Tactical Engagement Simulation Software™

Introduction

Tactical Technologies Inc. (TTI) supports electronic warfare (EW) knowledge and technology development. This support is provided to the international EW community through professional development training and TTI's family of software-based products and tools. This family of software is marketed under the trade name "Tactical Engagement Simulation Software™" (TESS™).

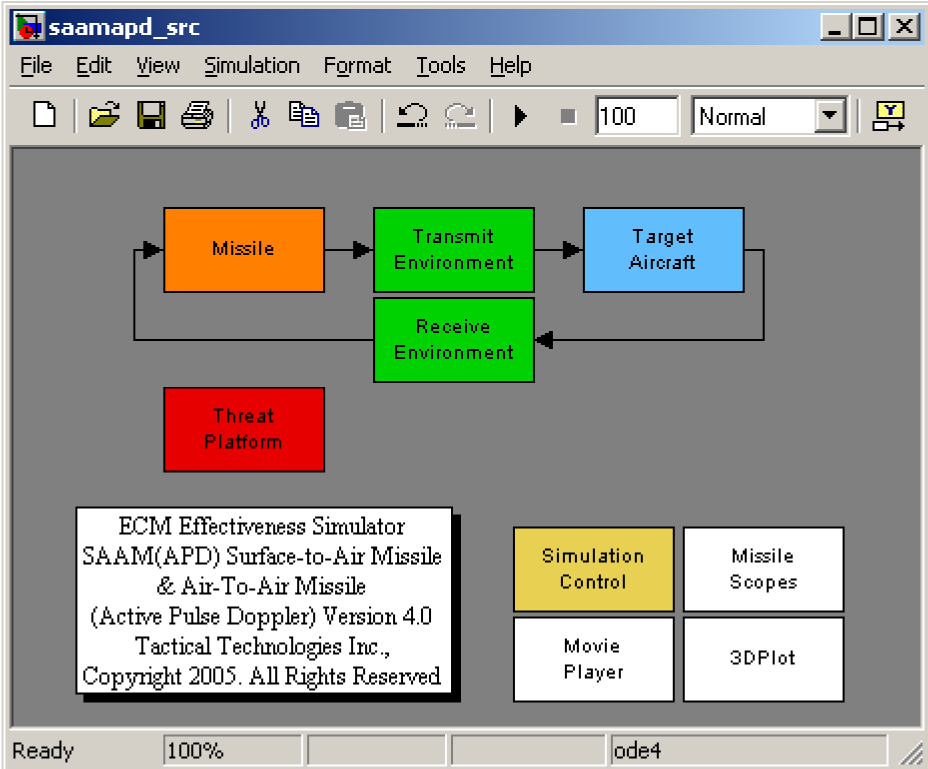
TESS supports weapon system modeling, tactical engagement simulation, engagement analysis and evaluation, and EW effectiveness evaluations in some of the most modern and advanced EW laboratories in over 20 countries. TESS is used by weapon system designers, engineers, researchers and the military to support their diverse requirements.

TESS utilizes high fidelity open-source material based on established and verified weapon system models and user defined input parameters to characterize the behavior of specific weapon systems of interest. TESS weapon system models can be used independently, or, in a TESS simulation framework where a user defined dynamic tactical engagement simulation allows the user to analyze dynamic interactions between threat and electronic attack systems. TESS simulators support dynamic engagement geometries, conditions, signal environments and tactics from platform maneuvering, through to the controlled activation of various electronic attack / countermeasure techniques. TESS simulators support naval, surface-to-air and air-to-air engagements with radar or infrared guided weapons engaging a target platform with user defined electronic attack capabilities.

TESS was specifically designed to allow the user to analyze and investigate dynamic system-on-system interactions in realistic engagement geometries in order to evaluate and optimize the effectiveness of electronic attack and electronic protective measures and techniques.

Tactical Technologies Inc.
356 Woodroffe Avenue, Ottawa, Ontario, Canada, K2A 3V6
tel: 613-828-0775 fax: 613-828-8310
www.tti.on.ca info@tti.on.ca

Simulation and analysis of threat and target platform system interactions, based on transmitted and/or received signals requires accurate behavioral characterization of these systems including their dynamic responsiveness and non-linearities. TESS supports these prerequisites and as a result provides the user with unprecedented insight into how they actually behave as a system in dynamic engagement based scenarios, as well as, how they can be influenced. The degree to which particular variables influence outcome and to assess their dependency on other conditions, the user needs to develop an extensive knowledge base that can only be derived by performing analysis on thousands of simulated engagements. System modeling and engagement simulation technology like that offered by TESS is virtually the only way to thoroughly investigate these issues and characterize them. Field trails and hardware-in-the-loop testing validate, compliment and substantiate these investigations.



