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Rosemary Wild
California Polytechnic State University

Kenneth Griggs
California Polytechnic State University

Eldon Li
California Polytechnic State University

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Rosemary H. Wild
Orfalea College of Business
California Polytechnic State University
rwild@calpoly.edu

Kenneth A. Griggs
Orfalea College of Business
California Polytechnic State University
kgriggs@calpoly.edu

Eldon Y. Li
Orfalea College of Business
California Polytechnic State University
eli@calpoly.edu

Abstract

According to a recent article in the Wall Street Journal (1/7/2003) we are entering the second generation of knowledge management; this phase will focus on applications that acquire or generate knowledge. Decision Support Systems provide promise as applications that generate, capture, or unleash knowledge embedded within organizational systems and processes. Decision Support Systems coupled with Web technologies have the potential to lead the way in knowledge creation endeavors that can support collaborative decision-making. In this paper we describe a Web portal architecture that supports collaborative decision making efforts through joint experimentation with a simulation model of key processes. We illustrate the proposed architecture with a specific application that focuses on collaborative decision making via a Web portal and simulation model intended to support high-level manpower planning and policy decisions. However, the architecture proposed is applicable to other types of collaborative decisions, such as new product development and management of emergency manpower systems.

Keywords: Web portal, simulation model, planning and policy decisions, collaborative decision making

Introduction

In today's competitive environment information alone is not always sufficient for sound decision making. Knowledge, sometimes defined as "processed information" (Alavi and Leidner 2001), is the current elusive target required for good decision-making. The trick is to identify those who have the knowledge needed and figure out how to extract, formalize, and distribute it for use by others. However, a good portion of an organization's knowledge does not necessarily reside in the minds of individuals or in documents, but is deeply embedded in organizational processes themselves. Decision Support System (DSS) modeling techniques such as computer simulation, data mining, collaborative filtering, and neural networks show promise as innovative approaches to capturing and creating both tacit as well as explicit knowledge that is very complex and difficult to articulate (Marakas and Elam 1997). Unfortunately, many DSS in use focus on single functional units within an organization and result, at best, in providing decision support for "stove-piped" environments. To remedy this, we suggest coupling Decision Support Systems with Web technologies to support virtual teams involved in collaborative activities.

Much of the research on virtual teams has examined cross-functional virtual teams within organizations (Duarte and Tennant 1999; Furst et al. 1999; O'Hara-Devereaux and Johansen 1994). A portion of this research has focused on knowledge sharing in virtual teams (Bowers 1995; Cramton 1997; DeMeyer 1991; Malhotra et al. 2001). The findings recognize that effective electronically-mediated communication, collaboration, and coordination depend on a shared understanding among team members of the problem, norms, and context for interpreting knowledge (Davenport and Prusak 1997; Madhaven and Grover 1998; Marshall and Novick 1995). Acknowledging the issues that must be addressed in "readying" team members to collaborate virtually, we focus on an IT architecture that will facilitate the sharing of knowledge among virtual team members.

In this paper we propose a Web portal architecture that enables enterprise teams to experiment with a simulation model of key organizational processes to assess, jointly, the impact of local decisions on other "communities" within an enterprise as well as on enterprise-wide performance. The potential benefits of such an approach to enterprise-wide decision making are promising. First, experimentation with a simulation model enables knowledge creation. The type of knowledge that surfaces is often impossible to know "before the fact". A well designed simulation model allows a peek into the future in which the dynamics of system component interactions can be uncovered and understood before actual decisions are made. Second, a Web portal enables teams that often operate in a stove-piped fashion to interact electronically by sharing output of simulation experiments conducted with a variety of input streams from a number of functional process teams. Thus decisions can be made in a collaborative fashion based on interactions with the simulation model from a variety of perspectives. An organization's ability to achieve its objectives is potentially enhanced when process teams have the capability to collaborate on decision making (Nemiro 2000).

In the following section we describe issues to consider when developing a conceptual simulation model that supports policy and planning decision making. We then present a prototype simulation model developed for U.S. Navy manpower planning that illustrates the integration of components required to achieve performance goals. Lastly, we propose a Web portal architecture that permits enterprise-wide teams to experiment with a variety of manpower policies, observe the output generated by different teams using different input policies, and conduct virtual meetings to share knowledge and discuss decision management. We will conclude with a discussion of how our proposed architecture can be generalized for other application scenarios.

