WHAT IS MACE?

MACE (Modern Air Combat Environment) is a physics-based, full spectrum Computer Generated /Semi-Automated Forces (CGF/SAF) application with a large and user-extensible order of battle, capable of many-on-many simulation yet having very high fidelity at the engagement level. MACE can simulate advanced, 5th generation systems including low observable platforms and Active and Passively Electronically Scanned Arrays (AESA and PESA radar) as well as highly contested battlespaces. MACE supports the Distributed Interactive Simulation (DIS) architecture including simulation management, entity state, fire, detonate and emissions PDUs. MACE is ideally suited for both stand-alone scenario creation/mission rehearsal and distributed mission simulation. MACE is certified for use on the USAF's Distributed Mission Operations Network (DMON) and is a Combat Air Force Distributed Mission Operations (CAF DMO) approved CGF/SAF.

WHO USES MACE?

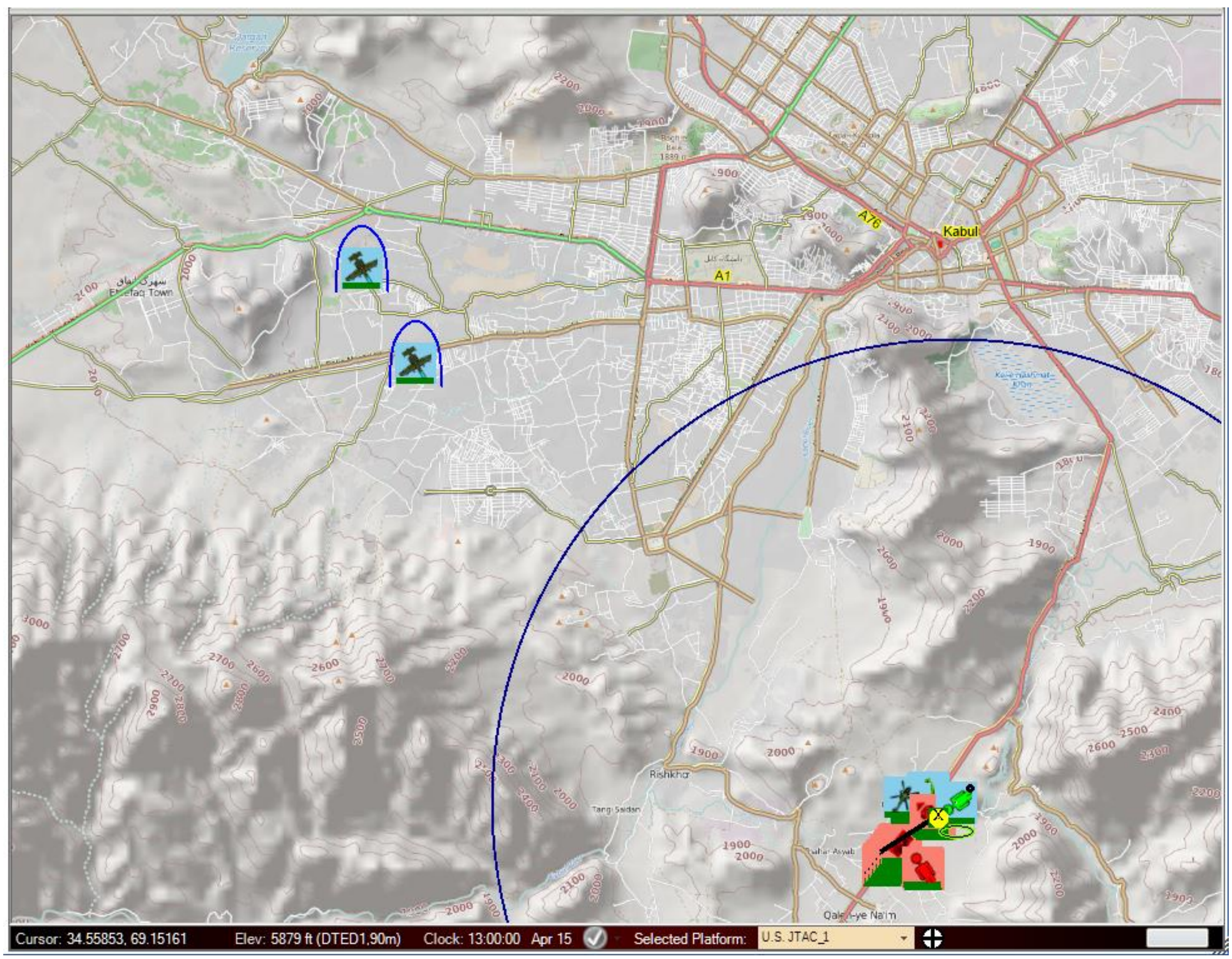
MACE is a Combat Air Forces – Distributed Mission Operations (CAF-DMO) certified CGF/SAF with over 800 licenses in production. MACE is currently used by the USAF A-10 program, the 160th Special Operations Aviation Regiment (SOAR), the Distributed Mission Operations Center (DMOC), the Distributed Training Operations Center (DTOC), the Distributed Training Center (DTC), AFSOC's Mission Readiness Operations Center (MROC) as well as over 100 fielded and fully accredited Joint Fires training devices including the Advanced Air National Guard JTAC Training System (AAJTS), Joint Terminal Control Training and Rehearsal System (JTC TRS), the JTAC/TACP Operational Simulation Suite (J/TOSS), AFSOC JTAC Simulator, the US Navy's Combined Arms Virtual Environment (CAVE), and the UAE's Combined Unit Training System (CUTS). In addition, the Air Force Research Lab (AFRL) uses MACE for their 5m JTAC domes as well as for the Joint Theater Air-Ground Simulation Suite (JTAGSS) for Air Support Operations Center (ASOC) training and in their Predator/Reaper Integrated Networked Combat Environment (PRINCE). Two major MQ-1/MQ-9 Reaper training systems also recently switched to MACE (~100 systems total between these two programs). Finally, AFSOC recently announced that all of their simulators would be re-baselined to use MACE as the constructive environment, including their AC-130, MC-130 and CV-22 simulators.

