The Joint Analysis System (JAS)
Complete Warfare Functionality in a Common Environment

JAS was Congressionally directed as part of a major initiative in 1996 to improve M&S and was designed as a stand-alone analytical model. It was modified for use by JFCOM J9 in 2005 to act as a highly automated wargame and support "what if" exercises providing advantageous features of both the fully automated model and wargaming worlds. And, it is Government owned.

General Architecture: The Joint Analysis System (JAS) was directed and funded by Congress and mandated to have a balanced land, maritime, air, space, and C4ISR warfighting functionality as well as a complete mobility and deployment capability allowing it to perform in one model the same functions as each of the Service's then combat theater-level models (JICM, ITEM, and Thunder/STORM) as well as supporting models such as COSMOS (C4ISR), MIDAS/ELIST (Logistics & Transportation), and EADSIM (TBM/TBMD). JAS was implemented as a very comprehensive "single engine" simulation and while it has many internal sub-models from planning to adjudication, they are all designed to work together rather than having to be connected in preparation for an analysis or exercise. JAS is an event-stepped, stochastic model generating a range of outcomes based on data and probability distributions. However, it has been tested to confirm that with the same initial seed and no changes, it has exact repeatability.

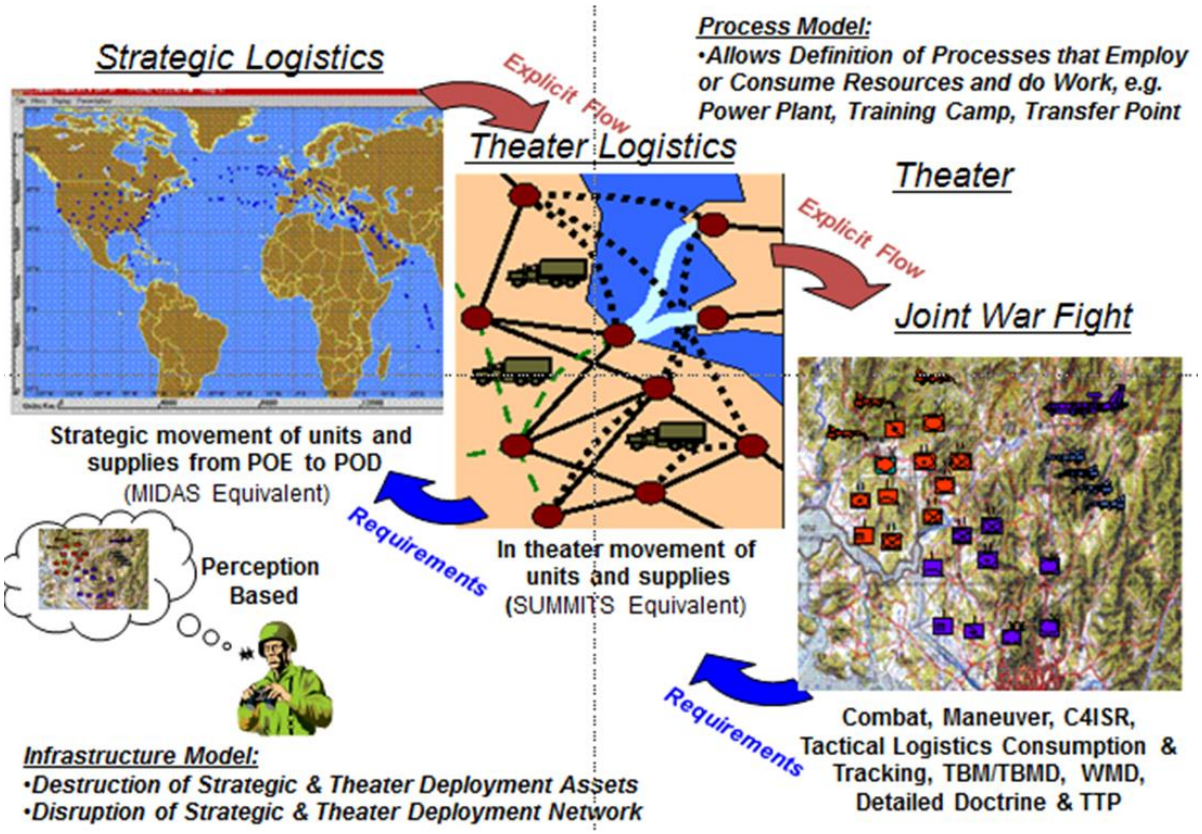

Figure 1: Complete Warfare Functionality in a Single Environment

JAS is agent-based allowing specific doctrine, orders, and operational rules to be applied by national force, types of units within that force, echelon and size of that unit within the force, purpose and mission of the force, and the perception of the force both with respect to the enemy and itself. All units (Basic Scenario Elements or BSEs) down to a single individual can be endowed with certain essential capabilities as shown in