# An Overview of

# The Joint Warfare System

# (JWARS)

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**Introduction**

The Joint Warfare System (JWARS) is a campaign-level model of military operations that is currently being developed under contract by the Office of the Secretary of Defense (OSD) for use by OSD, the Joint Staff, the Services, and the Warfighting Commands. The goal of JWARS is to provide these users with a simulation of joint warfare that will support operational planning and execution, force assessment studies, system trade analyses, and concept and doctrine development. Accomplishing this for analyses of the early 21st century requires a simulation that provides a "balanced representation of Joint Warfare". This balanced representation will have visibility into: 1) the C4ISR systems and processes that area an integral part of US CONOPS; 2) the impact of logistics, both strategic and intra-theater, on the warfight; and 3) maneuver warfare, at the operational level. These capabilities respond to known deficiencies in the current state-of-the-art in military modeling.[1] They also form the core modeling contributions of the simulation.

To describe JWARS in a nutshell:

- JWARS is a state-of-the art constructive simulation system. It is developed using high quality Computer Aided Software Engineering (CASE) tools in a language called Smalltalk. It is an event-stepped simulation that describes the behavior and interaction of military forces across the joint spectrum at a level of resolution previously unachieved at the campaign level. This more highly resolved view includes: 1) an explicit three dimensional battlespace, 2) the effects of terrain and weather, 3) logistically constrained force performance, 4) explicit representation of key information flows, and 5) perception-based command and control.

- JWARS development includes user involvement that is unprecedented for a constructive simulation. Ongoing activities include user's groups, user participation in the design process, and a study team that is exercising the simulation continuously. Additionally, JWARS development is being observed by a formal V&V contractor and is programmed for formal beta and operational testing.
- JWARS is not done. To date, many lessons have been learned about simulation software development and combat modeling. And, like its predecessors JWARS will continue to be modified throughout its life. The simulation system is a tool; nothing more, and nothing less. It is a complex tool that requires good, comparatively high resolution, data. And, most importantly, it requires a skilled multi-disciplinary team of analysts, and military domain experts to formulate, conduct, and interpret simulation experiments.
- JWARS can provide analysts an excellent foundation for conducting necessary and important analyses and research in support of the DoD. The limitations of the tool reflect the current knowledge boundaries of military modeling and simulation technology. The modeling advances that have been achieved in JWARS have the potential to facilitate meaningful research into emerging doctrinal concepts such as Joint Vision 2010/2020.

The remainder of this paper will describe JWARS design in a little more detail, emphasizing top-level concepts. Additionally, some of the relevant issues and limitations of the simulation will be discussed.

**JWARS Design and Components**

JWARS is an end-to-end constructive simulation of military operations that focuses on the operational level of war. The behavior of military forces can be simulated from ports of embarkation through to their activities in a warfight. This provides the potential for a “port to foxhole” view of a campaign, including the potential impact of both strategic and theater logistics.

The system is composed of three software domains that are integrated into a single executable package that is then used to perform studies and analyses. They are problem, simulation, and platform. The problem domain provides the software that describes the warfighting functionality of analytic interest. The simulation domain provides the “engine” that drives the simulation through time. It also provides the three dimensional battlespace. Conceptually, this battlespace is the Synthetic Natural Environment (SNE) in which the BSEs exist. The platform domain provides the JWARS hardware, and the Human Computer Interface (HCI) that helps analysts and others get data into and out of the simulation. Figure 1 provides an overview of the development domains.

