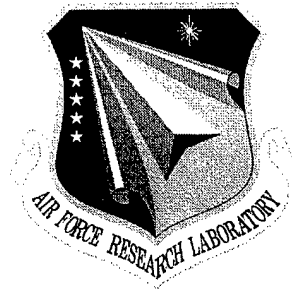AFRL-IF-RS-TR-2001-171
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August 2001

JOINT ASSISTANT FOR DEVELOPMENT AND EXECUTION (JADE)

BBN Technologies

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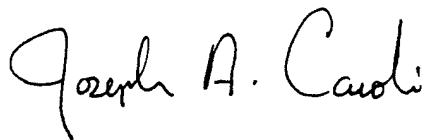

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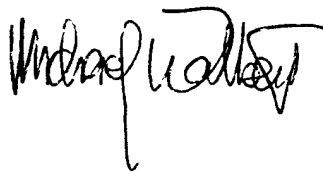AFRL-IF-RS-TR-2001-171 has been reviewed and is approved for publication.

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13. ABSTRACT *(Maximum 200 words)*

JADE (Joint Assistant for Deployment and Execution) is a knowledge-based mixed-initiative system that supports force deployment planning and management. JADE uses case-based and generative planning methods to support the development of large-scale, complex deployment plans in minimal time. JADE incorporates the technology of three tools: Prodigy-Analogy (a combined case-based and generative planner developed by Carnegie Mellon University); ForMAT (Force Management and Analysis Tool) that supports case-based force deployment planning developed by BBN Technologies); and PARKA (a highly-indexed knowledge based management system developed by the University of Maryland).

With JADE, a military planner can build a preliminary force deployment plan, including the Time Phased Force Deployment Data (TPFDD) in less than one hour. This speed in plan construction is possible because JADE supports the rapid retrieval and reuse of previous plan elements for use in the development of new plans. In addition, JADE employs an easy to use map-oriented drag and drop interface where force modules (FMs) from previous plans (cases) whose force capabilities and composition match the requirements of the current situation can be dragged from the case library and dropped onto a geographic destination. Plan modification and/or adaption is supported through remindings, e.g., each time that a force module is created or is copied into a plan (TPFDD) the user is automatically reminded of the need for geographical changes.

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List of Figures

List of Tables

ABSTRACT

JADE (Joint Assistant for Deployment and Execution) is a knowledge-based, mixed-initiative system that supports force deployment planning and management. JADE uses case-based and generative planning methods to support the development of large-scale, complex deployment plans in minimal time. JADE incorporates the technology of three tools: Prodigy-Analogy (a combined case-based and generative planner developed by Carnegie Mellon University); ForMAT (a Force Management and Analysis Tool that supports case-based force deployment planning developed by BBN Technologies); and PARKA (a highly-indexed knowledge based management system developed by the University of Maryland).

With JADE, a military planner can build a *preliminary* force deployment plan, including the Time Phased Force Deployment Data (TPFDD) in less than one hour. This speed in plan construction is possible because JADE supports the rapid retrieval and reuse of previous plan elements for use in the development of new plans. In addition, JADE employs an easy to use map-oriented drag and drop interface where force modules (FMs) from previous plans (cases) whose force capabilities and composition match the requirements of the current situation can be dragged from the case library and dropped onto a geographic destination. Plan modification and/or adaptation is supported through *remindings*, e.g., each time that a force module is created or is copied into a plan (TPFDD) the user is automatically reminded of the need for geographical changes.

With support from the Defense Advanced Research Projects Agency (DARPA) and the Air Force Research Lab (AFRL), JADE researchers have been able to apply academic research to an area of military operational planning and scheduling. JADE is a solution to the challenge of rapidly producing force deployment plans and is currently available for transition to the operational military planning community. This report describes JADE, its current status, and the results of two recent efforts to transition JADE to the operational environment, e.g., JEFX 2000 (Joint Expeditionary Force eXperiment) and ACOA (Adaptive Course of Action).

BACKGROUND

JADE derives its name from the beautiful jade green that colors the island of Oahu in Hawaii where the Pacific Command (PACOM) is headquartered. The acronym JADE stands for *Joint Assistant for Deployment and Execution*. Its purpose is to assist in the development of force packages (combat forces and supporting forces) that need to be deployed to some location in support of the operational planning and plan execution of a warfighting CINC (Commander in Chief) such as PACOM. Many of the facets of JADE were developed in response to requirements specified by PACOM planners. The largest and most precise casebase in JADE was created with support from PACOM planners to support the development of deployment plans for situations

other than war that arise in the Pacific Command theater. For PACOM, JADE is best utilized when it can inter-operate with their chosen *Course of Action* planning environment. For PACOM, this environment is comprised of a tool suite that is being developed by the ACOA (Adaptive Courses of Action) program. (For more information about JADE and ACOA, see Appendix B.)

JADE is the result of a technology integration experiment (TIE) that was initially conducted as part of a joint DARPA/Air Force Research Lab (AFRL) program called DARPI (DARPA Rome Planning Initiative) and later through the DARPA program Planning and Decision Aids (PDA). The experiment involved the linking of the following three independent technologies:

- Prodigy-Analogy (a combined case-based and generative planner developed by Carnegie Mellon University);
- ForMAT - Force Management and Analysis Tool (a case-based force deployment planner developed initially at The MITRE Corporation, and subsequently by BBN Technologies); and
- PARKA (a highly-indexed knowledge based management system developed by the University of Maryland).

When the PDA program terminated in 1999, work on JADE was carried on with extended funding from AFRL and with funding from the DARPA/DISA (Defense Advanced Research Projects Agency/Defense Information Systems Agency) Advanced Information Technology Services Joint Program Office (AITS-JPO) through the ACOA (Adaptive Courses of Action) program. The purpose of this extended funding was to support the transition of JADE into the operational military environment.

JADE supports force deployment planning, the results of which are normally embodied in a data structure called the TPFDD (Time Phased Force Deployment Data). For the operational military deployment planner, the TPFDD is created using the *Joint Operations Planning and Execution System* (JOPES) software. Associated with each TPFDD is an Operational Plan (OPLAN) which describes the mission and specifies where and when the forces involved in a mission are to be deployed. The OPLAN for deliberate planning is stored and maintained until such time that its execution is called for, which may be years after it was first constructed. At this time the plan will generally have to be modified to fit the particular details of the current situation, which often is a crisis situation. See [2, 3, 4] for more information.

The TPFDD specifies the combat forces and the combat service support required in order to support the mission. Transportation phasing, mode and geographical locations are also specified. In the early phases of plan development, combat and support units may be specified generically (e.g., fighter aircraft), as can movement times (i.e., latest departure, earliest departure, latest arrival, earliest arrival), origins and destinations. As the plan matures or transitions from a deliberate plan to an executable plan, each specification for a generic requirement is replaced by

information associated with the actual unit(s) or equipment that will be used. Once the planners have identified what is to move, they must check to see if the plan is logistically feasible. Once they determine how and when they would like units and equipment in the plan to move, they need to check to see if the plan is transportationally feasible. This last step is supported by tools available at the US Transportation Command (USTRANSCOM).

Historical experience indicates that while the TPFDD has served as a useful tool for deliberate planning, it is often not used to support time sensitive problems. JADE was developed to move beyond JOPES tools in support of an agile operations planning and execution system that is easy and intuitive to use and that quickly provides required information in support of time sensitive planning.

JADE can be used to support both deliberate and crisis action (time sensitive) planning. JADE software enables a military planner to build a preliminary force deployment plan (TPFDD) in less than one hour. JADE uses a knowledge-intensive planning technique that employs case-based and generative planning methods to handle large-scale, complex plans in minimal time. The tool supports the rapid retrieval and reuse of previous plan data, both deliberate plans and previously developed crisis plans. To support plan development, constraint checking is provided and the results are used to provide the user with reminders of steps to do *during* the force deployment planning process.

JADE Software

Two versions of JADE are available: (a) a stand-alone version that runs on a Windows NT platform that can be configured to communicate with external systems; and (b) an ACOA-JADE version that runs within the ACOA environment. The ACOA version of JADE is configured to derive planning data such as preferred forces, planning guidance, and planning state information from the ACOA Campaign Object. The standalone version of JADE exists to support those users who have not embraced the ACOA model. During the course of this project, we have worked with planners from CINCs other than PACOM and with Air Force planners who were involved in JEFX 2000. For these users, the standalone version of JADE was provided to support the development of the Force Deployment Plan.

JADE runs in both the Windows NT environment and on Sun Workstations in the Solaris environment. JADE is written in Common Lisp. The graphical interface is an object-oriented GUI built using CLIM, a Common Lisp interface to O/S-native window system. JADE requires a minimum of 250 megabytes of disk space for the application binaries and to store the data used and generated by the system. This does not include space required for COTS products such as Netscape, ORACLE etc.