the figure below including sensing (even if only at eyeball range), keeping track of owned resources, and moving (if only at a walking pace). Command and control functions allow BSEs to understand orders, and when a unit issues orders to subordinate units, they understand and implement formations, pre-defined attack/defend doctrine, etc., all of which can be input/modified by users. Explicit messages, both up and down the chain, allow orders and warnings, status/sensor reports as well as fire support and logistics requests to be passed up and down the line. Thus, an order issued at division level is communicated to subordinates and contains all the information they need to form themselves and their subordinates into appropriate formations and move realistically or to defend in place. Sets of formations can be built by users and a basic set of them is included with each scenario.

Environment: JAS has weather (18 months of actual weather data), sea surface and subsurface data, and terrain/features (DTED/DFAD) data for major portions of the world which can be automatically loaded into the model to support scenarios occurring in those areas. These are all Government furnished although some transformation is required (again, this is already done for scenarios in those areas). Additional sets of data can be added. The model can also be run with default data or specific weather data mods to reflect certain critical time periods or conditions.

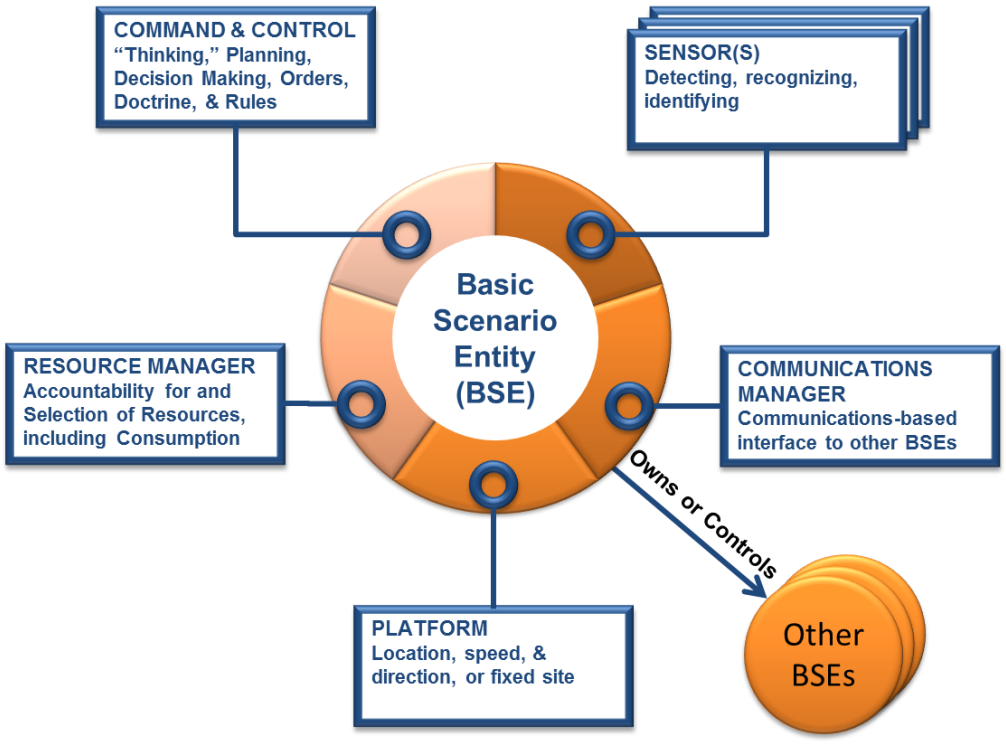

Figure 2: Agent-Based Basic Scenario Entities are Fundamental Components of JAS

Modifications for Exercise Support: When JAS responsibility was transferred to the Joint Forces Command (JFCOM) J9 in 2006, the model was modified to also support man-in-the-loop exercises where the White Team can cause the model to pause based on:

- an internally detected, user-specified event, rule, or condition, or
- a timed-based, user-input/schedule, or
- an immediate pause action by the exercise controller.