Simulink Model for SAAMAPD Simulator

TESS provides the user with various output displays to monitor signals, states and system behavior during a typical simulated engagement. To appreciate "how and why" certain things are happening. TESS allows the user to probe into its weapon system and sub-system models to investigate these issues, and on completion of each engagement, generates miss-distance (based on closest-point-of-approach) and probability-of-survival results as useful metrics in effectiveness evaluations. Depending on the user's specific interests and focus, he can also record any other relevant data of interest. TESS's documentation feature records all input/set-up conditions along with the test results in a test file which provides the user with a test audit trail, directly supports the recreation of a particular simulation and supports further analysis and knowledge development.

A number of TESS's features are the result of the use of an open commercial-off-the-shelf environment. TESS runs on standard PC's with Microsoft Windows® and MATLAB® and Simulink® from The MathWorks Inc. This approach enables accessibility, availability and flexibility into TESS, while taking advantage of one of the most advanced mathematical modeling and simulation architectures. TTI believes in openness. We believe our clients need to have direct access to the technology and need to be able to independently evaluate, validate and verify the physics underlying our products. We also believe that users should be free to modify and evolve our products to suit their own specific needs. As a result, TTI offers source code and Software Description Documents (SDD) as standard product options.

General Description

The TESS product family consists of:

1. RF and IR guided weapon system engagement simulators which include a particular class of the weapon system, a target platform and signal environment set of models,
2. User tools that support weapon system library creation and retrieval, target platform configuration, and batch simulation run management, and
3. options which range from product source code, detailed software documentation and maintenance & support coverage, to multiple missile salvos, virtual reality displays and customized features.

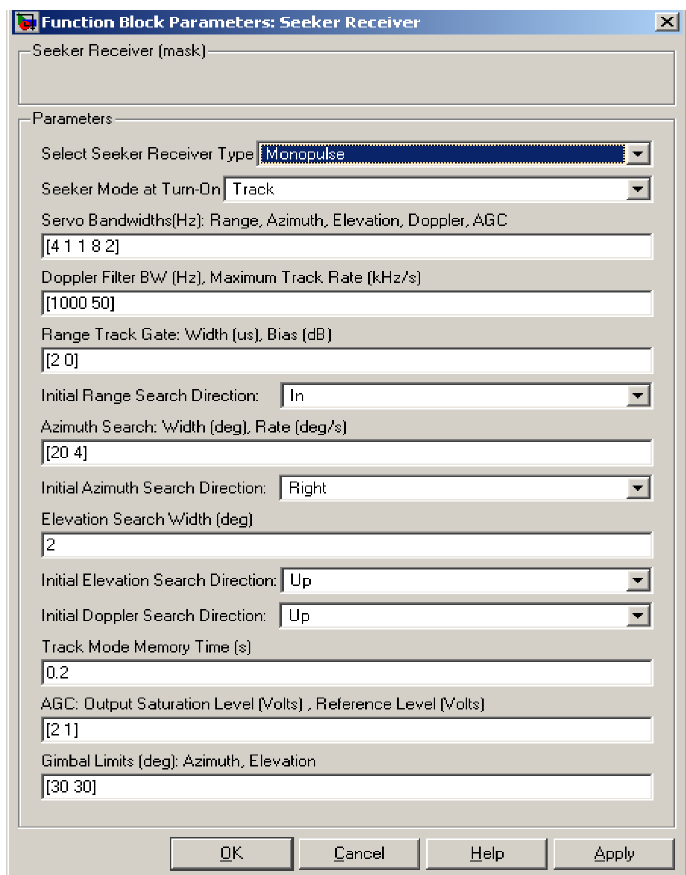
The TESS simulator family currently includes:

- Active Pulse-Doppler Radar guided Surface-to-Air and Air-to-Air Missile simulator,
- Active Radar guided Anti-Ship Missile simulator,
- Semi-Active Radar guided Surface-to-Air and Air-to-Air Missile with non-coherent target tracking radar simulator,
- Semi-Active Radar guided Surface-to-Air and Air-to-Air Missile with coherent target tracking radar and Surface-to-Air Missile with Track-Via-Missile guidance simulator,
- Command Guided Surface-to-Air Missile and Anti-Aircraft Artillery simulator,
- Passive Infrared (IR) guided Surface-to-Air and Air-to-Air Missile simulator,
- Passive Infrared (IR) guided Anti-Ship Missile simulator,
- Multifunction Surveillance Radar simulator, and
- Integrated Anti-Ship Missile Defence system simulation infrastructure that supports evaluation of combined soft & hard kill ship protection.

The target platforms in the TESS simulators include maneuvering ships or aircraft that can be equipped with a wide array of electronic attack capabilities and systems. A typical TESS engagement simulation can utilize a combination of maneuvers, chaff and/or flares, on-board and off-board jamming and active and/or passive decoys. These electronic attack / countermeasure tactics and techniques can be deployed independently, simultaneously or sequentially as defined by the user and evaluated for effect.