Developing a Conceptual Simulation Model to Support Policy and Planning Decision Making

The goal of a simulation model to support policy and planning decisions is to provide an integrated experimentation environment in which the impact of a variety of combinations of an organization's rules and policies can be assessed relative to performance targets. The following factors should be identified at this stage to develop a conceptual model.

1. Critical success factors: the performance measures that contribute to the overall success of an organization (these measures need to be "operationalized" as output data);

2. Key processes: those organizational processes that have the greatest impact on critical success factors;

3. Enterprise teams involved in key processes: those organizational units that are responsible for decisions related to key processes;

4. Input options: the existing or potential mix of rules and policies that are enforced to achieve the objectives of key processes;

5. Classes of entities: those objects (people, information, processes, and "things") that interact within the organizational processes identified;

6. Entity attributes and actions: the data associated with process entities, the source of data values, and the actions that are taken to initialize and dynamically update data values;

7. Process models: a depiction of the flow of entities and information through a process;

8. Output Options: estimates of critical success factor measures as well as qualitative information related to performance measures and process objectives;

9. Historical data: data used to drive the simulation model for validation purposes;

To illustrate the integration of these factors into a simulation model for policy and planning decision support we will describe a research effort in which we developed a prototype simulation model for manpower management in the U.S. Navy.

A Policy and Planning Simulation Model for U.S. Navy Manpower Management

Manpower management is a complex and daunting endeavor in any large organization. This is especially true for the military in which manpower decisions have a direct impact on national security. Many of the same challenges facing business organizations plague the U.S. Navy. Functional units operate in a "stove-piped" fashion in which data, information, and knowledge are not distributed and shared across the enterprise. To address this problem, we developed a prototype integrated simulation model of the Navy's manpower, personnel, and training (MPT) process and developed a Web portal architecture to depict the distribution of the simulation model experimentation environment across the entire MPT spectrum.

Navy MPT teams must deal with a knowledge gap between the level of expertise needed to make informed decisions and the subject matter expertise of the staffs making those decisions. Two primary factors are involved. First, the organizational structure of the MPT system results in less than optimal sharing of information among functional areas, resulting in "stove-piping" of information and knowledge. Second, the continuous turnover of uniformed personnel results in an erosion of expertise and corporate knowledge of business functions that support the Navy's MPT processes. Many of these functions require extensive knowledge and analytical ability gained only from years of experience. Without this core knowledge and the benefit of past trial and error, process managers make less informed and potentially costly decisions. In addition, the impacts of uninformed decisions generally take a long time to mature. Accurate accession plans, strength plans, re-enlistment bonus levels, promotion flow points or retention goals can ensure sufficient, qualified personnel to man the Navy, but if inaccurate, can cause shortages or excesses that require years to counteract. In the first case, the Navy's readiness levels are severely impacted while the second case can lead to excessive personnel spending, reduced morale, and promotion bottlenecks, which will ripple through the community for years.

An accurately modeled simulation of the entire MPT process offers the potential to close this knowledge gap in several ways. First, a fully implemented version would represent the "as-is" condition of the MPT process. For it to produce accurate results it must incorporate the required business rules of the significant functions of the MPT process. These rules can easily be made available to all system users by way of detailed on-line documentation. By making this information generally available to all appropriate users, the time for new personnel to acquire needed skills and knowledge will be reduced. Second, because the system would contain modules for all key MPT process teams, it would make information related to functional teams available to all MPT personnel, reducing stove-piped information and stove-piped thinking. Third, users could freely experiment with key input parameters of any portion of the model and observe the impact of rules and policies on the performance of other components of the MPT process. This experimentation could reduce the time it takes for a user to gain a critical level of practical experience and learn about existing inter-relationships among MPT components. Fourth, because the model simulates the behavior of the system into the future, it provides the user with insights about the impact of decisions made today on the future. This capability instills the notion of looking into the future when making decisions, as opposed to responding to today's current crisis. Lastly, the output of the experimentation process will produce not only useful information, such as the cost associated with different policies, but also knowledge about the effects of certain policies on different communities within the MPT process and the ability of the Navy to achieve its goal of fleet readiness.

Conceptual Model for a Policy and Planning Simulation

To assess the feasibility of developing a simulation model to address the challenges of the Navy's MPT process, we focused on one enlisted community, Sonar Technicians. We first identified the model factors outlined previously to develop a conceptual model. All of the functional teams involved in the MPT process provided input during the model development stage which contributed to the face validity of the model.