Once the JAS model is paused, users can modify orders, doctrine, and several other factors. When the purpose of the wargame is Master Scenario Event List (MSEL)-controlled training. the White Teams can also conduct "magic" during a pause to keep the exercise under control and to increase or decrease its difficulty by instantaneously transporting forces, changing the numbers of forces, increasing or decreasing supplies, etc. The model can then resume the run at that same point incorporating the changes into the continuing scenario. However, when the purpose of the exercise is analytical analysis, only physically possible changes are allowed.

JFCOM also tested the repeatability of the model and supported the use of individual random number generators for every agent in the model to reduce the unintended spread of random effects from a single data change to subsequent random draws occurring elsewhere in the model. Surprisingly, this did not affect model run-time and significantly reduced the number of runs needed to obtain a high confidence in the distribution of outcomes. When combined with fast run times, the White Team could confidently "look ahead" much faster than real time to gauge how the current set of orders would "play out." The confidence in absolute repeatability with the same initial random seed coupled with the ability to run the entire scenario on a computer as small as a single laptop meant that distributed locations could all play in the same exercise without massive amounts of data being transmitted between them. By sharing new inputs from each site before resuming play, each participating site is guaranteed to get exactly the same outputs. Typically, the White Team would review and consolidate all proposed changes in orders, allocation of forces, priorities, KIQ, etc. and then create and distribute a single input package.

Some of the best exercise support capabilities come from the automation inherent in the original analytic model. Ground units can chart their own paths by road or cross-country while still attempting to keep user-designated formations, ships can be given a destination and will automatically sail around land masses (including small islands) and through major canals (Panama and Suez), and even up some navigable rivers. Amphibious landings automatically load landing craft and helicopters with troops, weapons, and support resources and then reassemble them back into units once these elements have reached a rally point. Losses along the way are automatically deducted from the resulting reconstituted unit. Air units build a common (joint) Air Tasking Order (ATO) that coordinates the operations of all four services and allies operating aircraft in the theater (although exceptions are allowed for commanders wishing to keep control of say, attack helicopters). And an unclassified set of commercial satellites is included that can be cloned and modified to become national assets by adding the appropriate data.

Run Times: Since JAS had to execute very fast so that many runs could be made in a very short time, the code was continuously scanned to search for routines that "wasted" time. The result was the ability to run complex scenarios at speeds 500+ times faster than real time on a single computer. The longest scenario run to date was 9 months of campaign level operations including a large amphibious landing and subsequent major land operations. It was completed over a weekend. Smaller, simpler scenarios with fewer forces have run 1000 times faster than wall clock time. And these numbers are based on computers built prior to 2010.

User Oriented: JAS was designed to be used by scenario developers and analysts rather than modelers. It has a transparent data -driven format that allows a scenario developer /analyst with no knowledge of the underlying software to make almost any change desired. In many places where it was found to be difficult to input such data, specific tools were designed to assist the scenario developer /analyst. For example, the JAS Human Computer Interface (HCI) is heavily map-oriented, has many pull-down menus to show available selections, and provides a "cloning" ability where weapon systems, infrastructure such as airbases, and even whole units can be duplicated, designated as new forces, and then inserted back into the scenario. With a few mouse clicks, any cloned asset can then be modified to represent new types of weapons, systems, units, etc. To eliminate typing in substantial amounts of data, JAS easily imports data from both external data bases and from other JAS scenarios. In addition, it includes the ability to "transform" older scenarios into the latest version of the code without the user having to make any changes in the older scenario's data. Any necessary changes are automatically included with the revised version of the code.