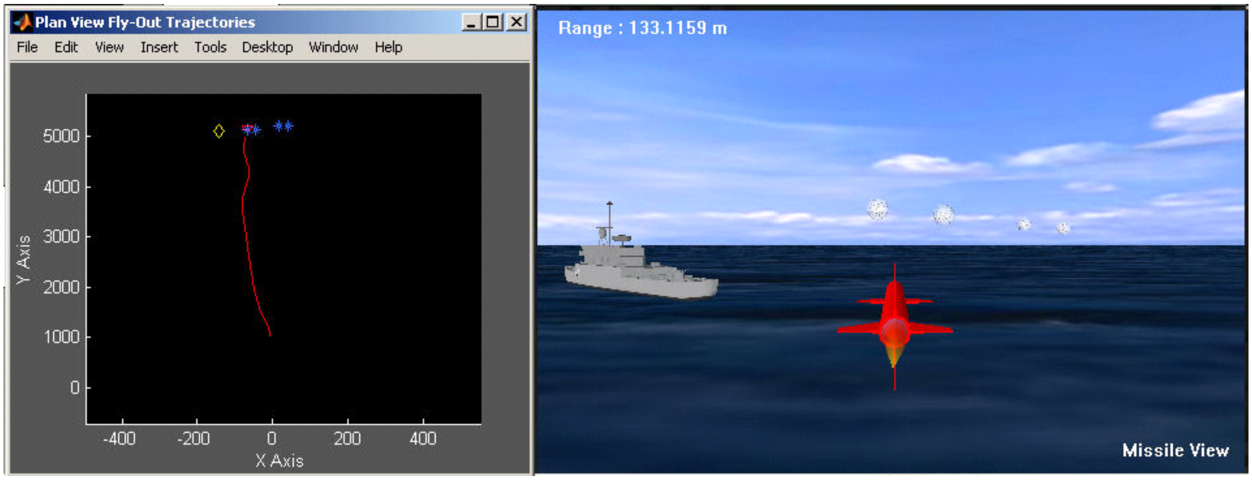
Modeling a specific weapon system requires the user to input parametric data into TESS's generic weapon system model to characterize its particular behavior. To facilitate usability, TESS was designed to utilize many of the parameters regularly available in standard Electronic Warfare Integrated Reprogramming (EWIR) Databases. Unfortunately, some of the characteristics required to create a high-fidelity dynamic model are not always defined in these sources, and some embedded tools were designed into TESS to help the user derive default values for these "missing parameters".

TESS is a high-fidelity physics-based modeling and constructive simulation solution for EW. Its models are based on physics and engineering equations and algorithms derived from open-source material and published literature written by numerous authorities in the missile, radar, infrared and electronic warfare disciplines.



APD Missile Seeker Receiver Parameters

TESS supports three-dimensional missile aerodynamics, missile auto-pilot and seeker control systems, target platform signatures and countermeasure signal waveforms. Its detailed subsystem models include the non-linear behavior found in angle, range and Doppler discriminators, saturating devices such as amplifiers, missile airframe control surface limiters and non-linear search, acquisition and track mode switching functions.



TESS 2D Plan Plot and Virtual Reality Display Outputs

As an analytical tool, TESS provides the user with various simulation options. The user can choose to run a single simulation, or a batch of simulations. In the batch mode, the user can choose to vary any, as well as, any number of variables in either an incremental or Monte Carlo fashion to support better deterministic and stochastic analysis.

Now in its fourth generation of products, TESS features an evolved modular architecture with well defined sub-system interfaces that provide “plug and play” versatility. This capability provides direct support to users interested in utilizing TESS technology in stand alone, distributed and/or custom applications from human-in-the-loop, hardware-in-the-loop, to the integration of legacy capability into a TESS environment, as well as, facilitating the use of TESS commercial-off-the-shelf system models as “building blocks” for other simulation requirements and applications.

