Correlated Environment Representation for the JLVC

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ABSTRACT: The Joint Live Virtual and Constructive (JLVC) Federation is the primary training federation at the Joint Forces Command (JFCOM) Joint Warfighting Center (JWFC) but remains a loose association of service-specific legacy simulations for the ground (JCATS), air (AWSIM), naval (JSAF), and intelligence (NWARS) components of a training campaign. These simulations each have existing capabilities for adjudicating weather effects, but each is supported by specific format and content requirements for the underlying weather data. Providing correlated weather scenario data and products to each of these simulations, as well as the simulation control staff and training audience, presents a formidable challenge. The natural environment Modeling and Simulation Executive Agents (MSEA’s) have sponsored the development of the Environmental Data Cube Support System (EDCSS) to meet this challenge. The EDCSS is used to manage the environment product requirements of each simulation or support component of a federation, and generate this suite of products for training exercises based on a consistent underlying environmental scenario developed by the exercise control group to meet defined training objectives. Furthermore, the EDCSS provides for distribution of the correlated products during exercise execution, allowing for each simulation to obtain and consume their custom products in the most convenient manner possible. This paper will present the environment data products negotiated for use by each of the JLVC components, and illustrate the EDCSS ability to support these requirements through a discussion of two recent COCOM level training exercises that leveraged the EDCSS.

1. Introduction

The U.S. Joint Forces Command Joint Warfighting Center (JWFC) continues to develop and implement the Joint National Training Capability (JNTC) to provide a Live, Virtual, and Constructive training environment to enhance the Joint mission training experience. The Joint Live, Virtual, and Constructive (JLVC) Federation is the primary construct to achieve this goal, supporting all major Combatant Command (COCOM) Joint training exercises. JWFC leadership have recognized the importance of weather in joint training events and directed development to include weather effects in simulations, with emphasis on target acquisition effects. Weather play must be consistent across the federation, with no system independently setting or controlling weather or its effects. This presents an interesting challenge, as each federate in the JLVC has differing environmental capabilities and requirements in terms of input content, format, and fidelity. In addition, correlated products must be provided to simulation control staff and the exercise white cell and training audience so all participants consider the same weather.

The Air and Space Natural Environment (ASNE) Modeling and Simulation Executive Agent (MSEA) sponsors development of the Environmental Data Cube Support System (EDCSS). EDCSS is used to define, produce, and distribute consistent environmental scenario products to all participants of JLVC-supported training events. To produce a scenario meeting objectives of an exercise, EDCSS leverages the Environmental Scenario Generator (ESG) to search historical archives and run operational environmental models to produce a single, integrated environment representation.

This paper provides an overview of the environmental support products utilized within the JLVC Federation and the capabilities of the EDCSS relevant to supporting large-scale Joint training events. Finally, an overview of
two recent COCOM exercises that leveraged EDCSS capabilities is provided.

2. The JLVC Federation

2.1 Overview

The JLVC Federation provides a realistic environment for Joint training of tactical to operational level military objectives. A major objective of the JLVC is to integrate service-specific modeling and simulation tools into a Joint environment, while allowing each service to utilize its primary constructive simulation. As such, the primary federates defining the JLVC Federation are the Air Force Air Warfare Simulation (AWSIM), the Navy Joint Semi-Automated Forces (JSAF), the Army Joint Conflict and Tactical Simulation (JCATS), and intelligence community National Warfare Simulator (NWARS). These, along with number of supporting simulations as depicted in Figure 1, are coupled together via a High Level Architecture (HLA) Federation Object Model (FOM) that governs the runtime exchange of information between simulations.

![Figure 1. Components of the JLVC Federation.](image)

2.2 Environment Representation in JLVC

The environment products defined for use in the JLVC were developed in close coordination with the JLVC development team which includes representatives from each of the component simulation’s program offices. The goal of the initial set of environmental support products defined here was to provide a common set of attributes that the JLVC simulations could make use of in their current form. As such, the emphasis was not to eliminate any possibility of inconsistency in the use of environmental data and effects across the federation, but rather to take a first step in improving the consistency and realism of weather play in the federation. The environmental support products defined for use in JLVC include:

**CSV Weather Files**

Comma Separated Value (CSV) weather data files provide general meteorological parameters in an easy to use file format. The content (i.e., parameters and levels), resolution, and temporal increment were defined in coordination with JLVC development leads. Content includes temperature, humidity, visibility, wind speed and direction, blowing sand and snow, cloud ceiling, fog, haze, thunderstorm coverage, precipitation type and intensity, temperature gradient, turbulence intensity, illumination, and a “present weather” code that encapsulates present conditions. Data is provided on a 1x1 degree spatial grid at 6-hour intervals.