Global Visualization: JAS provides a global Mercator map that portrays all participating units and their movement. If ground units move, ships leave port, aircraft sorties (of any type) are launched, satellites pass overhead, etc. the map can (as a user option) show them. The map can be zoomed into specific areas to better see the units and the infrastructure (roads, bases, etc.) of the area. The visualization does not display specific terrain data, although that data is used in computing line of sight and movement. If another visualization tool is desired, JAS can export the data necessary to populate it.

Saving Scenarios and their Data: JAS saves every scenario's initial conditions and records the scenario changes leading up to every run. This allows for a complete history of how a scenario was modified to achieve its current state as well as supporting rapid comparisons of the differences between two similar scenarios.

Modifying Software: JAS code is maintained in an unclassified configured set of software. Because it is government-owned, with government permission any capable software developer can be tasked to make modifications. To test software changes before adding them to the configured-set, JAS allows for (and closely tracks/reports) code located in data to act as if it were part of the configured-set. This capability also supports the use of classified code that will not become part of the unclassified configured set of software and allows contractors to temporarily

bring in proprietary code for evaluation. It was also found useful for supporting remote exercises when a quick update or software change was required as the new code could be electronically sent to the site and added to the scenario data.

Some of the JAS capabilities that might be of most use in modern conflicts are listed below:

- **Operations Based on Perception:** JAS is a perception-based model with the separation of perception from "ground truth" although both are recorded for later analysis. Sensors do not simultaneously detect and identify objects as targets unless they have that specific capability and the target is sufficiently exposed. They do have the ability to detect vehicles and personnel and then, in a separate process, classify them as armed trucks moving along a secondary road, but still do not necessarily automatically identify them as friend, foe, or neutral. JAS intel can carry sensor contacts as "unknown" or "suspected" pending a better sensor report.
    - The use of explicit perception also allows units to pass by one another without automatically engaging if they are not within range of their sensors (especially at night or in poor visibility). This holds true even when they are within range of their weapons. Units with better sensors thus gain an advantage of initiating combat or alternatively avoiding contact as circumstances dictate. However, once a unit is fired upon, it will react depending on its capabilities, orders, doctrine, and training.
    - Supplementing the concept of perception is the use of explicit communications to pass information from unit to unit. This flow is usually restricted in its capacity, which can be further reduced by jamming and/or destroying communications equipment. Conversely, communications can be increased by adding equipment or bandwidth, repairing damaged equipment, or destroying the jammers. With explicit communications networks and messages comes the option for cyberattacks that can be evaluated for their effectiveness in denying, delaying, or injecting erroneous info.
    - The application of intelligence in JAS extends beyond just finding targets for aircraft and artillery to shoot at and assessing the subsequent degree of target damage. It also contributes to Indications and Warning (I&W) of upcoming attacks or other upcoming enemy actions such as the imminent use of WMD. It can also be critical in determining when and where units maneuver to either engage or avoid enemy forces depending on their mission and the latest intel on the strength of opposing units.
    - While the model operates on perceived truth, it also collects and can display ground truth. This helps considerably in explaining the decisions made during either analytical runs or exercises. Also, to compare the current common operating picture with the best possible sensor picture, the model can be rerun with all sensors set at 100% detection probability. However, because of sensor ranges and/or the lack of a sensor in given areas at a specific time, the result still falls short of full ground truth.
- **Courses of action:** In JAS, COA can be automatically generated using a hybrid decision-making system that combines friendly capabilities, the threat picture, orders, and addresses

them with crisp and fuzzy rule sets and game-playing techniques. This can be complemented by a Commander's Behavior Model (CBM) that biases plan selection using individual commander "personalities" based on five criteria; the strength of their desire to preserve their own force, the strength of their desire to destroy enemy forces, the minimum amount of supplies they consider necessary, their ability to accept uncertainty in enemy size, and their degree of caution in moving with respect to the time available. This capability was intended to portray an adaptive opponent and was demonstrated for the Defense Modeling and Simulation Office (DMSO) sponsor that funded it. It remains in the model, but no DoD scenario has ever made use of it.