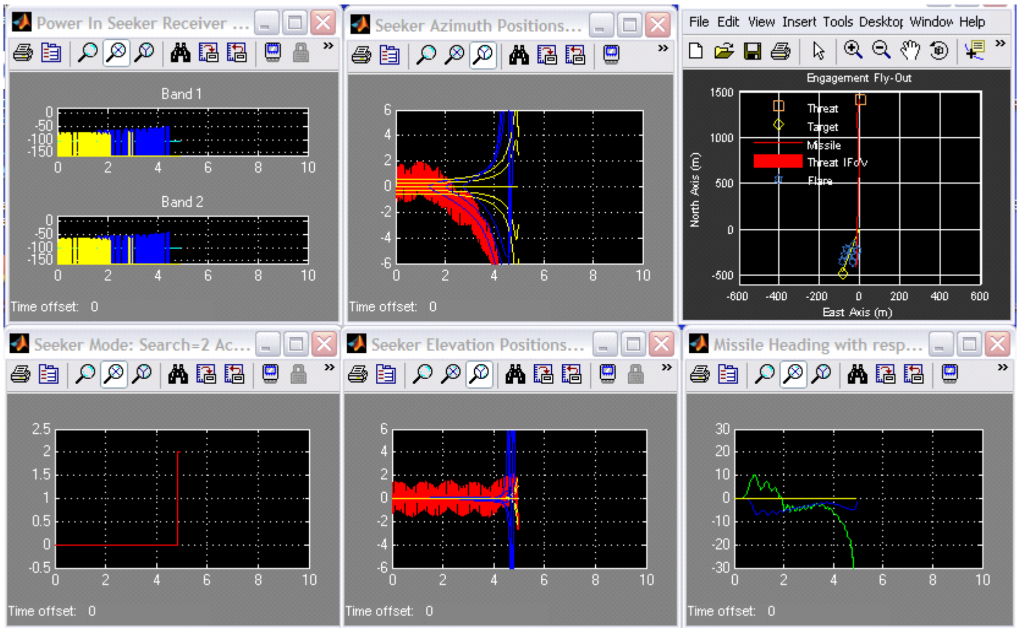
TESS Simulator Input Parameters

To model specific systems and simulate their interactive behavior in an engagement scenario, parameters describing the threat weapon system, sensors and target platform and systems need to be input. These parameters include typical transmit and receive system characteristics, as well as, the dynamic responsiveness of their control systems, non-linearities, environmental effects, and various look-up tables that describe target platform signatures, flare and/or chaff signatures along with specific information related to the engagement geometry conditions. TESS utilizes the EWIR Database parameter set definitions and units of measure, as a baseline for its parameter set to maintain commonality with the user’s certified source data. This helps to mitigate translation and conversion errors during the system characterization process. Unfortunately, as stated earlier, these databases do not always have all of the characteristics required to accurately model a weapon system to the level of fidelity required. As a result, various tools have been embedded into TESS to help the user “fill in the blanks”. These tools generate default values based on control system, electro-magnetic and aerodynamic engineering theory, and are a by-product of some of TESS’s internal parameter error checking algorithms.

Parameter entry can be accomplished manually with direct input into a TESS simulator using Simulink® Dialog Boxes, or more conveniently through the TESS Master Interface which supports the database archiving and retrieval of parameters. It is structured to support TESS’s complete system hierarchy which fully defines all of the system and sub-systems models and associated parameter sets. The Master Interface database management system (DBMS) is built on Microsoft Access® and can easily be linked to a client’s master database through customized SQL links for automated data downloads.

TESS Simulator Outputs

TESS generates various outputs to provide feedback to the user. These outputs allow the user to; monitor the simulation as it plays out, record the simulation for further analysis and/or presentation, and support post-simulation analysis. These outputs are both graphical and file records.



SAAMIR Simulations Display Outputs

They typically include 2D and/or 3D plots of the engagement, along with numerous displays including missile heading in azimuth & elevation with respect to target, power density at the seeker, power in the tracking cell, seeker mode, missile lateral acceleration in azimuth & elevation, to name just a few.

In addition, due to TESS's hierarchal architecture and MATLAB Simulink infrastructure, the user can also add scopes to monitor other points of interest in the system models. For effectiveness evaluations, TESS generates miss-distance and probability of survival metrics for each simulated engagement.

Master Interface

The TESS Master Interface is a high-level control panel that provides the user with three prime capabilities:

1. a common high-level user interface and control panel for the TESS simulator products,
2. a database management system for all system model parameters, test conditions and recorded results, and
3. a simulation execution manager for either a single simulated engagement or a consolidated batch of engagement simulations.

The Master Interface helps the user define the engagement simulation of interest be it surface-to-air, air-to-air, or anti-ship. It allows the user to select the specific threat weapon system, target platform and environmental conditions to be simulated, as well as, how the simulation should be executed, stochastic or deterministic, single or batch run.

