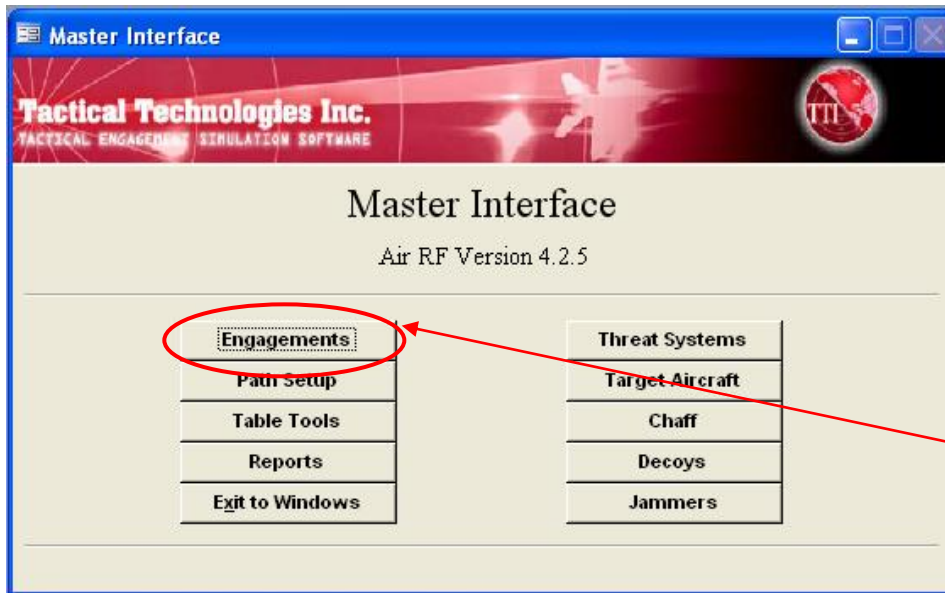


SAM(CG)/AAA

Demonstration Engagements

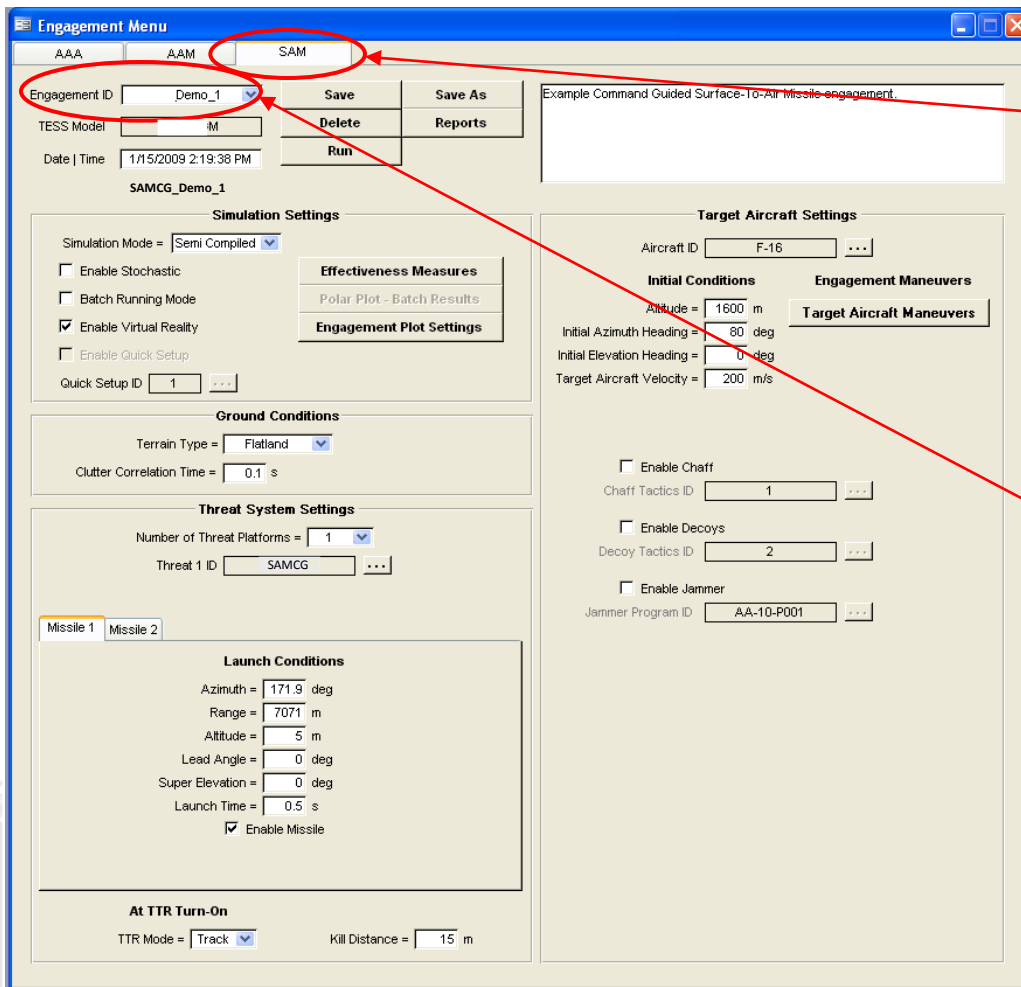
- The demonstration scenarios are:
 - 1) SAMCG Demo 1: Command-Guided Surface-To-Air missile versus target aircraft
 - 2) SAMCG Demo 2: Command-Guided Surface-To-Air missile versus target aircraft launching chaff and executing an evasive maneuver
 - 3) AAA Demo 1: Radar-Guided Anti-Aircraft Artillery versus target aircraft
 - 4) AAA Demo 2: Radar-Guided Anti-Aircraft Artillery versus target aircraft
- A brief interpretation of the major events occurring in each engagement is provided by reference to the time and spacial plots.
- Critical input parameters are shown.
- Selected output graphics are shown including time plots, Virtual Reality and 3D Plots.

AIR RF Master Interface



- SAM(CG)/AAA is controlled through the TESS AIR RF Master Interface
- The main screen of the AIR RF Master Interface is shown
- Clicking on the Engagements button opens the Engagement menu shown next page

AIR RF Master Interface - SAM Engagement Menu



Engagement Menu

AAA AAM **SAM**

Engagement ID: Demo_1 Save Save As
TESS Model: M Delete Reports
Date | Time: 1/15/2009 2:19:38 PM Run

SAMCG_Demo_1

Simulation Settings

Simulation Mode = Semi Compiled

Enable Stochastic

Batch Running Mode

Enable Virtual Reality

Enable Quick Setup

Quick Setup ID = 1

Effectiveness Measures

Polar Plot - Batch Results

Engagement Plot Settings

Ground Conditions

Terrain Type = Flatland

Clutter Correlation Time = 0.1 s

Threat System Settings

Number of Threat Platforms = 1

Threat 1 ID = SAMCG

Missile 1 Missile 2

Launch Conditions

Azimuth = 171.9 deg

Range = 7071 m

Altitude = 5 m

Lead Angle = 0 deg

Super Elevation = 0 deg

Launch Time = 0.5 s

Enable Missile

At TTR Turn-On

TTR Mode = Track Kill Distance = 15 m

Target Aircraft Settings

Aircraft ID = F-16

Initial Conditions

Altitude = 1600 m

Initial Azimuth Heading = 80 deg

Initial Elevation Heading = 0 deg

Target Aircraft Velocity = 200 m/s

Engagement Maneuvers

Target Aircraft Maneuvers

Enable Chaff

Chaff Tactics ID = 1

Enable Decoys

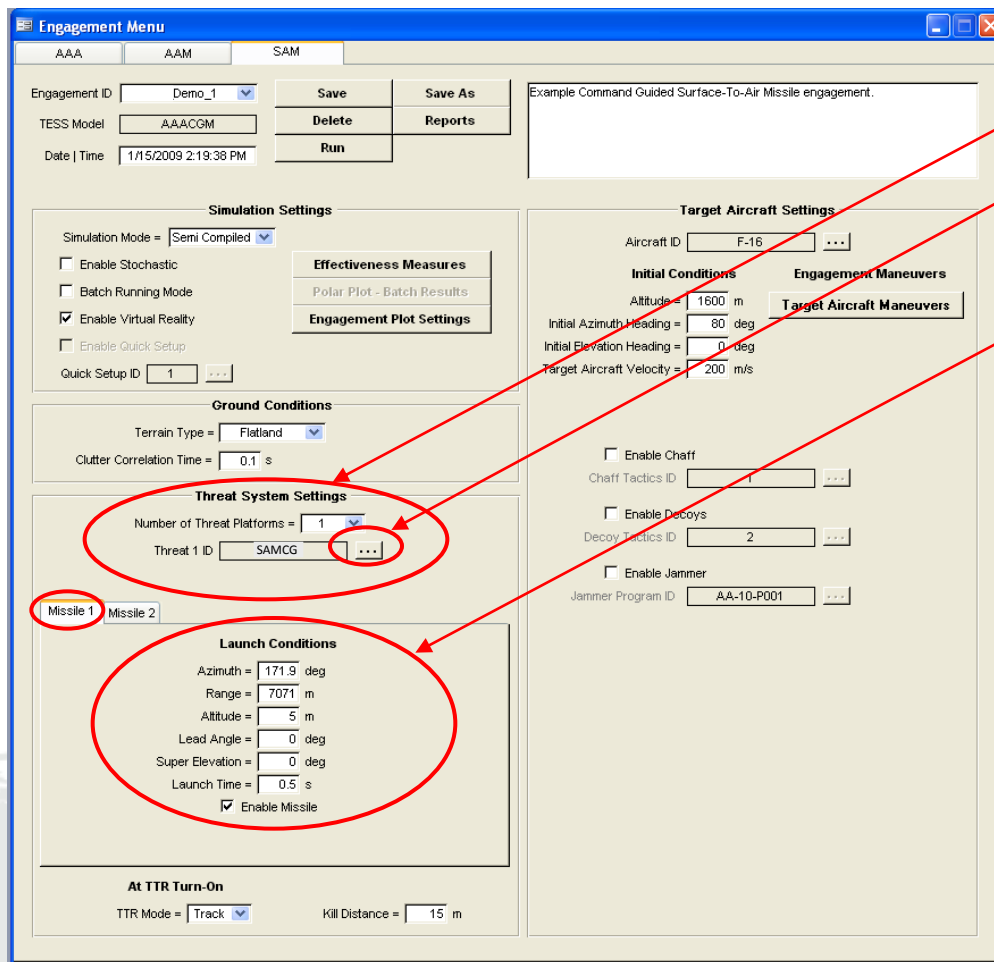
Decoy Tactics ID = 2

Enable Jammer

Jammer Program ID = AA-10-P001

- The SAM Engagement menu of the AIR RF Master Interface is shown
- The Engagement ID of the AIR RF Master Interface is indicated
- The sample engagements SAMCG Demo 1 and SAMCG Demo 2 are listed in the Engagement ID menu

SAMCG Master Interface Engagement Menu



Engagement Menu

AAA | AAM | SAM

Engagement ID: Demo_1 | Save | Save As | Delete | Reports | Run

TESS Model: AAACGM

Date | Time: 1/15/2009 2:19:38 PM

Example Command Guided Surface-To-Air Missile engagement.

Simulation Settings

Simulation Mode = Semi Compiled

Enable Stochastic

Batch Running Mode

Enable Virtual Reality

Enable Quick Setup

Quick Setup ID: 1

Effectiveness Measures

Polar Plot - Batch Results

Engagement Plot Settings

Ground Conditions

Terrain Type = Flatland

Clutter Correlation Time = 0.1 s

Threat System Settings

Number of Threat Platforms = 1

Threat 1 ID: SAMCG

Launch Conditions

Azimuth = 171.9 deg

Range = 7071 m

Altitude = 5 m

Lead Angle = 0 deg

Super Elevation = 0 deg

Launch Time = 0.5 s

Enable Missile

At TTR Turn-On

TTR Mode = Track | Kill Distance = 15 m

Target Aircraft Settings

Aircraft ID: F-16

Initial Conditions

Altitude = 1600 m

Initial Azimuth Heading = 80 deg

Initial Elevation Heading = 0 deg

Target Aircraft Velocity = 200 m/s

Engagement Maneuvers

Target Aircraft Maneuvers

Enable Chaff

Chaff Tactics ID: 1

Enable Decoys

Decoy Tactics ID: 2

Enable Jammer

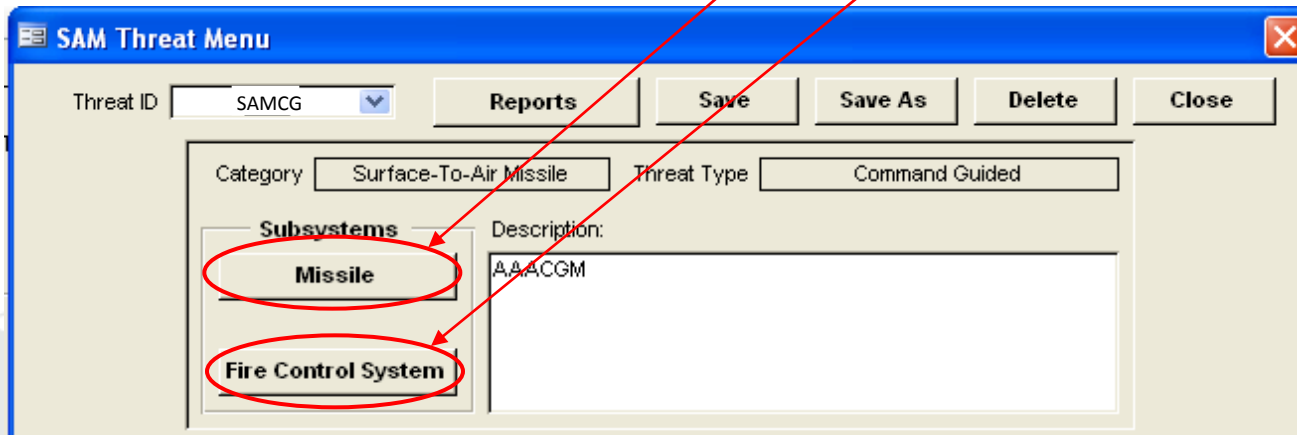
Jammer Program ID: AA-10-P001

- Threat System Settings
- Threat Menu access (see next page)
- Missile 1 Launch Conditions