The JADE system consists of a client program, and two major servers. One server, the Geoloc server provides information on Geoloc (geographical location) codes. The Geoloc server consists of two processes: a Java interface and a Parka-DB server that communicates via a TCP socket

connection. The other main server is the Suggestions server. This server monitors the user's actions and uses some of the collected information to provide remindings or advice to the user while they work. The client communicates with both the Geoloc and Suggestions servers using the TCP/IP socket protocol. When the servers and client are running on the same machine, all socket connections are local. JDBC (Java Data Base Connectivity) is used to communicate to other servers such as the GSORTS (Global Status of Resource and Training System) server. The JADE architecture shown in Figure 2 illustrates the client program and servers.

Using JADE for Deployment Planning

Deployment planning in JADE starts with the receipt of a mission statement. Information about mission tasks and forces is also required. In JADE, the mission statement can be analyzed, using a specially designed case-based parser, to produce a list of implied and/or specified tasks and force preferences (see Figure 1 for an example). Alternatively, this information can be directly obtained from other sources, such as the ACOA Course of Action planning environment.
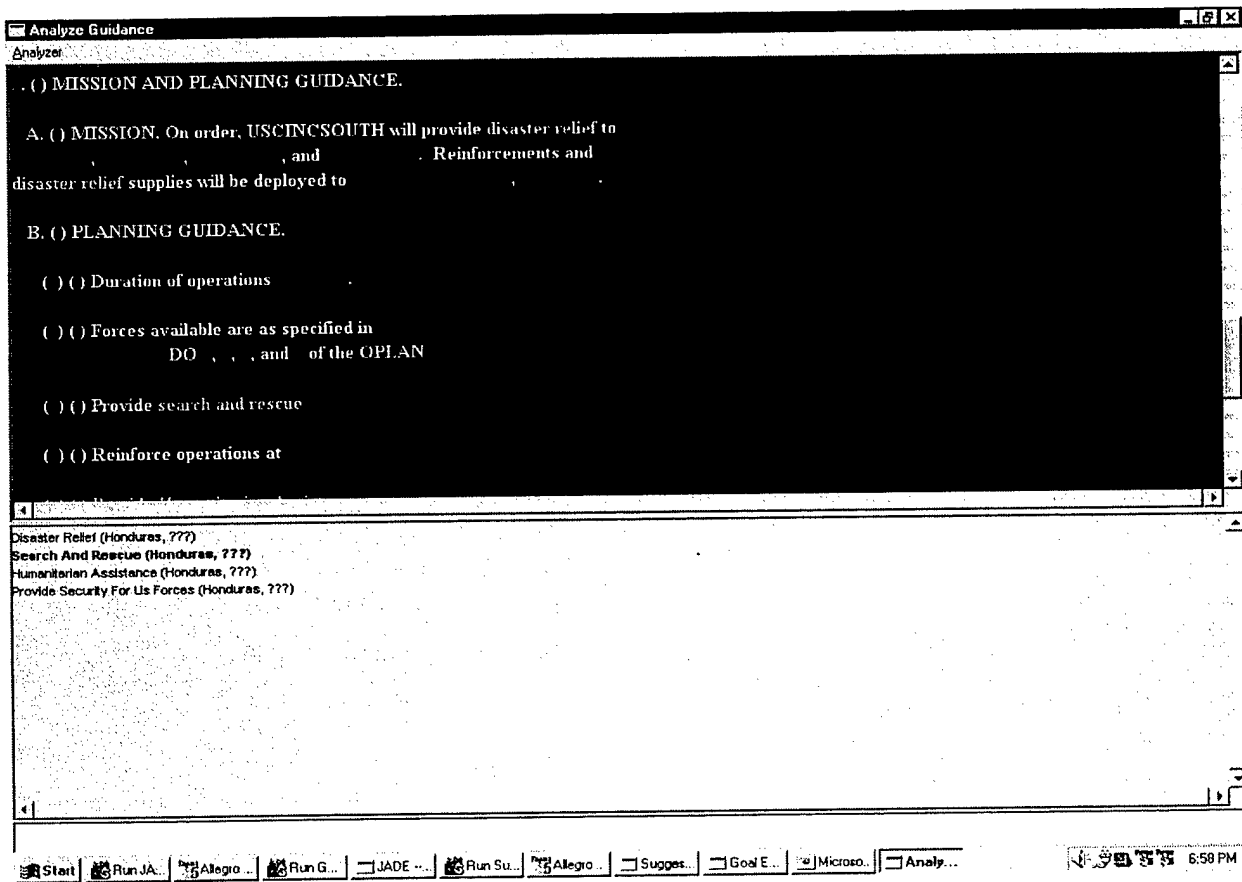

Figure 1 – Parsing Mission Guidance into Tasks

JADE follows a case-based reasoning (CBR) paradigm in supporting the matching of data about the current mission with data that describes the deployment plans that constitute the loaded

4

library of deployment plans or casebase. Results of the similarity matching are presented to the user for use in developing a new deployment plan. Each time the user creates a new deployment plan (TPFDD), the user may save that TPFDD into the casebase so that it is available for use in the future. Although a TPFDD developed in JADE will contain information that is not typically available in a JOPES-produced TPFDD, JADE can pass it's TPFDDs to JOPES or any other system that can read a standard TPFDD (B8) file format. JADE also supports the generation of a variety of reports that are available to analyze, brief and manage the developing deployment plan.

JADE's three major technology components (i.e., ForMAT, Prodigy, and PARKA) support the user in modifying force compositions, describing force capabilities, and in tailoring the evolving force deployment plan to changing mission requirements. To date, JADE's plan repository (casebase) is comprised of several different casebases. One of these casebases, "tutor" provides training, while the "prodigy" casebase supports general planning. The standalone version of JADE is delivered with these two casebases. However, new casebases can be created and tailored to fit the particular needs of a given user group. For example, Figure 2 shows a link from ForMAT to the ACOA Campaign Object. A casebase called "ACOA" was developed to support the ACOA user group.

Case-Based Reasoning (CBR)

Case-based planners [1, 6] rely on similarity matching mechanisms and enumeration schemes to select the best stored plan for re-use in a new situation. Similarity matching methods range from fully exhaustive factor comparison to optimized inductive tree mechanisms that generate decision trees with smoothed regularities and distinguishing differences. Enumeration methods are used to list, in the order of similarity, plans or parts of plans that match attributes of the current problem-solving situation. [7]

An integral aspect of CBR is in the generation and selection of indices. In fact, the success of CBR significantly depends upon the judicious choice of these indices. In JADE attribute/value pairs are the indices that are used for describing (and later retrieving) a force module (FM). An attribute/value pair (index) can be defined to describe any aspect of a FM that the user finds useful. Attributes can have multiple values, and each value can be nominal or hierarchical in nature. (See Figure 4 for some examples.)