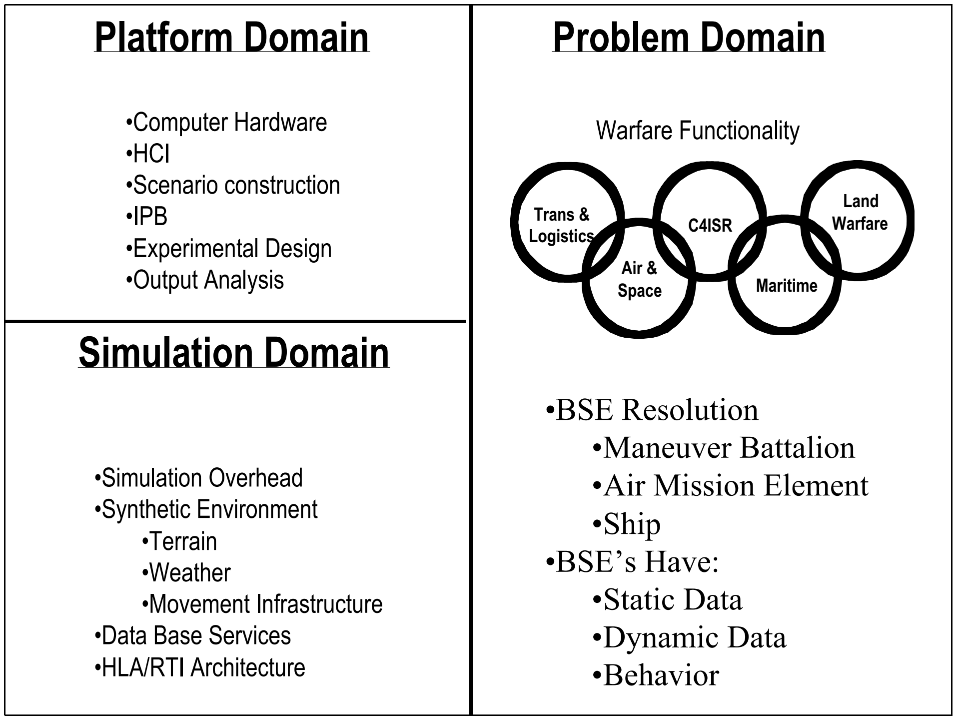


Figure 1: JWARS Domains

**JWARS Problem Domain**

The fundamental building block for representing military forces and systems in JWARS is called the Battle Space Entity (BSE). The nominal level of resolution of BSEs is at the battalion level for maneuver units, flight groups for air operations, ships for maritime assets, and individual platforms for critical ISR systems (e.g. JSTARS, U2s). Additionally, there are special case BSEs such as: ports, airfields, key headquarters units (e.g. division headquarters), and chemical clouds. BSEs contain data that represent both static and dynamic properties. Static data represent values that do not change, such as a unit's authorized strength, or the range of a missile system. Dynamic data (e.g. unit strength, location) can change over time. The data also point to behaviors that enable BSE interactions with each other and the environment. All BSEs have some organic command and control capability. The complexity of the C2 varies depending on the BSEs characteristics. Figure 2 graphically portrays the key components of a Battle Space Entity.

