ISMIS: A Military Transportation Decision-Support Framework

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Abstract

This paper discusses the challenges that the Information Revolution poses to transportation planning, execution and training in the US military services. Attention is drawn to the opportunities provided by global connectivity and the manner in which these opportunities can be applied to advantage in an integrated, collaborative, decision-support framework. The characteristics of military deployment operations are discussed in respect to system requirements such as parallel activities, internal representation of information (rather than data), intelligent assistance, and the integration of planning, execution and training functions.

The Integrated Strategic Mobility Interface System (ISMIS) is described as a framework that is designed to allow multiple decision-support applications and databases to seamlessly operate in a distributed military deployment environment. The Integrated Computerized Deployment System (ICODES) serves as an example of a typical decision-support application that supports the needs of ship load planning within the ISMIS framework.

Introduction and Challenges

The information society is bringing changes that are being felt in all areas of human endeavor. It is particularly evident that these changes are coming in rapid succession and that many of the methods and systems that commerce, industry and government have relied on in the past to deal with change and to support complex tasks are becoming less and less effective.

So also are the US military services confronted with societal and technical changes that will have profound influence on the way they must design, implement and operate their planning, execution and training systems. Prominent among these changes are the following three:

- Increasingly, the US military forces will be involved in joint operations, often involving foreign countries as allies. This requires an unprecedented level of coordination, flexibility, interconnectivity, global sensitivity and knowledge (e.g., foreign languages), training, and standardization.

- Planning, execution and training are being increasingly viewed as integral functions that must be supported in one holistic communication and coordination system. The traditional separation of these functions into distinct systems is expensive, time-consuming, and inefficient.

- There is an increasing recognition that communication should not be restricted to chain of command protocols. Information must be available where needed, rather than controlled by ownership. This suggests a ***network*** or matrix rather than hierarchical approach to the design and implementation of communication systems.

- Increasingly, computer-based decision support systems are being viewed as intelligent assistants in an interactive, real-time, human-computer partnership. This is a direct outcome of the greater complexity of global scale problems, the greater emphasis on rapid deployment, the need for the small unit or individual soldier to respond quickly to changing conditions when operating in a dispersed mode in the battlefield, and the greater reliance on individual initiation at all levels.

Military missions and all of their supportive operations are by nature complex problems involving intricate relationships among many variables, under conditions of uncertainty. During all phases they are subject to dynamic information changes that impact both the solution objectives and the strategies for orchestrating the solutions. Decision makers at every level must be able to understand and respond quickly to changing circumstances, and this applies equally to planning and execution. Training becomes an integral component of the decision making process, allowing the decision maker to simulate, explore and experiment prior and during the actual operation.

Decision-Support System Requirements

The US Department of Defense is moving aggressively to replace old methods and decision-support systems with new concepts and systems that reflect current and projected future societal changes and technological advances. In particular, the military services are intent on leveraging the opportunities that these changes and advances offer. Such efforts are not confined to prudent planning activities that every organization undertakes on a routine basis, but also respond to past and present experiences that demonstrate increasing difficulties with the status quo.

Several system requirements are readily discernable from the foregoing discussion. Foremost among these is the need for ***integration***. It is becoming increasingly clear that neither the tactical nor logistical support needs of military forces can be met without full integration of command, communication, coordination, documentation, intelligence, and training functions within one system umbrella. This system must have an ***open architecture*** that allows growth and provides flexibility. It must facilitate the addition of new modules and the replacement of existing modules in a manner that is transparent to the users. These requirements point to a ***distributed architecture***, incorporating ***object-oriented*** concepts, with a great deal of internal connectivity and some degree of redundancy.

The system must support a high level of ***parallel*** activity, even within the components supporting a particular functional area. The need for near real-time response capabilities is incompatible with large deep simulation software packages that have to run their full course once they have received the necessary input, and cannot be halted and/or redirected as soon as new information that would change this course becomes available. A ***collaborative*** system architecture that allows many smaller modules to continuously interact with each other and collectively contribute to the decision making process is more likely to satisfy these response needs.