SAMCG Demo Threat Menu

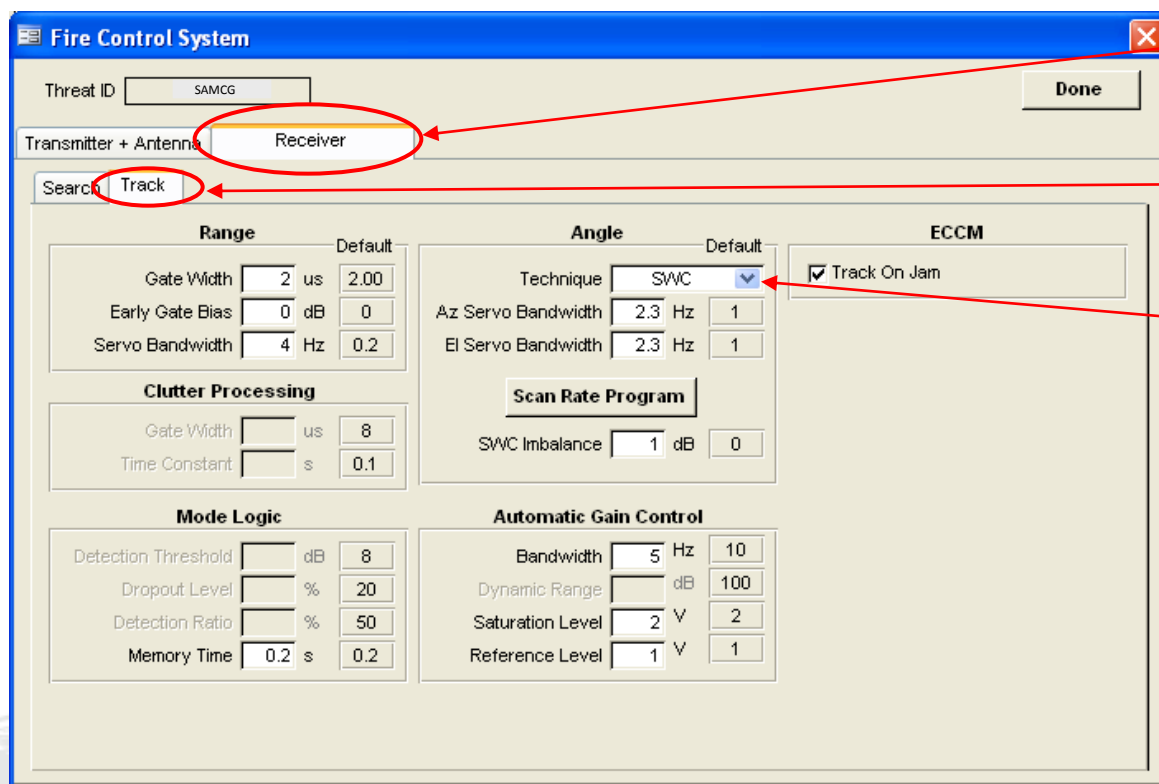
Missile Subsystem Menu access

Fire Control System Menu access (note that CG missile and AAA radars are identical)



SAMCG and AAA Demos

Select Fire Control System Parameters

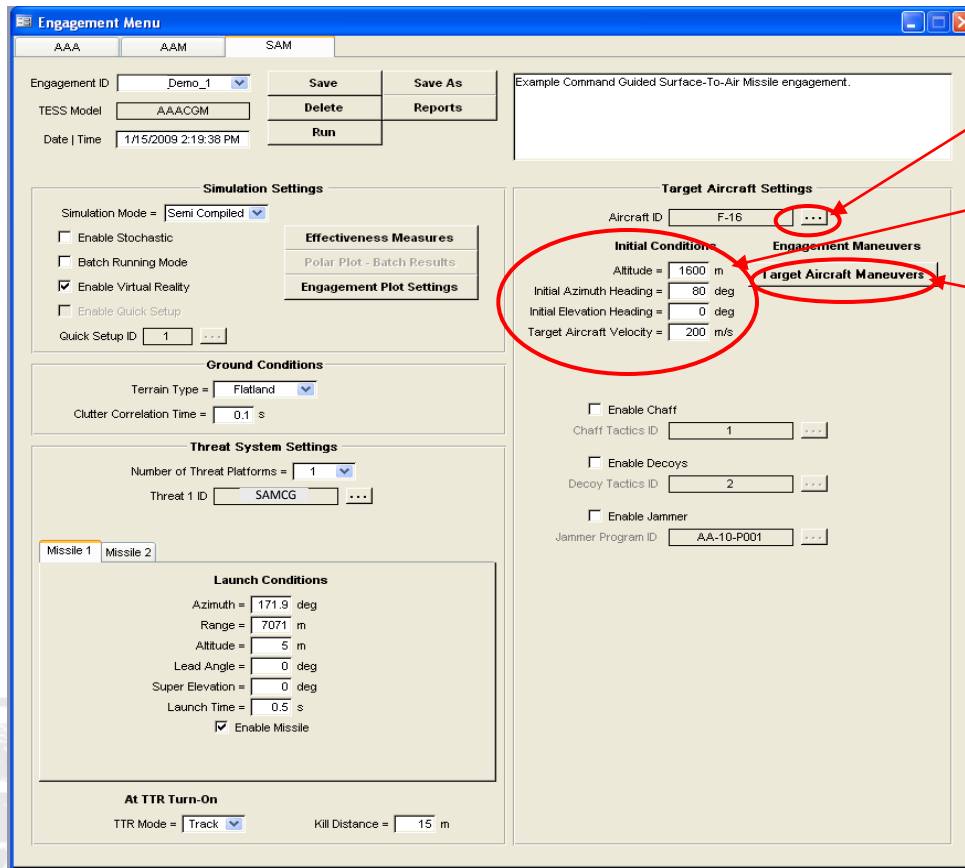


• Radar Receiver parameters tab

• Radar Receiver Track parameters tab

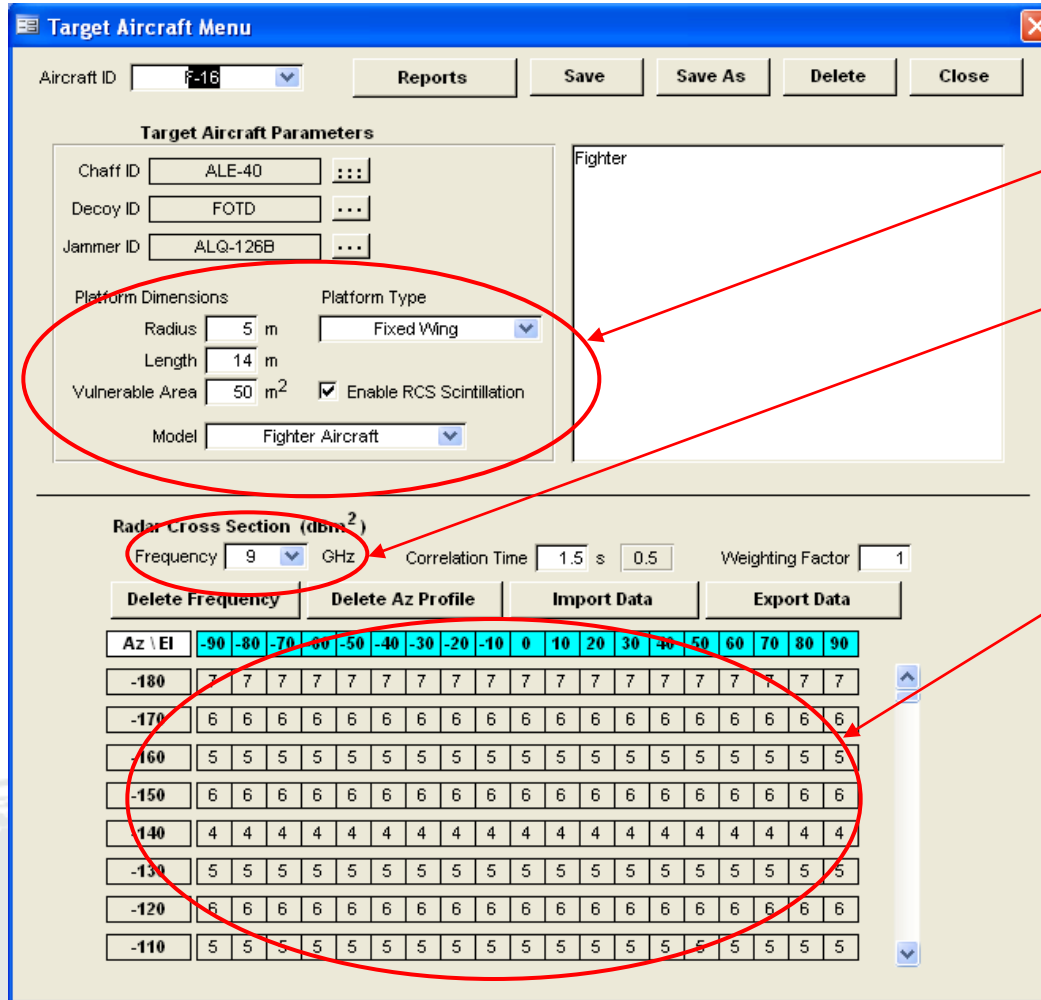
• Radar Angle Tracking Technique is set as Scan With Compensation

All Demos - Select Target Aircraft Parameters



- Target Aircraft Menu access (see next page)
- Target Aircraft Initial Conditions
- Target Aircraft maneuvers Menu access

All Demos- Select Target Aircraft Parameters



Target Aircraft Parameters

Aircraft ID: F-16

Chaff ID: ALE-40

Decoy ID: FOTD

Jammer ID: ALQ-126B

Platform Dimensions: Radius 5 m, Length 14 m, Vulnerable Area 50 m²

Platform Type: Fixed Wing

Model: Fighter Aircraft

Radar Cross Section (dbm²)

Frequency: 9 GHz

Correlation Time: 1.5 s

Weighting Factor: 1

Az \ EI	-90	-80	-70	-60	-50	-40	-30	-20	-10	0	10	20	30	40	50	60	70	80	90
-180	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
-170	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
-160	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
-150	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
-140	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
-130	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
-120	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
-110	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5

Target Aircraft properties

Target Aircraft Radar Cross Section frequency selection menu

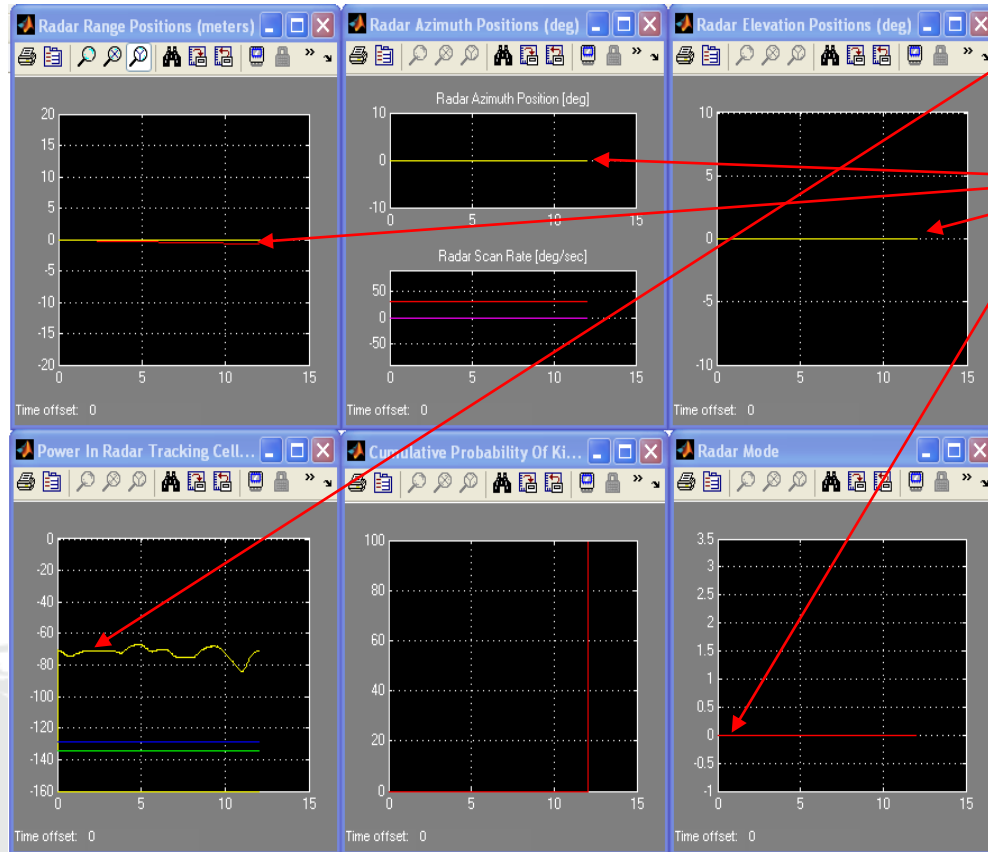
Target Aircraft aspect-angle dependent Radar Cross Section table for selected frequency

SAMCG Demo 1 - Overall Description

- The target aircraft is flying straight and level on an azimuth heading of 80 degrees clockwise with respect to North, at an altitude of 1600 meters
- At $t=0.5$ seconds after simulation start, a command-guided surface-to-air missile is launched from an azimuth bearing of 170 degrees at a horizontal range of 7000 meters
- The radar tracks the aircraft and issues steering commands to the missile
- The missile approaches and strikes the aircraft