Critical Success Factors

The over-riding strategic goal of the Navy is fleet readiness. Fleet readiness involves a complex array of activities but can be defined as having the right people with the necessary skills and knowledge in the right place at the right time. This must be achieved in a cost effective manner. This is a difficult objective to operationalize. However, we will define operational measures in the output discussion. The simulation model will run personnel through the system, matching them to available billets (jobs) as time progresses according to policies enforced as input to the system. Fleet readiness for each set of policies defined as input to the simulation model will be assessed according to the metrics defined as readiness measures.

Key Processes

Manpower management is a key process for achieving fleet readiness. The MPT process must be able to quickly identify threatening or advantageous changes to various key personnel system indicators. The ability of the personnel force to perform its mission depends on maintaining the appropriate number of trained and deployable personnel. This mix is achieved by monitoring, evaluating, and responding to changes in many interrelated indicators, including levels of losses, accessions, inventories, billets, skill manning percentages, promotions, demographics, skill acquisition, and costs. Failure of the MPT process to correctly anticipate events and take quick, proactive steps jeopardizes the force's ability to act effectively now and in the future.

Enterprise Teams Involved in the MPT Process

The key functions that make up the MPT process include Recruiting, Selection and Classification, Training Management, Distribution and Assignment, Community Management, and Force Structure Management. Recruiting, Selection and Classification involves hiring adequate numbers of acceptable persons for each of the Navy's enlisted rates. A rate can be considered a very simplified description of the type of work an individual performs, such as Sonar Technician, Machinist Mate, Electrician, etc. Training Management involves the development of unique skills required to perform those tasks associated with specific rates or required for specific jobs. Community Management is responsible for decisions and policies involved in maintaining an adequate number of personnel and a proper mix of skills and seniority (rank) to support all jobs associated with a community. Distribution and Assignment matches persons to available jobs (billets). Force Structure Management encompasses very high level decisions that determine the size and composition of all Naval Forces.

Unfortunately, managers within each of the functional areas do not always fully understand the impact of their decisions on other portions of the system or on personnel readiness of the Navy. For example, a Community Management policy to achieve balances among a variety of professions and geographical regions may be directly impacted by an operational goal involving a set of policies to achieve the most economic use of training resources or moving expenses. The current assignment process, which focuses on functional unit objectives, does not take into account the impact of functional decisions on the system as a whole or on fleet readiness. Most of the relevant research conducted in the past focused on large network models to try to optimize personnel assignments. For example, Liang and Lee (1985) present a systems approach to integrate manpower planning and operational processes. They established a quantitative linkage between planning and operational processes and Liang and Thompson (1987) developed a network formulation to handle this large scale multiple objective problem. Liang and Buclatin (1988) demonstrate how Navy training resources can be used more efficiently through optimal personnel assignment. While useful in a limited scope, these models do not provide insights into the effect of policies and decisions on the system as a whole or on fleet readiness. In addition, they do not include the dimension of time in their formulation. They often serve to satisfy the specific objectives of an individual functional unit, for example Training, which may specify operational targets but not take into account the effect of their decisions on the overall readiness of the fleet.

Input Options

Each of the functional units that comprise the MPT process can set values for a variety of input variables. The following is a sample of input options.

Distribution and Assignment

- Prioritize assignment policies such as the following:
  - *Maximize the number of "no cost" moves* – billet assignments that do not require a change of location for personnel
  - *Maximize the number of on-time arrivals to billets* (elapsed time between a billet vacancy and the scheduled arrival of personnel to fill the billet, taking into account the length of en route schooling required)
  - *Maximize the NEC (Navy Enlisted Classification) utilization* – a measure of how well a person's skill level matches the skill requirements of a billet

  - *Maximize requisition priority* – the type of duty required to satisfy a billet (e.g., Continental U.S., Shore Duty, Overseas Sea Duty, etc.)

Training Management

- Set class sizes allowed for each assignment period at various schools
- Set convening course dates
- Set graduation rates for both A- and C- schools
- Review course information

Recruiting/Selection and Classification

- Establish average cost for an enlisted move (rotational, operational, training)
- Set maximum limit on the number of moves permitted for a fiscal year
- Set environmental variables – effectiveness of future recruiting/trends for continuation rates
- Review all known "no cost" move combinations

Community Management

- Set enlisted community management policies such as:
  - sea/shore rotation rates
  - advancement rates and
  - continuation rates

Force Structure

- Establish future commissioning
- Establish future de-commissioning
- Establish future homeport changes of associated military activity

Classes of Entities

There are three classes of entities that populate the U.S. Navy MPT process: people, billets, and processes. The people class represents new recruits and existing personnel. The billet class represents jobs or work order requisitions. The process class includes the major enterprise teams within the MPT process described above.