The need for users to interact with the system at all levels and under many different circumstances, ranging from headquarter tactical planning to logistical execution to communication with the war-fighter or humanitarian assistance provider in the theater, establishes a need for at least a primitive level of ***artificial intelligence*** within the system. A prerequisite for providing such capabilities is the presence in that system of a high level ***representation*** of the real-world entities that the user reasons about. Graphical images of theater maps that are not represented in the computer system as objects (i.e., roads, buildings, rivers, enemy units, and so on) are empty shells that cannot be used by the system to analyze consequences, generate alternatives, and provide advice. The lack of a high level representation is one of the most limiting factors of the vast majority of software systems in use today. Methodologies have been available for at least a decade that address this issue with considerable success.

The current approach for achieving this objective is to represent information in the computer as objects with behavioral characteristics and relationships to other objects (Myers et al. 1993). While this approach is hardly sophisticated it does allow real world objects (e.g., airfield, tunnel, building, weapon, tank) to be represented symbolically so that computer software modules can reason about them. It is important to note that the relationships among these objects are often far more important than the characteristics that describe the individual behavior of each object. For example, the word ***house*** holds little meaning if we strip away the many associations that this word represents in our mind (Pohl 1999). However, such associations to our knowledge of construction materials, our experiences in having lived in houses, and our understanding of how our own home is impacted by external factors (such as rain, sunshine, neighbors, mortgage interest rates, and so on) constitute the rich meaning of the object *house* (Minsky 1982). Accordingly, any useful representation of information in the computer must be capable of capturing the relationships among the entities (i.e., objects) in the problem system.

Military users are increasingly suggesting system requirements, such as intuitive interfaces, real-time advice, analysis and interpretation capabilities, and virtual reality training facilities, that indicate a desire for a ***human-computer partnership*** rather than automation. Within the context of current technological capabilities and anticipated near term advances, this desire can be satisfied. This does not mean that we can build systems today that emulate human behavior to a level that is comparable with actual human capabilities. What we can do is to design and implement a system architecture that will support an evolving artificial intelligence capability. Even in its infant form this capability represents a substantial advancement over existing system capabilities, and over time it will become more and more powerful and sophisticated.

The system must integrate functional divisions that are based on historical roots rather than actual performance objectives and requirements. In the past planning, execution, and training functions have been treated as largely separate endeavors and have been accommodated in separate systems. These divisions are incompatible with the increasing need for real-time response to changing conditions, flexibility, faster deployment, and continuous access to realistic training environments.

The accelerating rate of change precludes the luxury of planning and implementing in discrete, sequential steps. Instead, planning and execution will merge more and more into parallel activities. Under these circumstances the separation of planning and execution functions into connected but separate systems is becoming a serious source of delay, disruption, and potential failure.

The case for integrating training with planning and execution is just as strong. The purpose of training is to prepare persons to deal effectively with future situations. If the future situation can be accurately predicted and there is sufficient time to formally describe and present this situation to the trainee, then there is no compelling reason to integrate training with planning and execution. However, in a changing environment prepackaged training tends to lag well behind the actualities of application. The greater the rate of change in the application arena, the further removed from reality and the less effective the training becomes. When the trainees recognize this disparity between what is being taught and what can be expected to occur, they become less and less interested in pursuing any of the prepackaged training activities. As a result the training program loses its effectiveness and the trainees are poorly prepared for the tasks that they are expected to execute under real world conditions.

Apart from the performance advantages, the integration of planning, execution, and training also offers potential cost benefits. Although a system incorporating three functional areas is intrinsically more complex than a system that accommodates only one functional area, it greatly reduces the tendency for duplication both in respect to software functionality and hardware facilities. For example, the need to generate real world context and data in a separate training system is a significant and costly requirement. If the training function is integrated with the planning and execution functions then the real world context and data also serve as the training environment.

Databases as Shared and Distributed Resources

The existence of a global communication network provides opportunities for integration that have not been available in the past. It allows integration to be addressed from a much more general point of view, in respect to information sharing and accessibility rather than the linkage of individual software applications (i.e., computer programs). In this view a database is not owned by any particular computer program, but is treated as a resource that is available to any number of programs that are authorized to access this information resource. The actual geographical and physical location of either the database or the program that wishes to access the information contained in the database is immaterial.