- **Maneuver:** Ground maneuver in JAS is the result of units following orders or unforeseen events that cause them to override their orders and take applicable doctrinal or TTP actions such as assaulting or defending in place when under fire. During scenario development or pre-exercise planning, ground units can be made to simulate executing their maneuver orders to confirm what routes will likely be selected and how long an uncontested movement will take. If the results are not satisfactory, the orders can be modified. However, requirements to engage or avoid the enemy along the way, unanticipated damage to tunnels/bridges, etc. during execution can cause those orders to not play out as expected.
- **Combat Damage:** JAS uses individual "weapon on weapon/target" data to determine the results of combat and lets the user designate the lethality/kill rate of new weapons (an unclassified set of this data comes with any scenario). This allows the user to add new weapons and weapon capabilities without requiring lengthy waits for aggregated direct fire kill rate data from feeder models such as COSAGE. If specific data is not available, the new weapon can be surrogated to existing ones in terms of its lethality against specific targets in given postures at different ranges and set appropriately by Subject Matter Experts or, for new Blue systems, the required operational capability. The importance of having direct fire combat at the individual weapon level rather than at some higher level of aggregation is fourfold. First, there is no limitation on the number of types of weapons that can be employed. Second, all manner of asymmetric and hybrid warfare is supported (mixes of primitive and modern weaponry and sensors). And finally, each side can kill enemy weapons and vehicles that are identical to the ones its own force is employing, e.g. as in a civil war or with new allies using equipment obtained from their former coalition. And finally, the user is not limited to weapons firing first at other weapons that kill them. Any weapon can fire at targets such as CPs or radars. For indirect fire, the lethality is in the projectiles fired, and these can be characterized as conventional (dumb), guided, or smart, each with their own lethality data and with explicit numbers of each type available to fire. Artillery rounds, rockets, mines, bombs, and missiles can also deliver chemicals or biologicals rather than explosives. The direct and indirect fire engagement algorithms used in the model were approved by the Army Materiel Systems Analysis Agency (AMSAA). There are both classified and unclassified weapon data sets available. When using classified scenarios, the Air to Air and Air to Ground munitions can use the same data sources as used in STORM.

- **Killer-Victim Scoreboard**: Based on user requests, JAS, as one of its standard outputs, has a highly detailed spreadsheet of every weapon-on-target engagement. It provides the firing unit, the weapon and munition, the target and target unit, and the result. Filtering this large spreadsheet allows rapid insight into what killed what, what didn't kill as expected, and what units did not engage in combat.
- **TBM/TBMD:** JAS has explicit TBM and TBMD representation with the ability to employ different doctrines for both offense and defense. TBM leakers cause explicit damage and casualties to all assets and personnel within their lethal radius and they can also deliver chemical, biological, and surrogate tactical nuclear warheads.
- **WMD Effects:** DTRA approved WMD effects, both offensive and defensive, are integrated within JAS. Chemical attacks produce chemical clouds that move with the wind, are visible on map displays, and can be defeated by protective equipment (MOPP) which protects to a user-specified degree. Units in MOPP can also have user-defined level of degraded performance. Biological attacks cause diseases that spread from unit to unit and/or through the civilian populations over time and incapacitate and/or kill. These capabilities along with the ability to attack chemical bunkers with specialized munitions were sponsored and funded by the Defense Threat Reduction Agency (DTRA). Currently, nuclear weapons are portrayed simply as very large conventional weapons with wind-blown pulses (clouds) of "radiation" emanating from the source of detonation that kill humans the longer they are exposed. EMP effects, on the other hand, are played explicitly (with DTRA exposure data) and can disrupt designated electronic systems either temporarily or permanently based on available data.
- **Multi-Sided Operations:** The JAS model is designed for multi-sided operations (more than the traditional two sides) and each national force, regardless of their side, has the ability to employ different Doctrine and TTP (Tactics, Techniques, and Procedures). JAS also allows for multiple national, reserves, irregulars, and/or militia forces within a given side, each of which can have unique combinations of training (affecting capability), weapons, sensors, and logistics and be supported by their own doctrine and TTP. These units also have the ability to change sides as circumstances change (rule or event-based) or as user-scripting dictates. JAS allows for situationally determined conflicts, e.g. "I will cooperate in an attack with my nominal allies against a common enemy and will not attack these "allies" - until I estimate that I can win against them or I am commanded to change allegiance."
- **Appropriate Doctrine:** JAS lets the user assign doctrine to units (agents) based on their country/organization of origin, type of unit (armor, infantry, special forces, militia, etc.), function (combat, combat support, combat service support), and echelon (team, company, battalion, brigade, etc.). Thus, an infantry company would generally avoid attacking an armored battalion on open terrain but could ambush or defend against the same armored unit from a prepared position with copious supplies of modern anti-tank weapons.
- **Asymmetric Attacks:** JAS allows small units to engage larger ones without automatically being forced into a long engagement by factors such as long fixed time steps. These engagements can last only minutes allowing the smaller unit to attempt to escape. Artillery

