AVAL 6.6

User’s Manual Direct Firing

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Direct Firing

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1 Building a scene

Simulations in direct fire mode are performed in a scene containing ground geometry, ground objects and one or more targets. The ground description is not required if the scene includes aerial targets only but essential if any target in the scene is described as a ground target.

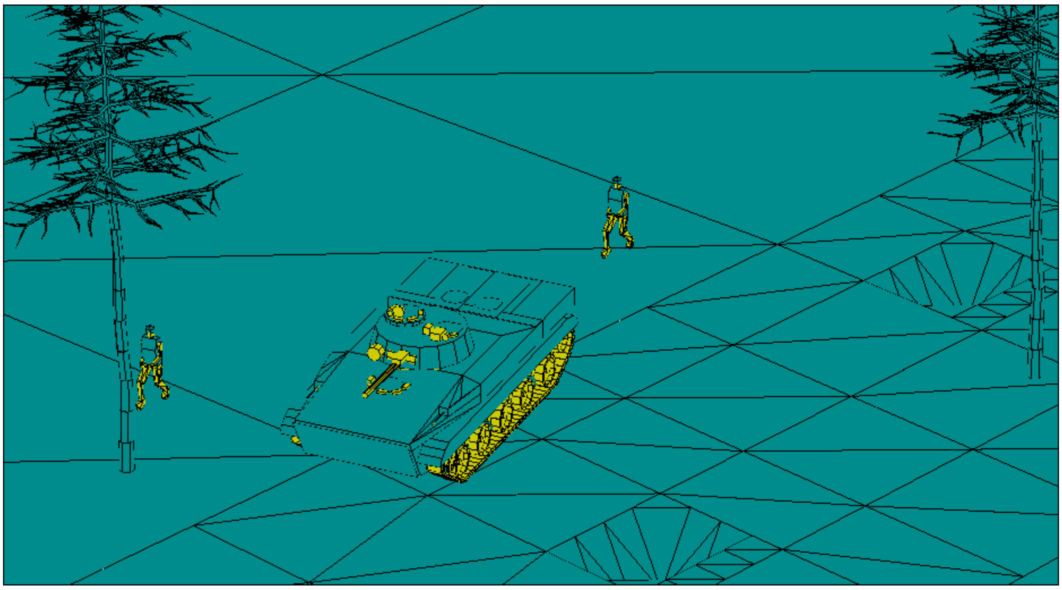

Figure 1 Example of a scene showing a ground meshes describing a few pits, three targets and two ground objects.

Both ground, ground objects and targets are described in separate files and included in the scene by their file path and a position in the scene coordinate system. A target description or ground object description can be used in several places in a scene. The format of the ground and ground object descriptions are discussed later in this chapter. Target descriptions included in a scene is of the same format as targets used in the single target mode of AVAL and any AVAL target can be used in scene. (See the *Target description manual* in the AVAL documentation for more information). Ground and ground objects are used in two ways during a simulation, they can cause burst points when hit by a warhead carrier and they decrease the penetration capacity of warhead effects if hit.

A direct fire simulation can be accomplished with either a complete description of a weapon platform or with a single warhead carrier. In a simulations with a weapon description the weapon aim ability and the ballistic performance of the warhead carrier is described and simulated. In simulations with a single warhead carrier a strait travel of the warhead is used in a user defined aimpoint in the scene.

1.1 Coordinate system

The position of all weapons, targets and ground objects are given in the scene coordinate system. In this system the x-axis is pointing towards north, y-axis towards wets and z-axis upwards.

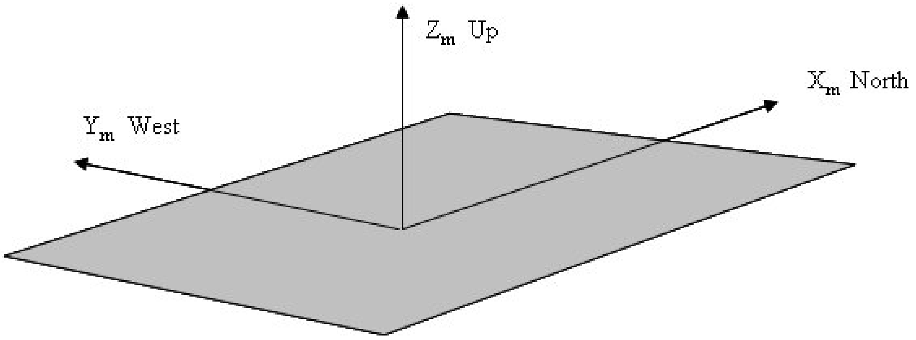

Figure 2 Scene coordinate system.

If a target is described as a ground target in the scene following parameters are used to define its position:

x_t	X-coordinate of the target position in the scene coordinate system.
y_t	Y-coordinate of the target position in the scene coordinate system.
Bearing	Target direction relative north (x-axis).

The z-level of the target is calculated so that the lowest z-coordinate of the target is on the ground. The elevation and roll angle of the target is calculated with respect to eventual ground slopes.

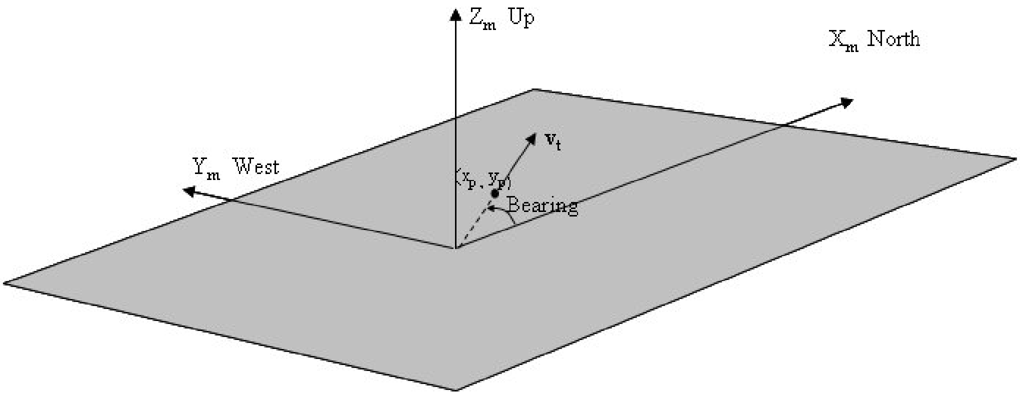

Figure 3 Scene coordinate system-

If a target is specified as an aerial target its position is described with following parameters:

x_t	X-coordinate of the target position in the scene coordinate system.
y_t	Y-coordinate of the target position in the scene coordinate system.
h	Target position above the xy-plane.
Bearing	Target direction relative north (x-axis).
Elevation	Target direction relative the xy-plane. Positive upwards.
Roll	Target rotation around its x-axis.
v_t	Target absolute velocity in its x-axis direction.

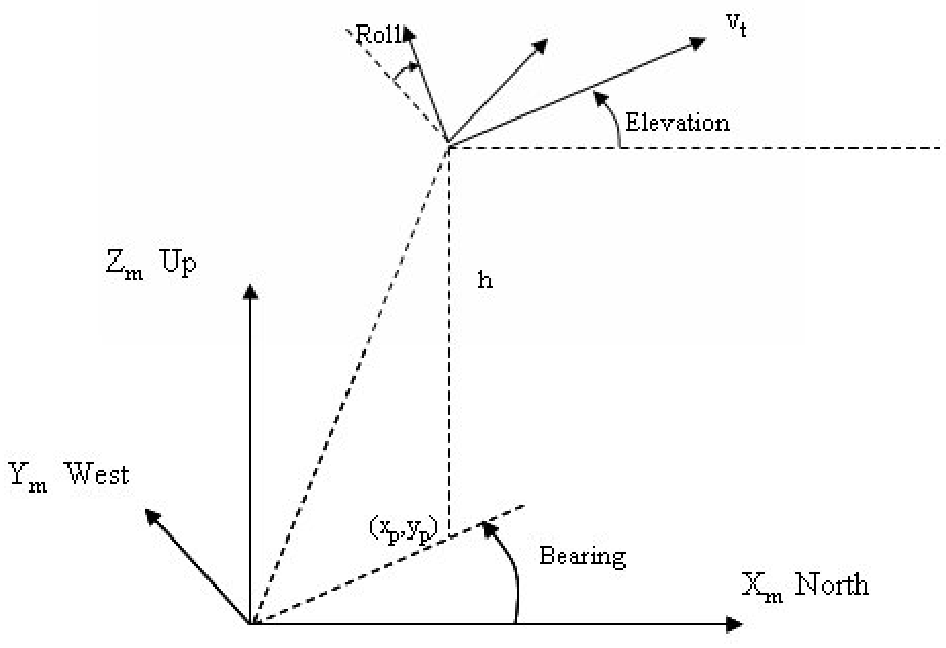

Figure 4 Coordinate system for an areal target.