However, there are two requirements that are of critical importance in this view of a database as a shared resource. First, the information stored in each database must conform to a common vocabulary. This ensures that the users of the information (both human users and other computer programs) have some understanding of the meaning of each individual data element, and provides a basis for avoiding ambiguity and duplication. Second, each information resource must make its data available in the format of an 'external view' that may differ significantly from the internal data storage structure of the resource. This obviates the need for imposing rigid standards on the internal structural format of each database. Past attempts to enforce such data storage standards have been singularly unsuccessful. However, data access and transmission standards (e.g., SQL, dxf, IGES, etc.) that provide an 'external view' of the data have been readily adopted by industry and commerce.

The information that is shared in a distributed communication environment is not limited to the data stored in databases. Individual software applications will be generators of information that may be stored in databases or, more often, will be shared directly with other applications. In this respect the military transportation infrastructure (Fig.1) that is gradually evolving in direct response to the global transportation management needs of the US Department of Defense can be viewed as consisting of a large number of sharable resources. Some of these resources are databases that serve as depositories of dynamically changing data. Others are software applications that analyze, evaluate and generate views of combinations of data that are of interest to users.

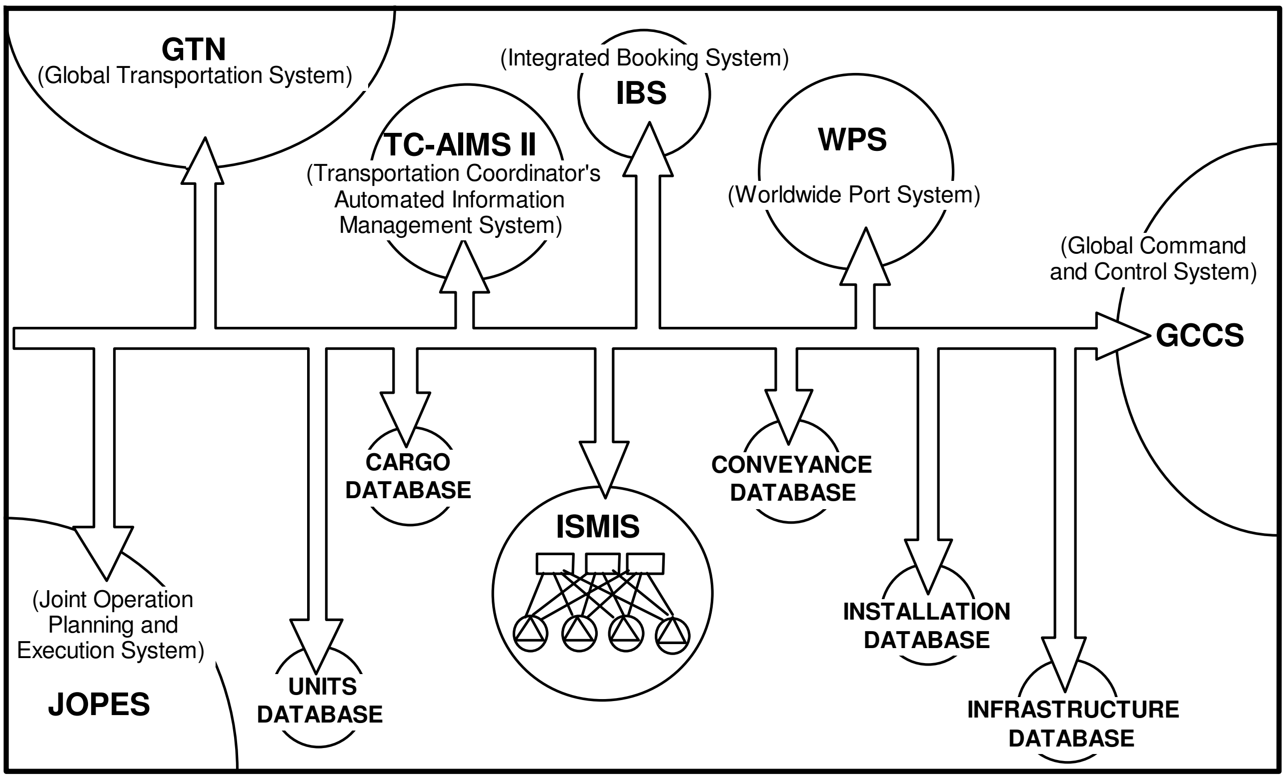

Fig.1: Current and Proposed Integration of Military Transportation Infrastructure