In retrieval, the attribute/value pairs are used to construct a query against the casebase for one or more FMs. JADE provides user interface tools to support the specification and retrieval of "exact" matches, as well as "generalized" retrievals. With an "exact" query, the user can find FMs that exactly match a query specification. "Generalized" retrievals utilize the hierarchical values of attributes to navigate generalization hierarchies in search of some relevant solution. Relevance is defined by the amount of similarity between a set of attribute/value pairs within a query and those indexing the FMs.
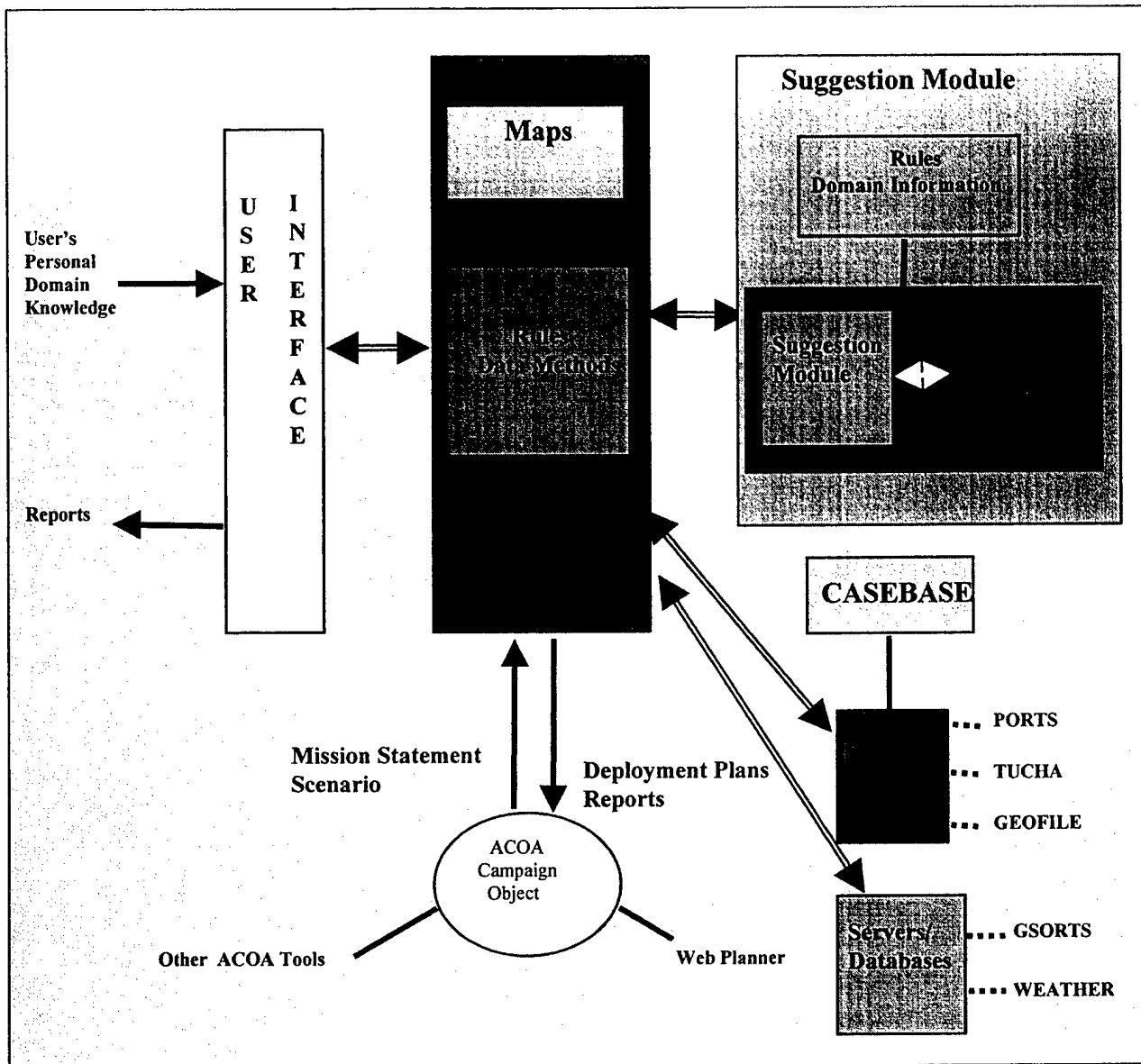
Figure 2—JADE Architecture

ForMAT

Users interact with JADE through a user interface that is directly connected to the ForMAT (Force Management and Analysis Tool) module. ForMAT was originally developed at The MITRE Corporation and used to support knowledge acquisition. The interface of ForMAT[1, 7] evolved through user interaction to become a rich environment for building force modules (FMs). A FM describes a force or set of forces that can be used to satisfy some mission requirement.

Typically, a FM is a grouping of combat, combat support, and combat service support forces, and ranges in size from the smallest combat element to the largest combat element. It may specify accompanying supplies and the required movement of resupply and personnel necessary to sustain forces for a minimum of 30 days. [7, 8]

In JADE, like in JOPES, the user builds a FM by specifying the Force Module Identification (FMID) and then entering the appropriate Unit Line Numbers (ULNs) which will comprise the FM. ForMAT provides the user with additional capabilities for creating, viewing, retrieving, and managing FMs. For example, through ForMAT the user can build a FM from a copy of a FM contained in another TPFDD (that is stored in the casebase). The user can cut and paste ULNs between FMs within a given TPFDD and create links between any number of FMs within a given TPFDD in order to build a FM hierarchy like the hierarchy displayed in Figure 3. Here the FMs A, B, C, and D are forces that comprise the parent FM (NEO). ForMAT enables the user to *explicitly* specify these parent-child relationships. This information is stored in the TPFDD and in the casebase.

ForMAT also provides the user with tools for linking the data of the TPFDD to the mission that the deployment forces are intended to support and for describing what capabilities the forces contain that enable them to support a mission. Mission guidance can simply be stored as a file or it can be obtained from another source, such as the ACOA Campaign Object. For example, in Figure 2 mission information is obtained electronically by ForMAT from the ACOA Campaign Object in the form of implied and/or specified tasks with a related force list. It is this linking of
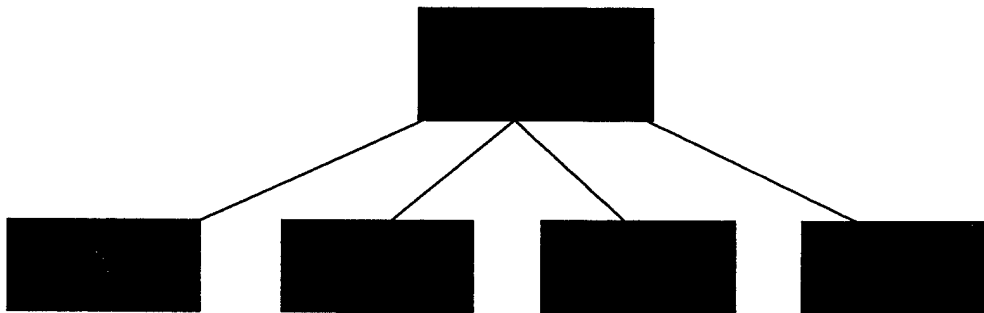
Figure 3 -- Example Hierarchical Force Deployment Plan (TPFDD)

forces with the tasks of the mission that extends the TPFDD into a Deployment Plan. Figure 4 displays a FM from JADE showing the ULNs on the right and some attribute/value pairs, including those descriptive of the mission tasks (called goals) on the left. Note: the other values/indices displayed on the left of the FM in Figure 4 are either generated automatically or manually created by the user as a way to better describe (annotate) the FM – it's composition and/or capability.
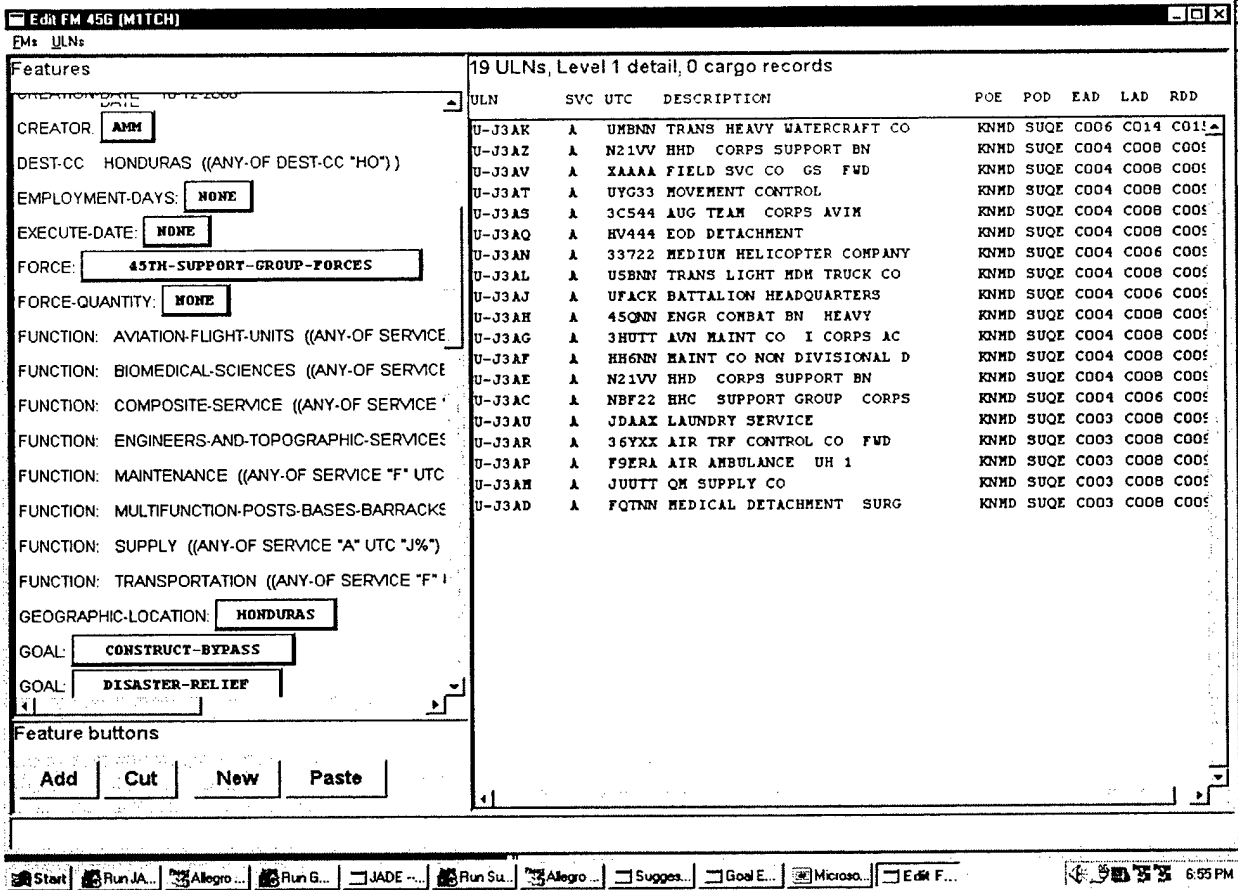
Features