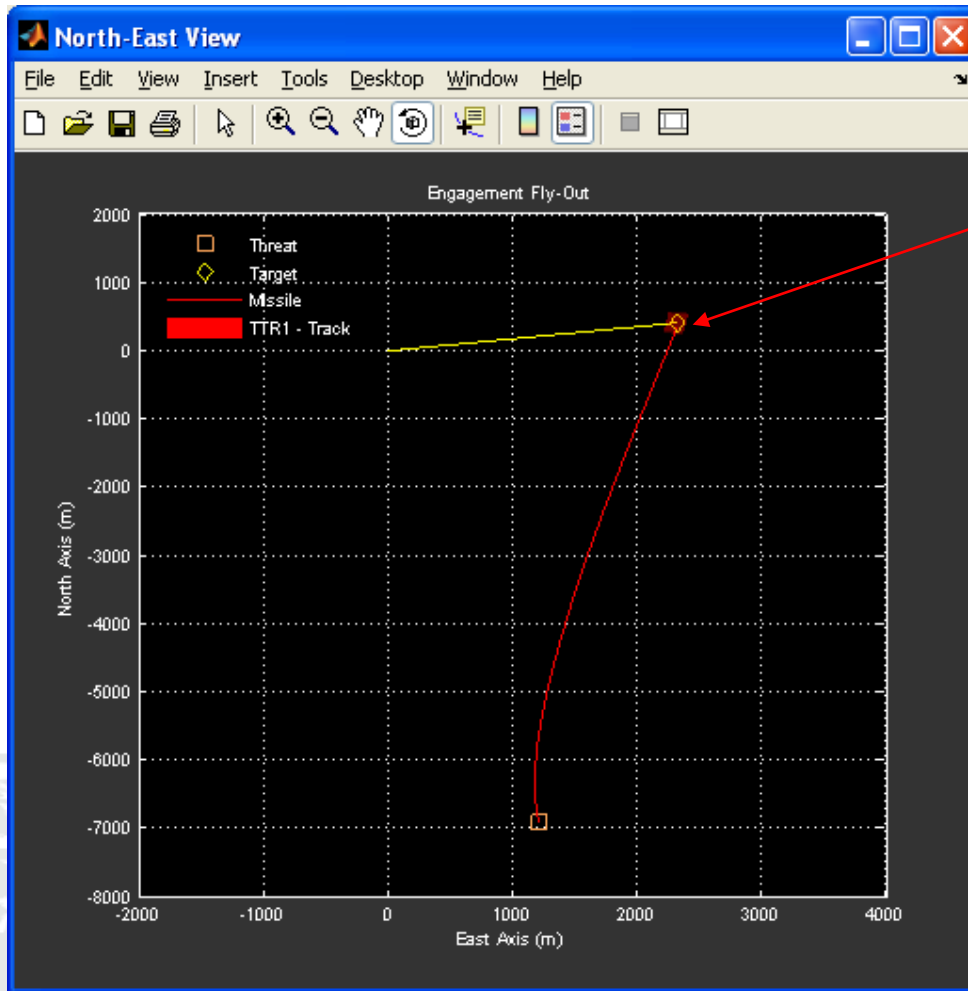
SAMCG Demo 1 - Select Engagement Output

Target Aircraft =Yellow
Chaff = dark blue Radar Track Point=Red



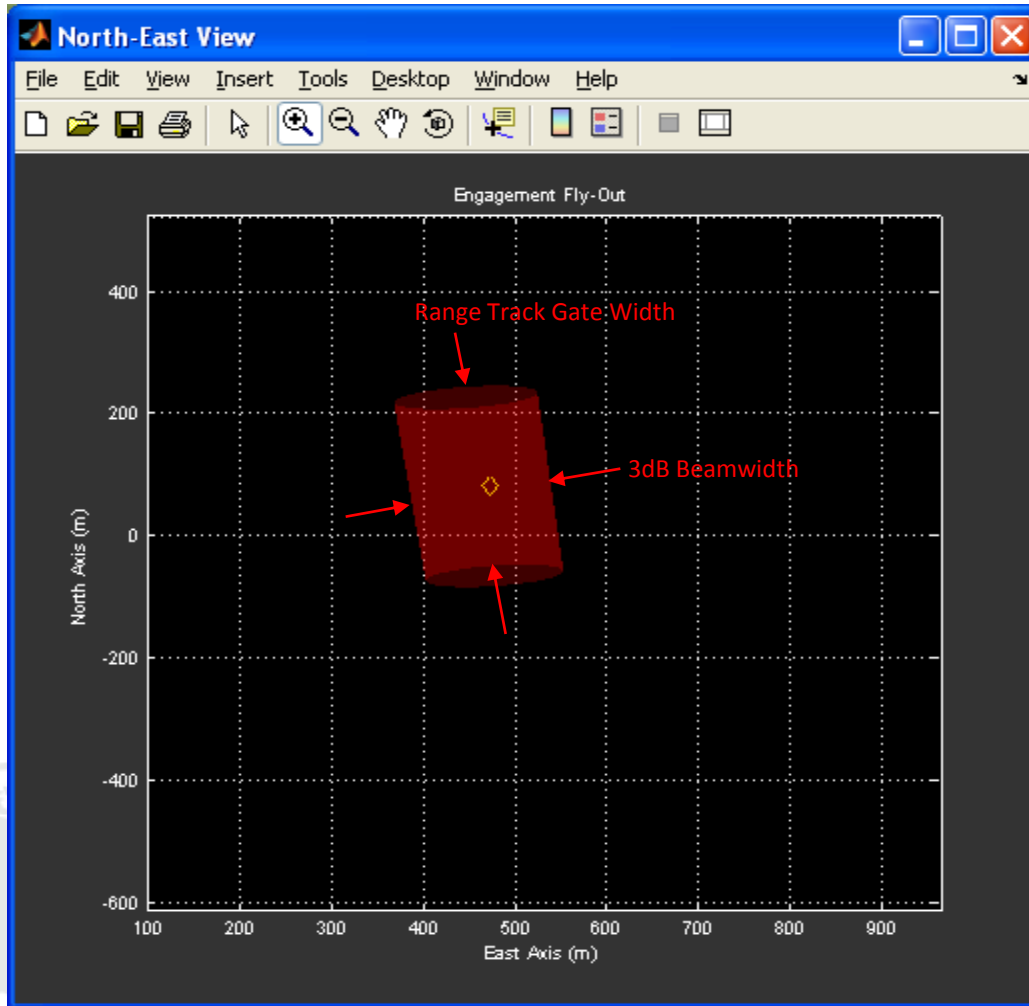
- Aircraft signature produces strong return
- Radar remains in track mode for duration of engagement
- Radar tracking aircraft in range, azimuth, and elevation
- Missile hits aircraft (see plots on following pages)

SAMCG Demo 1 - Select Engagement Output



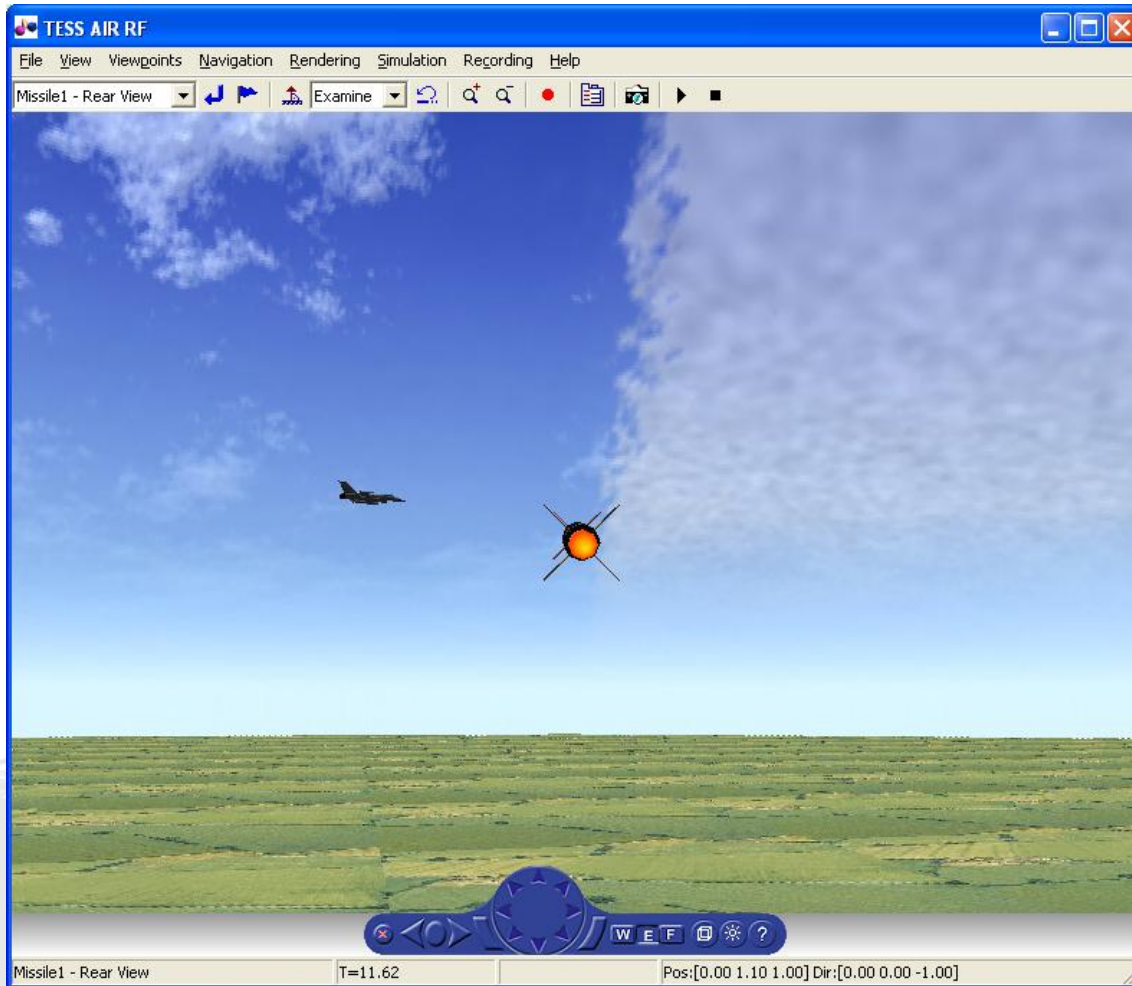
- Plan view
- Missile hits aircraft

SAMCG Demo 1 - Select Engagement Output



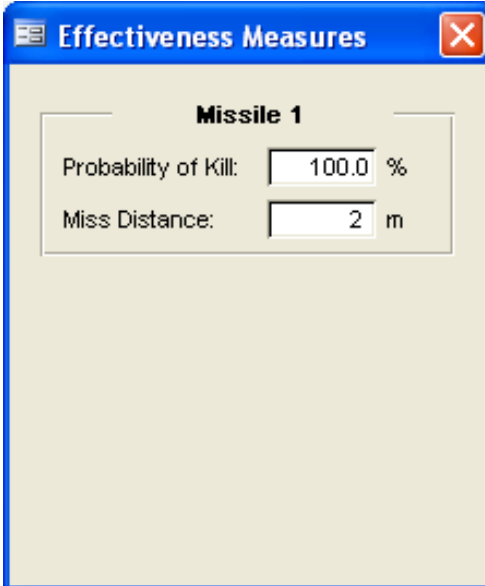
- Zoom Plan view of radar tracking cell at intermediate moment in engagement as radar tracks target aircraft
- Radar range track gate width indicated
- Radar antenna 3dB beamwidth indicated

SAMCG Demo 1 - Select Engagement Output



- Virtual Reality display shows missile approaching target aircraft at end game

SAMCG Demo 1 - Select Engagement Output



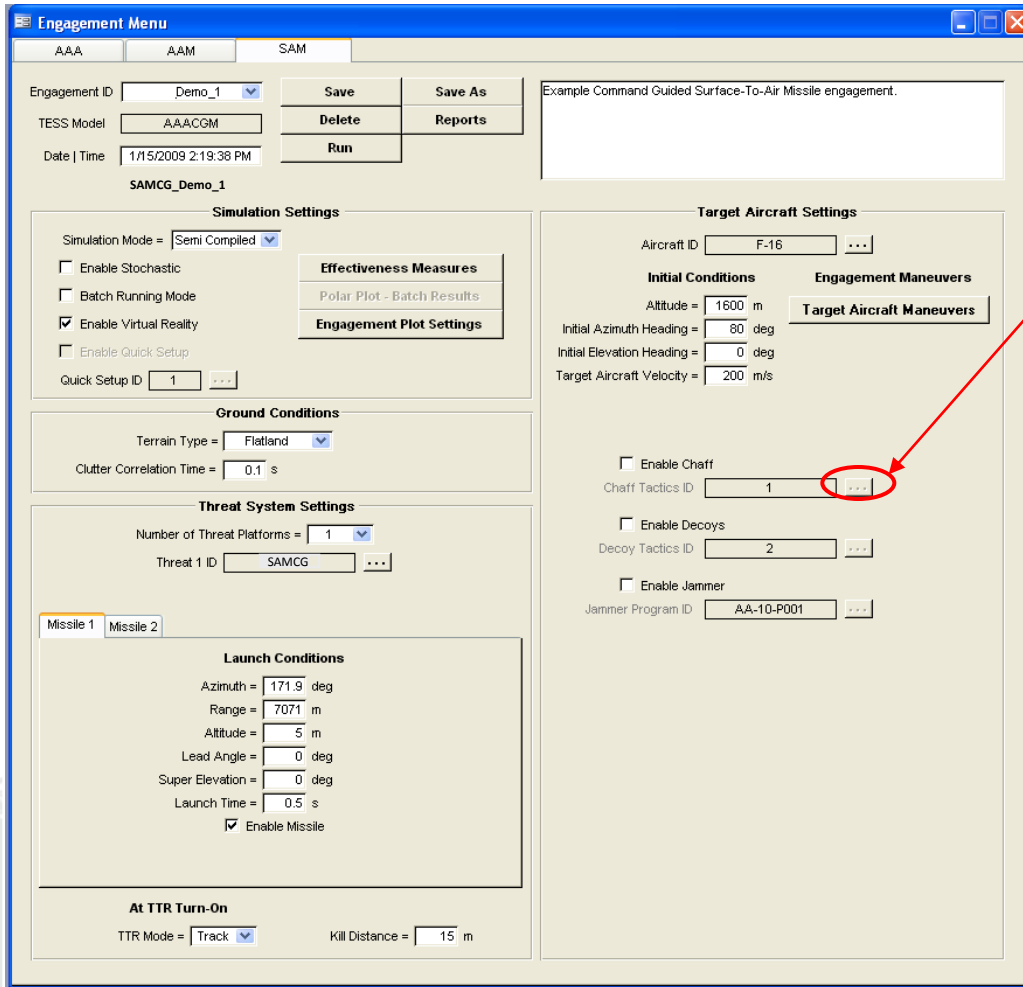
The screenshot shows a software window titled "Effectiveness Measures" with a close button in the top right corner. Inside the window, the text "Missile 1" is centered. Below this, there are two input fields: "Probability of Kill:" with a text box containing "100.0" and a "%" symbol to its right, and "Miss Distance:" with a text box containing "2" and an "m" symbol to its right.

