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on

Collaborative Decision-Support Systems

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Preface

The papers included in these pre-conference proceedings reflect the increasing focus on the utilization of computers as collaborating, decision-assistance partners in complex and often time-critical problem situations. There are high expectations that intelligent software agents will solve many of our current information system woes, such as lack of interoperability, multiple failure points, vulnerability to intrusion, making the right information available to the right person at the right time, and proposing solutions under time-critical conditions. Software agents do not have magical human-like capabilities. It is not possible to simply develop a piece of software code that is capable of reasoning about conditions and circumstances like we human beings appear to be able to do. Computers are not human beings and definitely do not have human capabilities. Yet, it is indeed possible to develop software agents that are capable of accomplishing human-like tasks such as recognizing certain conditions, reasoning about these conditions, forming conclusions, and taking actions on the basis of those conclusions.

At first sight the above statements may appear to be contradictory. Software agents do not have human-like capabilities and yet, they are able to accomplish human-like tasks. There is obviously a ***missing link***, a particular ingredient in a software environment that makes it possible for software agents to perform tasks that would normally require human intelligence. Although there is an increasing acceptance of the notion of intelligent computer-based agents, what is not generally understood are the kinds of fundamental capabilities that allow such agents to perform ***intelligent*** tasks and the nature of the software environment that is required to support these capabilities. In other words, how is it possible for a dumb electronic device to perform apparently intelligent human-like tasks?

First we should ask ourselves: What precisely are the capabilities that a software agent needs to have to be able, for example, to determine the information required by a given computer user at any point in time and to prepare alternative solutions for a particular problem situation? Clearly, such tasks require ***reasoning*** capabilities. The obvious next question then becomes: How can we make it possible for a piece of software code to reason about anything?

To answer this second question we need to examine in some detail what is meant by reasoning. In general terms, reasoning is a logical process involving the systematic interpretation of information. From our earliest school years we learn to assemble information into a form that facilitates various problem-solving activities. For example, we learn how to extract the few contextually important pieces of information from a passage of text, or how to rearrange a set of conditions to establish a suitable framework for drawing conclusions. In simplest terms this logical process can often be reduced to a set of conditions, the application of certain tests to these conditions, and the drawing of conclusions based on the outcome of the tests. For example (Figure 1): I usually commute to work by bicycle. Tomorrow morning I have to be in the office very early for a meeting at 7 am. IF it rains tomorrow morning THEN I will not commute by bicycle, but use my car instead. IF I have to use my car THEN I will need to leave 20 minutes earlier than normal to be able find a parking space, and so on .

Many years before computers became available this process of deductive reasoning was already well understood. Emil Post (1943) coined the term ***productions*** to describe sequences of IF…THEN conditions and conclusions. More familiar to the layperson is the term ***rules***. The IF-part (or predicate) of a rule establishes the conditions that must be satisfied before the THEN-part (or consequent) can be assumed to logically follow. As shown in Figure 1, a single rule may contain multiple conditions and/or actions. In addition, secondary conditions can be embedded in both the IF-part and the THEN-part of a rule.

Rules are of course not the only way in which we can structure problem conditions and a solution sequence. For example, a neural network consisting of interconnected layers of input, intermediate and output nodes, utilizes an entirely different approach for detecting a pattern of conditions. It essentially implements a sophisticated mathematical function to generate a very primitive numerical output (a set of decimal values between 0 and 1) to indicate that a particular input (represented in the same numerical manner) is similar to an input pattern that it has been mathematically trained to recognize. This is quite different from the approach that the rule shown in Figure 1 follows to logically define the conditions that must be met before any of the actions can take place. Instead, the neural network relies on a pattern matching approach that does not require an understanding of the meaning of the recognized patterns but simply the ability to recognize it. Furthermore, additional interpretation has to be provided by other means to convert the real world pattern into an abstract set of numerical values that are fed into the input nodes and convert the numerical output code generated by the neural network into a meaningful (real world) result.

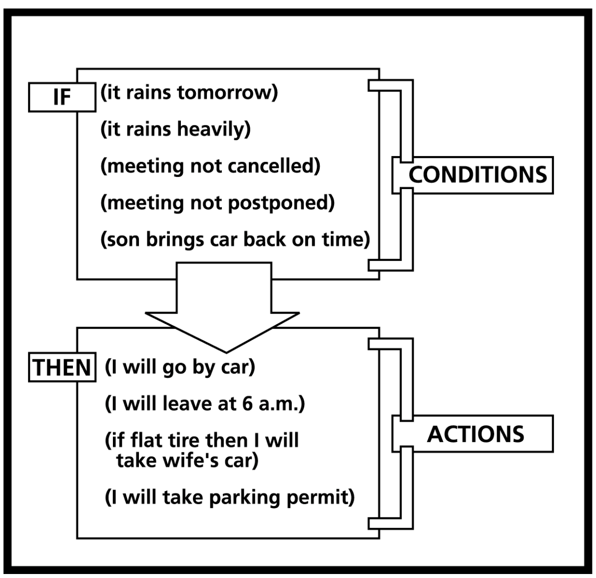

Figure 1: Typical rule (or production)

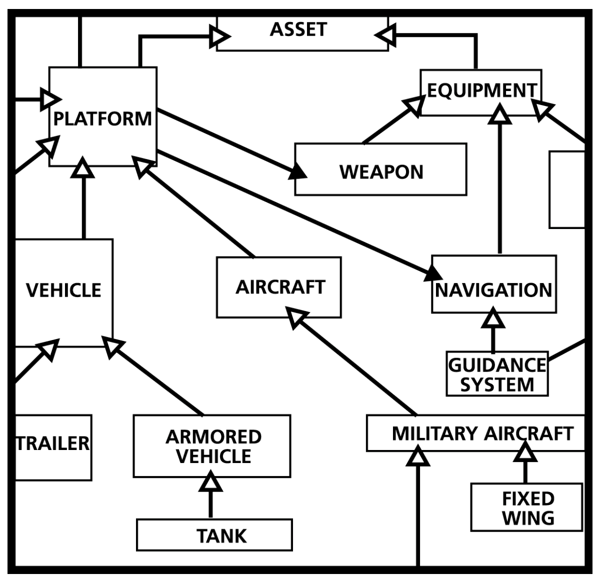

Figure 2: Small part of an ontology

Neural networks are powerful tools, even though they do not rely on symbolic reasoning capabilities. Software agents that are able to analyze problem situations, dynamically changing conditions, and events, must have some understanding of the meaning of the information that they are reasoning about. The 'missing link' that is mentioned in the title of this short article refers specifically to this issue of ***understanding***. In other words, how can we create a computer-based environment that conveys to a software agent sufficient meaning for that agent to undertake reasoning tasks of the kind exemplified by the rule shown in Figure 1?