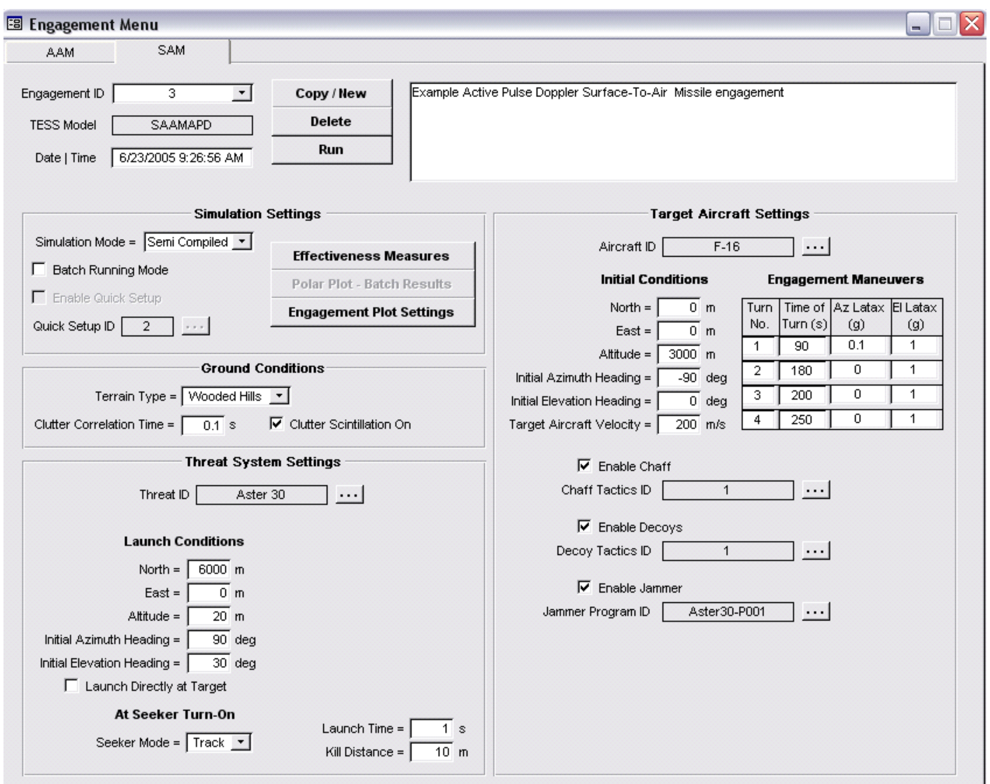
The user can either use an automatically created “Engagement ID” or give it his own unique identifier, as well as include some notations about the engagement which may be of interest. This information along with a date and time stamp becomes an integral part of the TESS simulation test file along with all of the other set-up information and recorded test results.

The user can select to run the simulation with the source code or semi-compiled versions of the simulator and select running in a batch mode, or, as a single run. In addition, the user can define the output plot settings to be used, and opt for setting-up a video recording of the engagement simulation “fly-out”.

In the “Conditions” portion of the engagement window, the user can select and characterize various signal environments related to the simulation. These would include ground clutter, weather, or, sea state.

The user then defines the initial conditions of threat weapon system and launch platform, and target platform describing their positions, headings and velocities at simulation start time (T=0) and the subsequent timing of platform maneuvers, and other events that include weapon launch, to the activation of various countermeasures.

Configuring these systems, tactics, and techniques for the engagement simulation can be accomplished directly in the Master Interface’s engagement window. The user can also use the Master Interface to build-up his database of threat systems, target platforms, flares, chaff, RF & IR jammers, and decoys. By selecting the systems of interest which appear in drop-down menus in the engagement window, the user can retrieve this data and rapidly configure his test simulations. Other features include copying and modifying a pre-defined engagement simulation configuration under a new engagement ID label, as well as, deleting of engagement configurations no longer of interest to the user. It should be noted that deletion of this engagement configuration does not delete the test records that may be associated with it, and which include all of the test set-up and result data.



TESS Master Interface Engagement Window

During the system modeling process, the Master Interface computes default values for a number of input parameters. These default value parameters are typically hard to find in, or to extract from traditional sources and are generated from their relational dependencies on other parameters, based on control system, electro-magnetic and aerodynamic engineering principles.

These parameters are typically critical to characterizing the dynamic fidelity of system models. For example, seeker range tracking servo bandwidth determines the responsiveness of the seeker to range gate deception techniques and limits the range gate pull off velocity. TESS requires a value for the range tracking servo bandwidth to accurately model this responsiveness, however, if the user does not have this data, the Master Interface will offer a default engineering estimate for this value based on other more accessible threat system parameters. Similarly, the Master Interface will offer suggested values for configuring the jammer's range gate pull off velocity and acceleration based on the user's input value for range servo bandwidth and other parameters.

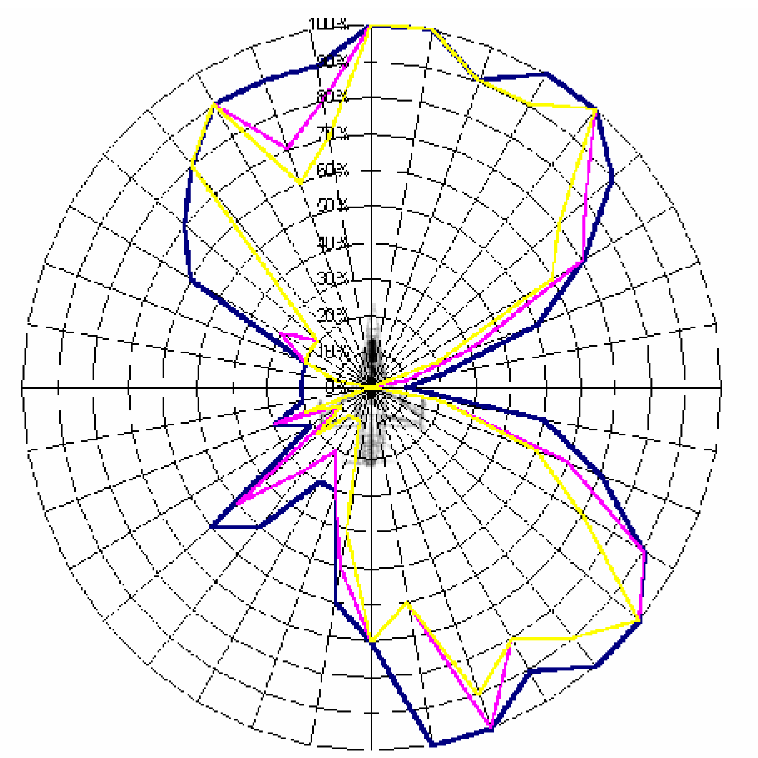
During engagement simulation execution, the Master Interface passes the appropriate data to the TESS simulator and initiates its execution. On completion the Master Interface, captures, displays and stores the miss-distance and probability-of-survival results. It can also generate engagement run reports that include a plan plot of the engagement, and plots of power density, power in the tracking cell, mode switching, seeker tracking position in azimuth and elevation, as well as, other data.