SIMULATE HIGHLY CONTESTED BATTLESPACES

MACE can simulate highly contested battlespaces including full Integrated Air Defense Systems (IADS) comprised of Early Warning, Acquisition, Height Finding and Target Tracking radar. In fact, *MACE can also simulate advanced, 5th-generation AESA and PESA radar over DIS*. Each sensor is modeled down to the pulse level to include the dynamic generation of high-fidelity emitter audio. MACE simulates air-to-air and surface-to-air missile fly-outs and air-to-ground weapons and ballistics. Instructors can make real-time, dynamic inputs into the scenario by adding or moving threats, including both surface-to-air missile (SAM) systems and aircraft equipped with airborne radar and air-to-air missiles. The MACE user interface makes managing the scenario simple. MACE allows users to add and remove entities, reload weapons, employ weapons, input environmental factors, direct electronic attack and perform a variety of analysis functions without any scenario interruption.

THE ADVANTAGE OF A TRUE GIS CORE

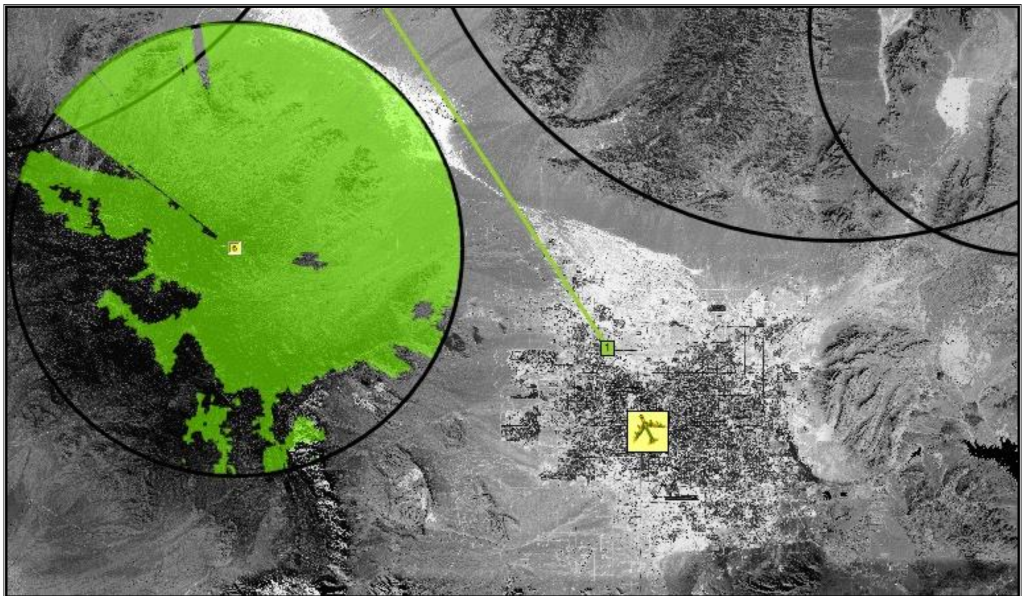
MACE is built upon a mature Geographic Information System (GIS) core. *BSI has built a worldwide tile server and road vector database derived from the OpenStreetMap project*. This means that your battlespace is the entire world and you have the GIS data you need to create scenarios appropriate for both training and mission rehearsal.



MACE's OSM Tile Server provides raster and vector GIS data for the Planet

MODERN, OBJECT ORIENTED AND MULTI-THREADED

MACE takes advantage of today's multi-core processors. MACE is multi-threaded to provide extremely fast line-of-sight and aerodynamic calculations – essential for real-time, many-on-many simulation. MACE supports both Digital Terrain Elevation Data (DTED) and Shuttle Radar Topography Mission (SRTM) elevation data and can also read elevation directly from some of the most popular commercial image generators to achieve extremely accurate weapons effects even down to the bullet level. MACE supports DTED0-DTED3, as well as 30m and 90m SRTM.



LOS Analysis for Site Northwest of Las Vegas

FULL-SPECTRUM BATTLESPACE SIMULATION

Most competing CGF/SAF programs were either purpose built by one of the branches of the armed services or, for our commercial competition, were purpose built for a particular weapons system trainer. MACE is different because it was designed from the ground-up as a full-spectrum CGF/SAF. It is a general purpose combat simulation that excels in the areas of Joint Fires and IADS simulation, specifically because of our full-spectrum, holistic approach to simulating the battlespace. Too often we encounter customer that are using one CGF/SAF just for pattern of life, another one just for IADS, and then one or more to generate airborne threats. Often when MACE is introduced into these environments, it quickly replaces one or more of these 'partial' CGF/SAF applications. In fact, several of our customers have been able to retire completely all other CGF/SAF applications and just use MACE. That's why we always say… *Don't Settle For Only Part of the Battlespace!*

LIVE-VIRTUAL-CONSTRUCTIVE SIMULATION

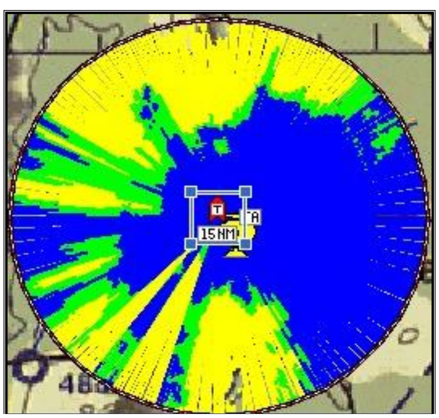
MACE is available with an integrated Test and Training Enabling Architecture (TENA) interface for interoperability with instrumented ranges. Our *Virtual SA-8 Simulator* provides person-in-the-loop virtualization of constructive MACE-generated SAM threats. In addition, any MACE platform (aircraft, lifeforms, vehicles) can be either constructive or virtual; simply make a joystick/gamepad input to take virtual control of a constructive entity. This video shows our *Virtual SA-8 vs a MACE-generated A-10*; the MACE operator makes a joystick input to take virtual control over the entity.