- Missile to Target Platform miss distance = 2 meters
- Probability of Kill = 100 %

SAMCG Demo 2 - Overall Description

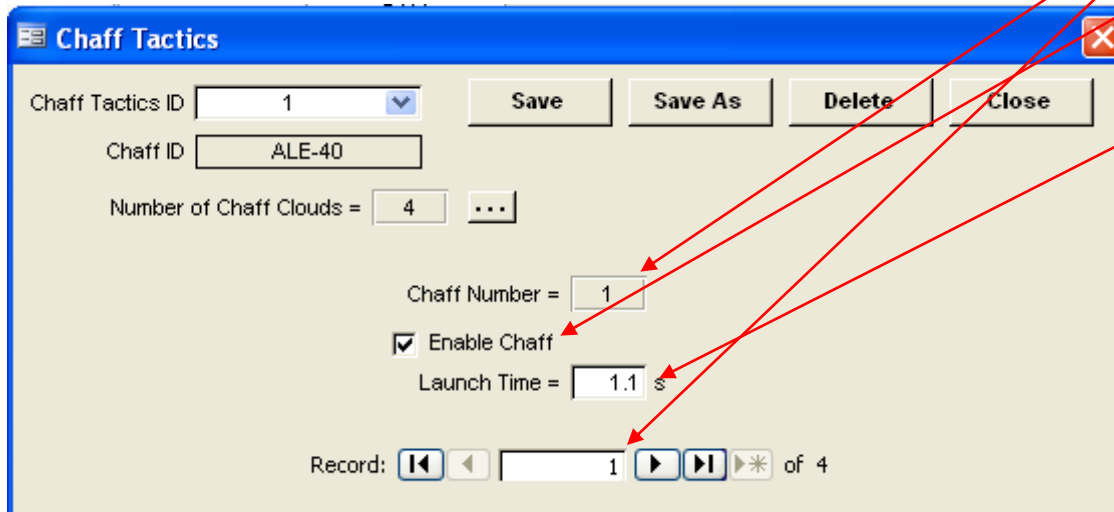
- The target aircraft is flying straight and level on an azimuth heading of 80 degrees clockwise with respect to North, at an altitude of 1600 meters
- At $t=0.5$ seconds after simulation start, a command-guided surface-to-air missile is launched from an azimuth bearing of 170 degrees at a horizontal range of 7000 meters
- The target aircraft launches a rapid sequence of four chaff clouds at $t=1.1$, $t=1.2$, $t=1.3$, and $t=1.4$ seconds
- The radar transfers track to the chaff centroid without break lock
- The target aircraft executes a 5g lateral acceleration maneuver at $t= 1.5$ seconds and resumes straight and level flight at $t=3$ seconds
- The radar tracks the chaff and issues steering commands to the missile
- The missile approaches and strikes the chaff

SAMCG Demo 2 - Select Chaff Parameters



Chaff Tactics Menu access (see next page)

SAMCG Demo 2 - Select Chaff 1 (of 4) Parameters



Chaff Tactics

Chaff Tactics ID: 1 [Save] [Save As] [Delete] [Close]

Chaff ID: ALE-40

Number of Chaff Clouds = 4 [...]

Chaff Number = 1

Enable Chaff

Launch Time = 1.1 s

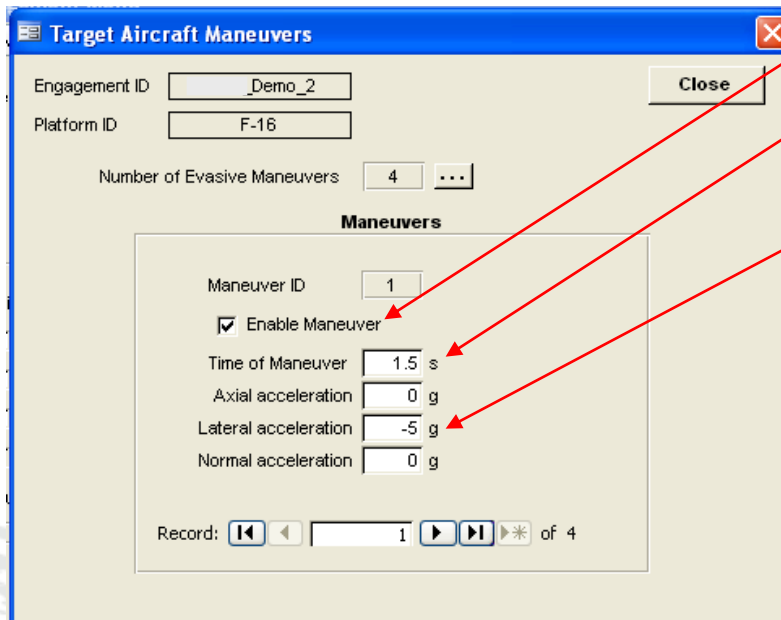
Record: [Navigation icons] 1 of 4

Chaff 1 selected

Chaff 1 Launch enabled

Chaff 1 Launch Time $t=1.1$ seconds

SAMCG Demo 2 - Target Aircraft Maneuver 1 (of 2)



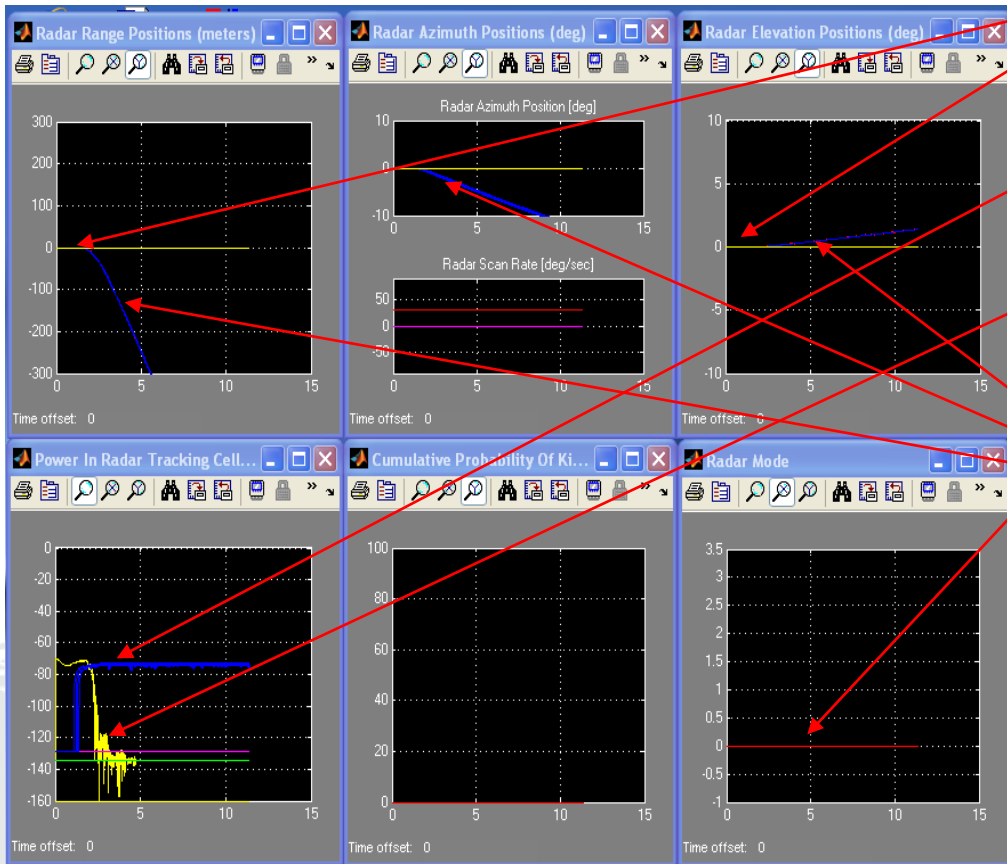
Maneuver 1 enabled

Time of maneuver
 $t=1.5$ seconds

5 g counterclockwise
lateral acceleration

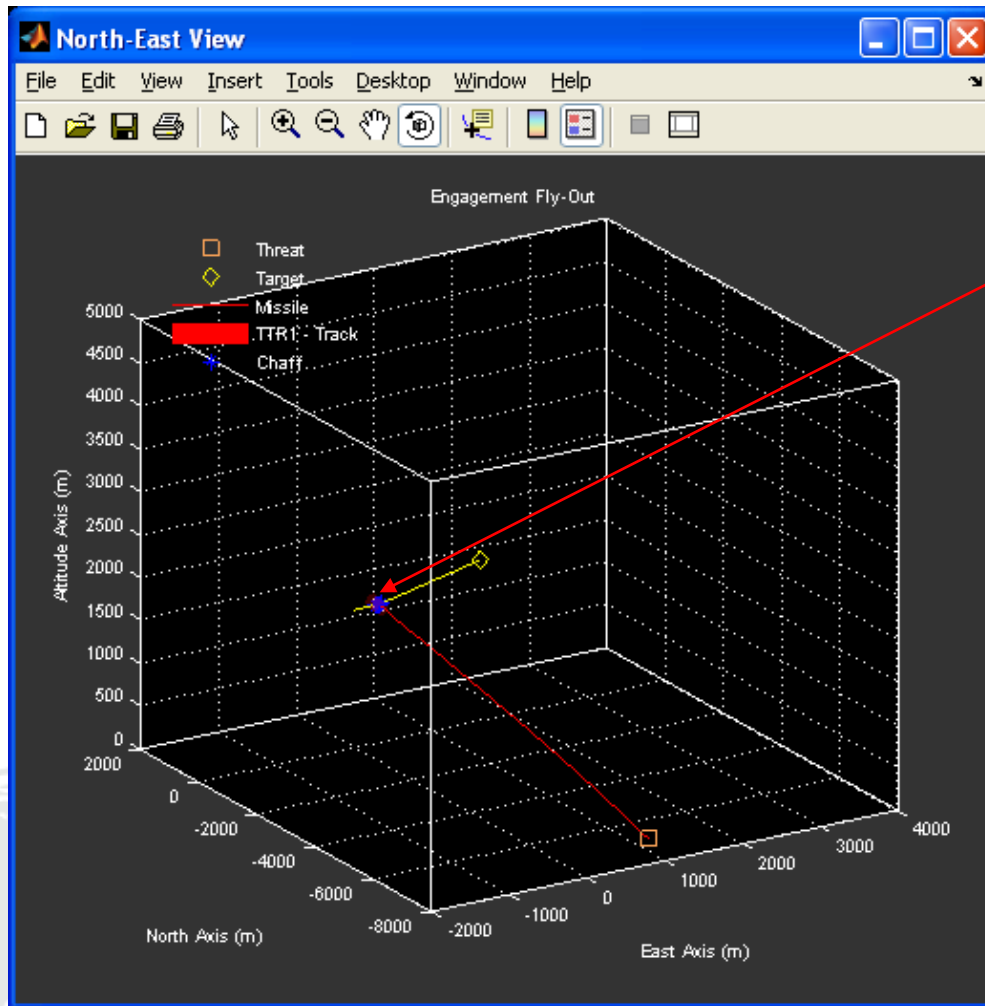
SAMCG Demo 2 - Select Engagement Output

Target Aircraft =Yellow
Chaff = dark blue Radar Track Point=Red



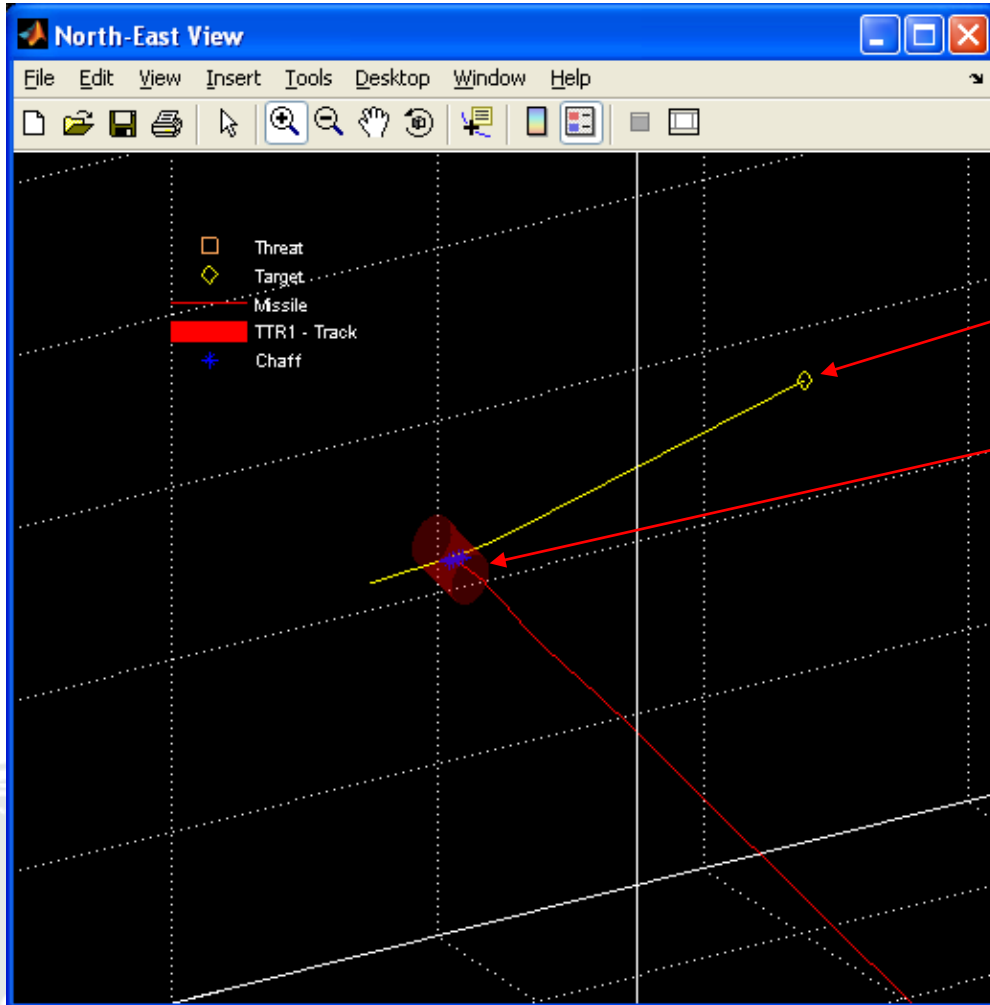
- Radar tracks Aircraft signature until chaff launches at t=1.1, 1.2, 1.3, and 1.4 secs
- Chaff return dominates Power in Radar Tracking Cell as chaff clouds capture radar track
- Aircraft return moves into radar antenna sidelobes as aircraft separates from chaff in azimuth
- Radar remains in track mode for duration of engagement
- Radar tracking chaff centroid in range, azimuth, and elevation
- Missile hits chaff (see plots on following pages)