To answer this question it is necessary to first draw a distinction between data and information. Data are simply numbers and words, while information adds to data another very important component, ***relationships***. These relationships are critical to any reasoning process because they provide ***context***. Without this context even a human being would have great difficulty making sense out of a bunch of data. What makes it so easy for us human beings to reason about a wide range of data is the context that we have accumulated in our cognitive system over time through an experience-based learning process. We automatically convert data to information as long as we can find in our memory the context within which the words and numbers (i.e., data) that our eyes see, convey meaning. In other words, subject to the existence of relevant experience our cognitive system automatically adds the relationships (i.e., context) that are necessary for us to reason about the data. Since this process is automatic, it is perhaps not unreasonable for us to forget that computers do not have this capability because they do not have an equivalent cognitive system. The same would apply if we were to ask a literate six-year old child to interpret the meaning of a typical printed, single-page agenda of a business meeting. Although the child may be able to readily read the agenda it is unable to make much sense of its contents because it has no prior experience of such meetings. In other words, the child lacks the context that is necessary for reasoning about the agenda.

For the computer to be able to support automatic reasoning capabilities we have to create a software environment that incorporates context. This can be achieved fairly easily by constructing an information model as a virtual representation of the real world context within which software agents are expected to apply their reasoning capabilities. Such an internal information model is referred to as an ontology. A small part of a typical example of such an ontology is shown in Figure 2. It describes the real world context in terms of objects with characteristics and relationships. For example, in a military command and control context such objects would include different kinds of weapons, a wide range of infrastructure objects, weather forecasts, friendly and enemy units, and even conceptual objects such as the notions of threat, planning, mobility, and readiness. Generally speaking, the more relationships among objects that are included in the ontology the more context is provided by the ontology, and the more powerful (i.e., intelligent) the reasoning capabilities of the software agents are likely to be.

Without the context provided by an internal information model (i.e., ontology) there can be no meaningful, automatic reasoning by software agents. Of course there could still be neural network agents and software modules that simply manipulate data based on some predefined data-processing scheme, but neither of these are capable of the kind of symbolic reasoning that is now being referred to under the title of ***intelligent agents***. Therefore, the 'missing link' or essential prerequisite for intelligent agents is the existence of an internal information model that provides the necessary context for the symbolic reasoning activities of the agents. We human beings do not have to consciously invoke any action to relate what we see, hear and feel to the context held in our brain. The need for this context to be created in the computer is therefore not intuitively obvious to us. This is no doubt the principal reason why such a fundamental aspect of intelligent computer-based agents is still largely overlooked.

Jens Pohl, June 2003

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Post E. (1943); 'Formal reductions of the general combinatorial problem'; American Journal of Mathematics, 65 (pp. 197-268).

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Section 1:

Management in a Changing Organizational Context

The Emerging Knowledge Management Paradigm: Some Organizational and Technical Issues

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Abstract

This paper addresses the expectations, organizational implications, and information processing requirements, of the emerging knowledge management paradigm. A brief discussion of the enablement of the individual through the wide-spread availability of computer and communication facilities, is followed by a description of the structural evolution of organizations, and the architecture of a computer-based knowledge management system. The author discusses two trends that are driven by the treatment of information and knowledge as a commodity: increased concern for the management and exploitation of knowledge within organizations; and, the creation of an organizational environment that facilitates the acquisition, sharing and application of knowledge.

Tracing the evolution of the structure of organizations, the author concludes that the web-like features of the Network Model are most conducive to the promotion of knowledge management principles, even though this model does have liabilities that require careful monitoring.

The paper further discusses in some detail the architecture of a knowledge management system that consists of a lower integrated data layer and an upper information layer. Attention is drawn to the need of the data layer to include not only archived summary data as found in Data Warehouses and Data Marts, but also near real-time operational data with convenient access provided by Data Portals. An important distinction is drawn between data-centric and information-centric software environments in terms of software with an internal information model capable of supporting agents with automatic reasoning capabilities. The paper concludes with a brief description of the mechanisms through which a Web-Services environment provides access to distributed data sources, as well as heterogeneous data-centric and information-centric software applications.

Keywords

agents, communication, complex adaptive systems, data, data-centric, Data Mart, Data Portal, Data Warehouse, enabled individual, information, information-centric, information management, knowledge, knowledge management, ontology, organization, organizational structure

Enablement of the individual

One of the more subtle consequences of the rapid advances in information technology over the past several decades has been the increasing focus on the individual. Enabled by powerful communication facilities and computer-based automation tools that vastly increase the capabilities of the user, an individual person can orchestrate and achieve more today than an entire organization was able to successfully undertake a mere decade or two ago. Recognition of the value of the individual is exemplified in multiple ways, ranging from the changing structure of business corporations, the rise of entrepreneurship and self-employment, to apparently exorbitant judicial compensation awards, and the increasing value placed on human life.

Emerging out of this technology driven environment are a new set of personal values and expectations that differ significantly from past social conventions. The enabling nature of this environment, in itself, presents a challenge through the increased opportunities that it offers to the individual. To take advantage of these opportunities, the individual who is proactive and willing to take calculated risks is likely to be more successful than the individual who is reserved and conservative. Similarly, the person who is self-reliant and willing to exercise leadership to reach objectives that are based on future trends, is likely to outperform the person who is subservient and intent on duplicating past successes.

As ideas, initiative and persistent motivation become more useful human qualities, risk taking will become recognized as being increasingly rewarded and conservatism as being increasingly penalized. Under these conditions traditional values such as prudent compliance, measured reactiveness and acceptance of the status quo will gradually fall out of favor. Instead, the more successful individual will have recognized the value of continuously monitoring events, identifying trends, and preparing for taking advantage of opportunities that are largely unpredictable in both their nature and timing.

The enablement and focus on the individual will undoubtedly also increase the level of societal stress and anxiety, as a significant number of persons find it difficult to keep pace with the tempo of technology driven change. Specifically, there is likely to be an increasing demand for freedom without a commensurate willingness to exercise self-constraint. At the same time the rapidly increasing desire for a higher quality of life and the mounting aspirations for personal achievement will for most persons fall short of their expectations.

Knowledge as a commodity

As information technology begins to permeate all aspects of life and the economy turns decidedly information-centric, wealth is increasingly defined in terms of information-related products and the availability of knowledge. Under these conditions employment, whether self-employment or organizational employment, is becoming singularly focused on the skills and capabilities of the individual. In other words knowledge has become a commodity that has value far in excess of the manufactured products that represented the yardstick of wealth during the industrial age.

How this new form of human wealth should be effectively utilized and nurtured in commercial and government organizations has in recent times become a major preoccupation of management. Two parallel and related trends have emerged. The first trend is related to the management and exploitation of knowledge. The question being asked is: How can we capture and utilize the potentially available knowledge for the benefit of the organization? The phrase "…potentially available" is appropriate, because much of the knowledge is hidden in an overwhelming volume of computer-based data. What is not commonly understood is that the overwhelming nature of the stored data is due to current processing methods rather than volume. These processing methods have to rely largely on manual tasks because only the human user can provide the necessary context for interpreting the computer-stored data into information and knowledge. If it were possible to capture information (i.e., data with relationships), rather than data, at the point of entry into the computer then there would be sufficient context for computer software to process the information automatically into knowledge. This is not just a desirable capability, but an absolute requirement for the capture and effective utilization of knowledge within an organization and will therefore be discussed in more detail later in this paper.