Entity Attributes and Actions

The attributes for the people entities include descriptive personal information as well as status information such as rate, pay grade, current billet ID, current duty type, and current location. The billet attributes include descriptive information such as billet ID, job category, rank of personnel required, primary job skills, date filled, and name of billet. The process attributes include similar descriptive information related to each of the enterprise teams involved in the MPT process. The actions for each entity class define the data requirements and data sources. For example, much of the personnel data is contained in the Enlisted Master Record (EMR) whereas billet data is contained in the Billet Master Record (BMR).

Process Models

The simulation model includes numerous process models that depict the movement of people and billets through the system. For example, the Arrival process model depicts the activities and flow of information for new recruits. The School Assignment and

Completion process models depict the processes and decisions related to assigning personnel to various schools for training purposes.

Output Options

The output options include both performance metrics related to fleet readiness as well as graphical displays and trace files. The following is a sample of output options.

Personnel Readiness

- Percentage of empty billets over specified time periods
  - Percentage of unfilled billets
  - Percentage of unfilled operational billets
  - Number of unfilled billets broken down by category such as duty type
  - Quality of billet assignments – gap between skills required and those possessed by the individual assigned to the billet
  - Overall gap between the readiness requirements and the ability of the set of policies "implemented" to achieve these requirements

Assignment

- Listing of all assignments that resulted in a PCS (Permanent Change of Station) move
  - Operational
  - Rotational
  - Training
- Costs by month for moves
- Costs by month for training
- Other statistics to support post run analysis

Pay Grade Distribution

- Graph depicting the resulting distribution of pay grades and length of service for the enlisted community

Trace Capabilities

- Trace files (database files)
  - Billet Trace File: information on each billet including the number of personnel currently assigned to the billet, the ID number of each person assigned, the training costs to fill the billet, and the quality of the billet assignments
  - Training Trace File: information on training courses including the number of available seats filled, the number of training requests unsatisfied, the skill sets of the training session, etc.

Historical Data

- To validate the model, historical data on sonar technicians was used. The simulation model was run first with one sonar technician at a time and then with an entire set in which the simulation output data were compared with historical data to verify accuracy.

Prototype Simulation Architecture

The conceptual model described previously serves as a representation for the empirical prototype simulation model. The architecture for the prototype system, depicted in Figure 1, integrates a simulation engine, an assignment module and assignment optimization routine, a relational database for data retrieval and storage, and a user interface for user input and output evaluation. Our prototype was developed to ensure proof of concept, that is, to make sure we could model the system to emulate the actual MPT system and to evaluate the capability of the system to produce output that would satisfy the goals of the system, particularly its ability to produce knowledge regarding the relationships that exist between local and global decisions and the effect of various policies on fleet readiness.