CREATOR: **AMM**

DEST-CC   HONDURAS ((ANY-OF DEST-CC "HO"))

EMPLOYMENT-DAYS: **NONE**

EXECUTE-DATE: **NONE**

FORCE: **45TH-SUPPORT-GROUP-FORCES**

FORCE-QUANTITY: **NONE**

FUNCTION: AVIATION-FLIGHT-UNITS ((ANY-OF SERVICE

FUNCTION: BIOMEDICAL-SCIENCES ((ANY-OF SERVICE

FUNCTION: COMPOSITE-SERVICE ((ANY-OF SERVICE

FUNCTION: ENGINEERS-AND-TOPOGRAPHIC-SERVICE

FUNCTION: MAINTENANCE ((ANY-OF SERVICE "F" UTC

FUNCTION: MULTIFUNCTION-POSTS-BASES-BARRACKS

FUNCTION: SUPPLY ((ANY-OF SERVICE "A" UTC "J%")

FUNCTION: TRANSPORTATION ((ANY-OF SERVICE "F" I

GEOGRAPHIC-LOCATION: **HONDURAS**

GOAL: **CONSTRUCT-BYPASS**

GOAL: **DISASTER-RELIEF**

Feature buttons

| Add | Cut | New | Paste |

19 ULNs, Level 1 detail, 0 cargo records

ULN	SVC	UTC	DESCRIPTION	POE	POD	EAD	LAD	RDD
U-J3AK	A	UMBNN	TRANS HEAVY WATERCRAFT CO	KNHD	SUQE	C006	C014	C01!
U-J3AZ	A	N21VV	HHD CORPS SUPPORT BN	KNHD	SUQE	C004	C008	C00!
U-J3AV	A	XAAAA	FIELD SVC CO GS FWD	KNHD	SUQE	C004	C008	C00!
U-J3AT	A	UYG33	MOVEMENT CONTROL	KNHD	SUQE	C004	C008	C00!
U-J3AS	A	3C544	AUG TEAM CORPS AVIM	KNHD	SUQE	C004	C008	C00!
U-J3AQ	A	HV444	EOD DETACHMENT	KNHD	SUQE	C004	C008	C00!
U-J3AN	A	33722	MEDIUM HELICOPTER COMPANY	KNHD	SUQE	C004	C006	C00!
U-J3AL	A	USBNN	TRANS LIGHT MDM TRUCK CO	KNHD	SUQE	C004	C008	C00!
U-J3AJ	A	UFACK	BATTALION HEADQUARTERS	KNHD	SUQE	C004	C006	C00!
U-J3AH	A	45QNN	ENGR COMBAT BN HEAVY	KNHD	SUQE	C004	C008	C00!
U-J3AG	A	3HUTT	AVN MAINT CO I CORPS AC	KNHD	SUQE	C004	C008	C00!
U-J3AF	A	HH6NN	MAINT CO NON DIVISIONAL D	KNHD	SUQE	C004	C008	C00!
U-J3AE	A	N21VV	HHD CORPS SUPPORT BN	KNHD	SUQE	C004	C008	C00!
U-J3AC	A	NBF22	HHC SUPPORT GROUP CORPS	KNHD	SUQE	C004	C006	C00!
U-J3AU	A	JDAAX	LAUNDRY SERVICE	KNHD	SUQE	C003	C008	C00!
U-J3AR	A	36YXX	AIR TRF CONTROL CO FWD	KNHD	SUQE	C003	C008	C00!
U-J3AP	A	F9ERA	AIR AMBULANCE UH 1	KNHD	SUQE	C003	C008	C00!
U-J3AM	A	JUUTT	QM SUPPLY CO	KNHD	SUQE	C003	C008	C00!
U-J3AD	A	FQTNN	MEDICAL DETACHMENT SURG	KNHD	SUQE	C003	C008	C00!

Figure 4 -- A Force Module in JADE

The Suggestions Module/Server

The Suggestions Module/Server is comprised of three pieces: the Prodigy Planner, the rules and domain files used by Prodigy, and a Frond End that links Prodigy to ForMAT (See Figure 1). The core component of the Suggestions Module/Server is a generative artificial intelligence (AI) planner, developed by Carnegie Mellon University (CMU) called Prodigy. Prodigy [9] is a multi-strategy planning and learning architecture that can solve planning problems in a number of different ways. Simply stated, Prodigy searches for a sequence of actions that transform an initial state (the current state) into a final state (the goal state). A domain theory is used to specify the legal actions that can be performed. The domain theory is composed of a hierarchy of object classes and a suite of operators and inference rules that change the state of the objects. A planning problem is represented by an initial state (objects and propositions about the objects) and a set of goal expressions to achieve. Planning decisions consist of choosing a goal from a set of pending goals; then choosing an operator (or inference rule) to achieve a particular goal; then choosing a variable binding for a given operator; and finally deciding whether to commit to a possible plan

ordering to get a new planning state or to continue subgoaling for unachieved goals. Different choices give rise to different ways of exploring the search space. (See [10] for more details).

Another strategy available to Prodigy is the case-based replay mode. In this mode, Prodigy uses *analogy* to create plans, interpret and store planning episodes, and retrieve and reuse multiple past plans that are found similar to new problems. Stored plans are annotated with plan rationale, and reuse involves adaptation driven by the plan rationale.

In JADE, we developed a *Front End* to the Prodigy planner that links it to ForMAT. The *Front End* collects information such as mission goals and state information about the planning context through ForMAT and presents it to Prodigy for use in planning. Prodigy then provides guidance through the *Front End* to the *Suggestions Module* which then presents guidance and/or suggestions to the user about how to modify or create a deployment plan (see Figure 5). For example, when the user is initially looking for FMs that will satisfy new mission requirements, Prodigy will use its own information about previous plans to make a suggestion about what particular FMs should be used, or what entire past plans are most similar to the current mission situation. The *Suggestions Window* will present this information, as well as information from ForMAT, to remind the user that forces are to be deployed to specific geographical locations and when certain forces are preferred for inclusion within a deployment plan. Because the Prodigy system uses mission goals and causal information, the resulting plan is in a mission-to-task
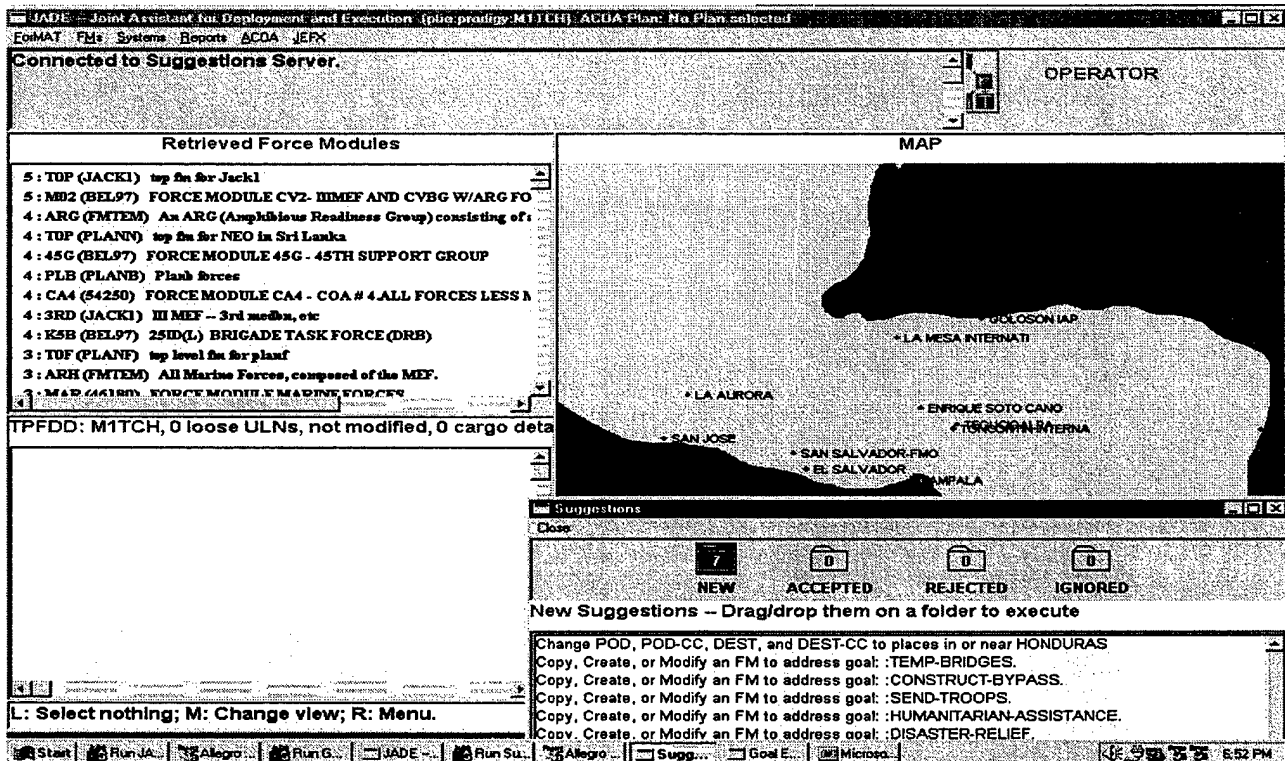

Figure 5 -- JADE Main Screen

9

framework. That is, the steps in the deployment plan are related to the causal reasons for which the forces are to be used (mission). Although Prodigy is capable of generating the entire deployment plan, in JADE, Prodigy is only used to provide suggestions to the user who has the ultimate decision in what gets deployed to where and when. Figure 5 is a screenshot of the JADE system, displaying the map and suggestions being provided in the Suggestions Window.