The second trend is related to the structure of the organization itself. Efforts in this area are focused on creating an environment that encourages and facilitates the acquisition, sharing, and application of knowledge. Commonly referred to as ***knowledge management***, these efforts have the goal of effectively developing and utilizing the human capital in an organization. More specifically, the objective of knowledge management is to enable all human and organizational capabilities and relationships for the benefit of the individual and the organization. This requires the encouragement of every member of the organization to be a contributor and a potential decision maker. How can this be achieved? Decentralization and concurrency are principal characteristics of knowledge management, aimed at creating an environment that builds relationships for the purpose of maximizing interaction, diversity, responsiveness, and flexibility.

In this respect knowledge management views an organization and its external environment as a complex adaptive system of many component parts acting in parallel. The principal component parts of the organization are the human players, including not only the employees but also the external individuals and groups that the organization interacts with. Holland (1988) characterizes complex adaptive systems as a network of many agents acting in parallel. Each agent is always ready to interact with the system, proactively and reactively responding to whatever the other agents are doing. As a network, a complex adaptive system is by its very nature highly decentralized. In other words, any coherent behavioral patterns of the system are due to the collective competitive and cooperative activities of its parts (i.e., agents or elements). It follows that such a system has many levels of organization, with the agents at any level contributing in a building block manner to the agents at a higher level. For example, a group of individuals will form a team or department, a number of departments will form a division, and so on through an organization. Most importantly complex adaptive systems are constantly changing, revising and rearranging their building blocks through their activities as they adapt to their experiences within the system.

Two essential requirements for the relative success of an organization, within the context of such a dynamically adaptive environment, are anticipation of the future and communication. Neither of these are necessarily akin to human nature. The fundamental (i.e., biological) experience-based nature of the human cognitive system provides us with few tools to deal with situations that are not the same or at least similar to past experiences. Anticipation of the future therefore represents a precarious excursion into unknown territory that is typically accompanied by an elevated level of anxiety due to uncertainty, frustration and fear. The uncertainty stems from the unknown nature of the future, which differs fundamentally from the certainty of the past. Therefore from a human point of view, dealing with the future represents an emotional effort that challenges our confidence to survive and prosper within our environment. We become frustrated as we see many of the methods and tools that have allowed us to survive and prosper in the past, progressively fail as we try to apply them to new conditions and situations. We are forced to stumble along as we learn by trial and error. It is therefore only natural for us human beings to avoid any excursions into the future unless they are forced upon us. With few exceptions we tend to cling to the apparently safe domain of the past, unless we are compelled to face the present and future by developments in our environment that severely threaten the comfort level of our current role. Clearly, the requirement for anticipation in a successful organization is not naturally satisfied by its human players and must therefore be continuously fostered by other stimuli.

Since a complex adaptive system depends greatly on the continuous interaction of its component parts, the maintenance of open communication channels between the human players of an organization is an essential requirement for knowledge management. The more active individuals or groups of players are the more critical the exchange of information and knowledge becomes to the welfare of the organization. Yet, there is a natural tendency for human beings to reduce their external interactions as they become more focused on their activities and, often to an even greater extent, as these activities appear to become successful. Both the concentration of their attention and the selfishness of their ambitions mitigate against the sharing of the knowledge acquired through their efforts. Again, this conflict between inherent human behavioral characteristics and the prerequisites for organizational success requires special attention in a knowledge management environment.

Evolving organizational structures

It is to be expected that organizational structures will evolve over time in direct response to societal changes. The evolution of the role of the individual from a compliant and subservient implementer to a proactive initiator, has had a profound influence not only on the structure of organizations but also on the manner in which they operate. Over the past century and in particular since World War II, the notion that the members of an organization need to be controlled through the application of hierarchical authority has been gradually displaced by the need to survive in an expanding market and under increasing competition. Advances in information technology have not only generated vastly improved ways of accomplishing tasks, but they have also created unprecedented opportunities for persons with few material resources to provide services and products in direct competition with much larger established organizations. The history of the microcomputer abounds with examples of very small groups of individuals who not only created new products but literally forced some of the largest industrial organizations to change their product lines, revise their marketing strategies, and abandon their existing organizational structures, for the sake of survival.

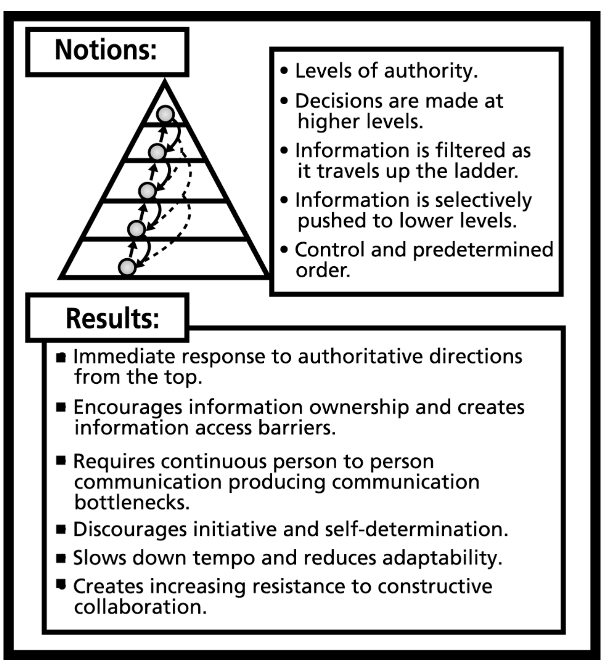

Figure 1: Strictly Hierarchical Model

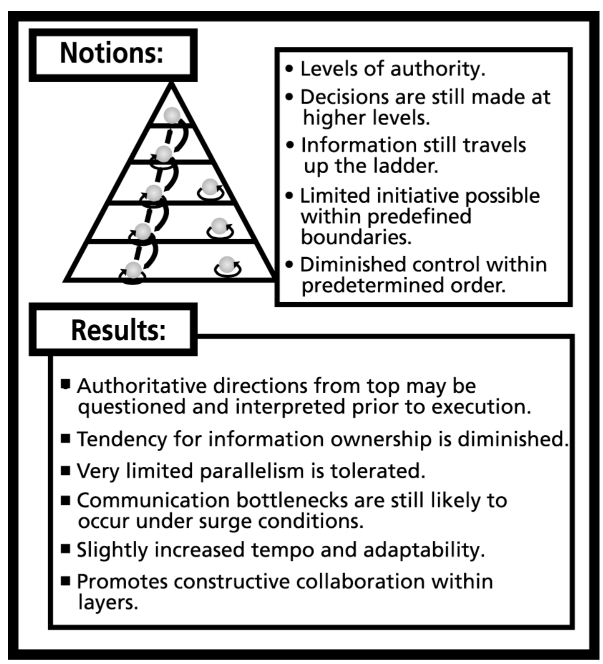

Figure 2: Loosely Hierarchical Model

During the 20th Century the formal structure of organizations has gradually adapted to take advantage of the potential contributions of the individual enabled by a new set of information technology tools and skills. However, even though the transition from the hierarchical authoritarian model to a web-like structure is readily discernable, examples of virtually all intermediate products of this transition can still be found today.