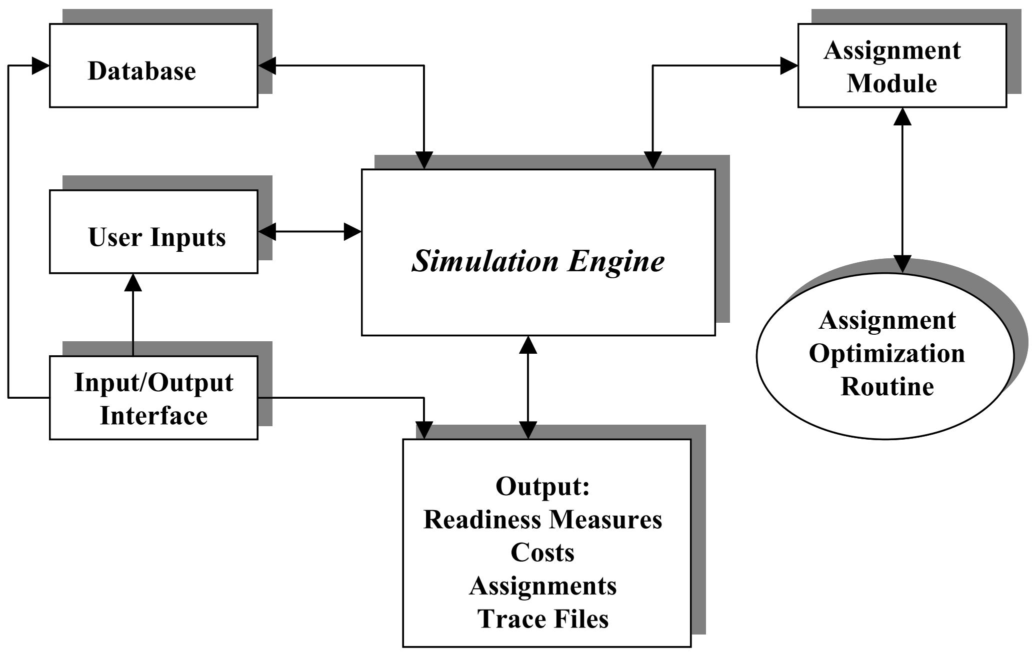

Figure 1. Prototype Simulation Architecture

Information on personnel, billets (jobs), and naval activities is stored in the database and retrieved when necessary by the simulation engine which emulates the actual movement of personnel from billet to billet, updating information in the database to reflect the current state of the system when decision junctures are reached. The assignment module manages the methods of personnel and billet objects, for example the recruit method and the job rotation method, that operate on the personnel and billets moving through the system. The simulation gathers information about "assignable" personnel and billets during specified time periods (for example, each month for an eight year time period) and invokes the assignment optimization routine to match personnel to billets. The assignments made depend upon the rules and policies specified as input driving the simulation model. The user input module permits various constraints and system policy priorities to be set related to each of the key functional teams represented in our conceptual model. As constraints are imposed and policies are implemented, personnel are moved through the system, assigned to available billets, receiving training when necessary, and in some cases leaving the system after a particular rotation. During this process output is generated that reflects fleet readiness measures, costs of moves, and relationships between these performance measures and policies or constraints imposed by the different functional teams.

The combination of user input values, including setting limits on the maximum number of moves allowed for a specified time period, setting priorities for assigning personnel to billets, providing estimates for attrition rates and advancement rates, setting class sizes for training and adjusting training start dates, and adding activities (commissioned) and deleting activities (de-commissioning) based on forecasted changes in force structure, provides a rich experimentation environment for managers from all functional teams to assess the impact of potential policy implementations on fleet readiness. If poor matches are made between personnel and billets, the simulation will be able to trace the cause of such mismatches. For example, if personnel are sent to assignments without the requisite skills, it may be there were no available seats in the necessary training sessions to accommodate the personnel requiring specific skills training. Or, the training required to fulfill a billet request may not be available until a date later than the on-time arrival date. Too many Permanent Change of Station moves may impact the ability to recruit and retain personnel. Further, it may be discovered that some of the constraints imposed by the Enlisted Community Management organization to maintain rank, occupation, and geographical balances are too stringent to permit assignments that would better satisfy fleet readiness objectives.

Our prototype simulation model demonstrated its ability to emulate the MPT system of the Navy for the rate classification Sonar Technicians. It was able to produce valuable tacit knowledge about the intricacies and dependencies of the various policies implemented within functional teams and the short- and long-term impact of these policies on strategic concerns, in particular fleet readiness. It was also able to produce valuable explicit knowledge such as quality of life issues related to "no cost" moves as well as costs associated with a variety of decisions associated with training, permanent change of station moves, and community skills and seniority mix. For the simulation model to be truly beneficial to the Navy, it must be available in a collaborative environment. In the following section we describe a Web Portal architecture that will permit MPT teams to operate in a virtual collaborative environment.

A Web Portal Architecture

A web portal is defined as "a secure, single point of interaction with diverse information, business processes, and people, personalized to a user's needs and responsibilities" (IBM). To this end, portals typically provide one or more of the following:

- a virtual view of the enterprise
- search facilities that span internal and external sources
- database and model access
- application access including simulation tools and legacy applications
- a user-defined personal view
- bulletin boards
- collaboration facilities including
  - forums
  - chat facilities
  - shared applications
  - a common whiteboard
  - video and/or audio tools
  - common document versioning
- local and/or enterprise-wide authentication and security
- subscription based communities
- a common development framework
- IP telephony management
- push facilities for user specific or enterprise information
- email, news, and group and individual calendaring
- metadata sharing
- map & chart creation and interaction
- XML