The following advantages of such a distributed, but integrated, transportation infrastructure are readily apparent:

- The notion of communication can be extended from the limited function of data transmission, to the much more powerful functions of processing data to information and applying artificial intelligence to assist in the cognitive processes that transform information into knowledge. The human decision maker working in partnership with the computer-based assistance provided by the communication system is now able to focus on the judgements that must be made to formulate decisions.

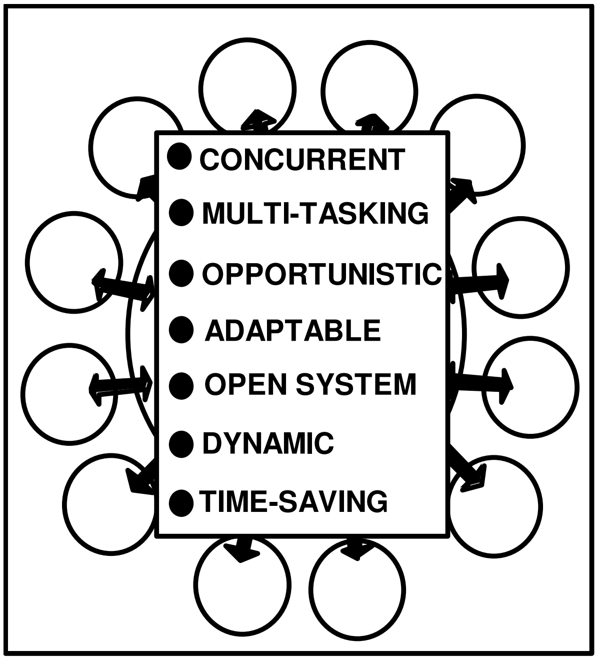

Fig.2: Parallel Decision-Support Systems

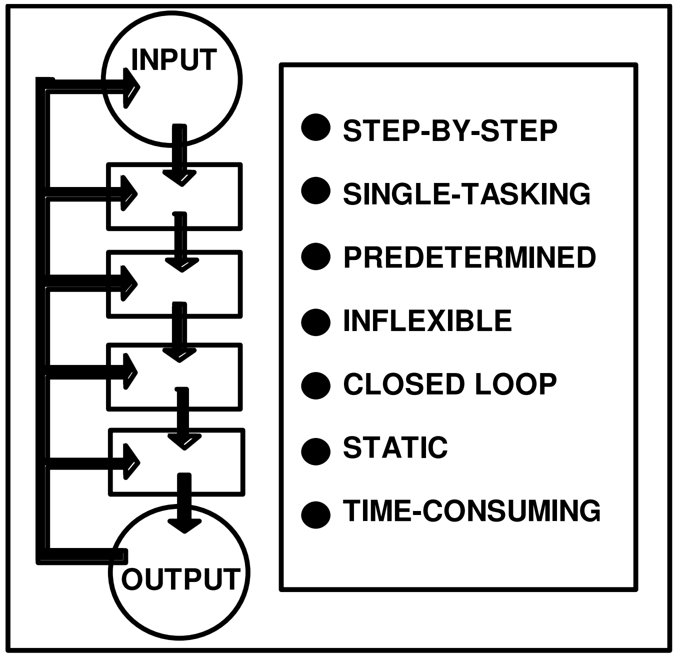

Fig.3: Sequential Decision-Support Systems

- The various software applications and their individual program modules can operate in parallel (Fig.2), sharing databases and contributing the results of their analyses, evaluations and inferences to each other and the users. To take full advantage of this operational concurrency the program modules must be designed to respond to changes in data and new information in real-time, opportunistically.