Batch Running

The Master Interface "Batch Running Mode" allows the user to define a series of simulations to be run based on the user's definition of how he would like various variables to be manipulated. The user is not restricted on which, or how many variables he can manipulate, and can specify whether each should be deterministically stepped through some defined range with a defined step size, or randomly distributed within some user-defined bounds. On completion of the definition process, execution of each required simulation run in the defined series is initiated by the Master Interface's Batch Runner, and on completion of each run its results are recorded in a test file and available for further analysis if desired.

Batch Runner supports:

- Both Monte Carlo and deterministic simulation runs;
- Variance of any and all simulation parameters can be either incremental or via Monte Carlo selection;
- Sensitivity analysis - the impact of input variances to output results;
- Selection of specific output data to be recorded at the end of every simulated engagement run;
- User status feedback detailing the current run in progress and the value of the variables being run;
- Quick examination and printing of input and output test result data;
- Direct export of the test result data to Microsoft Excel® for further custom analysis and graphing.
- Automated output of countermeasure effectiveness as a function of missile attack geometry.



Aircraft Survivability Plot

TESS Fidelity

TESS models, algorithms and equations are based on scientifically established and accepted physics and engineering as published in technical papers, texts and journals. To attain execution speeds that are sufficiently fast to support engineering applications, TESS physics-based models are at the subsystem as opposed to the component or emulative level. To achieve realistic system interaction results, TESS models focus on the incorporation of critical sub-system non-linearities such as possessed by tracking discriminators, saturating amplifiers and mode switching logic. This focus is a consequence of countermeasures inherently driving weapon tracking and guidance systems into regions of non-linear performance. The incorporation of such model non-linearities is essential to the conduct of realistic parameter sensitivity analysis and is a feature that distinguishes TESS from other lower fidelity and linearized simulation approaches. In those relatively rare instances in which known threat characteristics, particularly specific electronic protective measure circuits differ from those incorporated into TESS's subsystems, the user can modify or insert models of such special sensitive or proprietary circuits.

Verification & Validation

With TESS models being based on established science and engineering equations and algorithms they are directly traced for verification to established sources. Should a specific user require separate independent verification, the openness of the models enables the user to conduct such verification. Also, the TESS Software Description Documents describe not only the equations and algorithms but also provide references to their sources in the scientific and technical literature. No longer does the user have to "accept on faith" the verifiability of electronic combat simulations. Independent verification has also been carried out by the Canadian Defence Research Laboratory in Ottawa, with the resulting verification documentation being readily available. Through hardware-in-the-loop trials, the outcomes of a number of countermeasure/radar engagements have been matched to TESS generated results for the same engagements, and demonstrate the validity of TESS models including non-linear functions. Documentation of such validation tests is also readily available.

TESS Applications

TESS supports and compliments numerous EW laboratory requirements in over 20 countries around the world. From commercial labs experimenting with new techniques in threat or countermeasure systems, to defence research laboratories exploring weapon system characteristics, to the military evolving their operational self-defence capabilities, TESS provides a flexible low-cost and open solution to so many of the questions that need to be answered. Its weapon system models, architecture, engagement simulation and effectiveness evaluation capabilities are features that make it applicable across the application spectrum. Its unique contributions are high fidelity, flexibility, openness and modularity. From weapon system models that capture both dynamic responsiveness, as well as, their non-linear characteristics, to dynamic interactive system-on-system engagement simulations in the virtual realm, to the support of interactive real-time hardware-in-the-loop tests, and the integration of virtual threats into aircraft test ranges for "live" pilot/system engagement evaluations, TESS is quite unique.

Additional Considerations

TESS is an export-controlled product, however, it does not contain, rely on, or require any classified material or data.