fire and CAS occur without respect to the direct fire time step and immediately affect the battle outcome. This allows units to conduct ambushes and "hit and run" attacks where the smaller, more mobile unit can quickly disengage before the larger one can react. For example, a Special Forces team might engage an armored unit with a combination of a minefield, long-range high-lethality antitank weapons, and heavy mortar fire using smart rounds; and couple this with a quick withdrawal into terrain where surviving tanks would be hindered in their movement and subject to further short-range engagements from hidden positions.

- **Suppression and Withdrawal:** Alternatively, an attacking or defending unit may find itself taking more casualties or taking casualties at a higher rate than allowed by its combination of its doctrine and unit training/morale. This causes attackers to stop advancing and hunker-down or forces either attackers or defenders to withdraw from contact, either temporarily or permanently. Counterattacks are supported if the unit is reinforced sufficiently.
- **Noncombatants in the Battlespace:** JAS provides for the presence of non-combatant civilians as their own side. Members of this side consume resources, need shelter and medical care in greater or lesser amounts due to weather and disease, and can become casualties due to intentional hostile actions by any side or as collateral damage due to indirect fires. In JAS, both friendlies and/or neutrals, suffer casualties when they occupy a location too near a targeted enemy force. Outdated perceptions from old sensor reports and unreported unit/civilian movement exacerbate this problem.
- **Civilian Infrastructure:** JAS can represent civilian assets and infrastructure such as houses, cars, buses, roads, bridges, blocks of tenements, and infrastructure facilities that can be destroyed or need to be protected. Critical resources include power plants, water purification, and food storage facilities whose destruction can directly interrupt their function as well as indirectly generate large numbers of displaced persons or the rapid spread of disease.
- **Civilians can Choose Sides:** JAS supports the presence of civilians who are "neutral" during the day but can convert to combatants at night to take up arms, and then resume their civilian duties (change sides) at daybreak. Over longer periods, they could be farmers during growing season and hostile militia at other times. They can also be coerced and/or enticed to change sides or support one side more than another through user-defined rules on the effect of information warfare.
- **Surrender Allowed**: JAS has user-developed rule sets that allow units to surrender rather than being automatically annihilated when defeated, and it supports the subsequent requirement to maintain POW camps and prisons that can subsequently be attacked releasing prisoners. Rules can also be written to cause a victorious unit not to accept surrender and destroy the survivors.
- **Highly Integrated Logistics:** JAS supports the concept of tightly integrated logistics operations and every resource in the simulation is tracked. Subsequent consumption, storage, destruction, and loss are also recorded. Running low on unit ammunition not only triggers emergency requests for resupply (in addition to user-set threshold re-ordering levels), but

being “low on specific supplies” such as ammunition can be set in rules as a reason for attempting to withdraw from contact, avoiding engagement, etc. Running out of a specific ammunition stops use of that munition, and lack of a specific fuel stops movement of vehicles using that type of fuel and can also be set up to terminate or limit activities that depend on vehicles and generators using that fuel type. From a planning perspective, operations can be tied to having a user-determined “sufficient” level of logistics on-hand. The availability of logistics is one of the factors used in the Commanders’ Behavior Model (automated decision-maker) when that capability is used to reflect specific commanders.