The incompatibility of the traditional Strictly Hierarchical Model with modern knowledge management principles is clearly seen in the notions expressed in Figure 1. This model relies fundamentally on the concept of vertical levels of decision authority. In practice, however, most decisions are made at the highest levels because of the limited delegation of authority to lower levels. Control and predetermined order pervades every operational aspect of the Strictly Hierarchical Model. In particular, the insistence on control inhibits the flow of information both upward and downward. Information is filtered as it travels upward from level to level based on what the lower level believes the upper level would like to receive and hear. The more authoritarian the operational implementation of the hierarchical model the greater the degree of filtering, with the attendant increased isolation of the decision makers from the realities of the operational environment. For entirely different reasons the higher levels of the organization are often reluctant to provide the lower levels with more than the minimum information that they believe is required for the execution and implementation of instructions.

The single advantage of the Strictly Hierarchical Model is that it responds immediately, decisively, and effectively, under predictable conditions that have been anticipated and for which good plans of action exist. However, as soon as the original plan has to be modified due to changing conditions, there is a real danger that the organization will not be able to respond in a timely manner. The more dynamic the operational environment (i.e., driven by external and internal forces) the less effective the Strictly Hierarchical Model becomes. The inability of this organizational model to respond to dynamically changing conditions is exacerbated by information ownership and the propensity for producing communication bottlenecks. The intrinsic limitations placed on the flow of information within this organizational model encourages persons within the organization to consider themselves as custodians of information that is made available to others on a strictly selective basis. This creates serious barriers to the access of information both vertically and horizontally. In addition, the strictly controlled upward and downward flow of information through person-to-person channels tends to produce communication bottlenecks. As a result the operational tempo and adaptability of the organization are greatly reduced, leading to the discouragement of initiative and a general resistance to constructive collaboration.

The Loosely Hierarchical Model (Figure 2) somewhat improves the ability of the organization to respond to a moderately changing operational environment. While it still maintains levels of authority, with all but routine decisions being made at the higher levels, it tends to allow some limited degree of initiative within predefined boundaries. The slightly diminished insistence on control, within the context of the predetermined order of the organization, allows authoritative directions from the upper levels to be questioned and interpreted prior to execution. As a result a limited amount of parallelism is tolerated, leading to the encouragement of a moderate degree of constructive collaboration within the lower levels. However, while the tendency for information ownership is diminished in the Loosely Hierarchical Model communication bottlenecks are still likely to occur under surge conditions.

The need for more timely responsiveness to a dynamically changing environment forced two important recognitions: the need for increased parallelism; and, the need for more direct communication. These requirements led to the elimination of the concept of a pyramid of layers, thereby transforming the hierarchical model into a Star Model (Figure 3) of nodes grouped circumferentially around a central hub. The Star Model assumes that the nodes will function in a parallel mode with a much greater but still limited degree of autonomy and self-determination. However, while information flow from and to the hub is direct for each node, there is little provision for direct interaction among the nodes. One could categorize this model as a form of centrally directed and monitored parallelism that still maintains a significant degree of control. In this respect the Star Model is clearly a transitional compromise that recognizes the restrictive nature of control but at the same time still insists on the guaranteed availability of a dominant control mechanism.

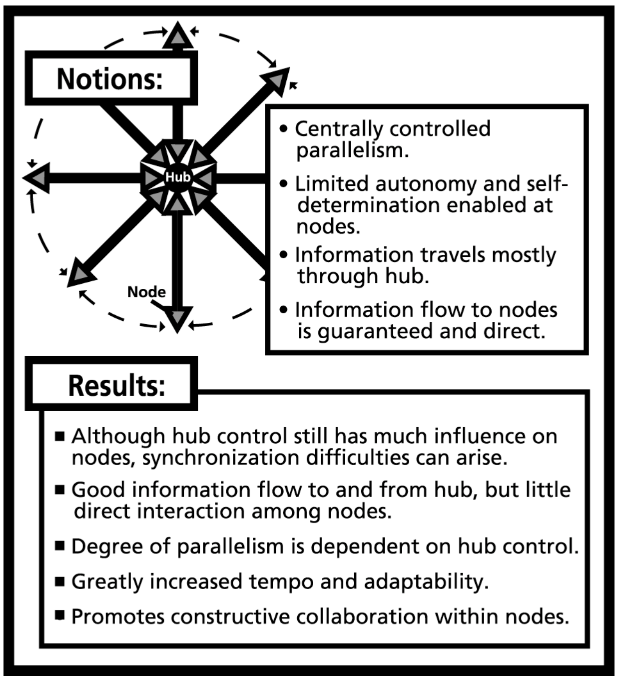

Figure 3: Star Model

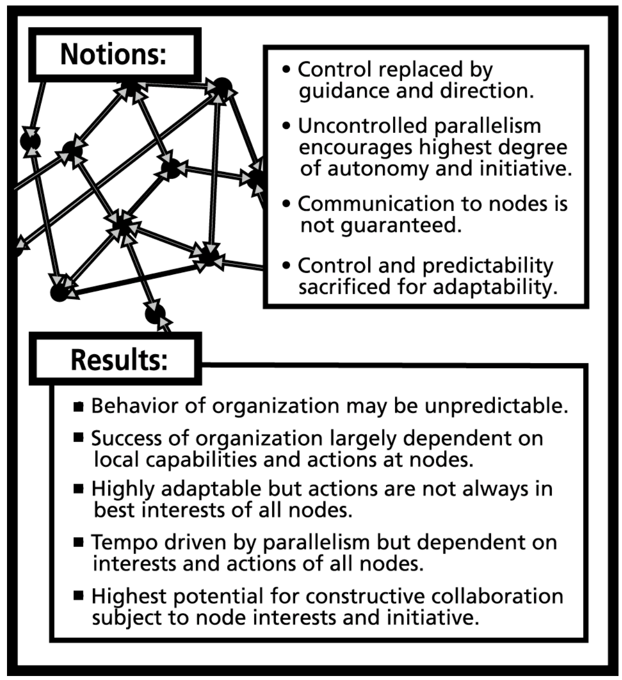

Figure 4: Network Model

Although the degree of parallelism that can be generated in a star-like structure is largely dependent on the degree of control maintained by the central hub, this organizational model provides greatly increased tempo and adaptability in comparison with either version of the hierarchical model. In addition, the Star Model promotes a more or less unrestricted degree of constructive collaboration within nodes even though any node-to-node interaction is constrained by the dominance of the hub.