In 1998 when TTI began its initial TESS development, it decided to use the MATLAB® Simulink® software environment for a number of reasons:

1. openness – providing hierarchal access into the entire product for independent user verification, validation and modification of the equations, algorithms and subsystems if so desired,
2. flexibility - to run directly as interpreted code, semi-compiled code, or, compiled C code* depending on the user's performance requirements, and
3. industry standard based – offering the benefits derived from advanced modeling and simulation language and infrastructure from a recognized supplier with support around the world.

TTI compliments this philosophy of openness with the availability of source code as a standard option, and a Technical Software Description Documents option that fully describes and provides detailed insight into TTI's software to the reference source level.

*TESS can be automatically converted into C using Real-Time Workshop®

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TESS Product Family

ASM(AR) - Active Radar Homing Anti-Ship Cruise Missile

ASM(AR) simulates 3-D engagements between an anti-ship missile and a ship defending itself with a maneuver, chaff rounds, active decoys (CW noise and pulse repeater) and on-board jammer. The on-board jammer includes user selectable jamming techniques and parameters, including range gate pull off, swept amplitude modulation, swept duty cycle, cross-eye, cross-polarization and noise. Both seduction and distraction chaff can be simulated. The missile uses proportional navigation guidance and includes a seeker with search, acquisition, track and home-on-jam modes. The missile seeker also includes user selectable electronic counter-countermeasures (ECCM) of leading/trailing edge track selection and chaff rejection discrimination. The ship's electronic countermeasures (ECM) may be applied, individually or in combinations, against the search, acquisition, tracking and home-on-jam modes of the missile seeker.

ASM(IR) - Infrared Homing Anti-Ship Cruise Missile

ASM(IR) simulates 3-D engagements between an anti-ship missile with an infrared homing seeker and a ship that is defending itself with a maneuver, infrared flares, an on-board infrared jammer and a towed IR decoy. The IR missile seeker includes user selectable spin scan, conscan, rosette and four-detector array angle tracking techniques and helix and rosette search techniques. The missile seeker includes selectable one or two color discrimination, and guidance is by a proportional navigation autopilot. The signature of the target ship is user defined as distributed hotspots as a function of aspect angle and wavelength. The propagation environment includes user enterable IR attenuation characteristics and background sea and atmospheric radiant intensity signatures. The target ship can deploy flares and the IR jammer, which employs swept amplitude modulation. All ECM types can be employed individually or in combinations against all search, acquisition and track modes of the missile seeker.

SAM(CG)/AAA - Command Guided SAM and Anti-Aircraft Artillery

SAM(CG)/AAA simulates 3-D engagements between either a radar controlled gun or a command guided surface-to-air missile (by user choice), and a target aircraft. The target aircraft is capable of executing up to 4 maneuvers in azimuth and elevation and is equipped with chaff rounds, active noise or repeater towed decoys and an on-board jammer. The jammer is capable of running user-defined range deception programs with up to 3 pulse trains each for range gate pull-off and the generation of false targets. The jammer is also capable of running swept amplitude modulation, cross-eye, cross-polarization, frequency modulation and noise jamming programs. The SAM(CG)/AAA target tracking radar is a non-coherent pulse radar. Electronic countermeasures (ECM) can be applied, individually or in user-defined combinations against the TTR's search, acquisition and tracking modes. The simulation's missile tracking radar (MTR) and command guidance link operate ideally and are unaffected by the target's ECMs. Missile steering control is by Proportional-Integral-Differential guidance while AAA round firing is under the control of a collision point estimation processor.

SAAM(SA)(no-coh) - Semi-Active Homing SAM and AAM with noncoherent TTR

SAAM(SA) simulates 3-D engagements between either a semi-active homing surface-to-air or air-to-air missile (by user choice) and a target aircraft. The missile system includes a non-coherent target tracking radar, a coherent CW target illumination radar, and a missile with a CW Doppler homing seeker. The target aircraft is capable of executing up to 4 maneuvers in azimuth and elevation and is equipped with chaff rounds, active noise or repeater towed decoys and an on-board jammer. The jammer is capable of running user-defined range deception programs with up to 3 pulse trains each for range and velocity gate pull off, and the generation of false targets. The jammer is also capable of running swept amplitude modulation, cross-eye, cross-polarization, frequency modulation and noise jamming programs. ECMs can be applied individually or in combinations against the TTR and/or the missile's seeker in their search, acquisition and tracking modes. The missile guidance is provided by a proportional navigation autopilot.