**IR Effects Hypercubes**

Hypercubes provide pre-computed sensor performance metrics consistent with the spatial and temporal variations in the weather scenario data set. For the JLVC federation, EDCSS computes Infrared (IR) sensor performance Hypercubes by executing the Target Acquisition Weapons Software (TAWS) for an array of target and sensor types, ranges, elevations, and azimuths at each grid point and time interval of the scenario. The resulting probability of detection values are packaged into a multi-dimensional Hypercube for rapid access at simulation runtime.

**GRIB Data Files**

GRiidded Binary (GRIB) encoded data files provide environmental data in a format standardized by the World Meteorological Organization. A broad array of parameter and level combinations are available, and EDCSS supports several “styles” to mimic operational forecast products. The JSAF style provides specific parameter and level combinations (atmosphere and ocean) required by the JSAF simulation.

**Graphics Overlays**

The EDCSS produces graphics overlays in several forms. Forecaster graphics follow the style of products typically produced at Air Force Operational Weather Squadrons. These provide charts of common meteorological fields such as pressure, wind, and geopotential. Simulated satellite and RADAR imagery provide cloud and precipitation maps derived from the modeled atmosphere. For JLVC, EDCSS provides all graphic products in both PNG and KML formats.

2.2.1 Air Warfare Simulation (AWSIM)

The Air Force’s Air Warfare Simulation (AWSIM) is a real-time, interactive, entity-level air simulation system for commanders, staffs and other organizations. AWSIM provides a robust capability for training, mission rehearsal, doctrine and procedures development, experimentation and operational plans assessment.
Weather play influences air-to-ground targeting in AWSIM, which is capable of utilizing environmental Hypercubes and/or CSV Weather files. Without these inputs AWSIM plays no default weather or atmospheric effects.

At run-time, AWSIM performs a simple Hypercube lookup to retrieve the probability of detection for a given air-to-ground targeting task, and a success rate is ultimately determined. If targeting fails, a Tactical Air Data Link – Joint (TADL-J) message reports a weather influence. AWSIM currently utilizes Hypercubes for only IR sensors but extension to other sensors (e.g., laser, optical) could be implemented similarly. ASWIM uses the CSV Weather files to report weather conditions at simulated air bases. In inclement weather ASWIM may force base closures, and in these cases a TADL-J message is reported.

Currently AWSIM’s ingest process is manual, with new Hypercube and CSV files loaded every 6 hours of an event. EDCSS facilitates this by providing a run-time client to periodically retrieve current weather products from the EDCSS Distributor.

AWSIM tasking is coordinated through the Graphical Input Aggregate Control (GIAC), which utilizes graphical overlays of weather. In its latest form, GIAC has a Google Earth-based interface that can overlay the EDCSS forecaster graphics and simulated satellite and RADAR imagery provided in KML form.

2.2.2 Joint Conflict and Tactical Simulation (JCATS)

The Joint Conflict and Tactical Simulation (JCATS) program is an interactive simulation tool sponsored by JWFC. Both the Army and the Marine Corps use the simulation for training and real-world rehearsals of tactical missions. JCATS simulates dynamics of individual soldiers, vehicles, and weapons.

JCATS utilizes CSV Weather files to populate its weather scenario object; otherwise JCATS has globally uniform weather. Data in this object affects visual and sensor acquisition and smoke and CBRNE plumes. For example, wind speed and direction influence smoke and plume direction, shape, and progression. JCATS also displays a weather icon representative of the conditions in each cell. EDCSS includes a run-time client to periodically request and receive weather products from the EDCSS Distributor. Files are loaded manually via the JCATS user interface.

2.2.3 Joint Semi-Automated Forces (JSAF)

The Joint Semi-Automated Forces (JSAF) system is the Navy’s core simulation tool for training and experimentation. It generates entity-level simulations which interact individually in a synthetic environment including terrain, oceans, and weather conditions that affect the behaviors and capabilities of the simulated forces.