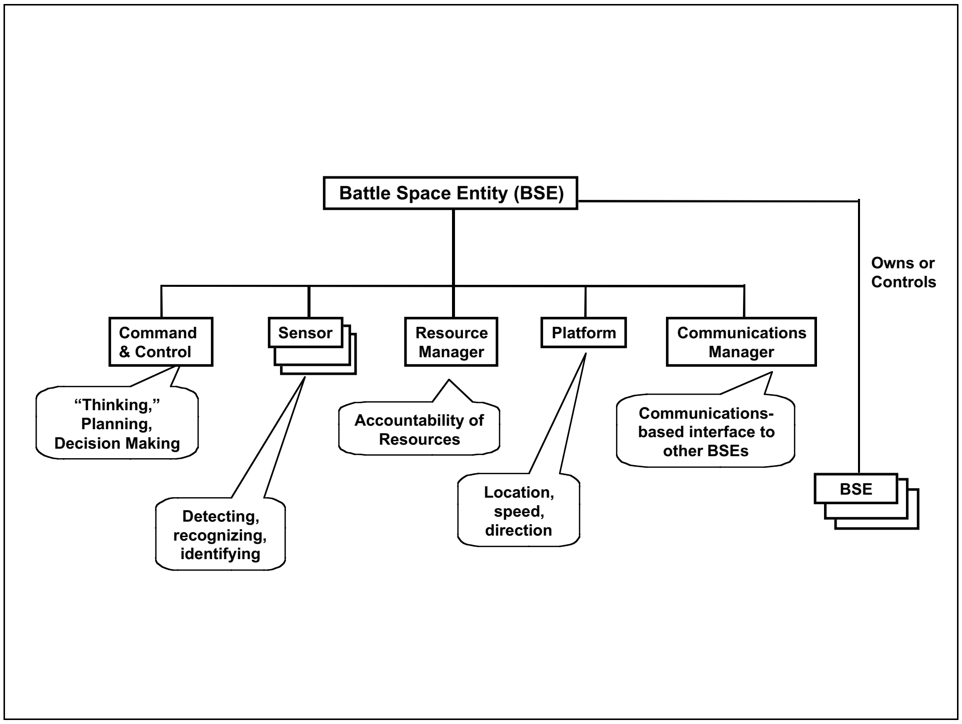


Figure 2: Battle Space Entity Components

A JWARS scenario contains a set of BSEs for all the forces that are to be played. The scenario also includes plans that the BSEs will attempt to execute as the simulation moves through time. One extremely important contribution of JWARS is that it simulates the activity of forces before the war starts. The current JWARS scenarios begin many days before any combat occurs, simulating the movement of units from their homestation and into the theater. Operationally, this part of the campaign is called "the road to war". Historically it has been treated in campaign level analyses as a set of assumptions (based on off-line analyses) that provide the starting conditions for the warfight that is simulated in a campaign model. This integrated view of a maturing theater will provide unprecedented visibility into the operational value of early C4ISR, strategic logistics, and alternative force flows.

The interaction of BSEs in JWARS (e.g. sensing, attrition) is adjudicated by a heterogeneous set of algorithms. These algorithms were provided to JWARS by domain experts or developed in-house as needed. The nature and resolution of the algorithms vary, depending on the type of activity being modeled, the functionality in the model with which an algorithm is associated, and the availability of data to populate the developmental scenario. Figure 3 provides an overview of the types of algorithms and the interactions they address.

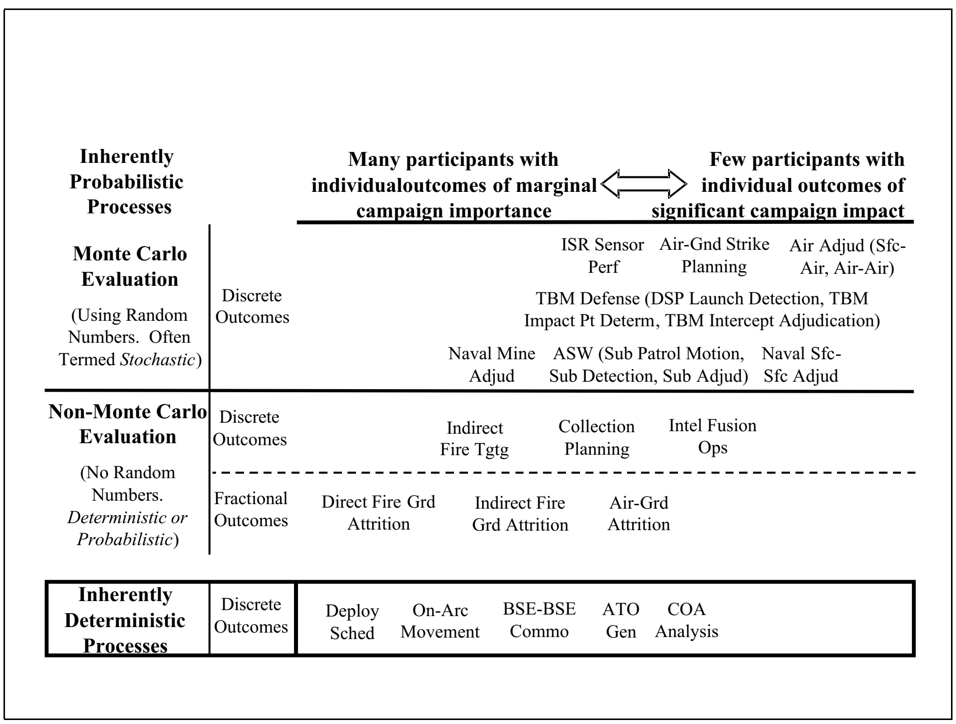


Figure 3: JWARS Algorithms

All of the interactions between BSEs in JWARS are scheduled as simulation events. The significance of individual events can range from relatively small (on the left side of Figure 3) to very significant (on the right). The deterministic algorithms address primarily the attrition of equipment in ground units. Individually, these types of events tend to have a relatively small impact on a campaign, and are accumulated using fractional outcomes. Cumulatively, however, these events could combine to have a significant effect (e.g. no halt occurs). There are also deterministic algorithms, such as collection planning, that do not lend themselves to fractional outcomes. Fusion is modeled probabilistically using Bayesian techniques. At the other end of the spectrum (on the right of Figure 3), events that have a very significant impact on campaign level decision making, and success, are evaluated stochastically, also with discrete outcomes.