PARKA

Another component of the JADE architecture is the PARKA knowledge base (PARKA-KB). PARKA-KB is a high performance knowledge base management system that was developed by the University of Maryland. Although it is similar to a relational database, it uses technology that supports and takes advantage of data hierarchies. It has been shown to effectively handle extremely complex "structure matching" queries against large knowledge bases. [5, 8]

In JADE, several PARKA KBs are used to support plan retrieval and the retrieval of the associated data that support deployment plan generation. PARKA-KBs store the TPFDDs (both FMs and ULNs); a representation of the country code information, referred to as the "GEOFILE" database; and a representation of seaports (referred to as PORTS data). These last two are used in the Geoloc Server. Using these PARKA-KBs, the JADE user can retrieve the desired FMs, ULNs, or information about the geographical location that forces are to be deployed to. Note: experiments were carried out regarding the storage of Tucha (Type Unit Characteristics) data in a PARKA database. Results indicate that Tucha data is better accessed directly or through another force deployment tool, such as JFRG (Joint Force Requirements Generator).

JADE APPLICATIONS

Table 1 displays the list of user organizations that JADE has been distributed to since 1999. All of these distributions refer to the NT version of JADE. Appendix A describes experiences with JADE during JEFX 2000, and Appendix B describes experiences with ACOA. In 1999 we presented a demonstration of JADE at SOUTHCOM (U.S. Southern Command). The deployment planner at SOUTHCOM was interested primarily in JADE's ability to provide analysis reports about already constructed TPFDDs. JADE developers were provided data from Hurricane Mitch while there, and were able to demonstrate how the report mechanisms in JADE enable the human planner to identify deployment trends. Figure 6 contains an example report about the Hurricane Mitch data.

User's Organization	Date and Version of JADE when first acquired	Date and Version of JADE when last acquired	Have we provided user support?
The MITRE Corporation in O'Fallon Il.	Jade 2.1, Aug 1999	Jade 2.4.1 alpha Nov 2000	Yes, training, installation, and usage support.
PACOM/ACOA	Jade 2.1 with ACOA patches; date: Aug 1999	Jade 2.2.4 with ACOA patches; date: Sept 2000	Yes, training, installation, and usage support.
JEFX	Jade 2.2.4 with JEFX patches; date: May 2000	Jade 2.3 with JEFX patches; date: July 2000	Yes, training, installation, and usage support.
SOUTHCOM	Jade 2.1 date: Nov 1999	Jade 2.2.4, Fall 2000	Yes, installation support.
MIATA TIE developer group at BBN Technologies	Jade 2.2.4 with CoABS patch; date: August 2000	Jade 2.2.4 with updated CoABS patch; date: Jan 2001	Yes, to enable JADE to communicate with the CoABS Grid
AFRL	Jade 2.1; date: July 1999	Jade 2.2.4; date: June 2000	Yes, installation and training.
BBN Technologies, Ofallon Il.	Jade 2.1.2; date: Oct 1999	Jade 2.2.1; May 2000	Yes, installation and training.
BBN Technologies, San Diego	Jade 2.4 alpha; date: Nov 2000	N/A	No.
JPO/ACOA	Jade 2.2.4 with ACOA patches; date: Sept 2000	Jade 2.4 with ACOA patches will be installed in early 2001	Yes, training, installation, and usage support.

Table 1 -- JADE Distribution

The Hurricane Mitch TPFDD data provided by SOUTHCOM was later used to support a demonstration for the DARPA CoABS (Control of Agent Based Systems) program. JADE was linked to other systems through middle agents that were designed/developed as part of a project called MIATA (Mixed Initiative Agent Team Administration). In order to support MIATA, JADE was enhanced to communicate as an agent to other agents via a structure called *the Grid.*
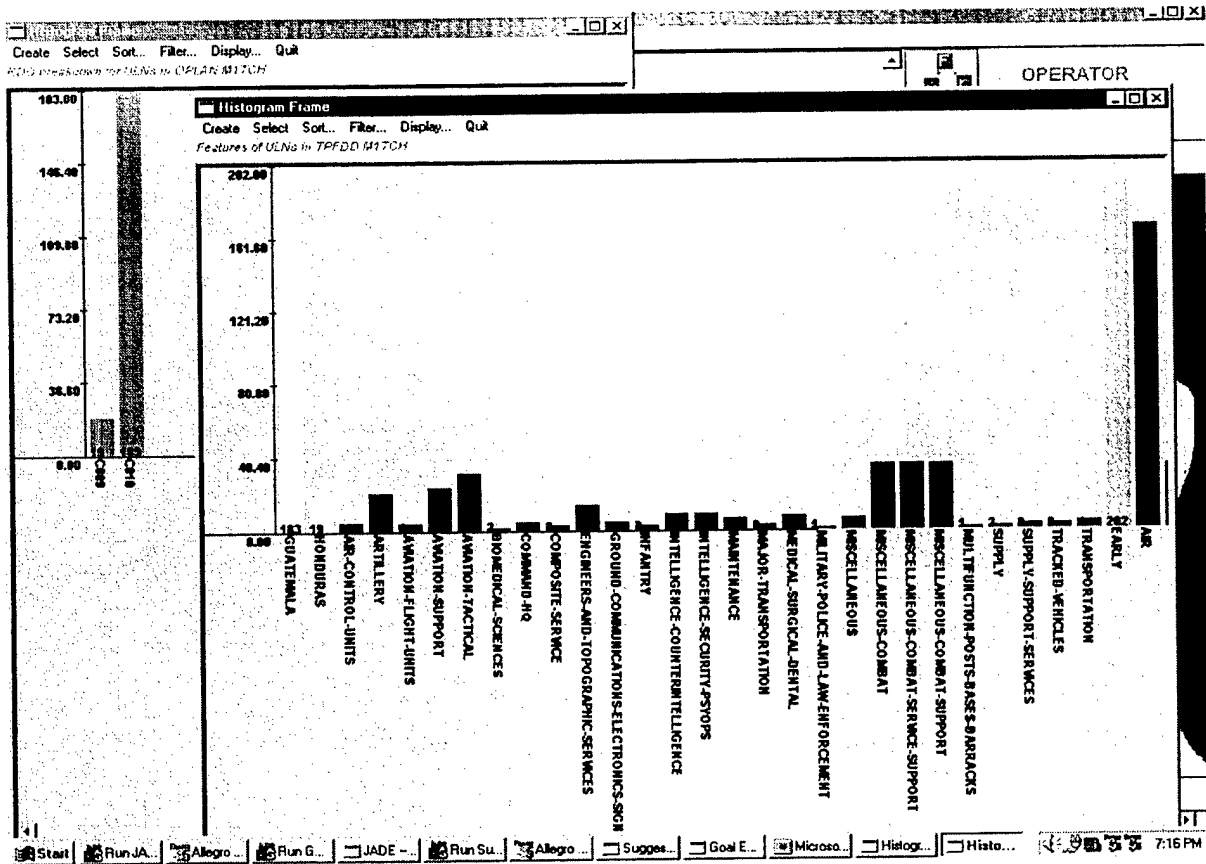
Figure 6 – JADE Report about Hurricane Mitch Force Deployment

Through the Grid, JADE could receive mission guidance and state information about conditions in the hurricane region. Using this data, the JADE user could create a TPFDD and send the TPFDD to the USTRANSCOM CAMPS (Consolidated Air Mobility Planning System) system for transportation planning through the Grid. JADE was involved in two successful MIATA demonstrations, one in June 2000, and another in February 2001.