SIMULATING AN IADS

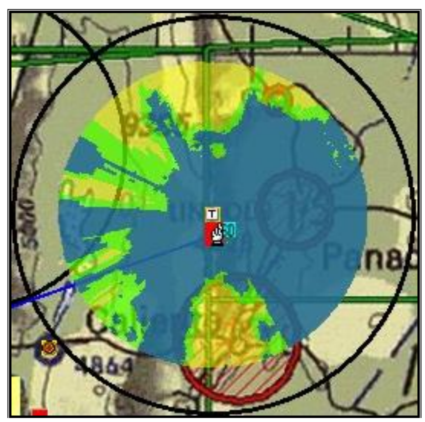
During mission simulation, the EW, HF, ACQ and TT radar sites in MACE are linked together to form an Integrated Air Defense System (IADS). The IADS can be imported from FalconView (4.0 or newer) or created in MACE -- you can even import a real electronic order of battle (EOB) in PCI format. The ability to realistically simulate an IADS is a clear differentiator between MACE and simulations which rely on scripting or simplistic rules to trigger radar activity. In MACE, a complex algorithm is executed for each sensor in the battlespace. Does the sensor have line-of-sight to the target? Is the target obscured by stand-off jamming? Has the sensor 'burned through' the jamming, if present? Has chaff bloomed in the resolution cell? Is the radar already tracking its maximum number of targets? Is the target beyond the sensor's maximum range as determined by the Radar Range equation, taking into account the sensor's frequency and target's radar cross section, and not just a simplistic 'max range' number? Is the site operating autonomously, or is it linked into the IADS? Can the site still communicate with its parent or child sites? Is the target already assigned to another target tracking site? Which target is the most attractive? *MACE answers every single one of these questions, for every single sensor in the battlespace, many times per second.*

RADAR RANGE EQUATION

MACE includes a very high-fidelity 'object model' for every sensor in the battlespace, sufficient for MACE to run the dynamic two-way Radar Range equation with pulse-level fidelity. The figures below each show a line-of-sight (LOS) analysis for a target tracking radar (TTR), in which the outer circle represents the kinematic limit of the associated surface-to-air missile (SAM). The analysis on the left was run by an application with insufficient data to run the Radar Range equation, and as a result the plot extends all the way to the kinematic limit. On the right, MACE's analysis includes both terrain *and* the radar range equation, in this case producing a detection limitation inside the kinematic range of the SAM. This particular analysis was run against a target with a radar cross section (RCS) of 1m^2. If a second analysis were run using a smaller RCS, the plot on the left would not change, but MACE's plot on the right would have an even smaller detection range.



LOS Analysis w/o Radar Range Equation



LOS Analysis w/ Radar Range Equation

USER CONFIGURABLE PARAMETRICALLY GENERATED EMITTER AUDIO

MACE provides the user with a toolset for defining an emitter's beam, scan and pulse patterns; each emitter supports multiple modes, and beam, scan and pulse patterns can vary by mode. This pulse-level fidelity enables the generation of emitter audio from the pulses as they're processed by the receiver. Both crystal video and super-heterodyne receivers are modeled within MACE. All the threat RADAR signals presented visually and aurally in MACE are actually being generated dynamically from the threat system's parameters -- meaning the various scan rates and modes will be accurately represented to the user.

