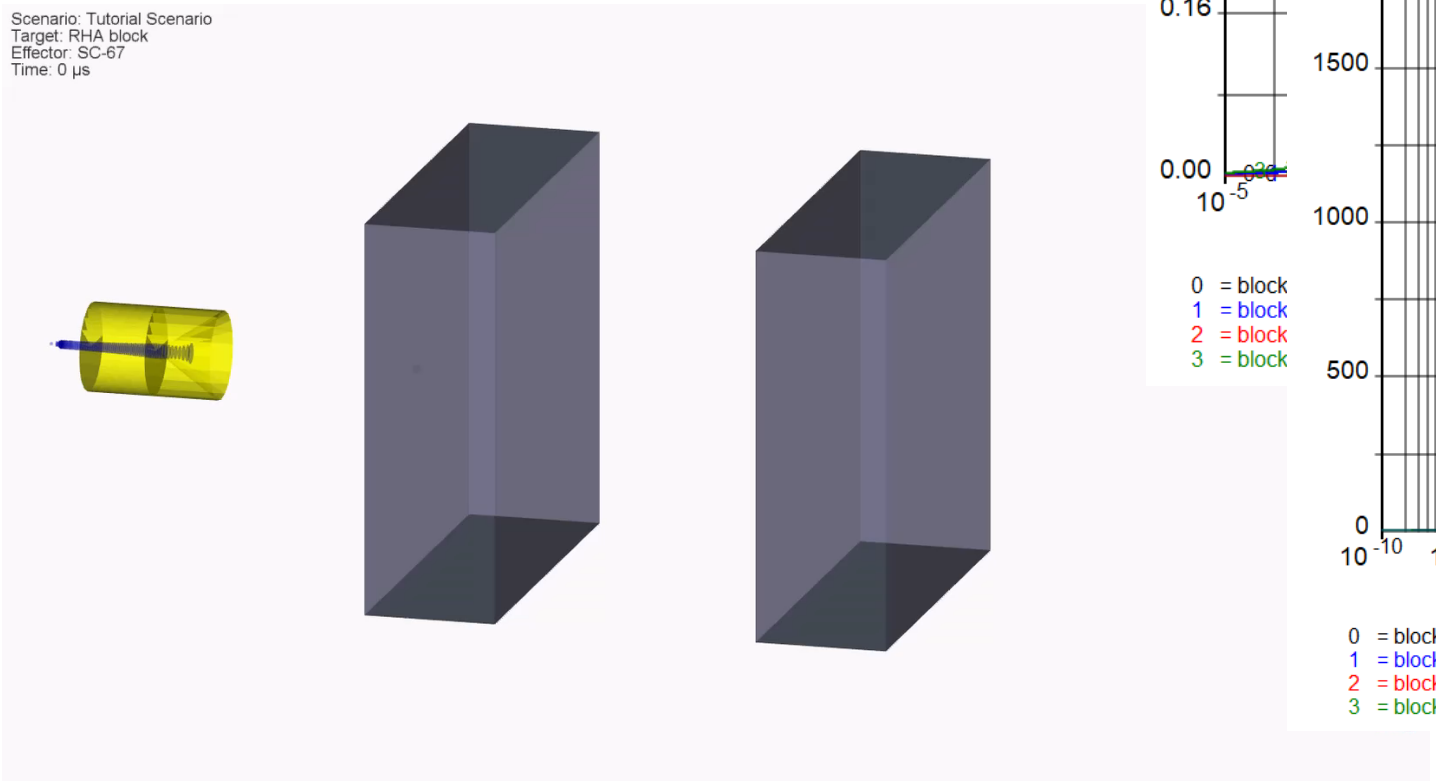
Note: ERA plates are stopped when hitting a target plate (→ no momentum transfer)