An essential feature of a portal to support collaborative policy and planning decisions is the integration of Decision Support System models (in the realm of manpower planning for the Navy, a simulation model), collaboration facilities, and operational and legacy data. Figure 2 depicts an architecture that blends these components. The architecture employs a "collaboration engine" that provides a common real-time enterprise view of the simulations as they are performed by each stakeholder. The collaboration engine manages user profiles, authentication, forums, chat rooms, community information, as well as simulation integration and other features. A server based presentation manager is included to handle the relatively complex display characteristics of the application as well as to provide data push functionality. "Data push" refers to the ability of the portal to update user data without a specific user request. The architecture is n-tier and distributed. Additional tiers can be integrated into the architecture and all components can be geographically disbursed. The primary objective of the portal is the integration of model experimentation results along with collaborative knowledge sharing facilities such that the ultimate goal of fleet readiness can be optimized. The portal architecture enhances the planning process by providing an infrastructure that keeps all participants aware of the impact of their assumptions and model results on overall fleet readiness as well as a shared understanding of the impact of local process team decisions on enterprise-wide performance.

Portal Technologies

The proposed portal would employ the following technologies:

Push Technology

Client side software is used to populate a continuously updated set of windows containing the latest simulation results, participant commentary, news, and fleet readiness metrics.

Collaboration Engine

A collaboration engine uses server side software that authenticates users and integrates various groupware functions (chat, whiteboard, shared applications, etc). The engine uses a set of persistent objects to support all user collaboration activities. The engine is accessed via a set of Application Program Interface (API) tools and objects.

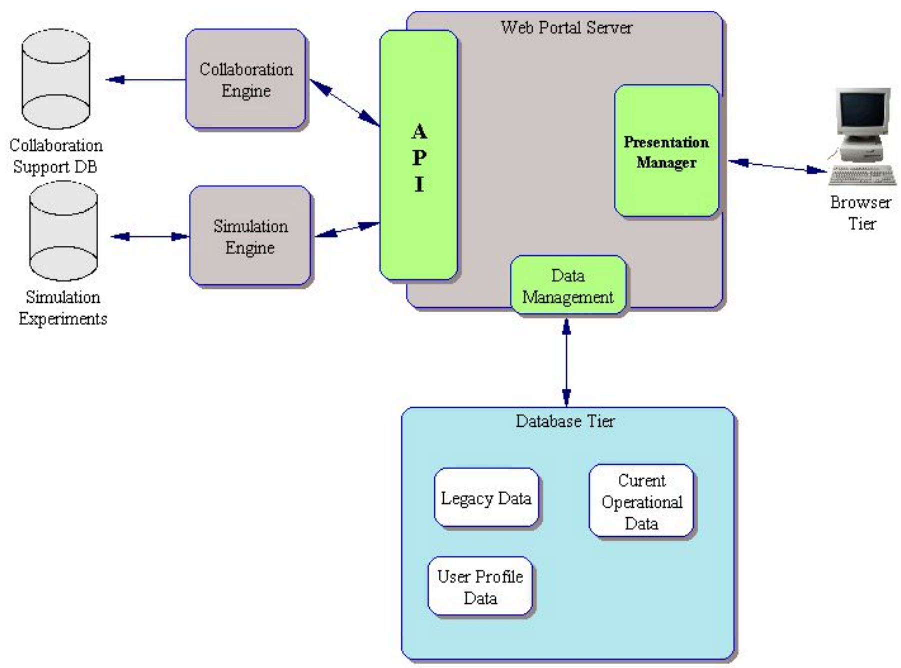

Figure 2. Web Portal Architecture

Simulation Engine

A simulation engine consists of a simulation application (currently MODSIM III) that allows users to set key model parameters and start each simulation run. It integrates the components in the simulation architecture depicted in Figure 1 and emulates the actual movement of personnel from billet to billet, updating information in the database to reflect the current state of the system when decision junctures are reached.

Presentation Manager

A presentation manager is used to manage all interactions between the portal server and clients. It implements control of the data push to clients, authentication, and multimedia interaction.

Data Management

This component supports interaction with legacy, current operational, and user profile data contained in heterogeneous, geographically dispersed platforms. It is responsible for transport and XML translation of the data.