- Hierarchically and sequentially controlled decision making processes (Fig.3) that tend to result in fragmentation and delays in 'First Wave' software architectures (Fig.3) are replaced by ***authorization protocols*** that maintain security without impeding the flow of information which is critical to the decision making environment. In a networked system of shared resources communication will not be constrained by ownership and authority. In 'Second Wave' software architectures (Fig.4) control is replaced by ***coordination*** which is exercised through communication and analysis of the problem situation (i.e., ***feedback***), rather than restricting the activities and contributions of individual participants.

- A great deal of meaningful and useful activity can take place at any node of the distributed communication system, thereby encouraging the ***decentralization*** of planning, execution and training functions. Decentralization is highly desirable for several reasons: reduction of communication and decision making bottlenecks; accelerated planning and failure recovery through redundancy; and, capture of real-time information through strategically located local nodes.

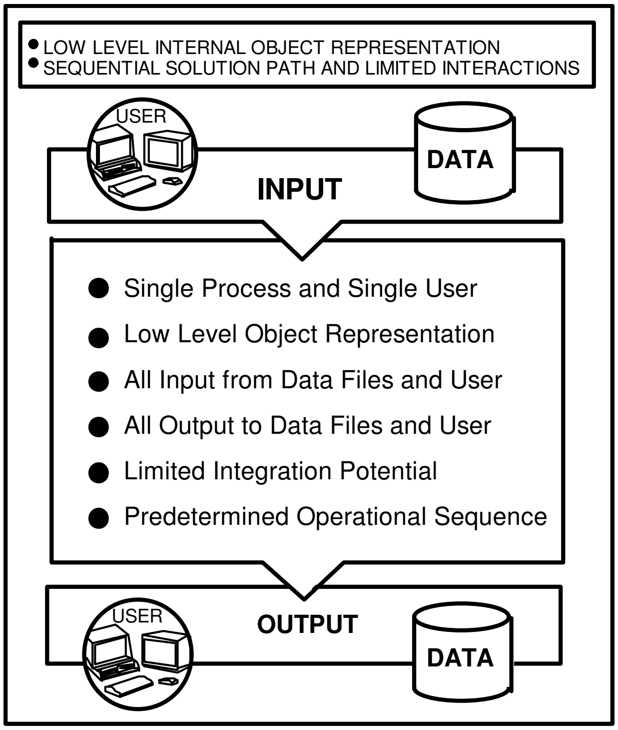

Fig.4: 'First Wave' Software

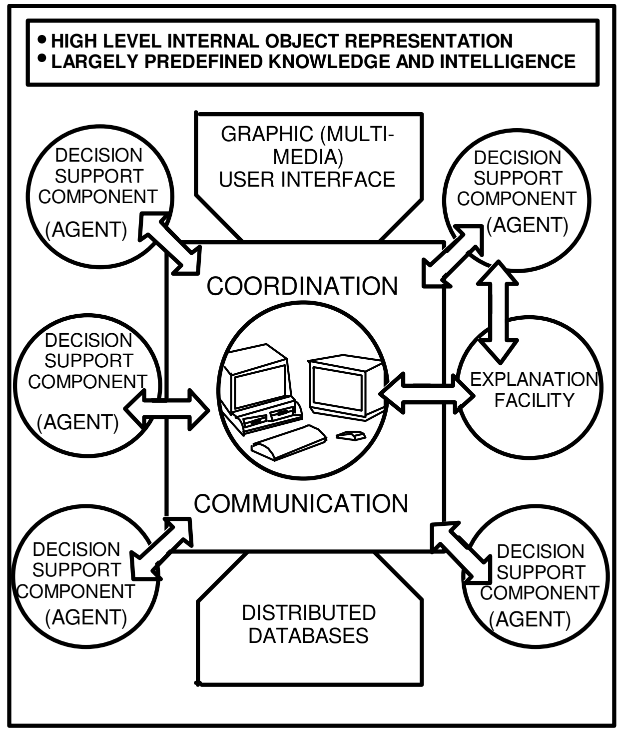

Fig.5: 'Second Wave' Software

Over the past several years the US Department of Defense has taken specific actions, through its various agencies, in several areas that are supportive of this type of integrated, distributed transportation infrastructure. This includes current efforts directed to the consolidation of many largely fragmented software applications into a smaller number of ***migration systems***, and the establishment of a data dictionary (i.e., the Transportation Logical Data Model) to serve as a ***common vocabulary*** for a collaborative, logistical decision-support environment.