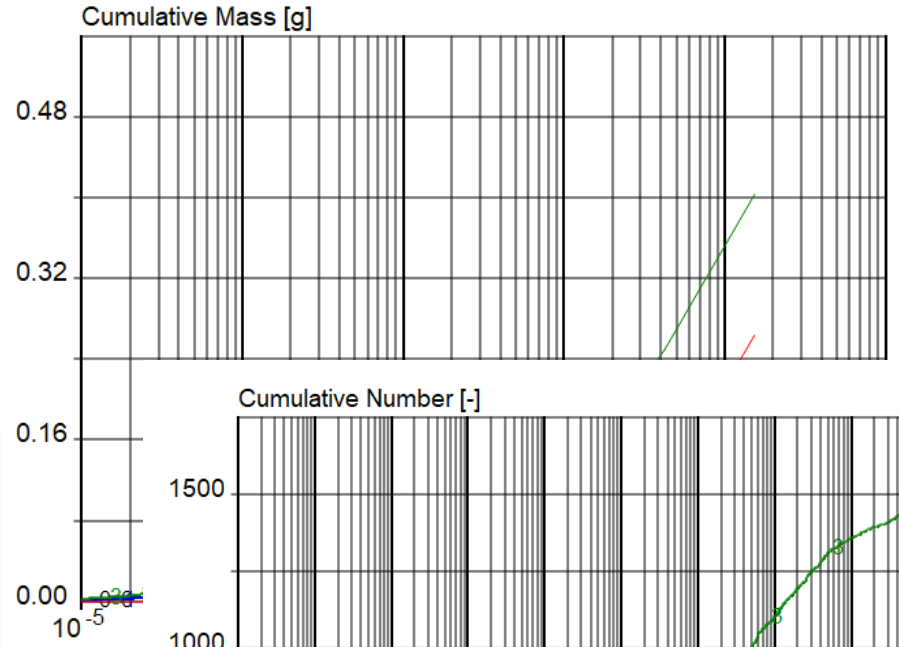


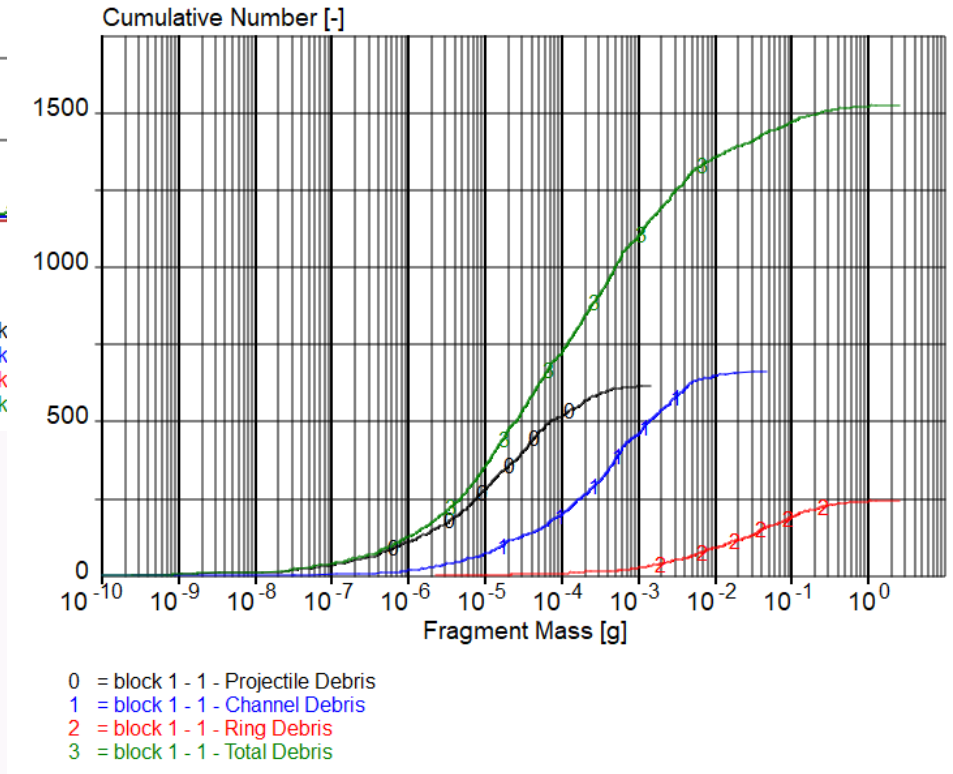
BAD Module

Behind Armor Debris can be fully evaluated:

- fragment mass distribution M(m) and N(m)
- fragment trajectories
- fragment terminal ballistics