In very recent times the increased demand for adaptability, self-determination and responsiveness, has progressively transformed the mandates of control and authority to the more acceptable notions of guidance and leadership. Consequently, the hub disappeared and the organizational structure flattened into a web-like Network Model (Figure 4). While there are now no barriers to the interaction of nodes, communication to nodes is by no means guaranteed. The Network Model sacrifices control and predictability for adaptability. It does this by encouraging virtually uncontrolled parallelism potentially leading to the highest degree of autonomy, initiative and self-determination. In this respect, the success of an organization with a web-like structure depends largely on the local capabilities and actions at the nodes. Although this organizational model has the highest potential for constructive collaboration, unrestricted due to the absence of control, the realization of this potential depends almost entirely on the interests and endeavors of the nodes.

Without strong leadership and a clearly articulated vision the Network Model has to struggle with three potentially serious liabilities. Firstly, lack of stimulation and purpose at the nodes can lead to inactivity and isolation. The model assumes that there is a natural tendency for node players to take advantage of their autonomy and exploit their essentially unrestricted freedom to full advantage. In the light of the previous discussion of human nature, this assumption may not be valid under certain circumstances. Secondly, very strong and highly motivated players at one or more nodes may become disruptive as they vigorously compete for resources and force the demise of other nodes. Such activities may not be in the best interests of the organization as a whole. Finally, the Network Model incorporates an innate propensity to be unpredictable. By maximizing its ability to adapt to both internal and external changes the model can adapt at a rate that outpaces the ability of its leaders to recognize the nature of the changes and maintain a relevant organizational vision. Under these circumstances there is a distinct danger that the organization will squander its resources in unproductive areas as the guidance provided by its leaders becomes less and less relevant to the actual activities of the nodes.

Clearly, the Network Model is most compatible with the principles of knowledge management. It provides the necessary freedom for an organizational environment in which leadership serves as a motivator, catalyst and enabler, rather than a taskmaster. However, in the absence of strong and tireless leadership the network model is vulnerable to internal manipulation by overly competitive nodes, to inactive nodes due to lack of stimulation or an unwillingness for node players to exercise initiative and self-determination, and to uneven performance and the formation of isolated groups (i.e., at the nodes) as responsibility assignments and accountability expectations are ignored.

Information-centric computer software

Apart from an organizational structure that encourages initiative and self-determination, and leadership that provides vision and guidance, there is a third prerequisite for a successful knowledge management environment. This prerequisite is related to the capture and exploitation of the information and knowledge that is generated within an organization. What is the nature and form of this information? It includes not only the continuous information streams such as e-mail messages, telephone calls, minutes of business meetings with external parties, and other documents, but also the information and knowledge that is generated within the organization. The latter is typically fragmented throughout the organization and much of it is potentially lost soon after it has been created and used for a particular purpose. It ranges from the minutes of internal meetings, proposals, reports, white papers, technical references, to the cumulative experience and knowledge that resides in the memory of the members of the organization. In most existing organizations attempts to capture this information vary from formal systematic efforts such as maintaining an on-line database of customer service calls and response actions, to some nebulous knowledge of who worked on a particular project and might therefore be able to contribute some key information to the current problem.

With the increasing realization that the information and knowledge generated through the internal and external activities of an organization constitutes a major asset and must therefore be a key component of any knowledge management plan, many organizations are asking themselves the following questions: What are the fundamental elements of this resource?; How can this resource be efficiently captured at the source and stored electronically?; Does this resource have to be processed (e.g., validated, analyzed, and evaluated) in some way to make it useful?; and, How can we provide convenient access and yet keep this valuable resource secure? These questions form the focus of the remainder of this paper.

The fundamental elements: The principal elements or building blocks of a knowledge management system are data, information, knowledge, and wisdom (Figure 5). Data essentially are numbers and words without relationships (Pohl 2001, 2003). We human beings are able to interpret data into information by utilizing the context that we have accumulated in our cognitive system over time (i.e., our experience). Computers do not have a human-like cognitive system and therefore any data stored in a computer will need to be interpreted by the human user (Figure 6). While the computer is able to order, recast, categorize, catalog, and process the data in many different ways, it cannot use it as the basis of any reasoning sequence. However, if we store not only the data but also at least some of the relationships that place the data into context then it is not difficult to develop software modules (i.e., agents) with reasoning capabilities. In this way it is possible to develop computer software with increasing understanding of what it is processing.

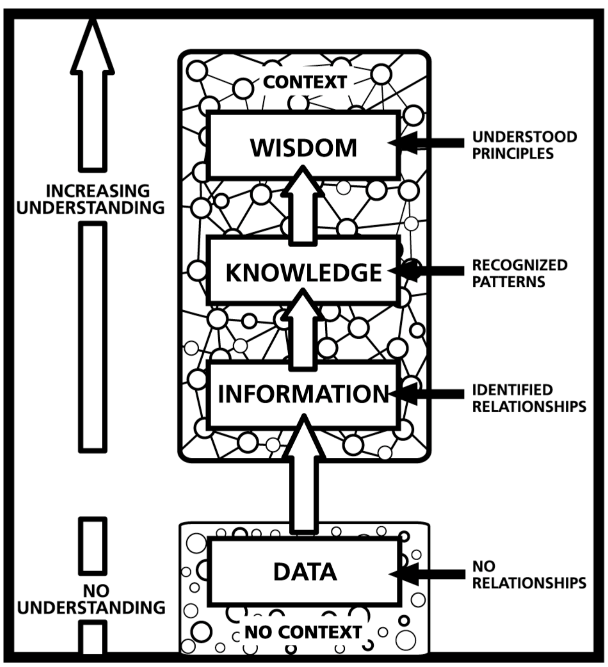

Figure 5: Importance of context

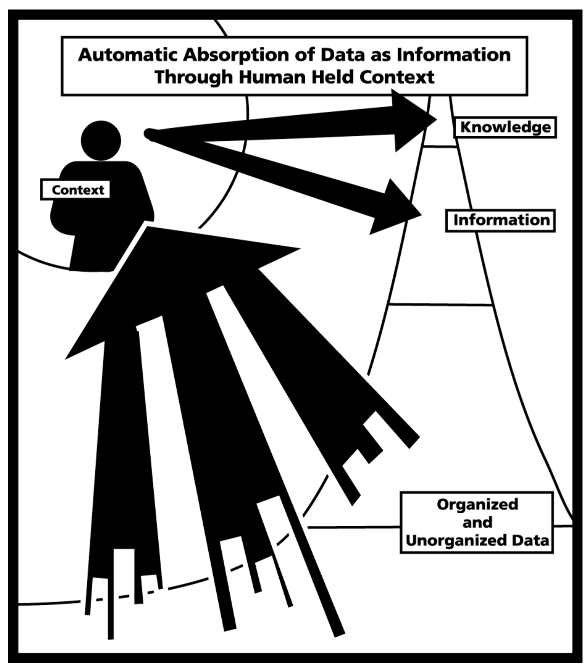

Figure 6: Human interpretation of data

The ability to represent information in computer software has been available for at least the past 30 years (Winston 1970, Biermann and Feldman 1972, Cohen and Sammut 1978). Hampered initially by a lack of hardware power and later by the absence of any compelling need to involve the computer in the direct interpretation of data, these information modeling techniques were not applied in the mainstream of computer software development until very recently. The compelling reasons that have suddenly brought them to the foreground are the increasing volume of computer-based data that is beginning to overwhelm human users, and the homeland security concerns that emerged after the tragic September 11, 2001 terrorist incidents in the United States.