1.2 Scene description

A direct fire scene consists of ground geometry, one or more targets and ground objects as mentioned earlier.

The scene can be defined in a dialog opened via ***Scene -> Create…*** in the menu.

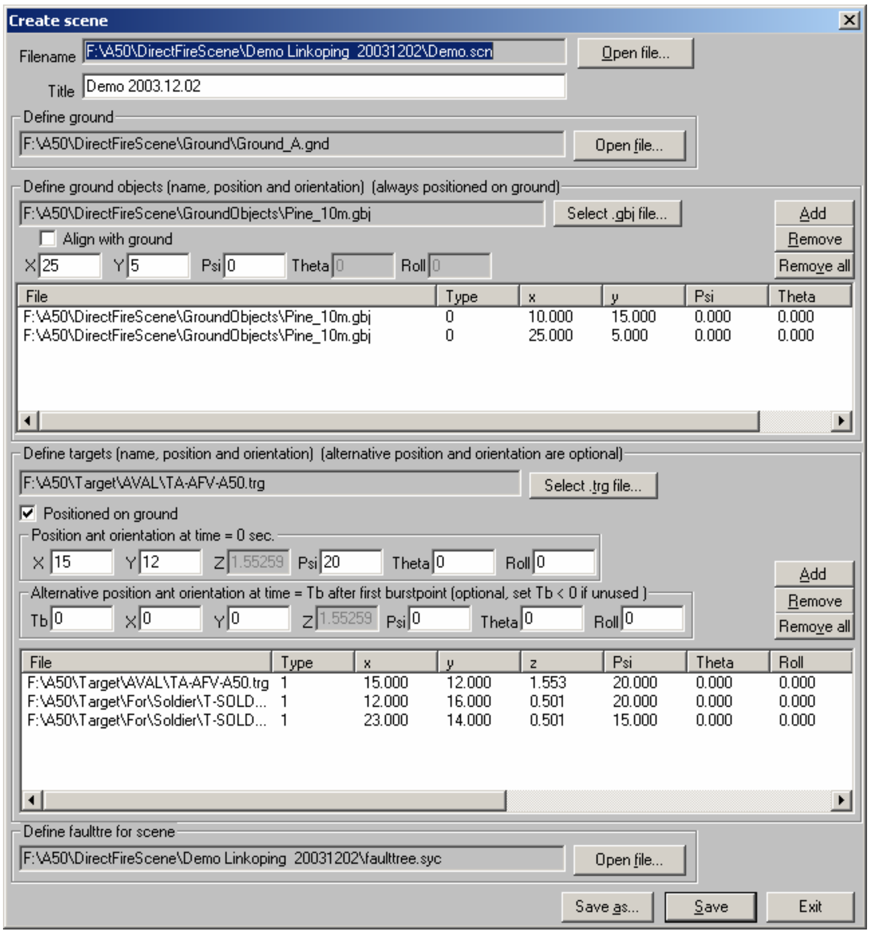

Figure 5 The Create scene dialog.

Scene and ground

In the upper part of the dialog a predefined scene can be opened or a new scene file can be created. Here the scene title and the file path to a ground description are given. The format of the ground description is discussed below.

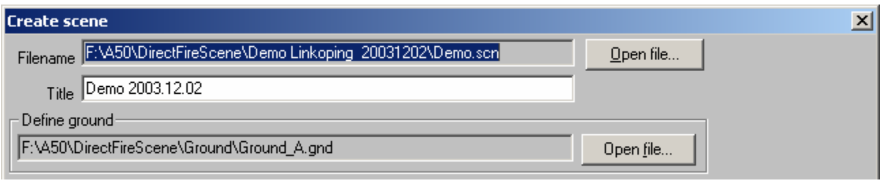

Figure 6 Upper part of the Create scene dialog with scene name, scene file path and ground file.

Ground objects

In the mid section of the dialog all ground objects are defined. For each object to use in the scene is given:

Full file path to a ground object description.

x and y	Position in the scene coordinate system. The z value is always the z value of the ground at given x and y.
Psi	Bearing relative the scene x-axis (north).
Theta	Elevation relative the scene xy-plane.

Roll Ground object rotation around its x-axis.

If the alternative **Align with ground** is checked the elevation and roll will be calculated with respect to the ground slope. This will force the z-axis of the ground object to be parallel to the ground normal.

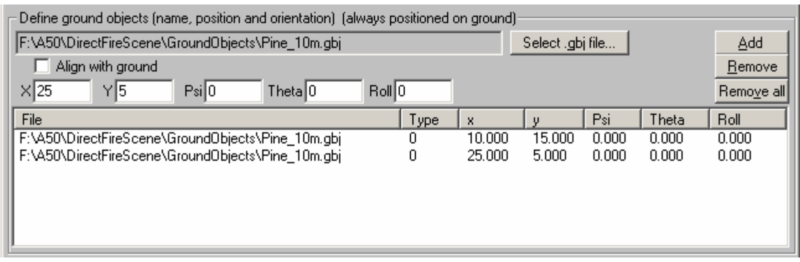

Figure 7 Mid section of the Create scene dialog with input data for ground objects.

Targets

The lower part of the dialog concerns targets and the scene fault tree.

Each target is defined with following data.

Position and direction:

X X-coordinate of the target position in the scene coordinate system.

Y Y-coordinate of the target position in the scene coordinate system.

Z Target position above the xy-plane.

Psi Target direction relative north (x-axis).

Theta Target direction relative the xy-plane. Positive upward.

Roll Target rotation around its x-axis.

The values of Z, theta and roll are calculated with respect to the ground geometry if the target is defined as a ground target, that is **Positioned on ground** is checked.

Alternative position and direction at time = Tb after first burstpoint:

Tb Reaction time for the target.

If this time is set to 0.0 no alternative position will be used. Else the target will get a new position and direction at the time Tb seconds after the first burstpoint in the scene.

X X-coordinate of the target alternative position in the scene coordinate system.

Y Y-coordinate of the target alternative position in the scene coordinate system.

Z Target alternative position above the xy-plane.

Psi Target alternative direction relative north (x-axis).

Theta Target alternative direction relative the xy-plane. Positive upward.

Roll Target alternative rotation around its x-axis.

Define fault tree for scene is the full path to a fault tree describing the events in the scene

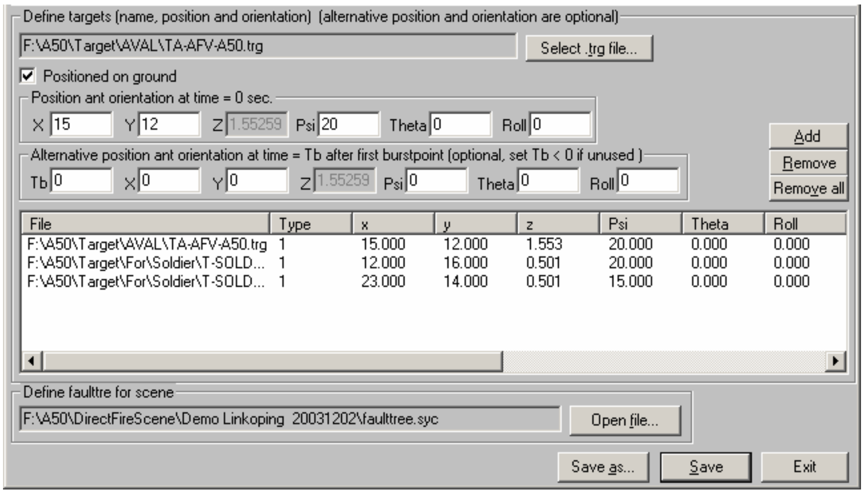

Figure 8 Lower part of the dialog with target data and fault tree.