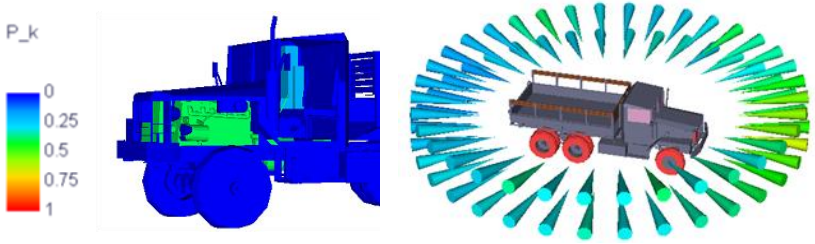




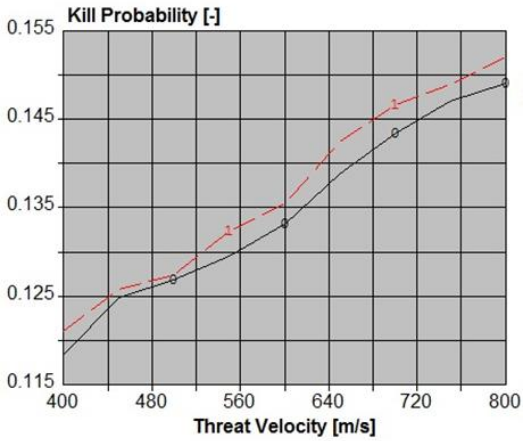
Augmented Output

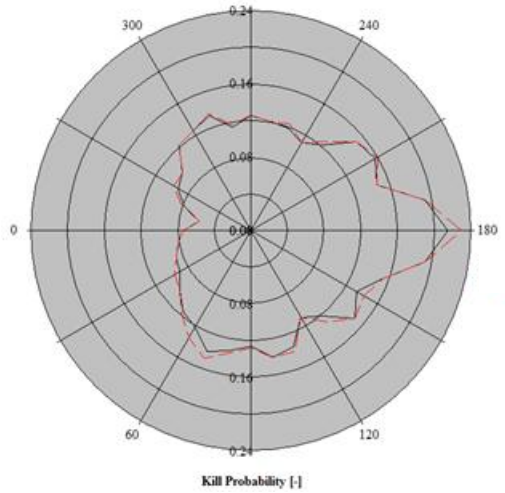
The output can be augmented according to user requirements:

- unidirectional (2D) and multi-directional (3D) graphics



- Cartesian and polar diagrams

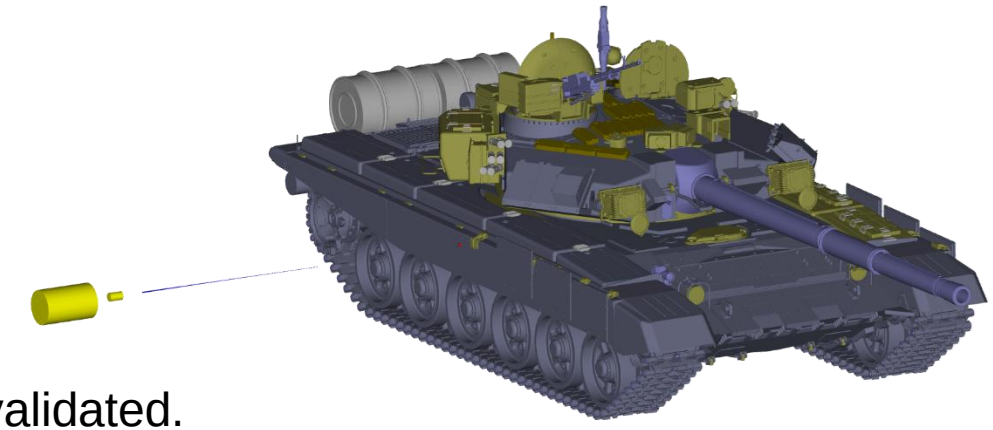




Summary

The presented shaped charge module of the Modular Analysis Package (MAP) offers a broad variety of features for a customized weapon effects and / or lethality / vulnerability (L/V) code.

A basic version for target modeling, shaped charge definition, scenario setup, analysis and output is readily available, but can also be enhanced and adapted to the specific customer requirements.



Thereby, MAP offers several advantages:

1. Calculation / analysis algorithms are tested and validated.
2. Customer-specific new model developments can easily be integrated.
3. Building up on existing functional modules significantly reduces the project duration for customization.
4. The modular structure provides the flexibility to include functional extensions to account for future requirements.

Thank You for Your Attention !