An Integrated Strategic Mobility Interface System (ISMIS)

In a distributed network of sharable resources planning, execution and training activities are supported by multiple program modules that are able to access the required databases and communicate with each other to exchange information and instructions that will initiate the execution of the desired functions. The program modules, therefore, must incorporate the necessary inter-process communication facilities that allow them to send and receive objectified information (e.g., information queries, results of evaluations, proposals, and requests for services) transmitted through the communication network.

In this respect, the integration of the planning, execution and training activities is largely a user-interface issue. The user selects the desired mode of operation and specific information sources to initiate a sequence of internal system activities that seamlessly access those system resources that are required for the completion of the task.

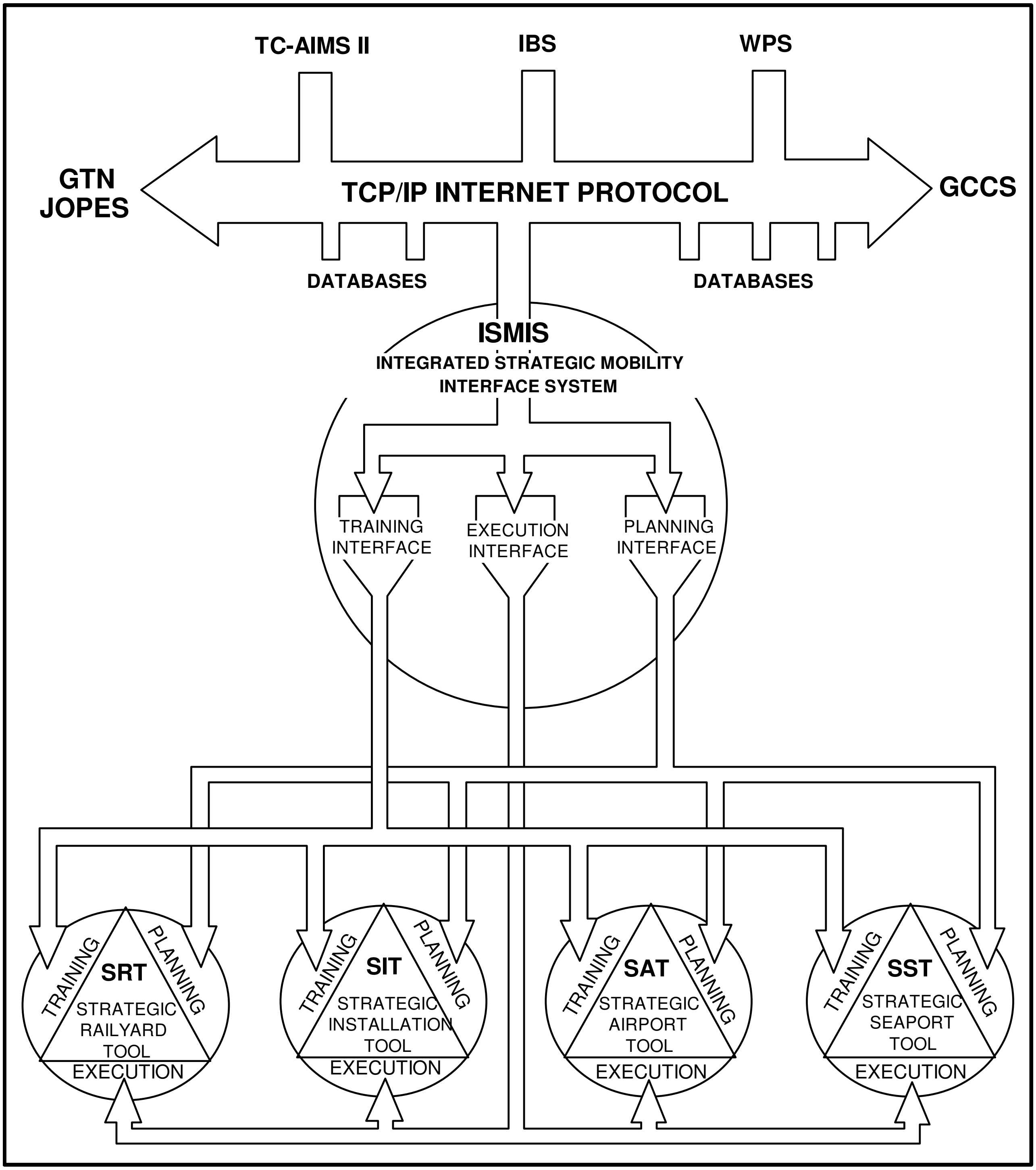

Fig.6: Proposed Integrated Strategic Mobility Interface System (ISMIS)

The proposed ISMIS framework shown schematically in Fig.6, would allow the user to execute any rail, road, air, and/or ocean cargo deployment task by automatically accessing the required combination of program modules. It is a relatively trivial matter to embed sufficient intelligence in the interface components for ISMIS to automatically infer, based on limited user-interaction, whether the user desires to undertake a planning, execution or training task, and transmit the appropriate objectified messages to the program modules that are capable of completing this task. The strategic rail yard, installation, airport, and seaport tools shown below the ISMIS interface modules in Fig.6, may themselves consist of multiple program modules that are capable of communicating among themselves and with the outside world. In this regard, the ISMIS architecture resembles a cluster of multiple multi-agent systems as an extension of the 'Second Wave' multi-agent software paradigm shown in Fig.5.

In each strategic tool the planning, execution and training functions are accommodated either by separate program modules or alternative modes of execution of the same module. For example, in the ship load planning task area, the differences between planning and execution modes may be accommodated by the Integrated Computerized Deployment System (ICODES) both through internal switches and the invocation of additional agents (CADRC 1994). Thus, in a planning mode where the user may wish to determine a suitable mix of vessels for a large cargo deployment, ICODES would automatically suppress its graphical cargo templating display through internal software switches and activate specific agents to infer recommendations from the outcome of the load planning operation.