The physical gap that is shown schematically between the realms of the data environment without context and no understanding and the information environment with context and ascending levels of greater understanding in Figure 5, is intended to underscore the fundamental difference between the two realms. The transition from data-processing software to information-centric software requires a paradigm shift in the human perception of the role of computers. Incorporating an internal information model (i.e., ontology) that represents portions of real world context as a virtual environment of objects their characteristics and the associations that relate these objects, information-centric software is capable of performing a useful level of automatic reasoning. A number of software agents with relatively simple reasoning capabilities are able to collaborate and through their collective efforts come to more sophisticated conclusions.

The architecture of a knowledge management system: Since the early 1970s the ability of computers to store large amounts of data has been increasingly exploited by industry and government. The potential bottleneck presented by these electronic data stores did not become apparent until more recent times with the increasing desire and expectation that their contents should be utilized for planning and decision making purposes. The need to integrate and analyze data from multiple sources led to the concept of a Data Warehouse that is updated periodically with summarized data collected from operational data sources (Humphries et al. 1999). Structured into compartments or Data Marts, each focused on a particular functional area, the Data Warehouse serves as a basis for analyzing historical trends with On Line Analytical Processing (OLAP) tools and projecting future conditions with Data Mining tools. However, the usefulness of these tools is greatly constrained by lack of context. Even though the data in Data Warehouses are typically stored in relational databases, they commonly contain few relationships. Therefore, the ability of OLAP and Data Mining tools to answer What?, Why? and What-if? questions is severely constrained by the very limited context provided by the data.

Data Warehouses are one level removed from operational data since they archive summarized data that are periodically updated according to some predefined timeline. While this makes their contents suitable for historical analysis and planning purposes, it does not allow them to be used for near real-time decision-making which is dependent on operational data. Since the operational data involves many data sources, gateways have been implemented in recent times to provide convenient access to disparate data sources. These gateways are referred to as Data Portals and do not in themselves store data. Apart from accessing the data sources the principal functions of the Portal include the presentation of data to the user. Some Data Portals also include data analysis tools aimed at enriching the presentation capabilities.

Data Portals and Data Warehouses represent a structured data level that integrates the multiple, fragmented databases, files, documents, and e-mail messages that constitute the often only moderately organized operational data flow. By providing access to both the operational data (Data Portals) and the archived summary data (Data Warehouses) this structured data level represents the integrating data layer that constitutes the bottom layer of a knowledge management system, serving as a necessary foundation for an upper information layer (Figure 7). The upper layer utilizes an internal information model (i.e., ontology) to provide context for the automatic reasoning capabilities of software agents. Essentially, these agents enabled by their reasoning capabilities constitute a set of intelligent tools that continuously monitor the events (i.e., changes) occurring in the operational environment.

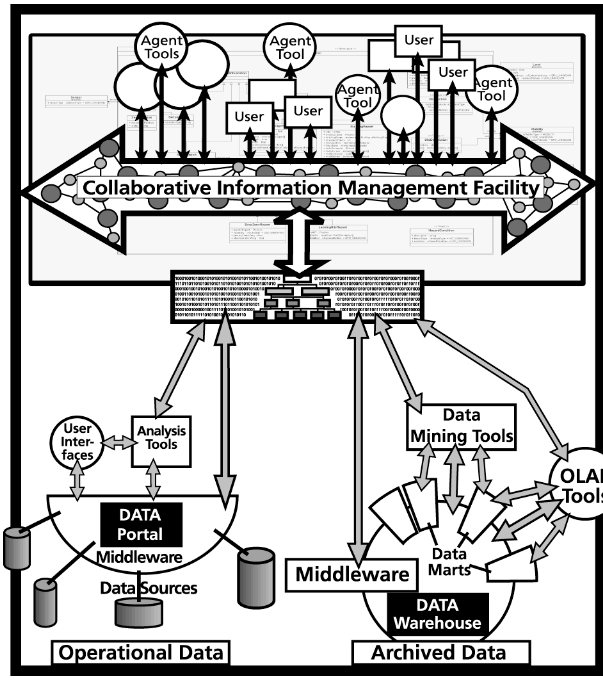

Figure 7: Schematic architecture of a knowledge management system

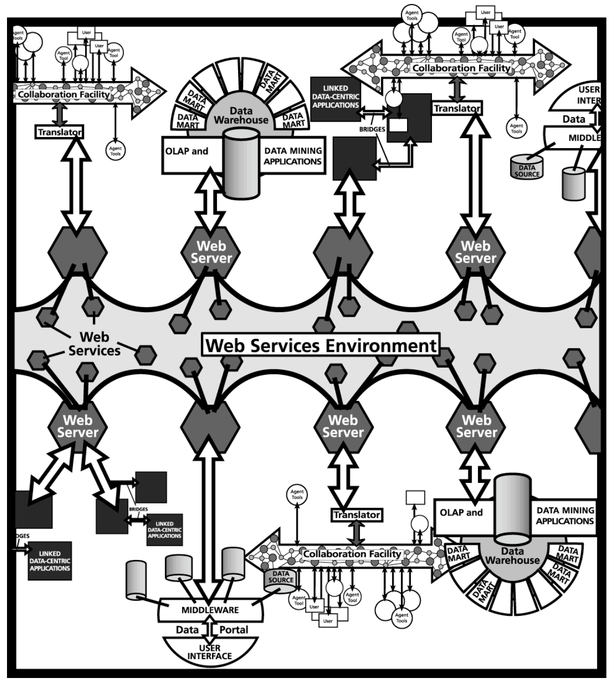

Figure 8: Integration of heterogeneous systems in a Web-Services environment

The interface between the lower data-processing layer and the higher information management layer consists of a translation facility that is capable of mapping the data schema of the lower layer to the information representation (i.e., ontology) of the upper layer (Figure 7). In this manner, the ontology of the information management layer can be populated with near real-time operational data and archived summary data from Data Warehouses. This mapping process should be bidirectional so that the results of agent actions can be readily transmitted to any data-centric applications that reside in the data layer.