SAMCG Demo 2 - Select Engagement Output



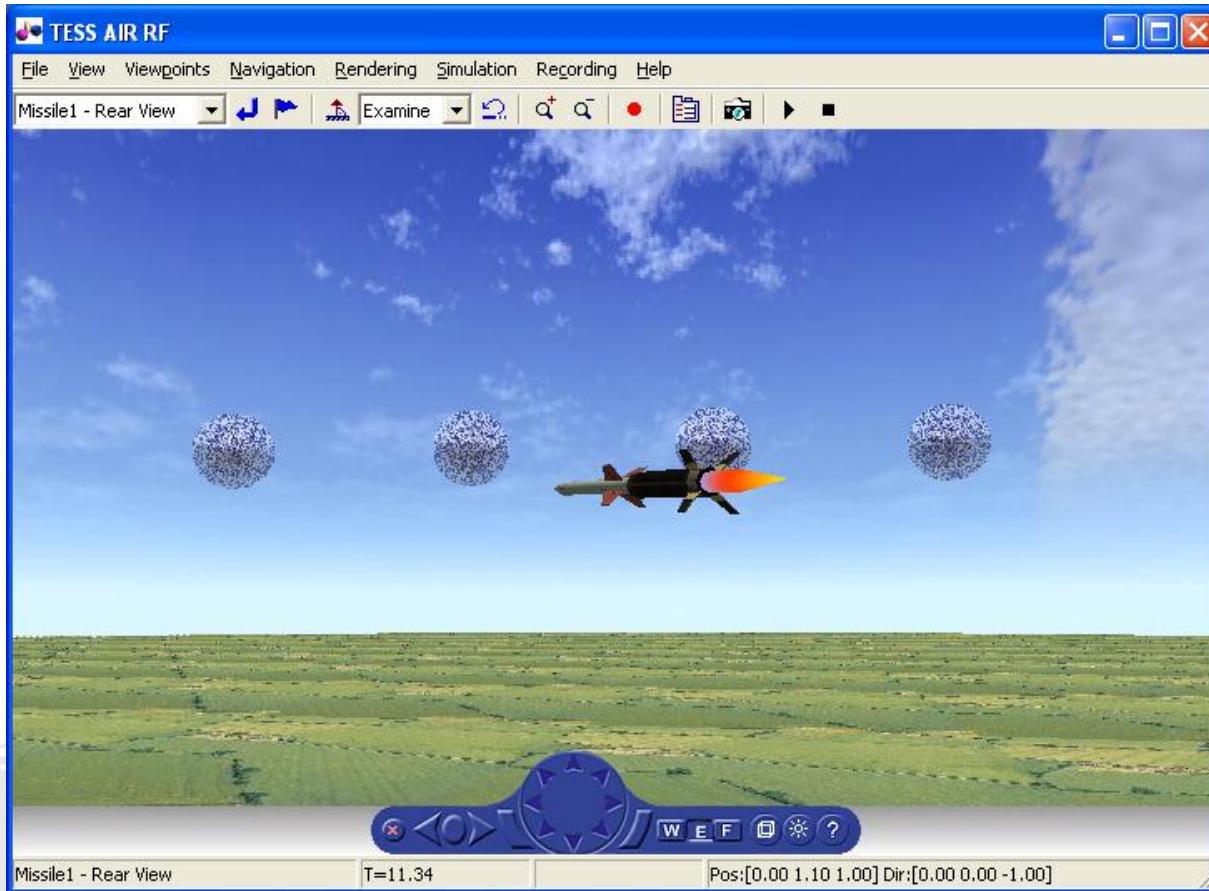
- 3D view
- Missile hits chaff

SAMCG Demo 2 - Select Engagement Output



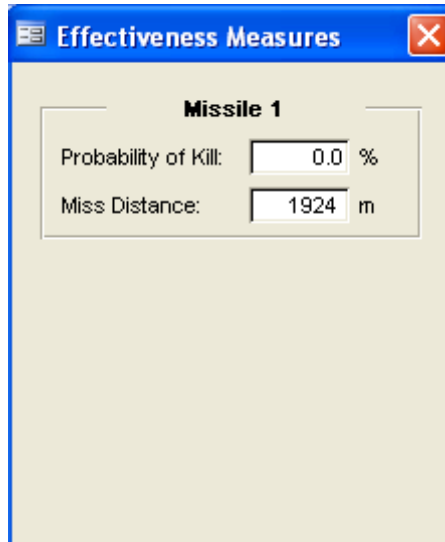
- Zoom 3D view
- Missile hits chaff
- Aircraft evades missile
- Radar Tracking Cell visible

SAMCG Demo 2 - Select Engagement Output



- Virtual Reality display shows missile engaging chaff at end game

SAMCG Demo 2 - Select Engagement Output



The screenshot shows a dialog box titled "Effectiveness Measures" with a close button (X) in the top right corner. Inside the dialog, there is a section titled "Missile 1" containing two input fields: "Probability of Kill:" with a value of "0.0 %" and "Miss Distance:" with a value of "1924 m".

- Missile to Target Platform miss distance = 1924 meters
- Probability of Kill = 0 %

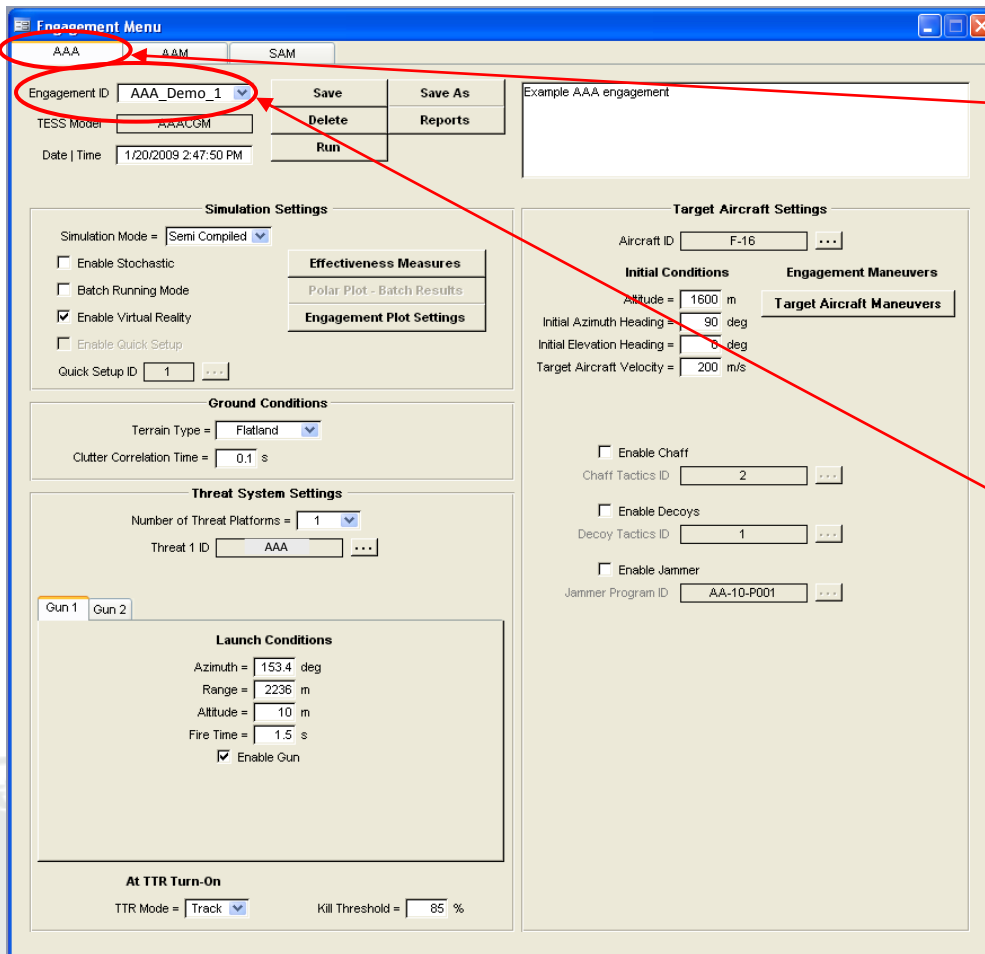
All Demos AAA fire

- The AAA Fire Control Solution is based on ballistic theories found in off-the-shelf sources such as *R. H. M. Macfadzean – Surface-Based Air Defense System Analysis - 1992 Artech House*, and in that reference in particular, the solutions of the differential equations (equation 4.9) on pg 99. A request for a Fire Control Solution for a new burst at any time triggers an iterative subroutine calculation that is made using the instantaneous azimuth, elevation and range track points of the tracking radar and generated calculations of track rate based on those measurements. The algorithm also uses static user-entered Muzzle Velocity, Projectile Mass, Projectile Caliber and Drag Coefficient parameters. The Fire Control Solution returns a pair of azimuth and elevation fire angles for the gun that are valid for the first shell in that burst. Using calculated rate estimates, the radar calculates a slew rate for the gun to be used during the remaining portion of that burst. A subsequent burst triggers a request for a new Fire Control Solution.

AAA Demo 1 - Overall Description

- The target aircraft is flying straight and level on an azimuth heading of 90 degrees clockwise with respect to North, at an altitude of 1600 meters
- The radar and anti-aircraft artillery (AAA) is located at a height of 15 meters, a horizontal distance of 2236 meters and an azimuth bearing of 153 degrees from the initial aircraft azimuth position
- Based on dynamic radar target tracking information and the user-entered gun and shell parameters, the Fire Control System requests a fire control solution for the target under track
- At $t=1.5$ seconds after simulation start, the AAA gun commences firing
- As each AAA burst reaches closest point of approach of the target aircraft, a cumulative probability of kill is calculated – reaching the user-specified 85% by the third burst in this engagement

AIR RF Master Interface - AAA Engagement Menu



Engagement Menu

AAA | AAM | SAM

Engagement ID: AAA_Demo_1 | Save | Save As | Delete | Reports | Run

TESS Model: AAAACGM | Date | Time: 1/20/2009 2:47:50 PM

Example AAA engagement

Simulation Settings

Simulation Mode = Semi Compiled

Enable Stochastic

Batch Running Mode

Enable Virtual Reality

Enable Quick Setup

Quick Setup ID = 1

Effectiveness Measures

Polar Plot - Batch Results

Engagement Plot Settings

Ground Conditions

Terrain Type = Flatland

Clutter Correlation Time = 0.1 s

Threat System Settings

Number of Threat Platforms = 1

Threat 1 ID = AAA

Gun 1 | Gun 2

Launch Conditions

Azimuth = 153.4 deg

Range = 2236 m

Altitude = 10 m

Fire Time = 1.5 s

Enable Gun

At TTR Turn-On

TTR Mode = Track | Kill Threshold = 85 %

Target Aircraft Settings

Aircraft ID = F-16

Initial Conditions

Altitude = 1600 m

Initial Azimuth Heading = 90 deg

Initial Elevation Heading = 0 deg

Target Aircraft Velocity = 200 m/s

Engagement Maneuvers

Target Aircraft Maneuvers

Enable Chaff

Chaff Tactics ID = 2

Enable Decoys

Decoy Tactics ID = 1

Enable Jammer

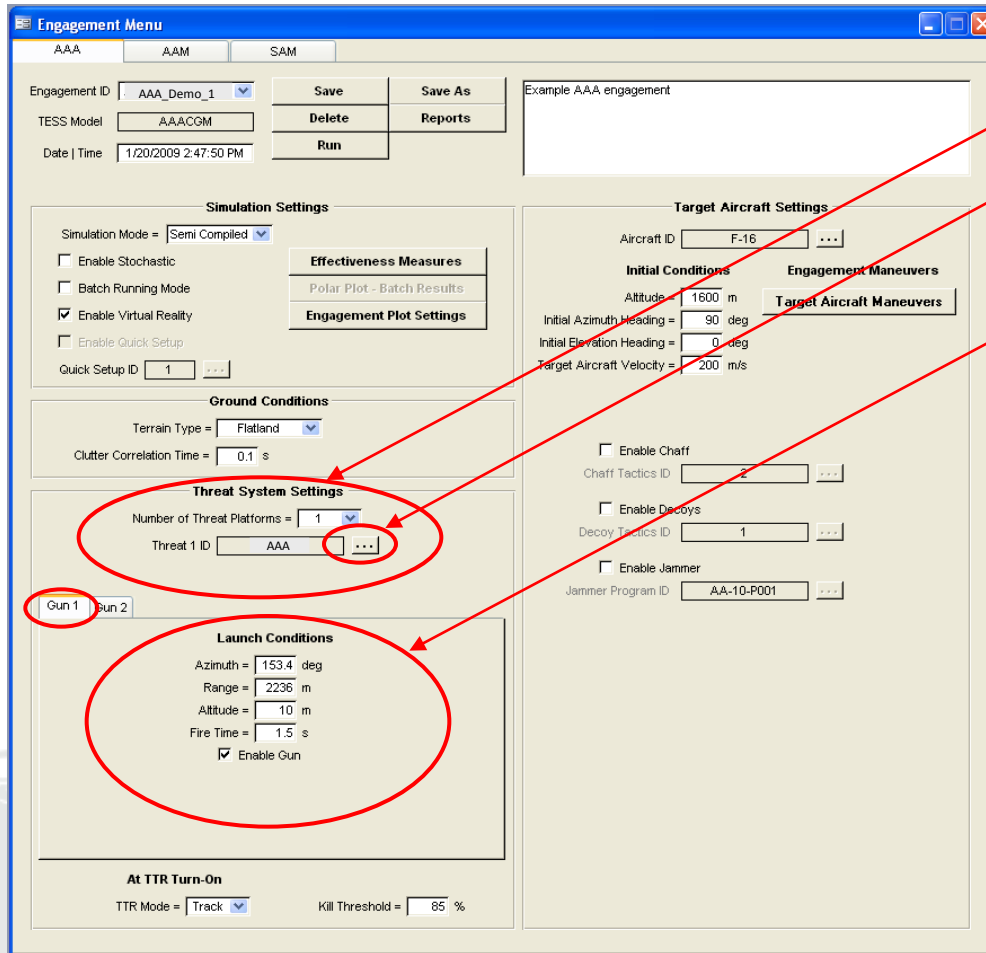
Jammer Program ID = AA-10-P001

- The AAA Engagement menu of the AIR RF Master Interface is shown

- The Engagement ID of the AIR RF Master Interface is indicated

- The sample engagements AAA Demo 1, and AAA Demo 2 are listed in the Engagement ID menu