ENERGY BASED AERODYNAMIC MODELS FOR CONSTRUCTIVE AIRCRAFT

MACE uses an energy-based aerodynamic model for aircraft flight. Specific Excess Power (P_s) is the primary driver for describing an aircraft's flight performance. At positive values of P_s an aircraft is free to turn, climb or accelerate, when P_s is negative an aircraft is forced to decelerate or dive or a combination of both. P_s is also useful to depict an aircraft's speed-altitude envelope; if P_s has reached zero, the aircraft can neither climb nor accelerate, and thus the aircraft has reached either its ceiling or maximum level velocity. When an aircraft maneuvers, it retrieves the specific excess power of the aircraft at its current altitude, Mach number, and *g*-loading. It then initiates a climb angle, turn angle, and rate of acceleration based on its specific excess power data-tables. As the aircraft's altitude, speed, and loading changes, its energy state changes as well. The Energy model continuously retrieves the available excess power and adjusts its climb angle, turn angle, and rate of acceleration to reflect the new energy state. An energy based aerodynamic model is a good balance between reasonably-close aircraft performance and limited CPU usage when trying to simulate large numbers of constructive forces. The final equation yields a relatively easy means of developing data tables that incorporate the necessary parameters (i.e. thrust, weight, drag, load factor, wing area, Mach number, and dynamic pressure) to produce accurate P_s data.

$$P_s = (MC)\left[\frac{T}{W} - \frac{C_{D_o} qS}{W} - \frac{\left(C_{D_i} / C_L^2\right) n^2 W}{qS}\right]$$

Ps Calculation for Constructive Aircraft

FLYABLE FLIGHT MODELS

MACE includes *6-DOF models for all rotary-wing aircraft*, *6-DOF hydrodynamic models for all surface and sub-surface platforms*, and *5-DOF physics-based flyable flight models for fast moving fighter-type and slower moving attack-type aircraft*. These models are not intended to provide flight training, but rather to construct a flight model that is "sufficiently realistic" for simulating aircraft response to person-in-the-loop flight control inputs. In MACE, you can quickly transfer an entity from constructive (computer) control to virtual (person-in-the-loop) control, and back again. For example, a white force operator could take control of and fly an F-16 in support of the blue forces, then with the click of a joystick button release the F-16 and take control of an enemy fighter in support of the red forces. These models can be applied to any air entity in MACE.

MISSILE FLYOUTS AND BALLISTIC FLYOUTS

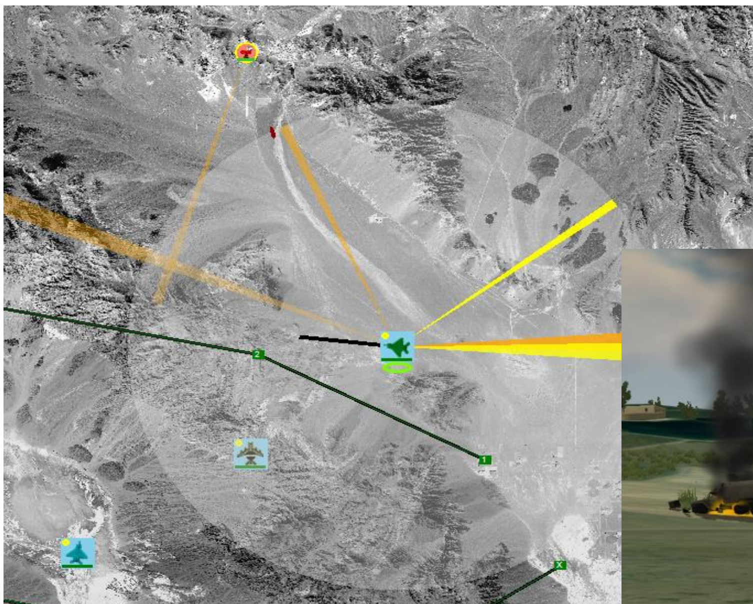
MACE uses a physics-based aerodynamic model and limited guidance model for missile fly-outs. Missile aerodynamics are derived from weapon thrust, drag, and weight. Weapon thrust is calculated by the motor's mass flow rate and specific impulse. Drag is calculated by the missile's drag reference area, coefficient of drag (subsonic and supersonic), speed, and atmospheric conditions at the flight altitude. Missile weight is reduced as propellant is burned. The missile flight profile is based on a four-stage approach that includes a free fall time, booster stage, sustained stage, and glide stage. The guidance model will shape the missile's flight path to a loft, direct intercept, or dive profile while maintaining the target within the seeker's gimbal limits in pitch.