A file with a direct fire scen has the file-extension ****.scn*** and contains:

- The scene title.
- Full file path to a ground description.
- Number of ground objects in the scene.

For each ground object follows one row with:

- Full file path to the ground object description and its position (x, y, z) and orientation (psi, theta, phi).
  Theta (elevation) and phi (roll) can be excluded whereas these angles are calculated with respect to the slope of the ground.
- After the ground objects follows a row with number of targets in the scene.

For each target follows two or three rows with:

- File path to the target description.
- Flag for target position (1 = ground target, lowest z-coordinate of the target is put on ground level, 2 = aerial targetl), position (x, y, z) and orientation (psi, theta, phi).
- Time and alternative position and orientation. At given time after the first burst point the target will be put in its alternative position for further calculations.

The third row can be omitted if the target shall be put in the same position through the whole simulation.

- The last row in the scene description contains a file path to the scene fault tree.

```
'Sample_scene'
!
'F:\A50\Ground\Mesh_104_100\Ground.gnd'
!
 4                      ! Number of ground objects
'F:\A50\Ground\Spruce_250.gbj'  40.000  33.000   0.000  0.000  0.000   ! File, x, y, psi, theta, roll
'F:\A50\Ground\Spruce_250.gbj'  15.000  35.000 30.000  0.000  0.000   ! File, x, y, psi, theta, roll
'F:\A50\Ground\Spruce_250.gbj'  20.000  16.000 60.000  0.000  0.000   ! File, x, y, psi, theta, roll
'F:\A50\Ground\Spruce_250.gbj'  10.000  20.000 90.000  0.000  0.000   ! File, x, y, psi, theta, roll
!
 2                      ! Number of targets
'F:\A50\Targ\soldiers\soldier_standing.trg'
 1    11.000  18.000  0.000  17.000    0.000   0.000          ! File, Posflag, x, y, z, psi, theta, roll
1.4   12.000  18.000  0.000  17.000  -45.000   0.000          ! File, Posflag, x, y, z, psi, theta, roll
'F:\A50\Targ\soldiers\soldier_standing.trg'
 1    12.000  20.000  0.000  14.000    0.000   0.000          ! File, Posflag, x, y, z, psi, theta, roll
'F:\A50\Scene\SceneFaultTree.syc'
```

Figure 9 Example of a file with a scene description

1.2.1 Ground description

The ground is described in the same manner as a target but includes only file path to an outer geometry file(s), file path to a material file and, if used, a file path to a signature file for laser and magnet sensors. These files are identical to those used in target descriptions and they are further discussed in the Target description manual.

```
'Ground'
 10  1  'F:\A50\Ground\Mesh_104_100\mesh_104_100.otg'
 20  0  'F:\A50\Ground\Mesh_104_100\Ground.MTL'
500  1  'F:\A50\Ground\Mesh_104_100\Ground.sel'
```

Figure 10 Exampel of a ground description (*.***gnd***)

1.2.2 Ground object descriptions

The ground objects are described as a target but includes only file paths to outer geometry file(s), material file and, if used, a file path to a signature file for laser and magnet sensors. These files are identical to those used in target descriptions and they are further discussed in the Target description manual.

```
'Spruce'
 10  1  'F:\A50\Ground\ Spruce.otg'
 20  0  'F:\A50\Ground\ Spruce.MTL'
```

Figure 11 Example of a ground object description

1.2.3 The scene fault tree

The scene fault tree is built in the same way as a target fault tree but the scene fault tree includes an additional row, row 3, with min and max number for scene events and the file path to a translation file. Except for the third row, the scene fault tree is identical to the target fault tree which is further discussed in the Target description manual.

In the scene fault tree all top events from the targets in the scene can be used as vital parts are used in the target fault tree. For this reason all top events in the scene targets that are used in the scene fault tree must be defined in a translation file as a scene event.

```
!SceneEvent     Target number     Target event
1001            1                 3001
1002            1                 3002
1003            1                 3003
1004            2                 3001
1005            2                 3002
1006            2                 3003
1007            4                 3001
1008            4                 3002
1009            4                 3003
```

Figure 12 Example of a translation file

Each scene event, with user defined numbering, is by the translation file connected to a top event of a specific target in the scene. Target number in the translation file is the number of the order the targets are described and read in the scene description file.

The defined scene events can be used to define sub events and top events in the scene fault tree.

```
'TestScene'                                         ! Scene name
0 0 ''                                              ! Virtual comp, min/max number, file path
1001 1009  'F:\A50\Scene\Translation.ftr'           ! Min and max scene event number, file path
0                                                   ! Number of multiple events
100 109                                             ! Sub events., min/max number
4001 4003                          ! Top events, min/max number
* 100  'Target  1 disabled'
L 1 1001 1002 1003
* 101  'Target  2 disabled'
L 1 1004 1005 1006
* 102  'Target  4 disabled'
L 1 1007 1008 1009
* 4001  'One target is disabled'
E1 100 101 102
* 4002 'Two targets are disabled'
E2 100 101 102
* 4003 'Three targets are disabled'
A 100 101 102
```

Figure 13 Example of a scene fault tree

2 Weapon platform description

The weapon description platform is further discussed in the document Reference manual ballistics.

The weapon platform description is divided in two:

- Fire and control.
- Ballistic data and warhead carrier.

For the weapon platform is also given its deviation in side and height. These deviations are randomized once for each salvo.

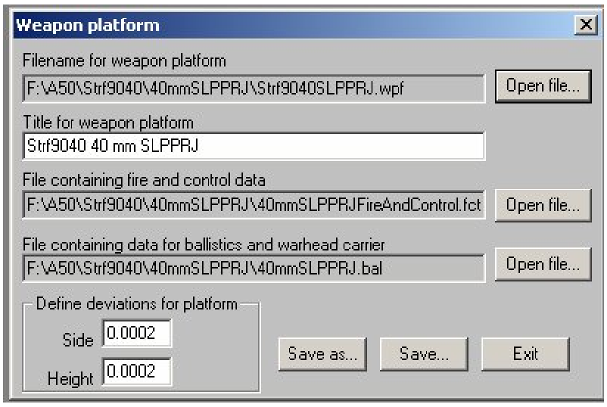

Figure 14 Weapon platform dialog box.

2.1 Fire and control

Fire and control is defined in a dialog opened via **Weapon > Fire and control…** in the menu. The weapon fire and control is divided in three parts:

- Range finder.
- Aim instrument.
- Range tables and corrections.

In the dialog is also given ballistic corrections to consider in the settings calculation.

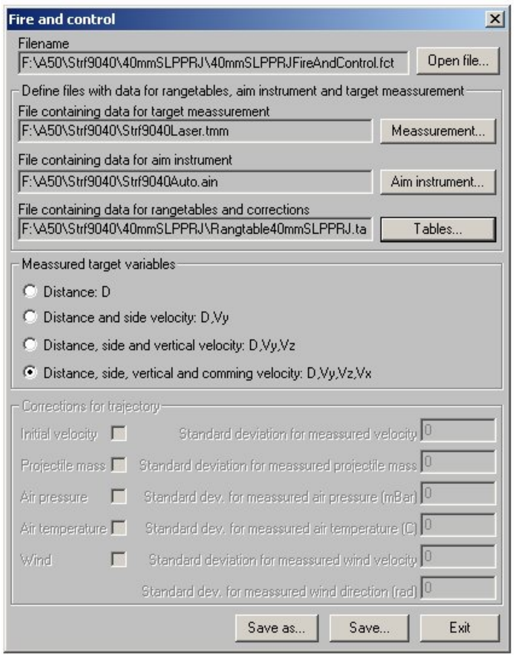

Figure 15 Fire and control dialog box.