JADE was demonstrated numerous times over the past few years [8]. Major efforts were made to polish the system interface and the system documentation. Testing of the system and of the documentation were performed with support from staff at the BBN O'Fallon IL office and from a force deployment expert located at The MITRE Corporation in O'Fallon IL. Comments from these users, and as gathered at multiple demonstrations resulted in interface and documentation improvements. Most notably were the development of JADE interfaces that mimic the interfaces that current operational deployment systems use. These include: the JET (JOPES Editing Tool) and TIAH (TPFDD In An Hour) view of the ULN fields, and the TPEDIT view of cargo and

12

PAX (Passengers). Figure 7 contains a JADE view of the Hurricane Mitch data that is similar to the JOPES JET View.
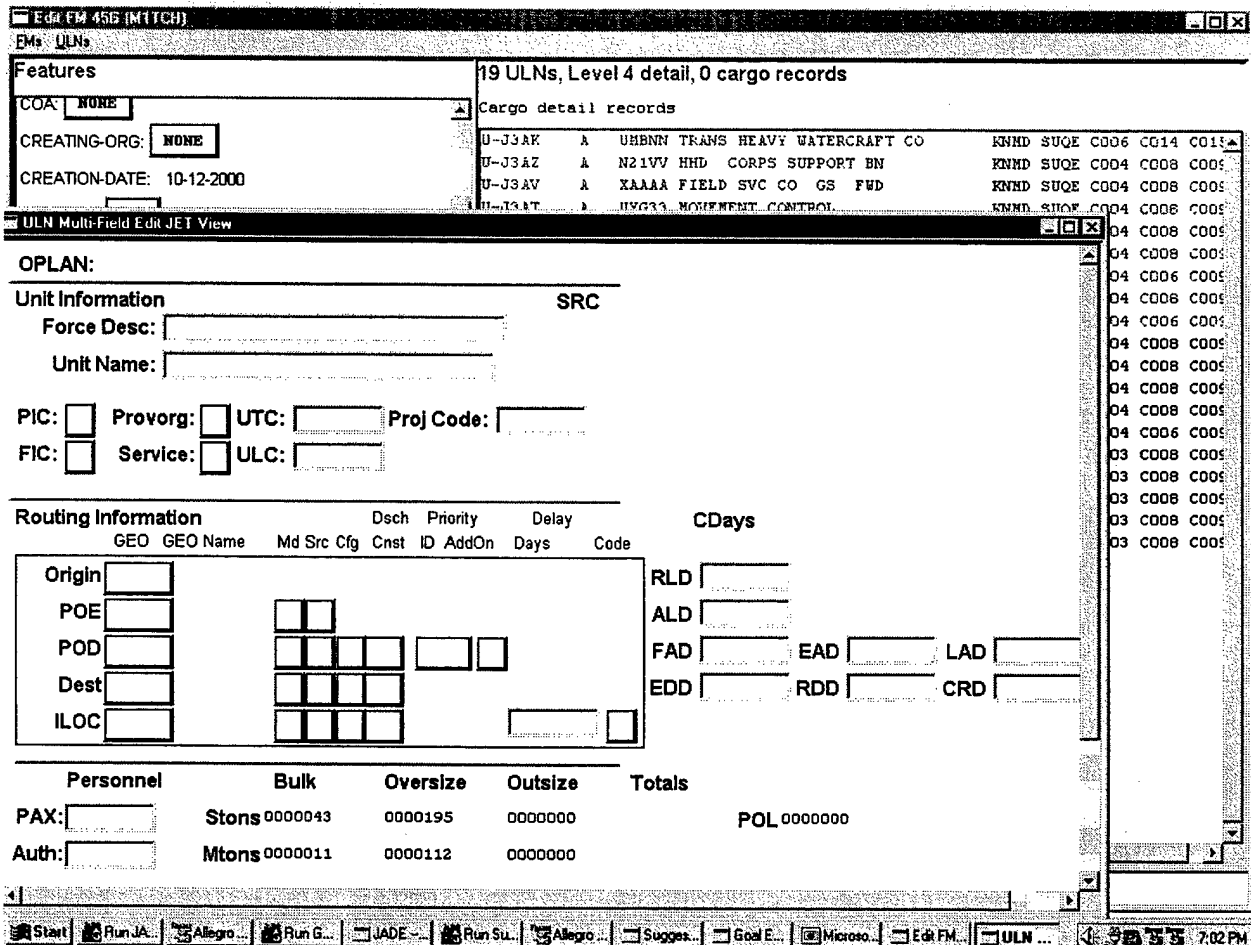

Figure 7 – JADE JET like View

TRANSITION EFFORTS

A primary focus of the past year has been to move JADE from use solely in an R&D environment to use by Government personnel in operational environments. Through ACOA and the JEFX 2000 experiment, we were able to place JADE within an operational environment, equipped with operational data and users. In both of these activities, we have been able to evaluate JADE's ability to support planning and execution. For example, within the ACOA context, JADE has become part of a planning and execution tool kit, known as the ACOA suite. Within the ACOA

13

context, JADE has been used to support the development of a TPFDD given mission, force and situation information available from the Campaign Object. JADE was also used successfully in another PACOM exercise called Tempo Brace (See Appendix B for more detail). PACOM, the primary ACOA user, views the transition of JADE to ACOA as a success and they plan to use JADE in an upcoming exercise, i.e., Ulchi Focus.

Within the JEFX 2000 environment, JADE was not connected to other systems, but information about the dynamic aspects of the exercise were fed into JADE to support the TPFDD development. See Appendix A for JEFX 2000 detail.

Although the Windows NT version of JADE (as opposed to the original Unix-based version) is what has been used to support ACOA and JEFX 2000, as well as other users, our concern with transition to the operational environment encouraged us to investigate the development of a web-based JADE. Although the inner components are still written in Lisp, the interface of the web-based version of JADE is written in Java. This version of JADE is available although it is incomplete. Development on the web version of JADE was stopped because the NT version was well received by potential users, and because the web-based version is slow in comparison with the NT version.

The NT version of JADE is the most sophisticated version of JADE and is the version that is being delivered to the sponsors at the conclusion of this contract. Because of the goal to have JADE be a transitionable system, the following have also been developed:

- System documentation, administration, and training materials.
- Testing material.
- A JADE software distribution package.
- Demonstration scripts.

LESSONS LEARNED

One of the main lessons learned during the development and transition of JADE was that the system, both internally and externally (via the interface) should conform to the user's view of the world. For example, the language (terminology like C-dates, etc.) used in the system should match with the user's perception of how that terminology is used. This not only reduces terminological ambiguity (which can lead to confusion and error in the use of the system) but reduces the amount of time it takes for an operational user (already familiar with the operational domain) to learn to use the system. Unfortunately, we overestimated the deployment planning skill level of the typical JADE user. The system and the user manuals now contain acronym expansions and more references to doctrine about deployment planning.

An integral aspect of CBR is the generation and selection of indices; in fact, the success of CBR significantly depends upon the judicious choice of these indices. With ForMAT a user defines the index by specifying an attribute/value pair, or the indices are automatically generated by the

14

Feature Augmentation Rules (FARs). For example, observation of novice users indicates that these users often cannot interpret TPFDD data field values. The FARs parse many of these code values into English which eliminates uncertainty about many of the properties of a FM. However, even though users report that the FM attribute/value pairs help them to understand the composition of a FM better, our observations to date indicate that the deployment planners do not optimize the use of FM attribute/value pairs in search. The addition of enabling the user to accept a suggestion from the Suggestions Window and enable that accepted suggestion to automatically trigger a search is one remedy we have found successful and that users report liking.

Another problem encountered with transitioning JADE is related to the user's requirement for simple, yet powerful methods for searching for information contained in the TPFDD. ForMAT contains a very sophisticated tool for performing queries on the FMs and on the ULNs, including wildcard searches. However, comments from users indicate that the interface provided to specify the search parameters is too complicated. The users report that they are more comfortable with a search screen available in a JOPES tool called JET. A future enhancement to JADE might involve the provision of a simpler interface for searching. We would still allow the more advanced users to access and use the current search mechanism. For example, when the novice user is in an exercise or operational situation and tasked with a problem such as: "build a deployment plan for a humanitarian mission that provides medical support and airlift to hurricane victims in Kauai"; we have observed that the users tend to use the JADE Goal Editor to create their queries. For example, the Goal Editor enables the user to compose a query associated with this statement by allowing the user to click on text in the mission guidance: *mission-type = humanitarian AND function = medical AND mode = airlift AND threat = hurricane AND destination = Kauai*. ForMAT treats the query as a disjunctive query, and using a combination of exact and general query strategies, searches the casebase; retrieving one or more FMs that satisfy one or more of the elements in the query. The Suggestions Module makes usage of the retrieved results easier by reminding to the user about force preferences. For example, when the user accepts a force suggestion, a query for that force is triggered against the list of retrieved force modules. While this reduces the options significantly, the user still needs to make a choice.

Although many analysis tools are available in JADE to support the mixed initiative development of a deployment plan, many users report that they are puzzled about the process of reusing previous plans and plan elements (FMs). To reduce some of this uncertainty, we encourage users to create and/or use casebases that relate specifically to their plannig problems, e.g., the *ACOA PACOM casebase* is for Pacific Command missions; the *JFEX Casebase* for JEFX-like missions.