AAA Demos - Select Threat System Parameters



Threat System Settings

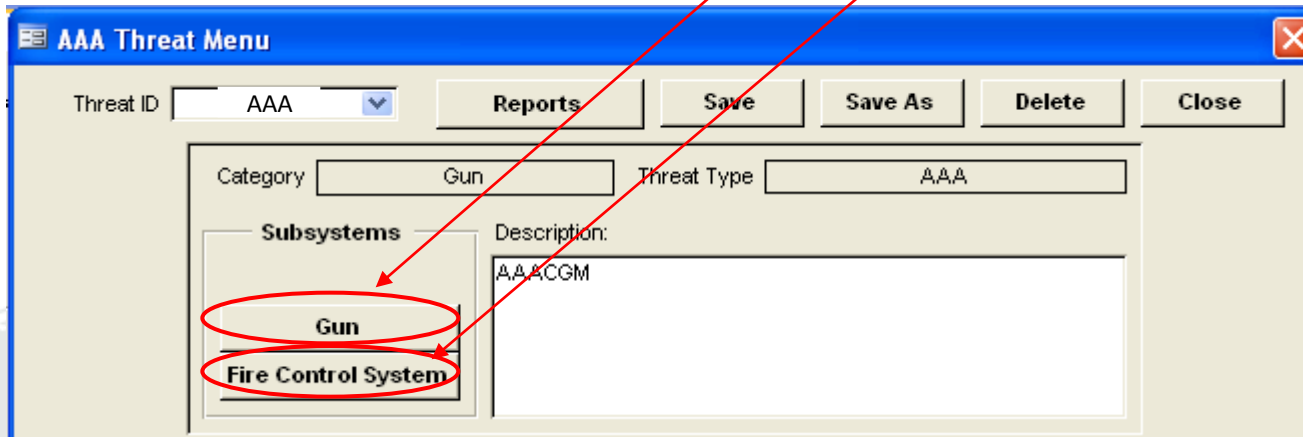
Threat Menu access (see next page)

Gun 1 Launch Conditions

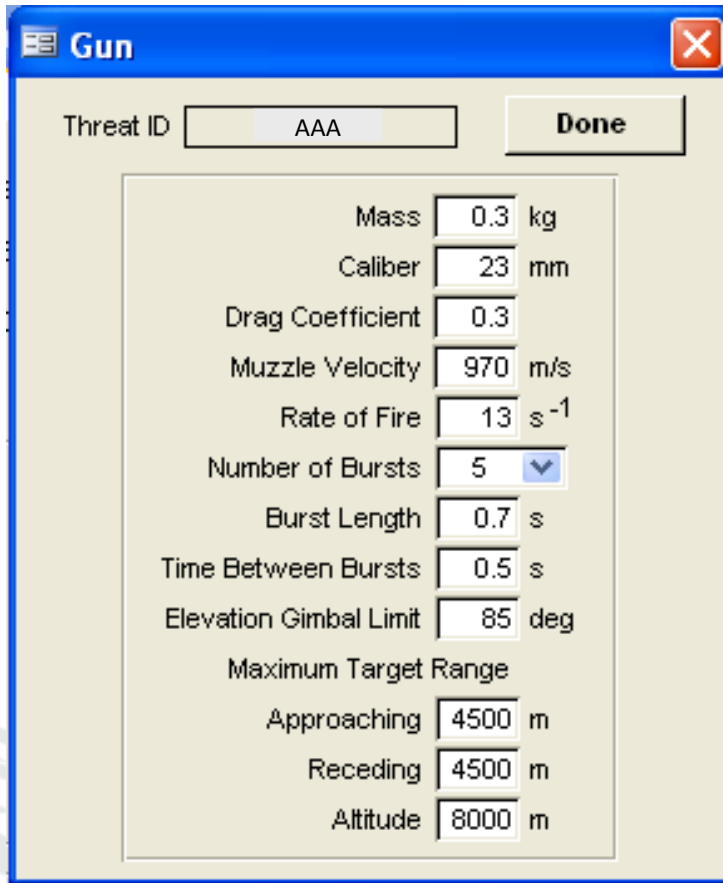
AAA Demos - AAA Threat Menu

Gun Subsystem Menu
access (see next page)

Fire Control System Menu
access (note that CG
missile and AAA radars are
identical)



AAA Demos - Gun Parameters



Gun

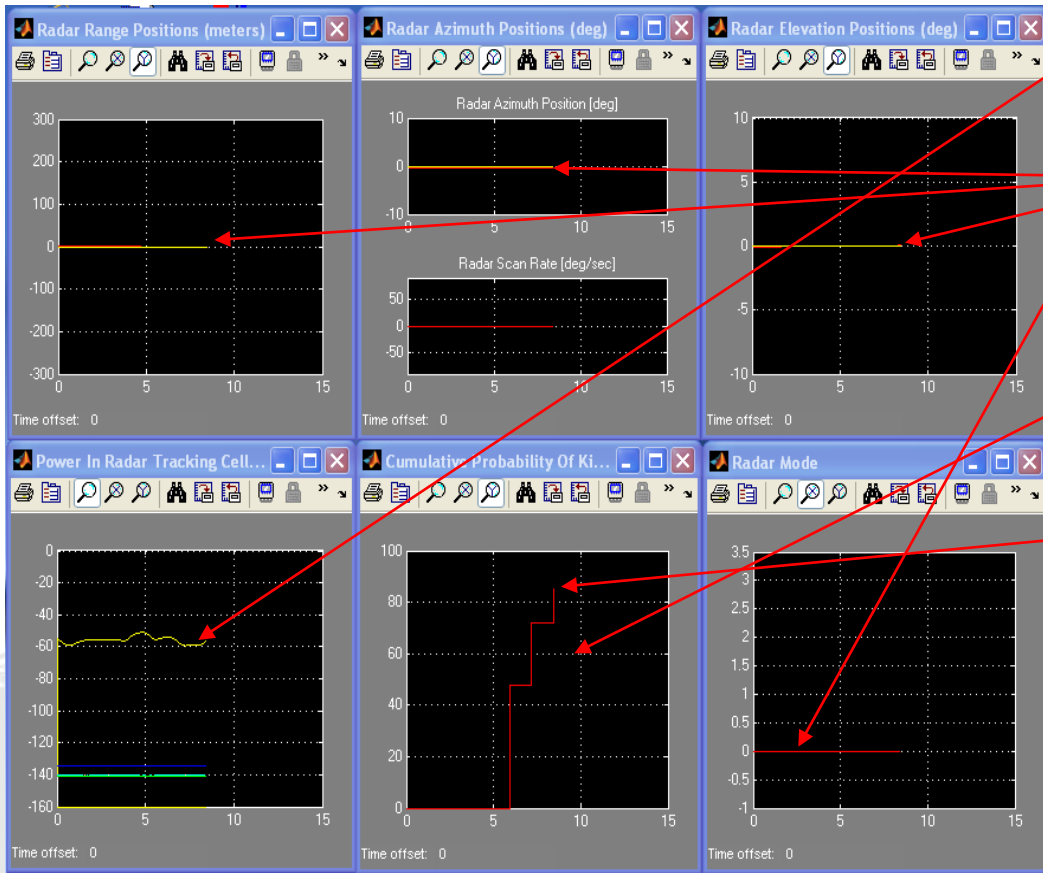
Threat ID:

Mass	<input type="text" value="0.3"/>	kg
Caliber	<input type="text" value="23"/>	mm
Drag Coefficient	<input type="text" value="0.3"/>	
Muzzle Velocity	<input type="text" value="970"/>	m/s
Rate of Fire	<input type="text" value="13"/>	s ⁻¹
Number of Bursts	<input type="text" value="5"/> ▼	
Burst Length	<input type="text" value="0.7"/>	s
Time Between Bursts	<input type="text" value="0.5"/>	s
Elevation Gimbal Limit	<input type="text" value="85"/>	deg
Maximum Target Range		
Approaching	<input type="text" value="4500"/>	m
Receding	<input type="text" value="4500"/>	m
Altitude	<input type="text" value="8000"/>	m

- Anti Aircraft Artillery
“Gun” parameter menu

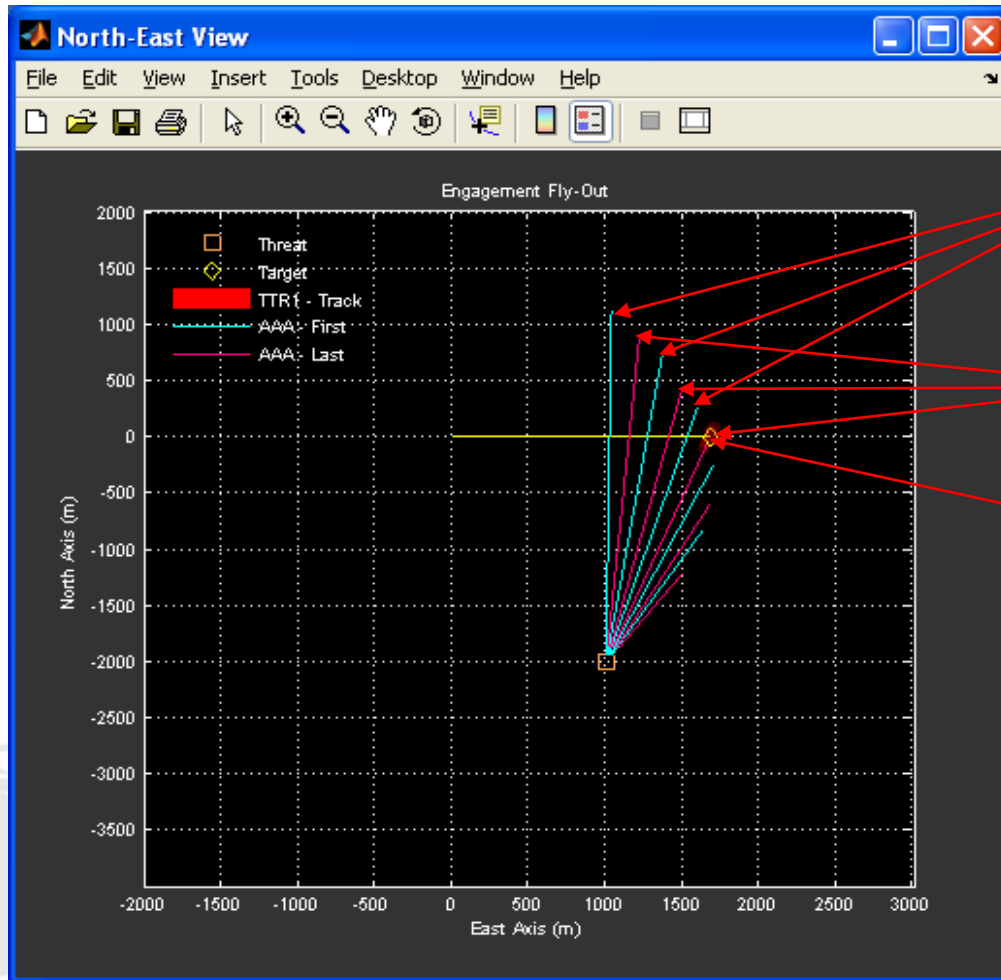
AAA Demo 1 - Select Engagement Output

Target Ship = Yellow Jamming = Magenta
 Chaff = dark blue Seeker Track Point = Red