Figure 3 also provides two insights into JWARS. First, assessing the mix of algorithms is a way to evaluate the "balance" of the simulation. These algorithms adjudicate virtually all BSE on BSE interactions in the model, and impact directly any measures of effectiveness that are collected. Therefore, it would be useful to compare and contrast different algorithms that evaluate similar physical phenomenon. (e.g. indirect fire vs. CAS) Second, all of the algorithms rely on either an accredited "feeder model" or an authoritative data source to support its operation in JWARS. The Joint Data Support (JDS) effort that is supporting JWARS has identified many of the feeder models needed to build a JWARS database.

JWARS was designed from the beginning to be C4ISR centric. That means that BSE Command and Control is largely based on perceived truth, not necessarily on ground truth. This is an advance over previous campaign level simulations in which command & control logic was based on ground truth.

The information flows in JWARS can be visualized using the Observe, Orient, Decide, Act (OODA) loop paradigm developed at the Air War College.[2] Figure 4 illustrates the information flows that implement the OODA loop concept in the simulation system. This description begins in the bottom center of the loop and proceeds clockwise. JWARS, like all simulations has a ground truth abstraction of the battlespace. This abstraction is a database that describes all of the forces, their plans, possible behaviors, and the environment in which they exist. This is necessary because BSEs in the simulation must be initialized with data that tells them what they believe to be true about the opposing force. This is analogous to the operational IPB process, and includes an initial collection plan.

In the lower left corner of the loop is data collection, or the observe phase of an OODA loop. BSEs use sensors to collect information on the opposing force. The quality of the information is a function of both the BSE sensor(s) and the signature(s) of the BSEs that are detected. Information in the form of situation reports and adjudication results are also sources of information that are used by command and control. These observations are packaged into reports and sent explicitly, via a communications architecture, to other BSEs (e.g. JTF Headquarters) consistent with the Command and Control concept of operations that is being represented. It is also important to note that the JWARS communications representation introduces delays for all explicit messages. The magnitude of the delay varies according to the types of networks that a BSE has access to, as well as the background load at the time the message is sent.

The processing and perceived truth nodes in the figure map to the orient concept in the OODA loop. The processing node represents the activity necessary to formulate a commander's perception. JWARS uses a set of pattern matching and fusion algorithms that combine new reports with previous perception; as well as introducing a processing, exploitation, and dissemination (PEDS) delay. The perceived truth node is analogous to a situation map. In JWARS it is called the JEF (JWARS Equipment and Forces). There can be one or more JEFs per side, allowing for the evaluation of concepts like the Common Operational Picture (COP).