SAAM(SA/TVM) - Semi-Active Homing SAM and AAM and Track-Via-Missile SAM with coherent pulse Doppler TTR

SAAM(SA/TVM) simulates 3-D engagements between a track-via-missile or a semi-active homing surface-to-air missile or a semi-active air-to-air missile (by user choice) and a target aircraft. The missile system includes a coherent pulse Doppler target tracking radar, a coherent ICW target illumination radar, and a missile with an ICW Doppler homing seeker. The target aircraft is capable of executing up to 4 maneuvers in azimuth and elevation and is equipped with chaff rounds, active noise or repeater towed decoys and a coherent DRFM-based on-board jammer. The jammer is capable of running user-defined range deception programs with up to 3 pulse trains each for range and velocity gate pull off, and the generation of false targets. The jammer is also capable of running swept amplitude modulation, cross-eye, cross-polarization, frequency modulation and noise jamming programs. ECMs can be applied individually or in combinations against the TTR and/or the missile's seeker in their search, acquisition and tracking modes. The missile guidance is provided by a proportional navigation autopilot.

SAAM(APD) - Active Pulse Doppler Homing SAM and AAM

SAAM(APD) simulates 3-D engagements between a surface-to-air or an air-to-air missile with active pulse Doppler homing radar seeker (by user choice) and a target aircraft. The target aircraft is capable of executing up to 4 maneuvers in azimuth and elevation and is equipped with chaff rounds, active noise or repeater towed decoys and a DRFM-based on-board jammer. The jammer is capable of running user-defined range deception programs with up to 3 pulse trains each for range and velocity gate pull off, and the generation of false targets. The jammer is also capable of running Doppler noise, swept amplitude modulation, cross-eye, cross-polarization, frequency modulation jamming programs. ECMs can be applied individually or in combinations against each of the search, acquisition and track modes of the missile seeker. The missile guidance is provided by a proportional navigation autopilot. The missiles operate autonomously from any ground or launch control. Hence, a ground-based target tracking radar is not included.

SAAM(IR) - Infrared Homing SAM and AAM

SAAM(IR) simulates 3-D engagements between either a passive infrared homing surface-to-air or air-to-air missile (by user choice) and a target aircraft. The target aircraft can be configured with 1, 2 or 4 engines and it is capable of executing up to 4 maneuvers in azimuth and elevation. The target aircraft is equipped with infrared flares, an on-board infrared jammer (DIRCM option also available) and a towed IR decoy. The missile's infrared homing seeker supports user-selectable spin scan, conscan, rosette and four-detector array angle tracking techniques and helix and rosette search techniques. The missile seeker also includes selectable one or two color discrimination and missile guidance is by proportional navigation autopilot. The IR signature of the target aircraft is user entered by choosing one, two or four engines and entering radiant intensity profile data as a function of aspect angle and wavelength. The propagation environment includes user-defined IR attenuation characteristics and background radiant intensity signature. The IR jammer employs swept amplitude modulation techniques. All ECM types can be employed individually or in combination against all search, acquisition and track modes of the missile seeker.

MSR – Multifunction Surveillance Radar

MSR simulates a pulsed, or pulse Doppler surveillance radar on a stationary platform observing an aircraft with electronic countermeasures doing a fly-by in 3-D. The user, as radar operator, can observe the aircraft with a plan position indicator (PPI) and an A-Scope as it generates deceptive signals and deploys countermeasures. The radar operator has control of various ECCM's such as CFAR, scope intensity and persistence. The aircraft flight profile can include up to 4 maneuvers in azimuth and elevation. The aircraft's countermeasure assets include chaff rounds, active decoys with noise or repeater capability and an on-board DRFM-based jammer. The on-board jammer is capable of running a user-defined multi-target range deception program, false targets, as well as support of Doppler noise, swept amplitude modulation, cross-eye cross-polarization and frequency modulation jamming programs. These ECM techniques can be applied individually or in user-defined combinations.

IASMD - Integrated Anti-Ship Missile Defence

The IASMD simulates 3-D engagements between (2) anti-ship cruise missiles and a ship equipped with both soft-kill and hard-kill weapon systems. The ship's soft-kill assets include multiple chaff rounds, active decoys (CW noise and pulse repeater) and an on-board jammer. An ESM system provides threat system detection and identification to the threat evaluation and weapon assignment (TEWA) system in the command information centre (CIC) that in turn controls the ship's defensive assets. The ship's hard-kill assets including semi-active anti-missile missiles and a close-in weapons system (CIWS) are managed under control of the CIC system and activated based on user-defined engagement criteria.

The on-board jammer includes user selectable jamming techniques and parameters, including range gate pull off, swept amplitude modulation, swept duty cycle, cross-eye, cross-polarization and noise. Both seduction and distraction chaff can be simulated. ECM techniques can be applied individually or in combinations, against the search, acquisition, tracking and home-on-jam modes of the attacking missile seeker.

The anti-ship missiles use proportional navigation guidance and include a seeker with search, acquisition, track and home-on-jam modes. The seeker also includes user selectable ECCMs of leading/trailing edge track selection and chaff rejection discrimination.

The ship's semi-active anti-missile missiles use a coherent pulse Doppler target tracking radar, a coherent ICW target illumination radar and a missile with an ICW Doppler homing seeker and a proportional navigation autopilot.

The CIWS use a coherent pulse Doppler fire control radar for targeting.