FUTURE WORK

A great deal of work has been extended to find a home for JADE. In 2000, JADE participated in two transition environments: (a) ACOA, and (b) JEFX. For JEFX the follow-on opportunity was a program called WRAP (Warfighter Rapid Acquisition Program). This program is intended to provide warfighters with new operational tools. As a result of JADE's participation at JEFX

2000, the JADE developers were invited to consider an alliance with a product called TIAH++ (TPFDD In An Hour Enhanced) that is being developed by Logicon to support USTRANSCOM deployment planners and also participated in JEFX 2000. TIAH++ identifies the functional requirements that are needed to support the transportation of forces to a location. We are currently evaluating whether warfighting CINCs, such as PACOM, see a benefit of combining JADE with TIAH++.

While JADE will continue to be used in ACOA, issues associated with compliance to DII-COE (Defense Information Infrastructure - Common Operating Environment) standards will need to be addressed before JADE can be accepted fully into the operational environment.

SUMMARY

JADE can be used to support both deliberate and crisis action planning. [2, 8] JADE software and casebases enable a military planner to build a preliminary force deployment plan, including a TPFDD in less than one hour. JADE is a knowledge-intensive planning technique that employs case-based and generative planning methods to handle large-scale, complex deployment plans in minimal time. Constraint checking is provided during plan development and the results of constraint checking are used to provide the user with reminders during force deployment plan development.

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APPENDIX A -- *JADE Experiences at JEFX 2000*

In 2000 the JADE prototype participated in the Joint Expeditionary Force Experiment (JEFX 2000). This provided an opportunity to demonstrate JADE in a crisis scenario under experiment conditions. Throughout the experiment the JADE developers received feedback from actual deployment planners. A focus of JEFX 2000 was Agile Combat Support (ACS), and this was the thread that included JADE in the ACS Crisis Action Planning (CAP) phase.

Three Spirals preceded the experiment, each with different goals:

> *Spiral 1 - Minimal system integration.*
> > Provides operator feedback to initiative provides on systems.
>
> *Spiral 2 - System integration to a maximum extent.*
> > Process testing at slower than real-time speed.
> > Produce a level 2 TPFDD is the ACS focus (done just prior to spiral 2 for testing).
>
> *Spiral 3 - Fully distributed, no live-fly.*
> > Train all participants on systems and procedures.
> > Full dress rehearsal.
> > Produce a level 4 TPFDD, a major ACS event (done in/around spiral 3).
>
> *Main Experiment - Remainder of experimental trials.*
> > Operational focus: Dynamic Aerospace Command (operational level) - Dynamic battle Control (tactical level); live-fly.
> > Distributed Air Tasking Order creation with JFACC afloat.
>
> *Live global mobility / ACS initiatives.*

JADE participated as a category 3 integrated initiative in all of the spirals and in the main experiment. As a category 3, JADE had access to certain live feeds and databases but no authority to electronically push data back into the JEFX planning environment. JADE developers attended design meetings, installed software, trained users, and supported users during the spirals and the experiment. In order to fully demonstrate JADE's capabilities during JEFX 2000, the following were required:

1. Access to in-place and/or beddown data.
2. Operation by an experienced force deployment planner.
3. Access to previously built JOPES TPFDDs. This included TPFDDs provided by the exercise coordinators, TPFDDs from previous exercises, or TPFDDs required from the JOPES database. The initiative providers made arrangements to access JOPES TPFDDs.

4. Access to actual or fabricated SORTS (Status of Readiness and Training System) data.
5. Access to the warning order and/or any other source of deployment guidance.

Access to 1 and 5 were provided through JEFX 00 documentation. Access to 4 was not provided. Items 2 and 3 were supported by the JEFX 00 coordinators.

In preparation for the experiment the following data sets were developed:
- A map-viewable set of GEOLOCs pertinent to the scenario.
- A casebase of FMs designed for the scenario
- A JEFX based short training script.
- A code patch for JADE with additional functionality for JEFX.

During the Spiral activities leading up to the experiment JADE developers were required to demonstrate a set of core capabilities for JADE. JADE was able to successfully pass the assessments during the Spirals. The JEFX military operator was provided with tutorial documentation and hands-on training before and during Spiral 3. The operator was very forthcoming with comments and suggested many enhancements to JADE, some of which were implemented for use during the experiment.

JEFX 2000 Results

During JEFX, the JEFX evaluation team reported that JADE satisfied the specified measure of effectiveness for the following core capabilities:

- Provision of search mechanisms for rapidly finding deliberate or crisis-based force modules from its library of TPFDDs for use in building a new TPFDD.

- Generation of explicitly hierarchical TPFDDs.

- Use of a map-based dragNdrop environment with suggestion support for TPFDD creation.

- Support for the linkage of individual Force Modules to the objectives of the mission as described in the commander's guidance (alert order, warning order).

- Use of commanders guidance (warning order, alert order), force list and/or other situation data to plan and revise the force deployment plan.

- Development of a TPFDD with up to level 4 detail given an adequate source of past used TPFDDs and an experienced force deployment planner.

JADE received a technical assessment rating of "blue" which means ready for use. But the warfighter and overall assessments were yellow which means "jury's still out".

Overall, the JEFX 2000 experience was helpful in pointing out areas were JADE needs improvement, mainly in supporting low level editing. Note: this is an area that was not initially developed because it duplicated the abilities of other tools.

Note: JADE was also used at PACOM as part of their participation in JEFX 2000. An experienced JOPES user, with some familiarity with JADE supported the demonstrations there.

APPENDIX B -- *JADE and ACOA*

The Adaptive Course of Action (ACOA) program provides a near real-time distributed collaborative environment that supports end-to-end joint planning by multiple participants including the supported CINC, supporting CINCs, and the commander of the Joint Task Force (CJTF) (See Figure 8). Through the use of collaborative and joint decision support tools, planners and operators are able to share a dynamic workspace for situational assessment and to rapidly adapt to situational changes.
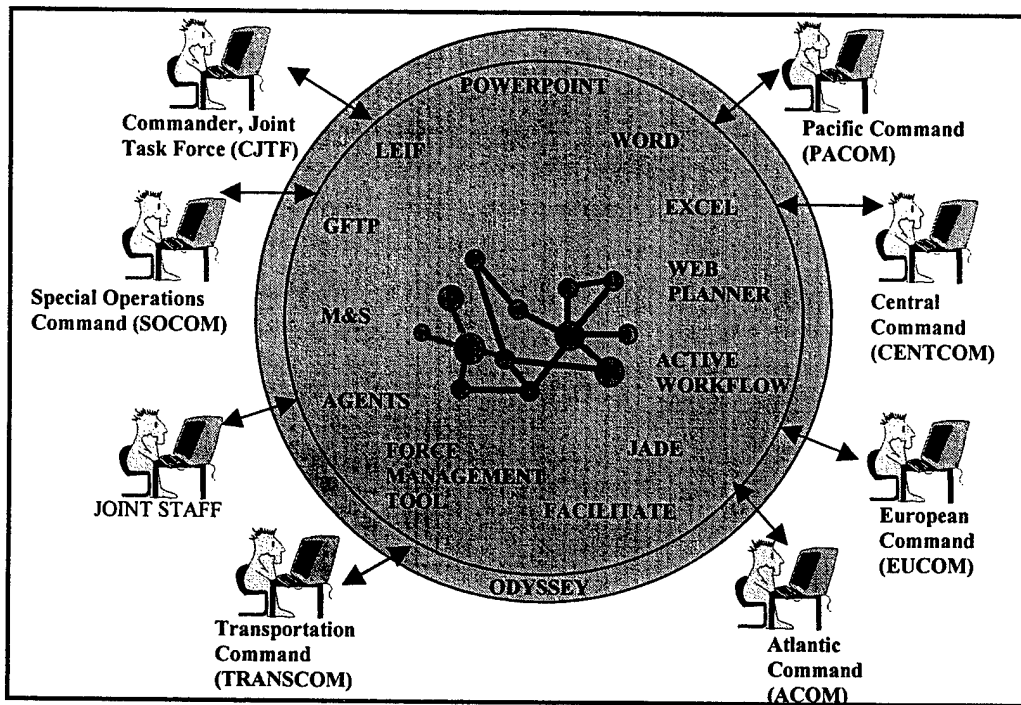

Figure 8 -- The ACOA Environment[1]

The principal Government sponsors of the ACOA-ACTD (Advanced Conceptual Technology Demonstration) include PACOM and the DARPA/DISA (Defense Advanced Research Projects Agency/Defense Information Systems Agency) Advanced Information Technology Services Joint Program Office (AITS-JPO). A major goal of the program is to cut crisis planning time in half. Both commercial-off-the-shelf and government developed emerging information technologies are being applied to meet the goal. The ACOA mission is stated as "develop and demonstrate

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[1] LEIF – Light Weight Extensible Information Framework, GFPT – Geospacial Force Planning Tool, M & S – Movement and Scheduling

advanced technology enabling geographically dispersed planning and executing forces to rapidly generate, assess, and adapt courses of action for military operations" [11]. The initiative is viewed as a dramatic reengineering of the JOPES process and not just a marginal improvement or fine-tuning. ACOA is being designed to significantly improve both planning and execution activities at all levels including unit, tactical, operational, theater, and strategic.