Portal Interface

A portal interface should contain several views representing the various process teams that will collaborate on policy and planning decisions. Figure 3 represents a hypothetical portal interface for the Navy MPT process consisting of a collection of views. Each view is detachable (can be opened in its own window) and is devoted to a specific aspect of the manpower process.

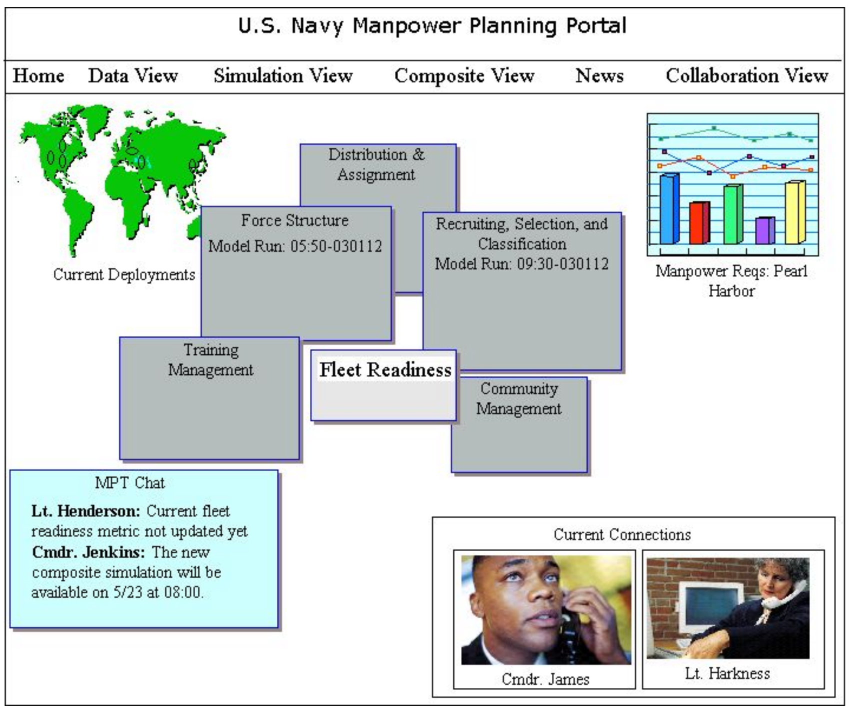

Figure 3. Portal Interface

The division of the portal into views is required given the complex nature of the interactions, the need to have a multitude of open windows (with accompanying screen clutter), and the need to break the application into functional units that parallel the underlying manpower planning process. They are summarized as follows:

- Home: Contains the authentication screen
- Data View: This view provides access to all current and legacy data used in manpower planning. Thus, the view would contain data and current and proposed rules and policies related to all MPT process functional units. In addition, this view supports the creation of interactive maps, tables, and charts.

- Simulation View: This view allows users to enter and run simulations and to store and display rules and policies enforced as well as simulation results.
- Composite View: This view integrates the data, simulation, and news views.
- News: This option gives users access to a variety of internal and external news sources as well as chat traffic.
- Collaboration View: This view has all of the features of the composite view with additional collaboration functionality. It allows users real-time secure, room-based chat, a group view of simulation results, a common white board, shared applications, shared interactive maps and charts, and audio and video connectivity.

Conclusion

Decision Support Systems coupled with Web technologies show promise for facilitating collaborative decision making activities. In addition, together they have the potential to pave the path for second generation knowledge management by providing applications that can capture and generate knowledge embedded in key organizational processes that can then be shared through the effective application of Web technologies. We have demonstrated the potential of such a coupling for U.S. Navy manpower planning and policy decision-making. Future research will include modeling other Naval communities and integrating model components to represent the Navy MPT system. This will entail rigorous field testing and will most likely require novel simulation validation techniques.

The collaboration required for planning and policy decisions in many organizations can benefit from a similar architecture to achieve their respective critical success goals. One obvious extension is emergency manpower planning. City, state, and federal organizations responsible for managing manpower in critical situations may benefit from a similar approach to collaborative planning. Another non-manpower application is new product development. In the automotive industry geographically dispersed product development teams experiment with computer simulations of virtual product prototypes. With each design iteration, engineering immediately analyzes the impact on manufacturing, finance recalculates the cost, and quality control re-examines quality issues (Scott 2002). Web portals provide a promising technological solution for distributing the power of Decision Support System models to dispersed process teams involved in planning and policy decisions and facilitate knowledge sharing among virtual teams for better decision making.

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