2.1.1 Range finder

Target measurement can be one of two types:

- Manual estimation.
- Laser measurement.

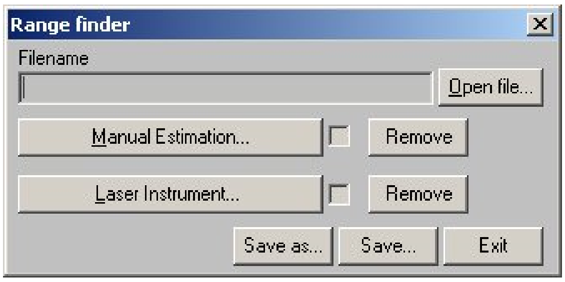

Figure 16 Range finder dialog box.

2.1.1.1 Manual estimation

A table is given describing estimated distance to the target and the estimated horizontal side velocity of the target.

Distance: For each correct actual distance is given the gunners estimated distance and a standard deviation for the estimation.

Velocity: For each correct actual velocity is given the gunners estimated velocity and a standard deviation of the estimation.

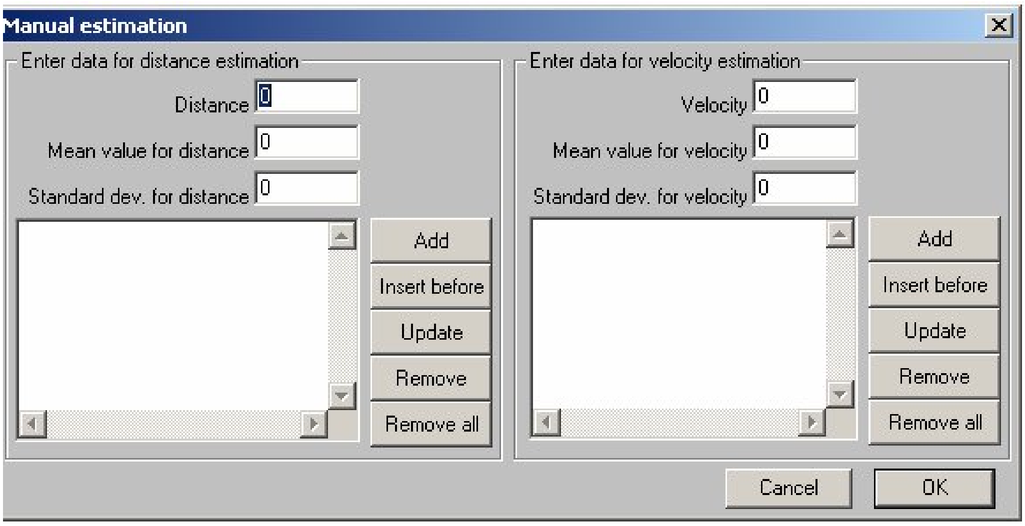

Figure 17 Manual estimation dialog box.

The estimated distance and velocity is randomized with Gauss distribution.

2.1.1.2 Laser measurement

The laser measuring can determine:

- Distance to the target.
- Horizontal velocity of the target.
- Vertical velocity of the target, perpendicular to the view of sight.
- Coming/leaving velocity of the target.

If only distance is measured one laser shot is used while determination of velocity is based on two laser measurings.

Following parameters are input data:

- The angle describing field of view for the laser.
- Fraction of the field of view as minimum reflection from target for true echo. (0-1).
- Resolution of the laser instrument. The calculated value is given as n · resolution.

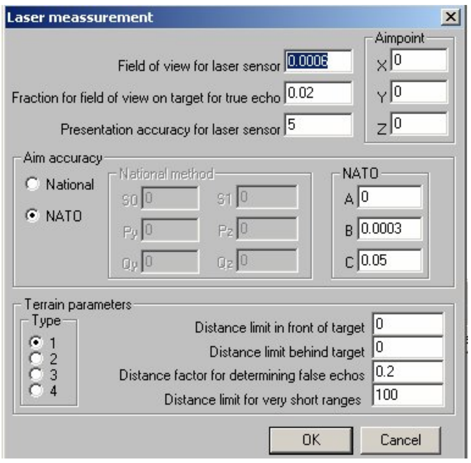

Figure 18 Laser measurement dialog box.

The aim accuracy of the instrument is given as a national method or a NATO method. This is further discussed in chapter Aim instruments below.

A selection of terrain, false echoes, is given as one of following for values.

1. No false echoes.
2. False echoes can occur in front of the target only.
3. False echoes can occur behind the target only.
4. False echoes can occur in front of and behind the target.

For the terrain is also given two parameters to set the interval in front of and behind the target where distance is randomized at false echoes.

Furthermore is given a factor used to describe the gunners' ability to judge an echo as a false echo. This factor multiplied with the truth distance, D, give us the distance D_{ML}. If the measured distance is outside the interval [(D +D_{ML}), (D-D_{ML})] the gunner will judge echo as false and a new measuring will start.

Finally a minimum distance for measuring is given. Any calculated distance smaller then the given minimum will be set to the min. distance.

2.1.2 Aim instruments

The direct fire module can describe five types of aim instruments:

- Conventional telescopic sight with markings for distance and side velocity.
- Telescopic sight with markings for distance only.
- Automatic sight with continues resolution for distance and side velocity.
- Automatic sight with discrete resolution for distance and side velocity.
- Semi automatic sight.
- Intuitive sight.

The input dialog for aim instruments is opened Via **Weapon > Aim instrument…** in the direct fire menu.

The dialog contains common data for all aim instrument types. These are further discussed in the document *Reference Manual Fire and Control Direct Firing.*

To define a specific instrument type select the corresponding button in the dialog and add specific data.

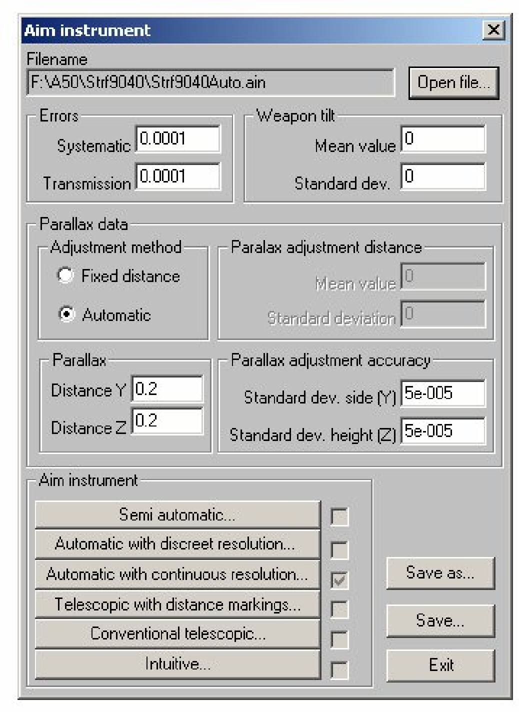

Figure 19 Aim instrument dialog box.

2.1.2.1 Semi automatic sight

The semi automatic sight uses the given resolution to select a distance regarding to the measured distance. The velocity mark to use is selected by the gunner and rules for this is defined with max measured velocity for each velocity mark to use.

For each distance interval the distance resolution to use is defined and the velocity marks in the sight.

For aim accuracy two methods are available to calculate the standard deviation in side and height, NATO standard and the Swedish FOI method. These are further discussed in the Reference Manual Direct Fire.