When required to operate in a training mode, ICODES would first interact with the user to determine the objectives and level of training desired, select the appropriate training context and then activate one or more agents to monitor and assist the user during the training session. Additional provisions can be made for evaluating the performance of the trainee and capturing portions of the training session for play-back and ***lessons learned*** analysis.

Conclusion

Application proposals such as ISMIS, that incorporate ‘Second Wave’ software concepts, are foreshadowing paradigm shifts in at least two areas: ***information representation***; and, ***user-interfaces***. We are still only in the transition stage between ‘First Wave’ and ‘Second Wave’ software (Pohl 1996). The evolution of ‘Second Wave’ software will place increasing emphasis on the high level internal representation of information, in terms of real world objects with behavioral characteristics and dynamically generated relationships. The need for computer-based systems to have some ***understanding*** of the information that they are processing is being recognized only gradually, mostly in response to the overwhelming increase in information availability.

While computer user-interfaces have come a long way from punched card beginnings in the 1960s to windows, icons, mouse, and pull-down menus (WIMP) in the middle 1990s, they are still relatively primitive and awkward. The type of virtual reality facilities that are expected to be available in *Cyberspace*, coupled to the human senses through body nets, still require significant technical advances (Pohl 1998). Speech synthesis is more mature, following two decades of development, and is starting to be used for various commercial applications such as airline reservation systems.

Typically, major changes (i.e., paradigm shifts) occur only when they can potentially bring major gains, or if failure to change will result in severe penalties. In either case, major changes take time. They usually require cultural changes and are best implemented incrementally. The implementation process is complicated by a need for human cognitive system to adapt to new conditions, to reevaluate relationships, beliefs and solution strategies. In short, this forces the human being into a situation where past experience tends to lose some of its value and risks have to be taken to develop new understandings and generalizations to form the basis for new experience.

Viewed from an optimistic stance, changes provide new opportunities. In fact, the more changes the more opportunities. These opportunities are not restricted to technical advances and solutions, but are equally prominent in management areas that involve the organization and orchestration of groups of persons to collectively accomplish a goal. Integration, cooperation, persuasion, and motivation are key elements that acquire new meaning in a rapidly changing environment.

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