JSAF has the option to subscribe to environmental data on the HLA or independently set globally uniform conditions. Obviously the latter is not ideal, as it is independent and inconsistent with other JLVC federates. EDCSS supports JSAF by providing environmental fields in GRIB data files. These files are ingested by OASES which publishes them to the HLA. JSAF subscribes to three classes of environmental data: 2D Atmosphere, 2D Ocean, and 3D Ocean. The 3D Ocean fields are the primary interest for underwater sound speed calculations. Other environmental effects are largely unexplored. Current EDCSS development includes an environmental plug-in to the NWDC-developed Joint Bus (JBUS) technology, which will replace the OASES functionality in the very near future.

2.2.4 National Wargaming Simulation – Next Generation (NWARS-NG)

The National Wargaming System (NWARS) simulates tasking, reporting, and the dissemination of information from national intelligence collection assets for the purpose of training and exercise support. NWARS-NG ingests CSV Weather files and uses the Total Cloud Cover field (only) to affect intelligence collection tasking and success. Targets under cloud cover receive low tasking priority. If collection is pursued, the cloud cover percentage influences its success.

3. EDCSS Capabilities

Past experience indicates that in addition to providing weather to JLVC simulations, weather products must be offered to the humans in the loop, i.e., participants in the white cell, simulation control, and the training audience. This concept is illustrated in figure 2. Simply stated, all participants must be aware of the environmental conditions and effects being played in the JLVC simulations. To provide this support, EDCSS builds a suite of products, such as simulated satellite imagery and forecaster graphics, that are focused on human consumption. These products are based on the same data being delivered to the simulations and are hosted on an event support site for easy viewing. In many cases these
materials are used by weather staff officers to provide daily weather briefings during an exercise.

Figure 2. EDCSS supports Simulation, White Cell, and Training Audience participants of an M&S event.

3.1. EDCSS Requirements Model

The EDCSS requirements model contains three objects: projects, components, and products. At the highest level, a project defines the “where, when, and who” of an event, i.e., the area, the dates of the event, and the participating “components”. A component is a generic term used in EDCSS for a consumer of a set of products, whether that be a simulation, a logical group of humans, or a supporting application. A project contains one or more components, and each component contains one or more products. This relationship is illustrated in figure 3. A product defines content, resolution, and format requirements and may be data, images, messages, or effects.

Figure 3. EDCCSS requirements model.

Product specifics have been determined for each component of the JLVC federation, and the relationship between a component and its products is maintained in EDCSS. For example, EDCSS maintains that the AWSIM component requires environmental Hypercubes and JLVC Weather CSV files at one-degree resolution and 6-hour increments. Therefore, to define a project a user must only provide the “where, when, who” information, and all downstream requirements are determined by the system. The EDCSS Production Site provides a web-based user interface in which a user may define a project and initiate the exercise support process.

3.2. EDCSS Production

Once a project is defined, it undergoes review by a subject matter expert (SME), who identifies one or more resources suitable for meeting the event objectives. The SME may identify an existing historical archive or request execution of an operational forecast model to produce the desired scenario at necessary fidelity. Key to this step is consistency between environment domains, i.e., coupling between the atmosphere, ocean, and terrain. For example, wind forces ocean dynamics, and rainfall influences terrain conditions.

The resulting scenario data set represents an integrated environment representation against which product generation is launched. A full suite of required products is generated and packaged for delivery to the EDCSS Distributor.

3.3. EDCSS Distribution

The EDCSS Distributor hosts the full suite of products for a project and disseminates them in real-time during an exercise. Products are available for review on a hosted event site or for download via web services.

The EDC Run-time Interface Module (RIM) is a simple client to automate download requests to the Distributor’s web service. Typically each federation in the JLVC runs the RIM to periodically request weather products from the Distributor. The RIM makes this request for a given component and, given the EDCSS requirements model, the Distributor identifies which products are required for the requesting component. Thus, each component receives the products it requires in the formats it requires. Alternatively, simulation operators may manually visit the event support site and download the necessary products.

4. EDCSS Support of COCOM Events in 2009

In 2009 the ASNE MSEA identified two Combatant Command (COCOM) theater-wide exercises in which the EDCSS technology would be tested. These were the Pacific Command (PACOM) Terminal Fury (TF) and European Command (EUCOM) Austere Challenge (AC) exercises.

The TF exercise took place in the Pacific region and required coordination between atmospheric and
oceanographic domains. The senior weather officer for TF requested specific environmental conditions that would set the stage for the war game. To produce the scenario, the Weather Research and Forecasting (WRF) model was executed to replicate a historical scenario that was identified as having the conditions desired by exercise planners. The WRF model output was used to force the Naval Research Laboratory’s Navy Coastal Ocean Model (NCOM), so the atmosphere and ocean were physically coupled. The output of the two models comprised the integrated natural environment from which all EDCSS products were generated.