Intelligent information management tools: There are many types of software agents, ranging from those that emulate symbolic reasoning by processing rules, to highly mathematical pattern matching neural networks (McClelland and Rumelhart 1988), genetic algorithms (Koza 1992), and particle swarm optimization techniques (Kennedy and Eberhart 2001). In general terms software agents are defined by Wooldridge and Jennings (1995) as "… *computer systems, situated in some environment, that are capable of flexible autonomous actions* …". The three critical words in this definition are situated, flexible, and autonomous. Situated means that the agent receives information from its environment and is capable of performing acts that change this environment. Autonomous refers to the agent's ability to act without the direct intervention of human users. In other words that the agent has some degree of control over its own actions and internal state. And, flexible means that the system is: responsive - by perceiving its environment and being able to respond in a timely fashion to changes that occur in it; proactive - by exhibiting opportunistic, goal-directed behavior and exercising initiative where appropriate;

and, social - by interacting, when appropriate, with other agents and human users in order to complete its own problem solving tasks and help others with their activities.

How do these characteristics of software agents translate to the kind of knowledge management system described above (Figure 7)? The agent tools are situated since they receive a continuous flow of operational information generated by the activities of the organization, and perform acts that may change that environment (e.g., creating alerts, making suggestions, and formulating recommendations). The agent tools are autonomous because they act without the direct intervention of human users, even though they allow the latter to interact with them at any time. In respect to flexibility, the agent tools possess the three qualities that define flexibility within the context of the above definition. They are responsive, since they perceive their environment through an internal information model (i.e., ontology) that describes many of the relationships and associations that exist in the real world environment. They are proactive because they can take the initiative in making suggestions or recommendations (e.g., transportation mode selection for a particular shipment, emergency team configurations in crisis management situations, or route selection for moving troops or equipment) and they do that in an opportunistic fashion. For example, when an emergency call is initiated, a Route agent may immediately and without any explicit request from the user, determine the optimum route under current traffic conditions that should be used by the ambulance to reach the injured person.

The ability of software agents to communicate (i.e., socialize) with each other and with human users to work on their own problems or assist others with their problems, is a powerful capability of the information layer in a knowledge management system. It allows several agents to collaborate and concurrently explore different aspects of a problem from multiple points of view, or develop alternative solutions for future negotiation.

Symbolic reasoning agents that are quite common in knowledge management systems incorporate collections of rules that monitor specific conditions and generate alerts when these conditions are satisfied. The general design of such an agent consists of three components: the conditions that trigger the agent (i.e., the functional specification of the agent); the objects and their attributes that are involved in these conditions (i.e., the part of the internal information model (i.e., ontology) that is used by the agent); and, the logic that defines the relationships among these objects and attributes.

One important aspect of autonomy in agent applications is the ability of agents to perform tasks whenever these may be appropriate. This requires agents to be continuously looking for an opportunity to execute. In this context opportunity is typically defined by the existence of sufficient information. For example, to identify a shortage of inventory either some agent has to monitor the consumption of the particular inventory item until there is a shortage and then issue a warning, or one or more agents collaboratively project that based on developing conditions there is likely to be a shortage of the given item at some specific time in the future.

The requirements for rule-based agents are defined in terms of two elements: conditions; and, actions. The conditions are the specifications of the situation that the agent monitors, while the actions are the alerts that should be generated when these conditions are true. Typically, conditions are specified in terms of objects, attributes and the relationships among them. Each condition is formed by a pattern of object, attributes, values, and Boolean tests. Patterns are grouped by logical connectors, such as AND, OR, and NOT. The more patterns and relationships that are specified, the more specific these conditions become. The right hand side of a rule represents the actions to be taken when the conditions are satisfied. The most general type of action is to generate an alert. However, there are many other kinds of actions that rule-based agents can perform (e.g., look for additional information, modify an existing schedule or generate a new schedule, develop a particular solution approach, simulate the likely outcome of a course of action, and so on).

The Web-Services environment: A knowledge management system may be implemented as a set of Web-Services on the Internet or in any intranet environment (Figure 8). Existing Web-Services environments typically comprise a Web Server that utilizes the Hyper-Text Transfer Protocol (HTTP) for communication, the Universal Description Discovery and Integration (UDDI) protocol as part of the standard definition of Web-Services registries, and a Registry that already contains an entry for the accessing application as well as any number of other Web-Services. UDDI is an international standard that defines a set of methods for accessing a Registry that provides certain information to an accessing application. For perhaps historical reasons UDDI is structured to provide information about organizations, such as: who (about the particular organization); what (what services are available); and, where (where are these services available).

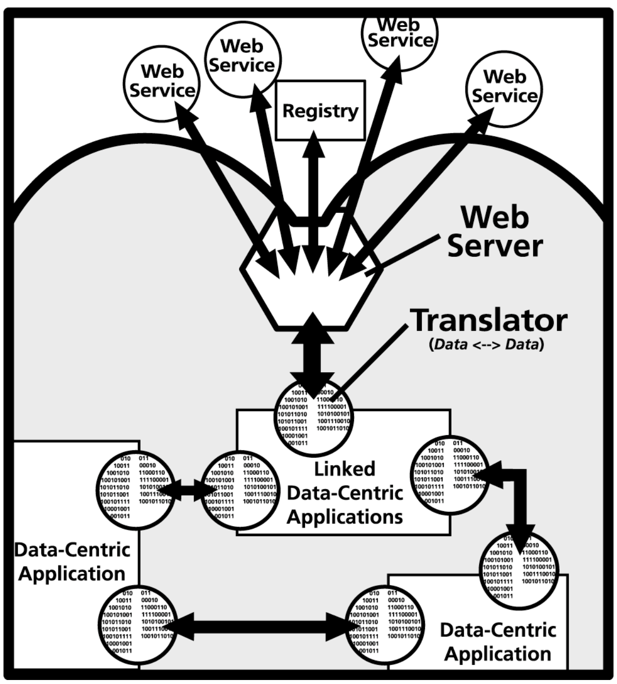

Figure 9: ‘Exposing’ a data-centric application to a Web Server

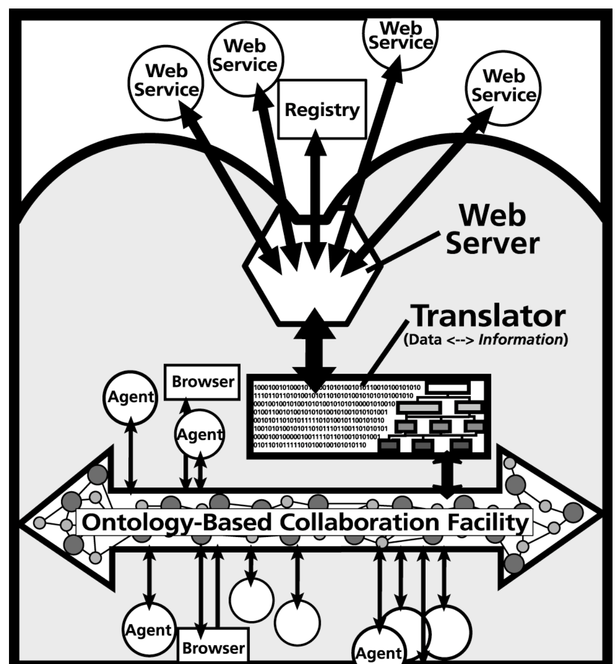

Figure 10: ‘Exposing’ an information-centric application to a Web Server

The Simple Object Access Protocol (SOAP) defines a protocol for the direct exchange of data objects between software systems in a networked environment (Figures 9 and 10). It provides a means of representing objects at execution time, regardless of the underlying computer language. SOAP defines methods for representing the attributes and associations of an object in the Extensible Markup Language (XML). It is actually a meta-protocol based on XML that can be used to define new protocols within a clearly defined, but flexible framework.