- **Extensive Transportation Assets:** JAS has a wide range of transportation capabilities including land, air, sea, and subsurface. For land, it has roads, bridges, tunnels, cross-country movement, pipelines, canals, and railroads. Roads and cross-country are used by a wide range of vehicles, which can be user-tailored to represent current assets from mules to dune buggies to huge trucks or future ones such as robotic and self-driving vehicles. They all have specific capacities to carry various loads (troops, bulk food, ammunition, liquids, heavy vehicles, etc.) as well as user-designated limits (speed, on/off road capability, etc.) and consume fuel based on the distance they travel. For vehicles in a convoy, the loss of an individual vehicle means the loss of the unique supplies or troops it carries, e.g. a single tanker fuel truck’s fuel or a proportion of the total supplies as carried by each cargo truck. Any vehicle can also carry weapons to defend itself. For air, cargo aircraft and cargo helicopters are well defined, but can be cloned and modified as needed to reflect everything from unmanned helicopter drones delivering supplies to large-capacity lighter-than-air vehicles with large loads, slow speeds, minimal fuel consumption, and high vulnerability to specified weapons. Airdrops are supported. For sea, explicit cargo can be loaded on a ship and, when given a destination, the ship will automatically generate a great circle route to reach port, avoiding land and even employing canals such as Suez and Panama, if necessary. Required minimum port facilities can also be specified and damage to them causes slowdowns in loading and unloading. For amphibious landings, each landing craft (sea and air) carries an explicit cargo and troops both of which are reassembled ashore as their appropriate combat or support units. Submarines are available but have not been used in any cargo role to date, except for SEAL team delivery. All platforms can have restrictions put on their ability to support operations, such as minimum requirements for air and seaport capabilities, e.g. length of runway, conditions of roads and railroad tracks, etc. Port repair rates are supported.
- **Representation of Unit Training:** In JAS, data on the training level of a unit and other factors such as its leadership and morale can contribute to its effectiveness in battle, both actively in engaging the enemy and passively in being subject to suppression or taking longer to complete a task. With this capability comes the associated ability to see improvements in a force’s effectiveness as its training level increases, its leadership improves, or its combat experience increases. This can be an explicit process or a user-specified “timed” event.

Technical Details: The JAS software is unclassified and is written in Smalltalk and previously existed in versions of the Windows, Unix, and the Linux Operating Systems. Currently, only re-implementation in the Windows System OS is planned upon its re-release, but additional funding would remedy that. JAS is usually distributed in a "packaged" (compiled) mode that does not require obtaining a Smalltalk software license to operate. The associated relational data base is Oracle and an Oracle client is all the external software that is needed to run the model although other Microsoft Tools (Excel and Access) are useful for manipulating inputs and outputs.

High Level Architecture (HLA) Compliance: JAS has little need of linkages to peer-level models since almost all its capabilities are included at approximately the same level of resolution. Where HLA has been used successfully, is in multi-resolution modeling to link JAS with higher resolution (more detailed) models such as detailed engineering fly-out models for air defense and virtual training models for 3D visual representation of individual vehicles and terrain. With respect to the latter, JAS was at one time linked by HLA to the Joint Semi-Automated Forces (JSAF) model and could populate an empty JSAF model through HLA transfer of disaggregated data in a matter of minutes. The two models then ran concurrently in wall clock time with JSAF having responsibility for the location, consumption, and combat results of the specific platforms and other elements represented in the area assigned to it and for any connected man-in-the-loop simulators. When a specific detailed vignette of interest was completed or a time limit was reached, control was returned to JAS, JSAF then "went to sleep" and JAS proceeded at high speed to the next vignette of interest and then repeated the cycle.

SIPRNET Authorization: JAS was approved for use on both NIPRNET and SIPRNET and, prior to being archived, regularly communicated over both networks. It was also approved for use on several High Performance Computing (HPC) platforms. Approved users could load scenarios or communicate with scenarios hosted on the HPC servers allowing for very large numbers of simultaneous runs to be conducted.