Over 9,000 environmental support products were generated for TF, including satellite and radar graphics, simulated weather observations and forecasts, numerical forecasts (i.e., GRIB data), CSV Weather files, and “TV style” graphics for a two week period. However, only one simulation (JSAF) and two human components (White Cell, Training audience) considered weather during the exercise. The weather scenario and supporting products were utilized at the COM to brief the training audience and support White Cell activities. The White Cell used weather products to drive the flow of the game and was by far the primary consumer of the products. JSAF utilized 3D Ocean fields for underwater acoustics calculations. Simulation controllers were reluctant to consider weather in other federations participating in TF. In general there was a lack of confidence and knowledge of its effects to the simulations. Thus, although weather was briefed daily and used to drive actions in the exercise, it was not being played in simulations other than JSAF. Regardless, White Cell participants provided very positive feedback on the realistic, plausible, and consistent environment provided by the products.

The AC exercise took place in the European domain and had similar environmental requirements. For this scenario the WRF model was executed to reproduce a historical period with relatively benign conditions over the exercise area. Over 5,000 products were produced and again the White Cell was their primary adopter. The weather White Cell used the EDCSS products to provide a complete set of products to nine separate cells supporting the exercise. In all, over 10,000 products were derived and disseminated to the training audience. In addition to standard EDCSS products, the White Cell derived products such as flight level wind and aviation hazard charts, air refueling track forecasts, wave height forecasts and ship route weather, DTRA dispersion model data, and cyclic flight weather briefings. This provided the most realistic portrayal of the natural environment to any exercise, and weather was fully integrated into the battle rhythm. However, again there was a lack of adoption by the simulation controllers, so the weather played in the White Cell and training audience was not played in the simulations.

5. Conclusions

5.1. Summary

JLVC Federation leaders recognize the importance of weather to joint training and have adopted the ASNE MSEA-sponsored Environmental Data Cube Support System as the solution for providing a consistent, authoritative natural environment to the federation. EDCSS manages a requirements model and provides a simple interface for users to request environmental scenarios for exercise support. It leverages historical archives and operational forecast models to provide an integrated environment representation from which a full suite of products is produced. The EDCSS Distributor manages the distribution of these products at run-time, ensuring each component of the federation receives the products it requires in the format it requires as the exercise and weather evolve. Consumers of the products include machine (e.g., simulations, C4I devices) and human (e.g., white cell) elements.

EDCSS was demonstrated in two COCOM-level exercises in 2009. However, in each case the white cell and training audience were the primary (and enthusiastic) adopters. Simulation controllers declined to address weather, so environmental factors considered by the white cell were not played in the exercise simulations. This reluctance appears to stem from a lack of confidence of weather effects in the simulations.

To address this lack of adoption by simulation controllers, EDCSS is being more actively involved in JLVC test and evaluation events. EDCSS has provided weather and tested its effects to each JLVC federation in four week-long federation tests in summer 2009. Weather capabilities and effects are being documented as part of the JLVC development cycle and will be ultimately delivered to operational control. To date, all test results have been positive and no new development has been necessary to utilize the existing weather capabilities, thus supporting the premise that lack of play in 2009 COCOM events was due to a lack of confidence, not a lack of capability.

5.2. Future work

A topic needing significant attention is the investigation of consistency of weather effects between simulations. Although EDCSS provides a consistent environment to all simulations in the federation, each federation may respond to the weather differently. For example,
simulations may use different algorithms to calculate visibility from atmospheric inputs. A better model is to "out source" such calculations to a common system (i.e., EDCSS) to guarantee consistency across the federation.

Additional support should be added for pre-computed effects. Currently AWSIM is the only simulation to use environmental hypercubes (for IR sensor performance). Hypercubes could be developed for ground mobility, additional sensor types, or any rules-based effect. Pre-computing such effects minimizes computational burden to simulations and provides consistency across the federation.

Finally, EDCSS could be used to integrate weather into MESL development tools and simulation initialization procedures. JNTC is currently developing the Joint Training Data Services (JTDS) tool for providing Order of Battle and terrain data for exercise initialization. Coordination between JTDS and EDCSS could provide an integrated interface for defining all exercise data requirements.

**Author Biographies**

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