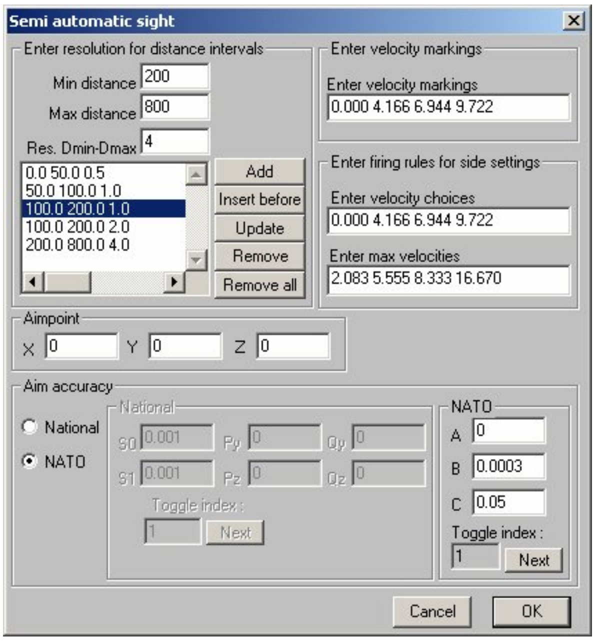

Figure 20 Semi automatic sight dialog box.

2.1.2.2 Automatic sight with discrete resolution

The automatic sight uses the given resolution to select a distance and velocity regarding to the measured distance and velocity.

For each distance interval the distance resolution to use is defined as well as the max velocity and velocity resolution.

For aim accuracy two methods are available to calculate the standard deviation in side and height, NATO standard and the Swedish FOI method. These are further discussed in the document *Reference Manual Fire and Control Direct Firing*.

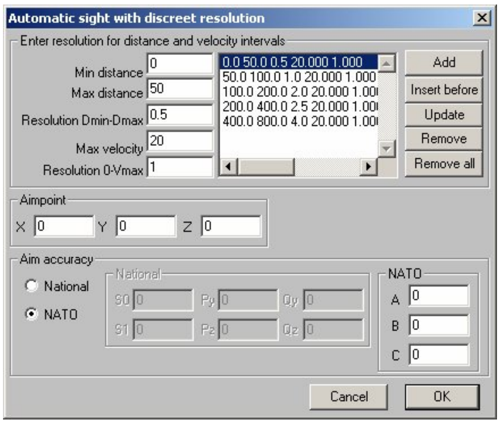

Figure 21 Automatic sight with discreet resolution dialog box.

2.1.2.3 Automatic sight with continuous resolution

Input data for this sight is bounded to the target aimpoint and aim accuracy.

This automatic sight will use the measured values for velocity and distance.

For aim accuracy two methods are available to calculate the standard deviation in side and height, NATO standard and the Swedish FOI method. These are further discussed in the document Reference Manual Direct Fire.

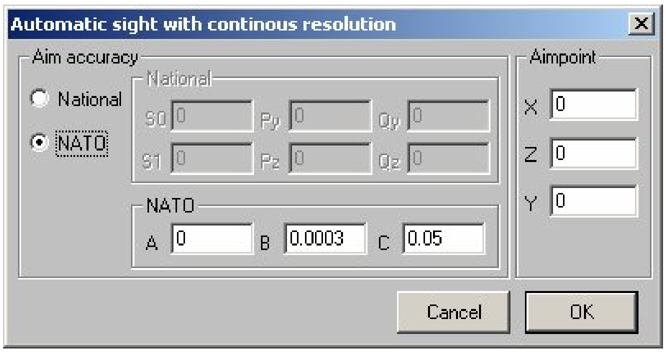

Figure 22 Automatic sight with continous resolution dialog box.

2.1.2.4 Telescopic sight with distance marks

Each distance mark sight is defined in the left hand side of the dialog

Since the sight does not have velocity marks a specific aimpoint must be defined for each selected velocity according to results from target measuring.

The firing rules define which distance mark is selected for a number of measured distance intervals. For each interval is also given velocities to select depending on measured velocities and which aimpoint to use for each selected velocity.

Two methods are available to calculate the standard deviation in side and height, NATO standard and the Swedish FOI method. These are further discussed in the Reference Manual Direct Fire.

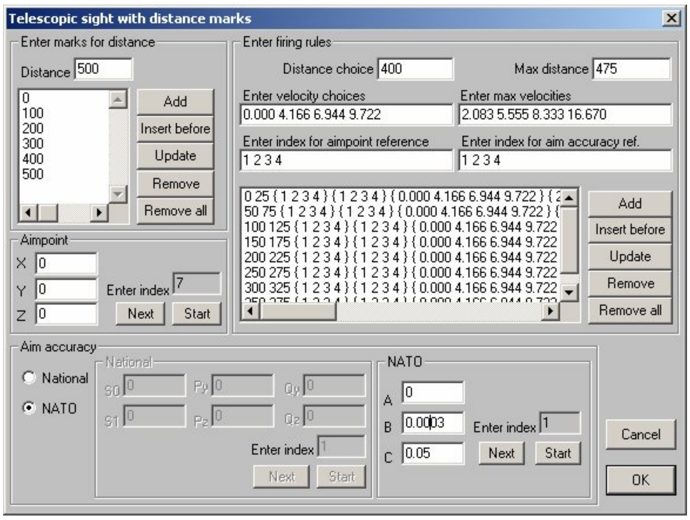

Figure 23 Telescopic sight with distance marks dialog box.

2.1.2.5 Conventional telescopic sight with distance and velocity marks

Each distance mark and velocity mark in the sight is defined in the left hand side of the dialog.

The firing rules are defined in the right hand side of the dialog.

For each distance mark the gunner will selct in the sight a max measured velocity is given. For each velocity mark the gunner will select in the sight a max measured velocity is given.

(Velocity is given in m/s)

Two methods are available to calculate the standard deviation in side and height, NATO standard and the Swedish FOI method. These are further discussed in the Reference Manual Direct Fire.

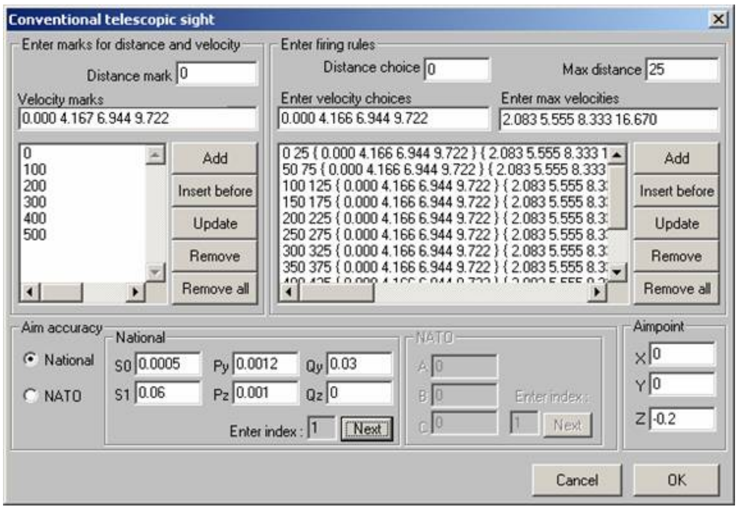

Figure 24 Conventional telescopic sight dialog box.

2.1.2.6 Intuitive sight

Three aimpoints, in target coordinate system, are defined to use for different side velocities for short ranges.

For longer ranges the errors in side and height are randomized.

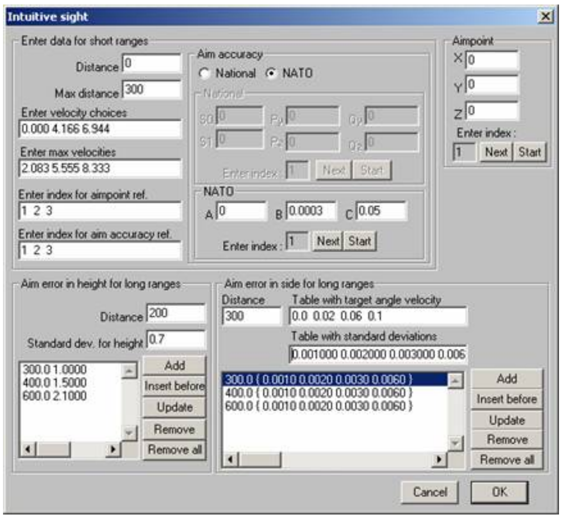

Figure 25 Intutive sight dialog box.