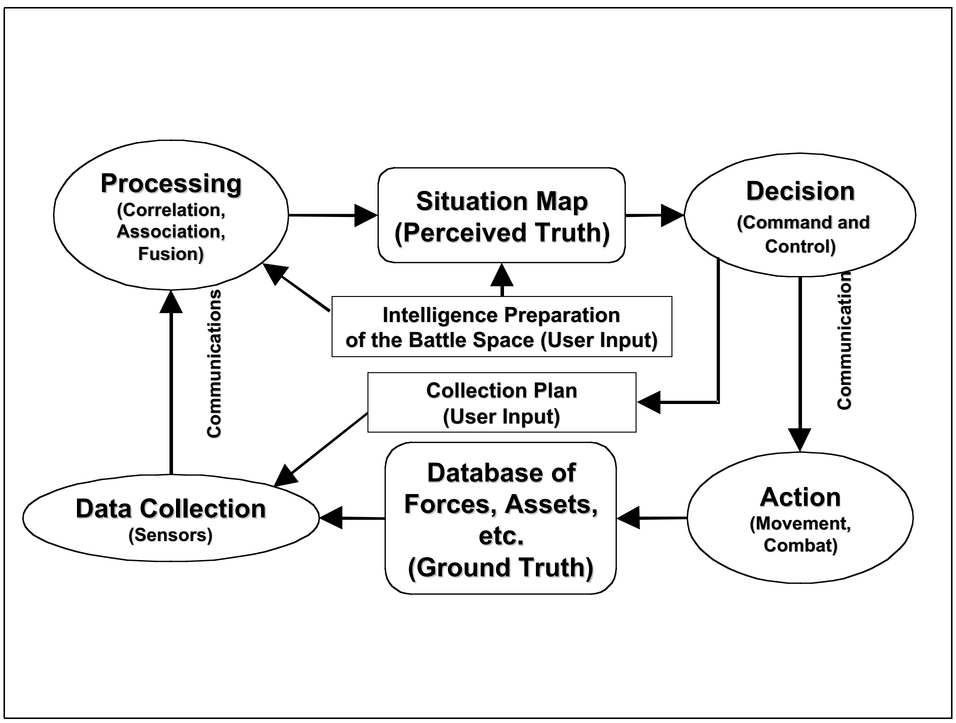


Figure 4: JWARS Logical Structure

The decision node in the figure represents JWARS C2. It is implemented in a number of different ways. First, users input plans for the forces on both sides. One example is an execution matrix visible through the HCI that serves as a commander's decision support template. The model then uses these templates during simulation execution to make high level decisions based on the current situation. One sample is a counterattack that is scheduled to begin on Day D using unit X. The user inputs this schedule, as well as other criteria that will be considered at decision time. (e.g. unit strength, or location) Then on Day D of the simulation run, the C2 evaluates the ability of a unit to initiate its assigned mission based on the input criteria. If it is unable to follow the execution matrix, the C2 logic of the simulation reports that the force is off plan and some corrective action is required. Second, there are also run-time mechanisms for making decisions in JWARS. One such mechanism is a rule processor. This processor allows users to change parameters of key C2 related variables in the model through the HCI. These decision rules should be based on subject matter expert input. There are also planners and behavior templates that generate tasks and plans to be executed over some time horizon. Examples include the ATO generator, collection planner, strategic lift scheduler, and maneuver sequence planner. Finally, there are decision rule sets input by the user that enumerate phase and state possibilities for the Joint Task Force level command and control.

The final node in the figure is the action node, which maps to the act node in an OODA loop. Actions are adjudicated based on ground truth, and the ground truth database is updated.

**Simulation Domain**

The Simulation Domain provides the overhead that allows the simulation to function. It contains the necessary infrastructure such as the event list, random number generators, coordinate systems, and data collection agents. These resources, referred to as managers, are implemented as object oriented code that software engineers draw upon to implement JWARS problem domain functionality. This design provides a modularity that will allow JWARS to implement new concepts relatively easily. The Smalltalk development environment also allows the distribution of computational requirements to multiple processors. This provides JWARS with an ability to capitalize on rapidly emerging advances in distributed computing.

The simulation domain also provides a synthetic natural environment (SNE) within which the BSEs must operate. This battlespace maps to the WGS-84 ellipsoid, and uses the Global Coordinate System (GCS). This representation makes the location of all entities in JWARS globally consistent. Additionally, the simulation uses environmental data, such as terrain, weather, mobility networks, and bathymetry to affect the performance of military units and systems. This environment affects the performance of BSEs and the interaction of BSEs. Environmental characteristics that are modeled include: visibility, sea state, terrain roughness, and winds. In a sixty day, JWARS scenario there are many thousands of calls made to the environmental manager for relevant information. Terrain, acquired from standard NIMA data sets, is stored in Compact Terrain DataBase (CTDB) format. It is processed using ERDC Vicksburg developed algorithms into user defined cells for maneuver, and into a mobility network to support intratheater movement. Weather data is derived from the DMSO Environmental Scenario Generator (ESG).

The JWARS Operational Requirements Document (ORD)[3] has very demanding traceability requirements with respect to both input and output data. Meeting these requirements necessitates the inclusion of a robust database management system. JWARS Release 1.1 meets these requirements using ORACLE 8 as the database engine. Both input and output data are stored in ORACLE. Most of the data are in binary form and requires the JWARS HCI to view and manipulate. The HCI then provides tools and controls that meet the prescribed traceability requirements.