Some of the ACOA tools provide step-by-step guidance for planners involved in joint planning, and some ACOA tools generate products at various stages of planning and provide analysis capabilities to enable the planners to test alternative planning strategies. For example, there are several tools in ACOA that are oriented toward supporting COA and force planning. Two of these tools are the WebPlanner and JADE. The WebPlanner extends the ability of joint planning tools and information to all members of the joint planning team. It accelerates multi-staff collaboration during situation assessment, execution planning, and execution. It provides for the generation of planning products through its tight integration with Microsoft Word and PowerPoint. Finally, the WebPlanner provides an automated assistant that guides novice users through the critical steps of plan development.

In ACOA, JADE works with other tools like the WebPlanner to develop the overall campaign. For example, the WebPlanner provides JADE with information about the developing mission/situation through its Word documents, about which tasks need to be accomplished, and about the forces that are preferred for use during an operation. JADE then is used to develop the supporting deployment plan. Through JADE, a user has the ability to save a deployment plan to the ACOA campaign object and to locally save previously executed plans and hypothetical force compositions. Plans can then be reused when needed to support the rapid construction of an 80% deployment solution to a given situation. This ability to use past experience to rapidly build new plans also gives the ACOA CINC the ability to quickly analyze the costs and benefits associated with using different force compositions to achieve mission goals.

How JADE communicates with ACOA

At the center of ACOA is the Campaign Object Server. It is the main mechanism for sharing data between the ACOA applications (represented as the molecular structure displayed in the center of Figure 8). The server implements the Campaign Object data model that is used to store the shared data for a campaign. One part of this schema models the data used in campaign planning such as alert and other orders, force lists, and course of action information and evaluation. The deployment object section of the Campaign Object models the deployment object schema developed by the Deployment Object Working Group (DOWG). JADE accesses orders, tasks, and forces from the planning section for use during TPFDD development. When complete, JADE stores deployment data from the TPFDD to the deployment object of the Campaign Object Server.

All ACOA applications interact with the Campaign Object Server through a CORBA interface. CORBA (Common Object Request Broker Architecture) is a transaction based API (Application

Programming Interface) that allows applications to manipulate data stored on the server as though it were data local to the client.

JADE communicates with the Campaign Object Server using a separate Java program that acts as a "bridge" between the two programs (see Figure 9). This bridge server runs in parallel with the JADE application on the client machine. JADE communicates with the bridge server using a socket interface identical to the one used to communicate with the GEOLOC Server. A custom API is built around this interface to handle the functions necessary for JADE to share data with the Campaign Object Server.
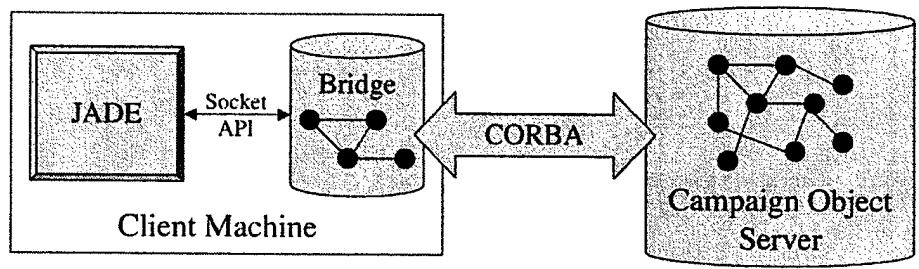
Figure 9 -- JADE and ACOA API Architecture

The bridge server is written in Java and uses the VisiBroker 4.1 implementation of CORBA to communicate with the Campaign Object Server. VisiBroker was selected over the Lisp CORBA interface ORBLINK because of better compatibility with the Campaign Object server which is also implemented using VisiBroker.

The API used between JADE and the bridge server handles the basic functions necessary for interacting with the Campaign Object. The following list summarizes the functionality of the API without going into details.

- Read data (forces, goals, Alerts and orders, Deployment Object)
- Write data (Deployment Object)
- Delete a data object (Deployment Object maintenance)
- User Login to the Campaign Object Server

Demonstration Highlights

During the course of the ACOA program, the suite of tools, including JADE, was used in military exercises and demonstrated to interested parties. The following are a few of the more prominent ones.

Tempo Brave - December 1999

The ACOA tools were used in the Tempo Brave exercise at the end of 1999. The software was installed at PACOM and on board a Navy ship and the casebase was populated with a set of

23

TPFDDs. A few selected users were trained to make use of the library to support both deliberate and crisis planning. During the exercise a trained operator used JADE to edit the deployment plan when there was a problem with other deployment tools on board the ship. Within the ACOA environment JADE succeeded in developing and editing the TPFDD that was then sent to PACOM and imported into JOPES. Feedback from Tempo Brave has been used to improve JADE -- specifically to support Level-4 detail refinement of force deployment requirements.

Force Planning Working Group (FPWG) Demonstration - December 2000

Near the end of the ACOA program the ACOA tool suite was demonstrated to the FPWG (Force Planning Working Group). A complex demonstration was developed to show how ACOA could support all aspects of crisis action planning, from situation assessment through to deployment planning. For the demonstration three computers represented many different players collaborating to develop the plan. As part of the process JADE was used to develop a TPFDD by downloading Goals from the server, retrieving FMs from the casebase, using these to create a TPFDD, and saving the TPFDD back to the Campaign Object Server. The demonstration was well received by the members of the FPWG in attendance.

Future Demonstrations/Exercises

PACOM plans to continue to use JADE to support demonstrations and military exercises. In particular, PACOM plans to use JADE during the 2001 Ulchi Focus Exercise.

ACRONYMS

ACOA	Adaptive Course of Action
ACS	Agile Combat Support
ACTD	Advanced Conceptual Technology Demonstration
AFRL	Air Force Research Lab
AI	Artificial Intelligence
AITS-JPO	Advanced Information Technology Services Joint Program Office
API	Application Programming Interface
CAMPS	Consolidated Air Mobility Planning System)
CAP	Crisis Action Planning
CBR	Case-Based Reasoning
C-date	the date in which the deployment begins
CINC	Commander in Chief
CJTF	Commander of the Joint Task Force
CLIM	Common Lisp Interface Manager
CMU	Carnegie Mellon University
CoABS	Control of Agent Based Systems
CORBA	Common Object Request Broker Architecture
COTS	Commercial Off the Shelf
DARPA	Defense Advanced Research Projects Agency
DARPI	DARPA Rome Planning Initiative
DII-COE	Defense Information Infrastructure - Common Operating Environment
DISA	Defense Information Systems Agency
DOWG	Deployment Object Working Group
FAR	Feature Augmentation Rule
FM	Force Module
FMID	Force Module Identification
ForMAT	Force Management and Analysis Tool
FPWG	Force Planning Working Group
GEOLOC	Geographical Location
GFPT	Geospatial Force Planning Tool
GSORTS	Global Status of Resource and Training System
GUI	Graphic User Interface
JADE	Joint Assistant for Deployment and Execution
JDBC	Java Data Base Connectivity
JEFX	Joint Expeditionary Force eXperiment
JET	JOPES Editing Tool
JFACC	Joint Force Air Component Commander
JFRG	Joint Force Requirements Generator
JOPES	Joint Operations Planning and Execution System

JPO	Joint Planning Office
LEIF	Light Weight Extensible Information Framwork
M&S	Movement and Scheduling
MIATA	Mixed Initiative Agent Team Administration
NEO	Noncombatant Evacuation Operation
O/S	Operating System
OPLAN	Operational Plan
PACOM	Pacific Command
PARKA-DB	PARKA Database
PARKA-KB	PARKA Knowledge Base
PAX	Passengers (Personnel requiring non-organic Transportation)
PDA	Planning and Decision Aids
R&D	Research and Development
SORTS	Status of Readiness and Training System
SOUTHCOM	Southern Command
TCP	Terminal Communication Protocol
TCP/IP	Terminal Communication Protocol/Internet Protocol
TIAH	TPFDD In An Hour
TIAH++	TPFDD In An Hour - Enhanced
TIE	Technology Integration Experiment
TPFDD	Time Phased Force Deployment Data
TUCHA	Type Unit Characteristics
ULN	Unit Line Number
US	United States
USTRANSCOM	United States Transportation Command
WRAP	Warfighter Rapid Acquisition Program

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