2.2 Ballistics

The dialog for ballistic input data is common to indirect fire module.

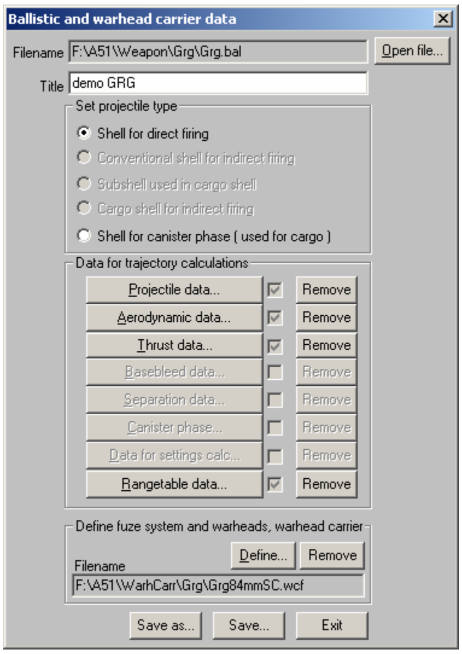

Figure 26 Ballistic and warhead carrier data dialog.

2.2.1 Projectile data

The projectile data block consists of geometry data and deviations for the projectile.

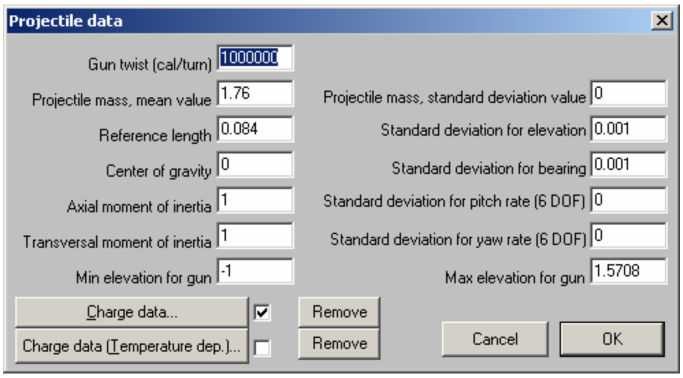

Figure 27 Projectile data dialog.

Charges are given either as a simple input with V_0 and deviation for each possible charge to use or in a more complex table where V_0 and deviation is given as a function of the gun powder temperature for each charge.

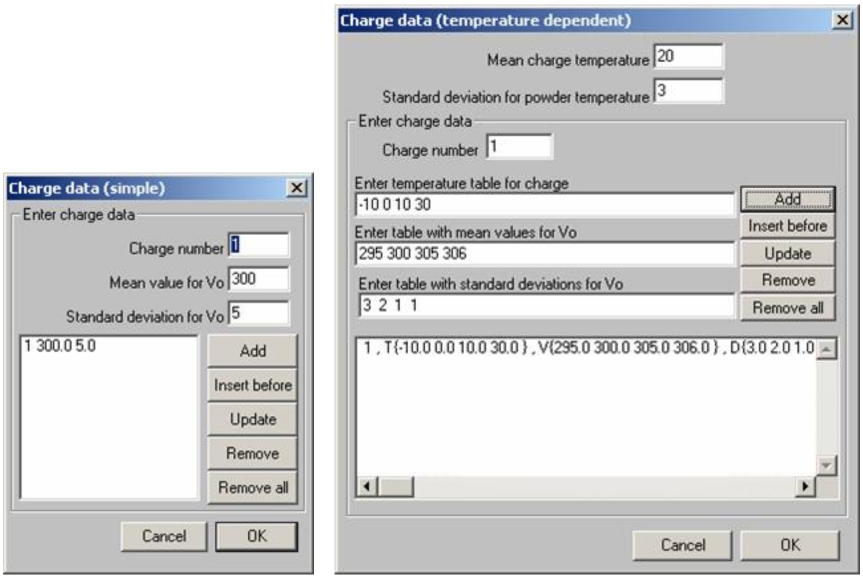

Figure 28 Charge date dialogs, simple and temperature dependent.

2.2.2 Aerodynamic data

The aerodynamic data block includes input coefficients for the ballistic calculations.

For point mass trajectory method the drag coefficient, CD, is sufficient. For the NATO and 6DOF trajectory method at least also the normal force, CN, and moment coefficient, CM, must be defined.

See the Reference Manual Ballistics for more information.

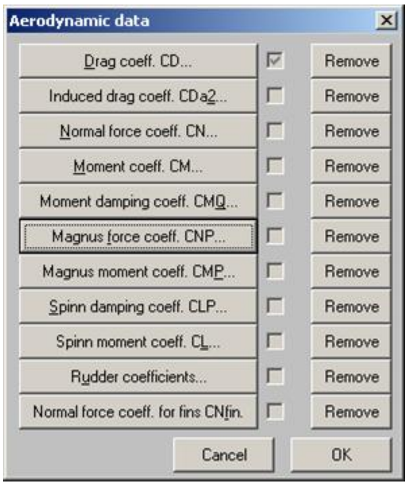

Figure 29 Aerodynamic data dialog box.

2.3 Firing sequence

Following three types of firing sequences can be described for a weapon.

- Single shot.
- Multiple single shot.
- Automatic firing.

The firing sequence is defined in a dilaog opened via *Weapon > Firing sequence…* in the direct fire menu. The file generated from this dialog is used in the burstpoint calculation.

Single shot

The weapon will fire one round in each Monte Carlo cycle.

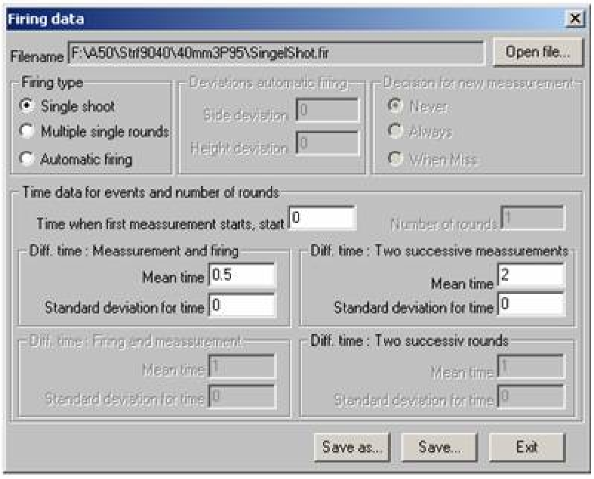

Figure 30 Firing data dialog, Single shoot option chosen.

Multiple single shot

Given number of rounds are fired from the weapon in each Monte Carlo cycle. Rules for new measurements on the target is given as never (target is measured once before first round), always (target is measured before each round) or when miss.

New weapon settings are calculated for each round.

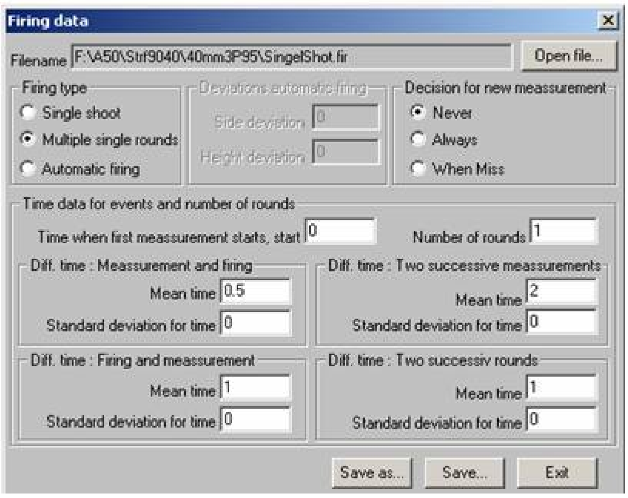

Figure 31 Firing data dialog, Multiple single shoot option chosen.