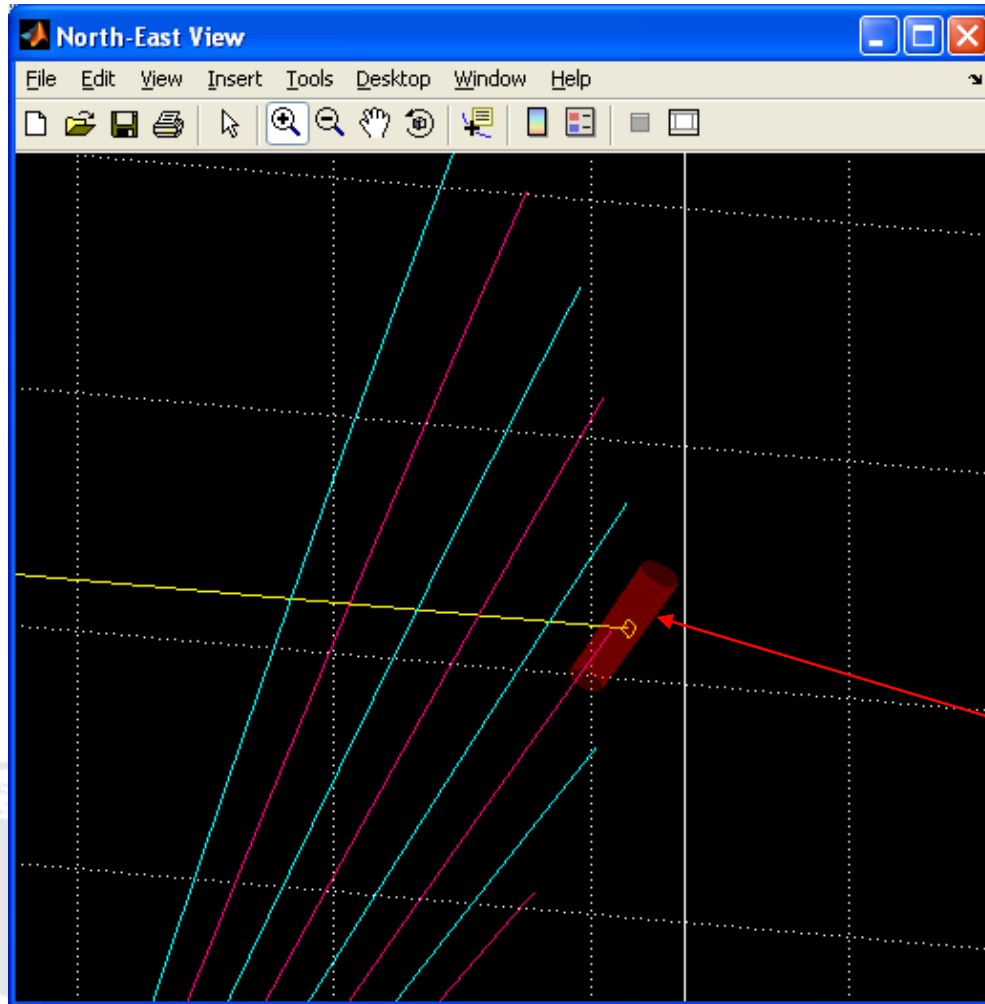
- Aircraft signature produces strong return
- Radar remains in track mode for duration of engagement
- Radar cleanly tracking aircraft in range, azimuth, and elevation able to provide accurate fire control solution to AAA gun
- AAA bursts provide a calculation of cumulative probability of kill as AAA burst reach point of closest approach to target aircraft
- AAA fire provides 85% probability of target kill after third burst (see plots on following pages)

AAA Demo 1 - Select Engagement Output



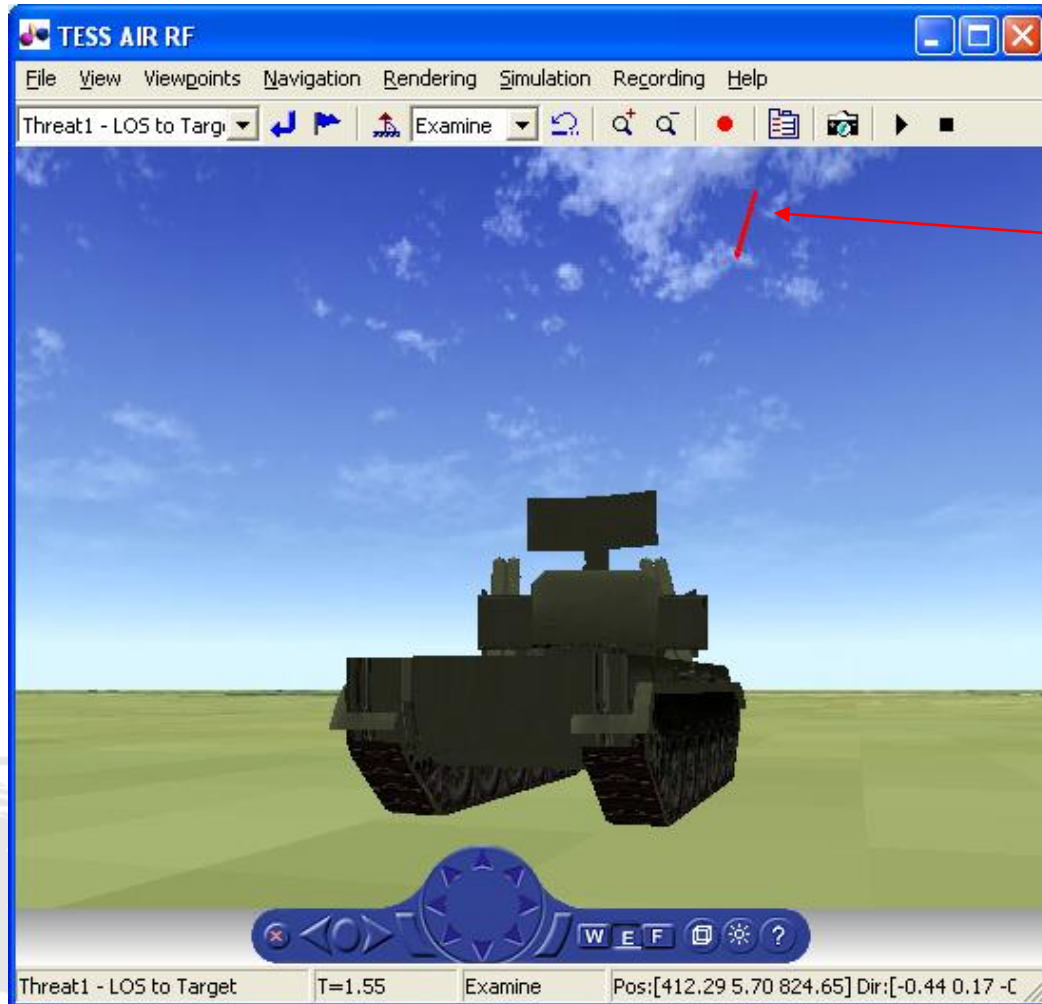
- Plan view
- First shell of each AAA burst shown in cyan
- Last shell of each AAA burst shown in red
- Target aircraft shown (yellow diamond icon)

AAA Demo 1 - Select Engagement Output



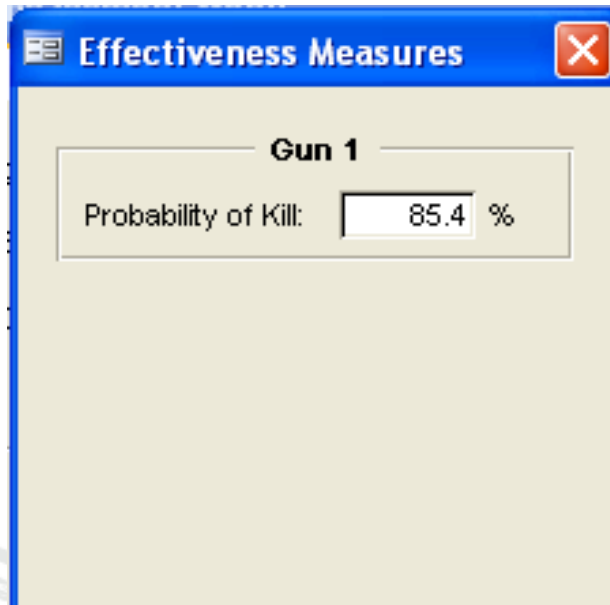
- Zoom 3D view
- First shell of each AAA burst shown in cyan
- Last shell of each AAA burst shown in red
- Target aircraft shown (yellow diamond icon)
- Radar tracking cell visible

AAA Demo 1 - Select Engagement Output



- Virtual Reality display shows threat vehicle
- AAA fire visible

AAA Demo 1 - Select Engagement Output



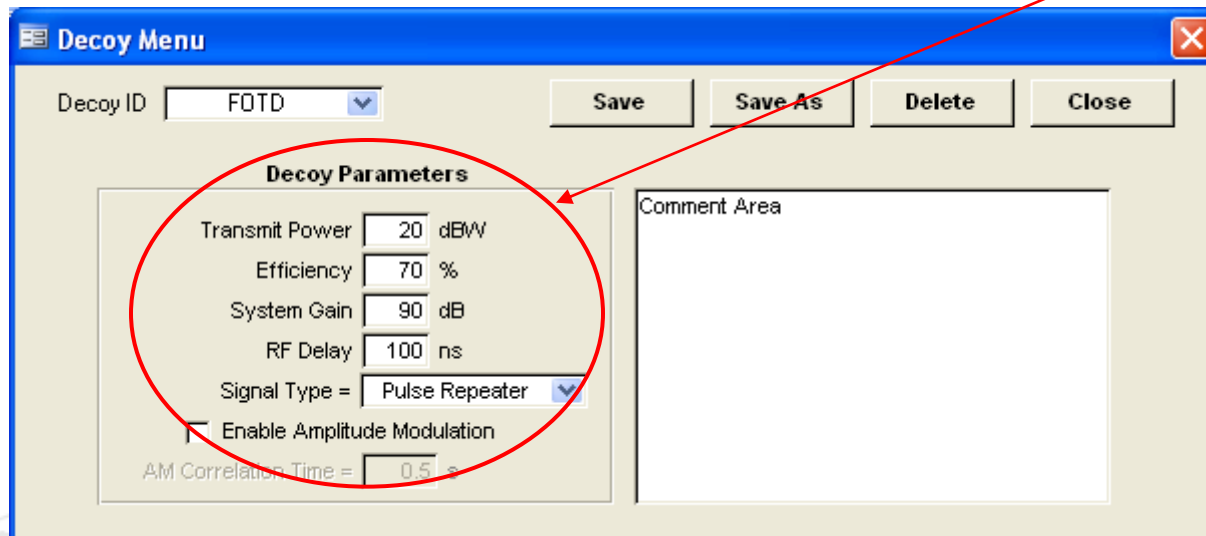
- Probability of Kill = 85.4 % (exceeds user-entered threshold of 85% and halts simulation)

AAA Demo 2 - Overall Description

- The target aircraft is flying straight and level on an azimuth heading of 90 degrees clockwise with respect to North, at an altitude of 1600 meters and immediately deploys a towed decoy
- The radar and anti-aircraft artillery (AAA) is located at a height of 15 meters, a horizontal distance of 2236 meters and an azimuth bearing of 153 degrees from the initial aircraft azimuth position
- Based on dynamic radar target tracking information and the user-entered gun and shell parameters, the Fire Control System requests a fire control solution for the target under track
- At $t=1.5$ seconds after simulation start, the AAA gun commences firing
- As each AAA burst reaches closest point of approach of the target aircraft, a cumulative probability of kill is calculated – reaching the user-specified 85% by the third burst in this engagement

AAA Demo 2 - Select Decoy Parameters

- Decoy Menu
- Decoy Parameters (parameters apply to all decoys for specified Decoy ID)



Decoy Menu

Decoy ID: FOTD

Save Save As Delete Close

Decoy Parameters

Transmit Power: 20 dBW

Efficiency: 70 %

System Gain: 90 dB

RF Delay: 100 ns

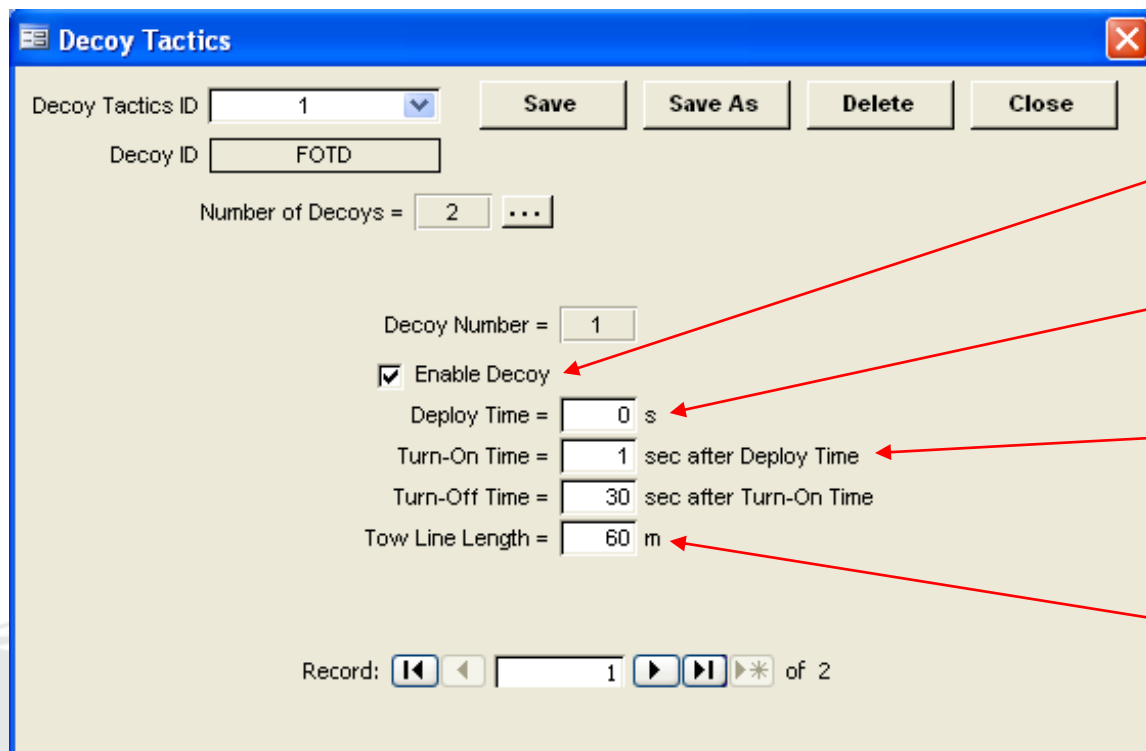
Signal Type = Pulse Repeater

Enable Amplitude Modulation

AM Correlation Time = 0.5 s

Comment Area

AAA Demo 2 - Select Decoy Parameters



The screenshot shows the 'Decoy Tactics' window with the following settings:

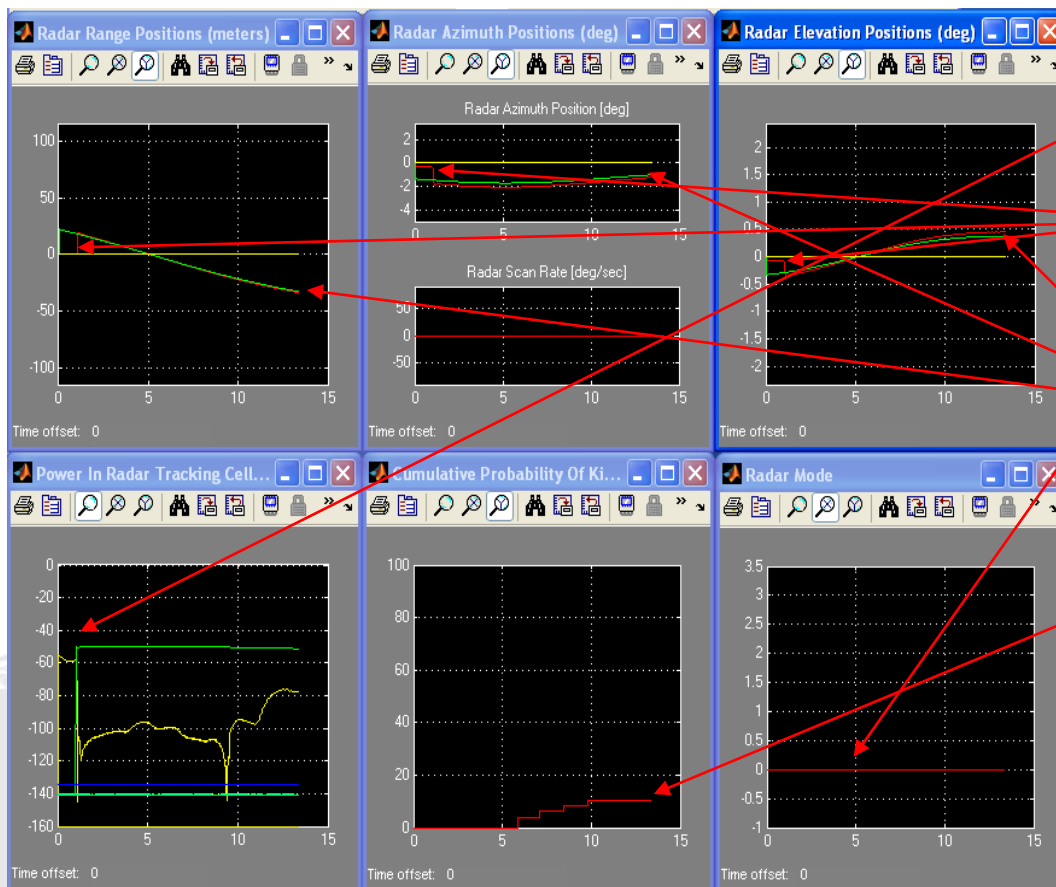
- Decoy Tactics ID: 1
- Decoy ID: FOTD
- Number of Decoys: 2
- Decoy Number: 1
- Enable Decoy
- Deploy Time: 0 s
- Turn-On Time: 1 sec after Deploy Time
- Turn-Off Time: 30 sec after Turn-On Time
- Tow Line Length: 60 m

At the bottom, there is a record navigation bar showing 'Record: 1 of 2'.

- Decoy Tactics menu (parameters apply to individual decoys)
- Decoy 1 Launch enabled
- Decoy 1 Deploy Time $t=0$ seconds
- Decoy 1 Turn-On Time = 1 second after deployment
- Decoy 1 Tow Line Length = 60 m

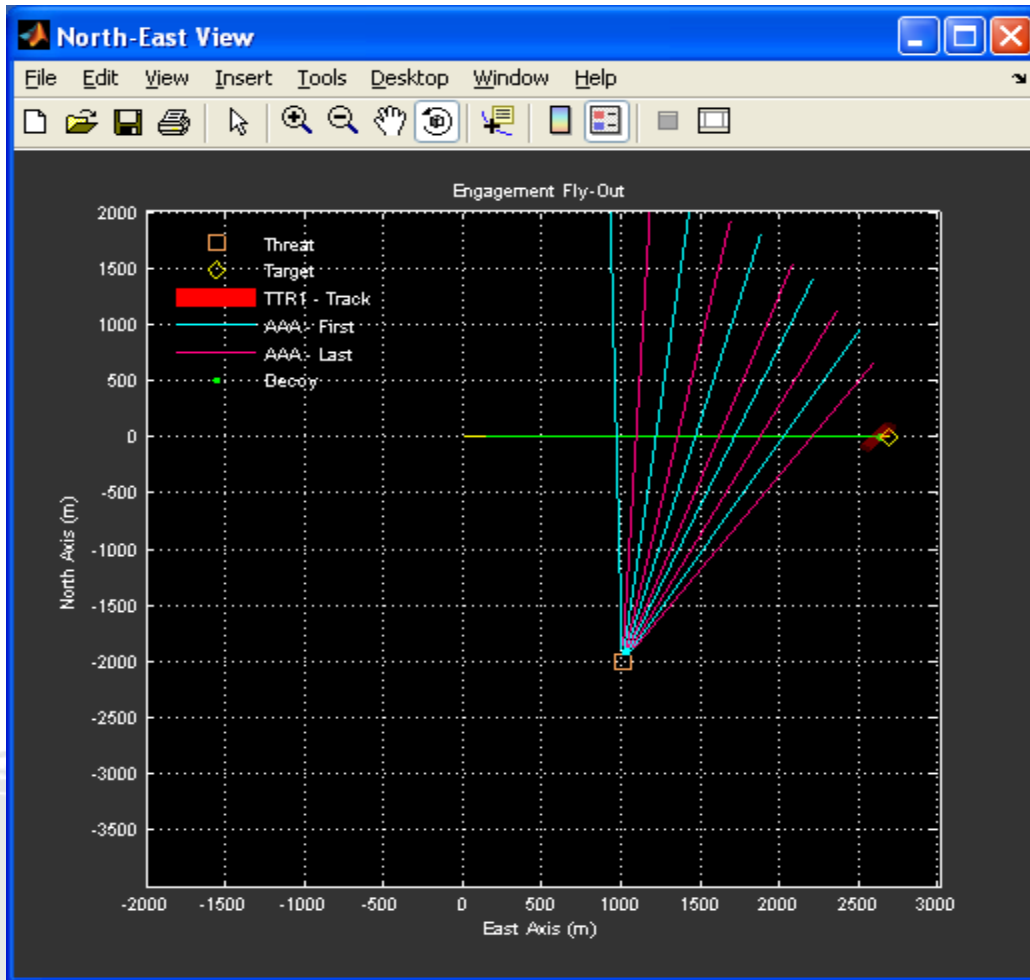
AAA Demo 2 - Select Engagement Output

Target Ship = Yellow Jamming = Magenta
Chaff = dark blue Seeker Track Point = Red



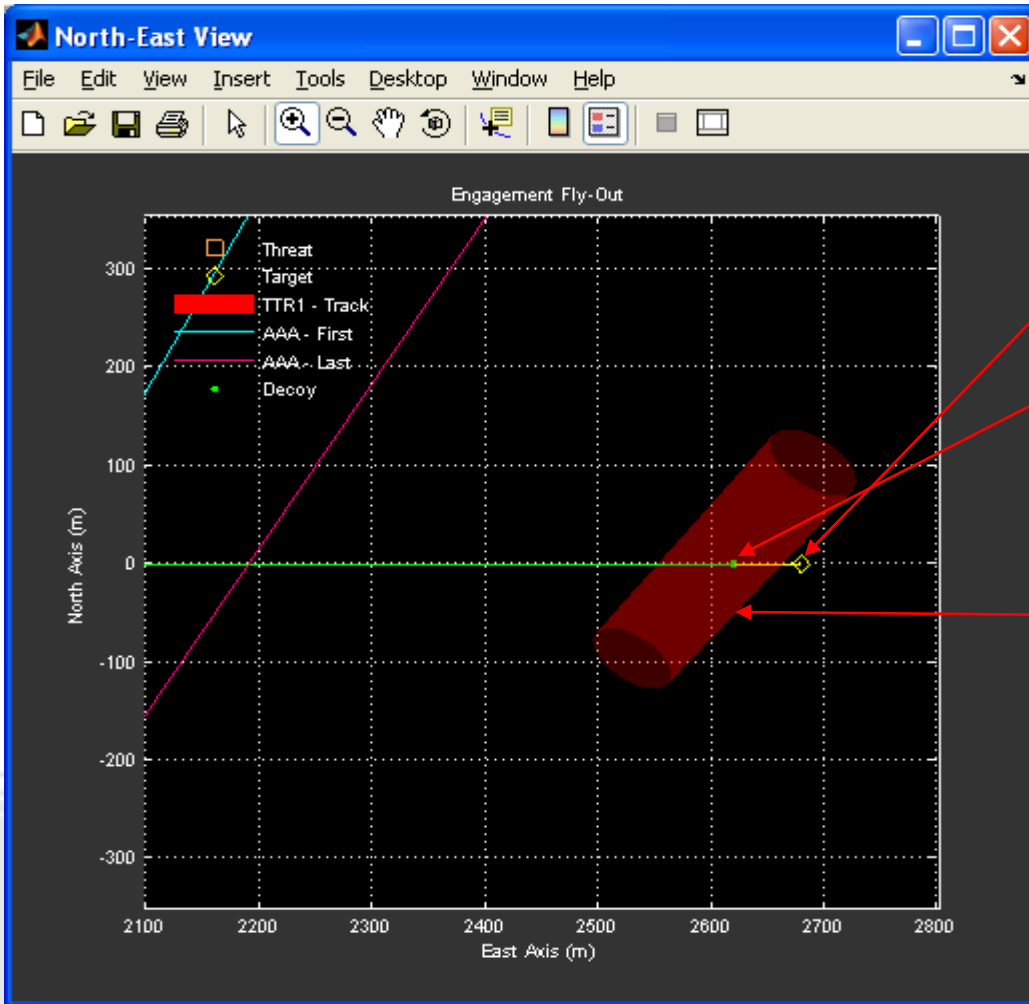
- Target Aircraft deploys towed decoy at t=0 seconds
- Decoy turns-on at t= 1 second with sufficient power for the radar to transfer track to decoy
- Radar transfers track to decoy without break lock
- Radar remains in track mode for duration of engagement
- Radar cleanly tracking towed decoy in range, azimuth, and elevation and provides to provide accurate fire control solution to AAA gun
- AAA bursts provide a calculation of cumulative probability of kill as AAA burst reach point of closest approach to target aircraft
- AAA fire provides 10.6% cumulative probability of target kill for all bursts

AAA Demo 2 - Select Engagement Output



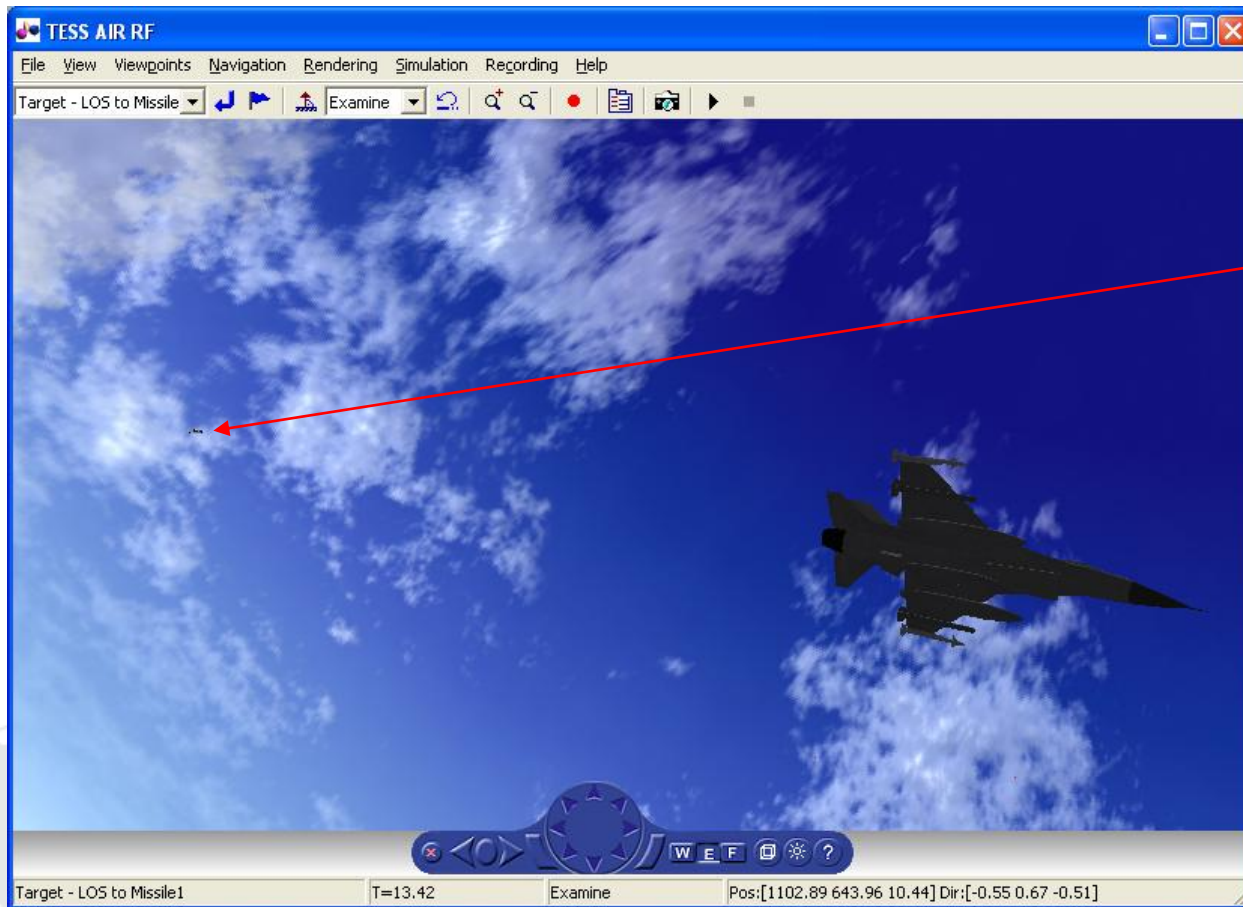
- Plan view
- First shell of each AAA burst shown in cyan
- Last shell of each AAA burst shown in red
- Target aircraft shown (yellow diamond icon)
- Towed decoy shown (green dot icon)
- Radar tracking cell visible

AAA Demo 2 - Select Engagement Output



- Zoom Plan view
- Target aircraft shown (yellow diamond icon)
- Towed decoy shown 60 meters behind aircraft (green dot icon)
- Radar tracking cell shown tracking towed decoy

AAA Demo 2 - Select Engagement Output



- Zoom Virtual Reality display
- Target aircraft shown
- Towed decoy shown

AAA Demo 2 - Select Engagement Output

- Probability of Kill = 10.6 %