MACE also uses a physics-based aerodynamic model for ballistic fly-outs. The ballistic flight path is determined from drag and weight. Drag is calculated by the weapon's drag reference area, coefficient of drag (subsonic and supersonic), speed, and atmospheric conditions at the flight altitude. The weapon's pitch is matched to its flight path angle. The ballistic model / equations are flexible enough for bombs, artillery, and bullets.

FULL SPECTRUM BATTLESPACE SIMULATION

Ask yourself – can your CGF/SAF generate lifeforms that *pathfind around obstacles*? That are aware of each other and *avoid collisions*? That can *enter/exit other vehicles*? Does it have 9-Line, 5-Line and Call for Fire interfaces? Can this same CGF/SAF simulate an entire IADS? Can *it simulate AESA/PESA radar down to the pulse level, including Fresnel propagation*? Does it have fixed-wing, rotary-wing and hydrodynamic models? *Sea states? Physics-based IR simulation*? A full library of CAF-DMO compliant *self-protect and user-programmable jamming systems*? Does it support *Voice Recognition/Synthetic Response*?

If not, then it is NOT the One SAF you are looking for. It is not 'next generation' and you certainly should not be excited about it! Don't Settle… get MACE!



F-15 w/ jamming pod, jamming 4 threats

First-person shooter simulation

MACE supports 6-DOF hydro models and simulation of sea states

OPEN ARCHITECTURE AND EXTENSIBILITY

MACE is purposefully designed as a data-driven application, the end user can add or edit their own threat data, even down to the pulse level for generating emitter audio. MACE also has a Plug-in API for writing your own code to extend MACE to meet your needs (in C#, for Visual Studio 2017).

MACE-EW FOR ELECTRONIC WARFARE TRAINING AND SIMULATION

Because of its capability to generate high-fidelity radar signals and the library of EW displays included, MACE-EW is also widely used as a stand-alone or networkable Electronic Warfare training simulation. BSI has provided two separate EW training classrooms to the UK and one to Australia. In addition, all USAF Combat Systems Officers (CSOs) train in-flight using BSI's simulated suite of EW displays. Both MACE and MACE-EW have the same signal generation capability; MACE-EW is differentiated by the inclusion of *2 separate panoramic receivers, a direction finding (DF) display*, a simulated ALE-50 Towed Decoy and a simulated USQ-113 communications jammer.

Simulated EW Displays standard in the EW Version of MACE

INTEGRATION WITH IMAGE GENERATION SOFTWARE

MACE uses both the Distributed Interactive Simulation (DIS) stand Common Image Generator Interface (CIGI) standards to provide your Image Generation (IG) software with very detailed descriptions for rendering entities in your 3D Battlespace. MACE includes a vast library of entities including civilian and military aircraft, surface-to-air threats, vehicles, targetable buildings and humans. Examples of entity articulation include flight control surfaces, mechanical RADAR movements, human actions such as running or raising a weapon, and vehicle articulations such as break lights and moving parts. MACE has been extensively tested with MetaVR's Virtual Reality Scene Generator (VRSG), Bohemia Interactive Simualtions' VBS Blue IG and FlightSafety's Vital 1100.

In addition, MACE 2019R1 and later versions will ship with BSI's *Augmented Reality Mission Rehearsal and Observation (ARMOR)* plug-in for 3D viewing of the MACE battlespace in screen, Virtual Reality (VR) and Augmented Reality (AR) modes. Please visit our website at www.bssim.com or contact us at sales@bssim.com to learn more.