Automatic firing

A target measurement is performed before the salvo. The rounds are delivered with given time delay between each round.

The hit accuracy is randomized once for the first round in a salvo and the hit deviation is given for rounds within the salvo relative the first hit point.

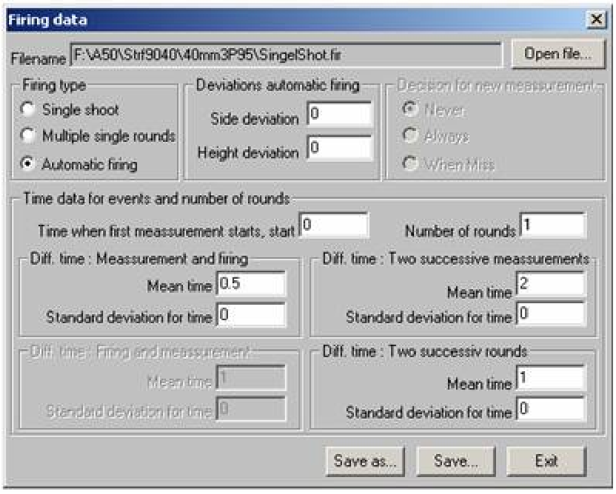

Figure 32 Firing data dialog, Automatic firing option chosen.

3 Direct fire simulation

Simulations in direct fire mode are performed in a scene containing ground geometry, ground objects and one or more targets.

A direct fire simulation can performed be with either a complete description of a weapon platform or with a single warhead carrier. In a simulations with a weapon description the weapon aim ability and the ballistic performance of the warhead carrier is described and simulated. In simulations with a single warhead carrier a strait travel of the warhead is used in a user defined aimpoint in the scene.

The simulation is performed in following steps:

1. Create case (Burstpoint calculation)
2. Define simulation
3. Perform the simulation.

A case can be created in one of following three ways:

- Generate burst points with a weapon platform against a single target with aim point in the target coordinate system. In this case the scene can only contain one target and a ground description.
- Generate burst points with a weapon platform against a scene with aim point in the scene coordinate system.
- Generate burst points with a warhead carrier against a scene with aim point in the scene coordinate system.

The different types of case files generated in AVAL are separated with following file extensions:

.vcs vulnerability case single target (‘*Single target*’)

.lcs lethality case single target(‘*Single target*’)

.lcm lethality case multiple targets (‘*Direct fire*’)

Created with a warhead carrier and aim point is given in the scene coordinate system.

.wcss weapon lethality case single targets (created in the ‘*Direct fire*’)

Created with a weapon platform description and aim point is given in the target coordinate system.

.wcsm weapon lethality case multiple targets (‘*Direct fire*’).

Created with a weapon description and aim point is given in the scene coordinate system.

In the direct fire mode only lethality simulations can be performed. Vulnerability simulations are performed in the single target mode.

3.1 Create case with weapon platform

The burst point calculation is started from a dialog which is opened via **'MC simulations > Create case > Weapon against scene'** in the direct fire menu.

In the dialog following complete description, discussed earlier, are loaded:

- Case file. Create a new file or open an existing with all data ready.
- Weapon platform
- Firing sequence file
- Atmosphere file used for the ballistic calculation
- Direct fire scene

If the scene contains a ground description, no ground objects and exact one target the option **Aimpoint location on target** will be available.

With the option **aimpoint on target** the aim instrument of the weapon is used, otherwise only the distance measurement of the weapon is used in the burst point calculation.

The start position of the projectile is given with coordinates in the ground coordinate system and the height over ground.

Following options are available for the ballistic calculations:

- Trajectory method.
- Coriolis effect.
- If V_o is described as a function of powder temperature mean value and deviation of gun powder temperatur is given.
- Latitude of weapon position.
- Distance from target where to interrupt the ballistic calculation. From this point a strait trajectory is used to calculate burstpoint.

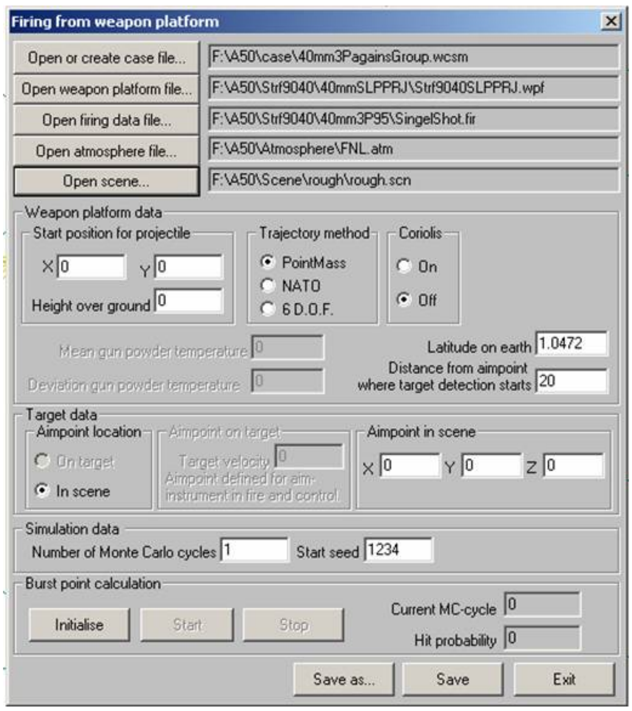

Figure 33 Firing from weapon platform dialog box.

If the aimpoint is set to the target coordinate system the position and direction of projectile is transformed into the target coordinate system. In this transformation the target velocity is taken account and the relative velocity of the projectile is used.

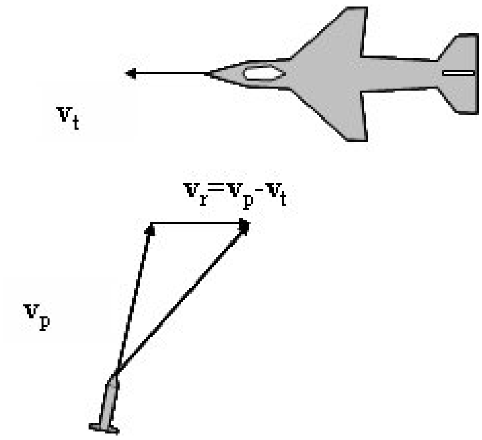

Figure 34 Projectile and target relative velocities.

The result of a burstpoint calculation can be displayed in the direct fire window by opening the created case file via **MC simulation > Read caseK** in the direct fire menu.

3.2 Create case with warhead carrier

The burst point caclulation is started from a dialog which is opened via **'MC simulations > Create case > Warhead against scene'** in the direct fire menu. The dialog is basically the same as used to defin a case in single target mode why the load ground and target velocity options are disabled in this mode.

In the dialog following complete description, discussed earlier, are loaded:

- Case file. Create a new file or open an existing with all data ready.
- Warhead carrier file
- Direct fire scene

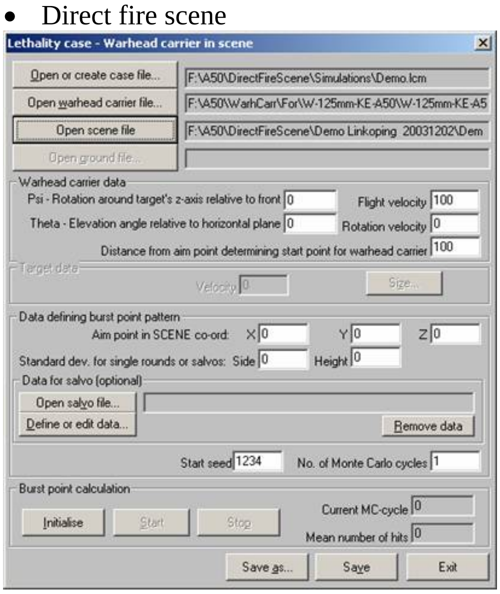

Figure 35 Lethality case - Warhead carrier in scene dialog.