Similar to other developing simulations, JWARS is required to be HLA/RTI compliant. This requirement will be met in part through a Run-Time Interface (RTI) binding that is part of the Visual Age Smalltalk development environment. This will allow simulation federations that involve JWARS to be developed relatively easily. Additionally, other simulations that use Visual Age Smalltalk will be able to reuse the RTI binding, potentially reducing their development cost.

**Platform Domain**

The JWARS platform domain includes the hardware on which the simulation runs and the Human Computer Interface (HCI) which users interact with to control the simulation. The HCI is used to support scenario construction, Intelligence Preparation of the Battlefield, run control, and output analysis. Most analytic requirements can be met by interacting with the simulation using the HCI.

JWARS is developed in IBM Smalltalk. Smalltalk generates a "virtual machine" that adapts the computer code to its host environment. This minimizes the labor that is necessary to adapt the software to specific hardware configurations. The current release of JWARS runs using a client-server architecture. The simulation runs on the server side in the UNIX environment (currently Sun) and the HCI runs on the client side on Windows NT 4.0 platforms. JWARS allows multiple users to setup and execute simulations simultaneously. Specific hardware requirements depend on the needs of the user site, and are being coordinated as part of the fielding process.

The HCI design is based on a RAND Corporation study of analyst workflow.[4] The system also includes security features that limit a user's ability to modify JWARS. The most common user of JWARS, an analyst, has the ability to create and modify scenarios, specify simulation run parameters, and work with JWARS output. Modelers have greater flexibility. They can create new entities and modify the structure of existing entities. Developers have the ability to make changes globally throughout the system. Site administrators have local control over the privileges accorded to individual JWARS users.

JWARS collects data using instruments that are provided by the simulation domain. JWARS users can select the data they wish to collect through the HCI. During simulation execution the data is then collected and stored in ORACLE. After the run analysts can visualize the results through a limited set of analysis tools that are organic to JWARS. Additionally, any instrument that is collected can be exported as a delimited file for use in COTS analysis tools. During initial JWARS testing, the participating analysts developed many "home grown" tools to view the data.

**JWARS Issues and Limitations**

JWARS is working to the state-of-the-art in operational level combat modeling. That said, there are modeling issues and limitations that have implications for potential JWARS users. There are three key issues. First, the JWARS algorithms, although "validated" by the submitting service or proponent, may not be globally consistent. For example, the assumptions in the indirect fire algorithm (and its feeder model) may not be compatible with the assumptions in the air-to-ground attrition algorithm (and its feeder model). The second is a corollary to the first issue. Previously, "balance" in JWARS has been defined by the warfighting functionality identified in the ORD. This view, while extremely useful to support development, does not ensure that the data and algorithms representing similar physical events are of compatible resolution. The third modeling issue is data. The issue has both technical and managerial aspects. Technically (again a corollary to the first issue), the data needs to be consistent across military domains and compatible with the environmental data that supports the simulation. On the management side, JWARS demands unprecedented quantities of data to construct a working scenario. Meeting this demand will require resources.

JWARS is a new tool that implements many new modeling concepts, and is tremendously complex. The complexity of the model is a function of the complexity of the multi-billion dollar "system of systems" we are attempting to describe. That said, there is a significant (albeit necessary) learning curve. It will take some time to develop a core team of analysts that are proficient with the tool. It will be slightly longer until an experienced user base is prepared to present "end-to-end" JWARS results to senior leaders.

## Summary

JWARS can provide analysts with an excellent foundation for conducting important analyses and research in support of the DoD. The limitations of the tool reflect the current knowledge boundaries of military modeling and simulation technology. The modeling advances that have been achieved in JWARS can enable research into emerging concepts and doctrine.

Additional information about JWARS design and algorithms is available at http://www.jointmodels.army.mil.

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**About the author:**

Dan Maxwell is a member of the MITRE principal technical staff. Prior to joining MITRE he served as a senior operations research analyst and the US Army representative to the Joint Warfare System (JWARS) Office in the Office of the Secretary of Defense (OSD), Program Analysis and Evaluation Directorate. Dan has also served in the U.S. Army Concepts Analysis Agency where he provided analysis in support of many DoD studies. He holds a Ph.D. in information technology from George Mason University, an MBA from Long Island University, and a B.S. in criminal justice from the Rochester Institute of Technology.

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