The firing position is defined by the bearing (Psi) and elevation (Theta) angles towards and the distance from the given aim point. The aim point is given in the scene coordinate system as well as the deviation in side and height for a round or salvo.

If more than one round is desired in each Monte Carlo cycle a salvo-file can be created and used. It is then possible to fire several salvos including several rounds in each Monete Carlo cycle.

If more then one salvo is used the mean value and deviation for time delay netween salvos are given.

For each salvo number of rounds is defined and the hit point deviation for each round and time delay between rounds. '

The deviation can be set to be relative the salvo hit point or relative the last round hit point or as a predefined pattern

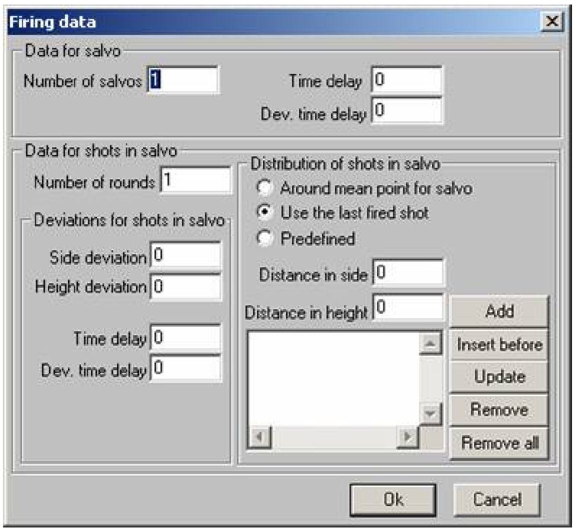

Figure 36 Firing data dialog box.

3.3 Define simulation

Simulering av vapenverkan defineras i dialogbox som öppnas från direkteldsmodulens meny via **MC simulation > Simulation > Lethality > Define…**

This dialog creates the simulation input file (***.lsm***) with, start seed, evaluation times, burstpoint files and simulation settings.

Burstpoint files are added with the **Add case...** button.All used cases must be created with the same scene and the exact same number of Monte Carlo cycles.

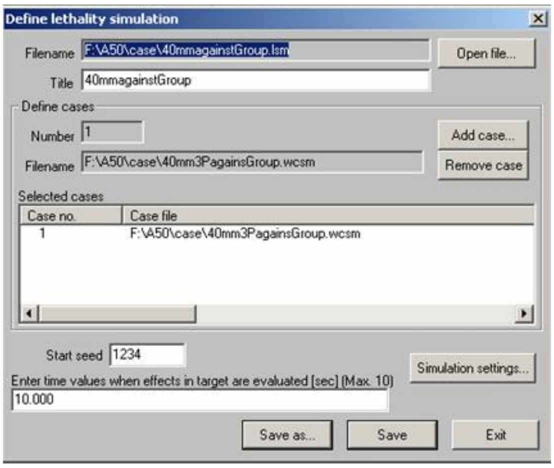

Figure 37 Define lethality simulation dialog-

The **Simulation settings…**button opens a dialog for selecting which warhead effects to include in the simulation. Each effect and time steps for time simulation, (fire, fuel leakage and water leakage), can be set on each target separately.

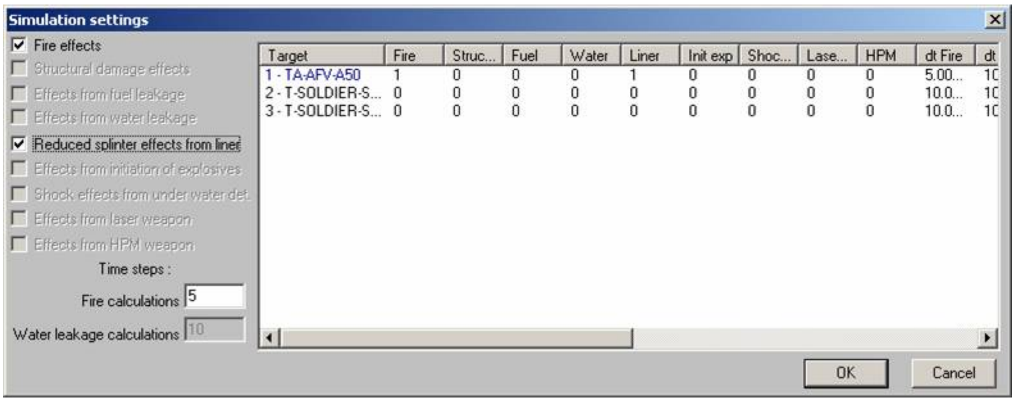

Figure 38 Simulation settings dialog.

3.4 Simulation

The simulation is started via **MC simulation->Simulation->Lethality->Simulation** in the menu.

Select the simulation file created via define simulation, initialize to read used files and start the simulation.

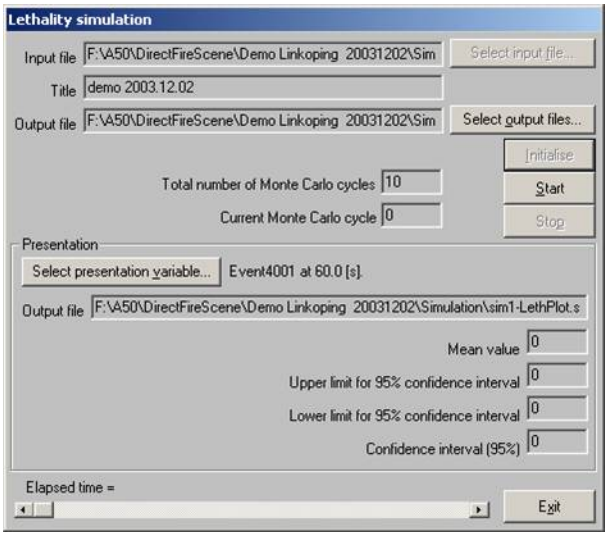

Figure 39 Lethality simulation dialog.

The simulation can be viewed directly after the simulation in the scene window by selecting **MC simulation->Lethality** in the menu. To view results from a previos perfomed simulation it can first be loaded by selection **MC simulation->Read simulation.**

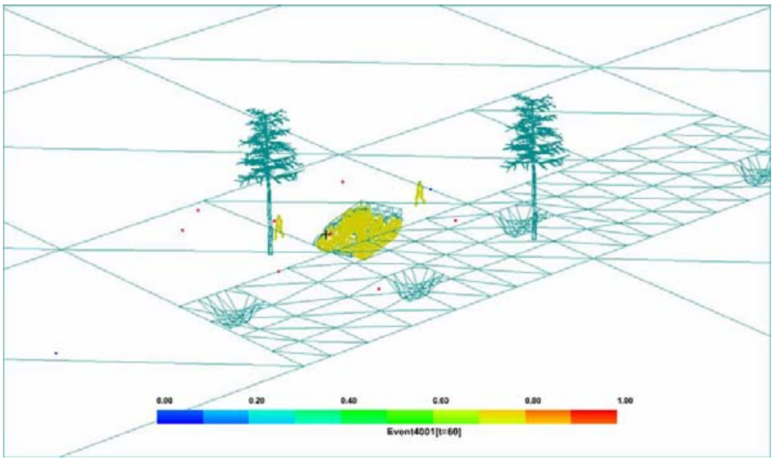

Figure 40 Plotted simulation result.

Output files

The simulation produces two files with results concerning the scene, the files are saved in the same directory as the simulationfile.

SimFileName-Leth.*txt*	Information of simulation settings, calculation time etc.
	Statistics for hits by warhead effects on each target
	Results of the scene sub and top events
	Results of top events for each target in the scene
SimFileName-Leth.*skv*	Results for each scene top event for each MC

For each target in the scene one file is created

SimFileName-LethTarget_N.*skv*	Results for each scene top event for each MC

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