Web-Services are designed to be accessed by software. In the currently prevalent data-centric software environment they are generally clients to the middleware of data sources. The middleware collects the required data and sends it back to the Web-Service, which reformats the data using the SOAP protocol and passes it onto the requester. Depending on its original specifications, the requesting application will have the data downloaded on disk or receive it directly on-line. If the Web-Service is a data-centric application then a data-to-data translation must be performed in much the same way as would be necessary when passing data between two data-centric applications (Figure 9). In the case of an information-centric Web-Service a data-to-information translation is performed when the Web-Service receives data from an external source and an information-to-data translation is performed whenever the Web-Service sends information through the Web Server (Figure 10).

Exposing the data sources within the data layer and the information-centric components of the information management layer of a knowledge management system (Figures 8) to a Web-Services environment provides a means of integrating and conveniently accessing a heterogeneous set of software applications. By treating these applications as Web-Services and advertising these services in a registry enables the implementation of client applications that can utilize functionality from multiple applications (i.e., Web-Services). Clients can discover services based on service type, rather than being restricted to a specific service at a known location. The use of SOAP and other XML-based languages for communication frees both server and clients from dependence on a particular programming language or operating system.

Conclusion

We have entered a period of transformation with several dominant traits that are individually distinct and yet, on deeper examination, appear to be closely related. Separately, they are readily discernable as the enablement and increased value associated with each individual person, the flattening of organizational structures, and the elevation of the computer to the role of an intelligent assistant in an emerging human-computer partnership. However, considered in conjunction they have a common thread.

While the capabilities of the individual are being significantly increased by the availability of more and more powerful computers and faster communication networks, it is the skill that the individual acquires to utilize these enabling facilities that largely determines the value of the individual to the organization. To take advantage of the enabled individual, organizations have had to adapt both in terms of their structural model and management practices. Clearly, persons with powerful tools, expert skills to use these tools, and confidence in their abilities, will demand a high degree of autonomy, a share in the decision making process, and the freedom to exercise their initiative. As the potential value of the contributions made by the individual person increases there is likely to be greater concern by the organization to capture the information and knowledge that is being generated by all of the contributors in the organization.

Soon the volume of information generated by the organization increased to the point where it could no longer be maintained by the human contributors who were, in any case, busy generating more information. It became necessary to utilize the computer to assist in the management of the informational resources of the organization. While initially these management functions could be conveniently divided into the data-processing tasks undertaken by the computer and the interpretation of information into knowledge undertaken by its human users, over time even the information interpretation component became overwhelming.

Closer examination of the data-processing bottleneck has drawn attention to the fundamental difference between data and information, and the need to represent information rather than data in software applications. In this way, by providing context, information-centric software is able to support intelligent tools (i.e., software agents) with reasoning capabilities. The implications are profound and represent a paradigm shift. The role of the computer is being transformed from a visualization and computing device with no ‘understanding’ of what it is processing, to an intelligent assistant that is able to make intellectually meaningful and useful contributions to its human users. In this respect the new knowledge management paradigm is a natural outcome of the gradual merging of human and computer capabilities into a collaborative partnership.

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Appendix – Glossary of Terms

Data: Numbers and words without relationships. Even though data are often stored in a relational database management system, typically only minimal relationships are stored with the data. Without adequate relationships, data do not contain sufficient context to support automatic reasoning capabilities by software agents.

Data-Centric: Software that incorporates an internal representation of data (i.e., number and words) with few (if any) relationships. Although the data may be represented as objects the lack of relationships, and therefore the absence of context, inhibits the inclusion of meaningful and reliable automatic reasoning capabilities. Data-centric software, therefore, must largely rely on predefined solutions to predetermined problems, and has little (if any) scope for adapting to real world problems in near real-time. Communication between data-centric software applications is typically restricted to the passing of data-string messages from one application to the other. This imposes a larger transmission load than communication between information-centric applications. Since a data-centric application has no 'understanding' of the data that it is processing, a complete set of data must be transmitted so that the receiving application can process the transferred data in the appropriate predefined manner. For example, if the data to be transmitted involves the new location of an automobile then a complete set of data describing the automobile (including its new location) must be transmitted. In the case of information-centric applications only the new location and some object identifier would need to be transmitted, because both the transmitting and receiving applications have some 'understanding' of the general notion of an automobile and the specific instance of that notion representing the particular automobile that has changed its location.

Information: Data with relationships to provide adequate context for the interpretation of the data. The richer the relationships the greater the context, and the more opportunity for automatic reasoning by software agents.

Information-Centric: Software that incorporates an internal information model (i.e., ontology) consisting of objects, their characteristics, and the relationships among those objects. The information model is a virtual representation of the real world domain under consideration and is designed to provide adequate context for software agents (typically rule-based) to reason about the current state of the virtual environment. Since information-centric software has some 'understanding' of what it is processing it normally contains tools rather than predefined solutions to predetermined problems. These tools are commonly software agents that collaborate with each other and the human user(s) to develop solutions to problems in near real-time as they occur. Communication between information-centric applications is greatly facilitated since only the changes in information need to be transmitted. This is made possible by the fact that the object, its characteristics and its relationships are already known by the receiving application.

Context: Meaning conveyed by the combination of data with relationships.

Data Portal: Provides access to operational data, with an emphasis on the presentation of data (usually to human users). Data Portals may also incorporate data analysis tools, and are often accessed in a Web-Services (e.g., Internet) environment. A Data Portal typically does not store data but provides access to data sources that contain stored data.

Data Warehouse: Stores and manages summarized (i.e., archived) data, usually in a relational database management system. The summarized data are periodically updated according to a predefined timeline. Data Warehouses often employ sophisticated data indexing mechanisms (e.g., based on key word indexing schemas) to facilitate the rapid retrieval of data.

Data Mart: A subset of the data stored in a Data Warehouse that is focused on a particular functional area.

OLAP: On Line Analytical Processing (OLAP) tools extract answers to Who?, What?, and Why? queries, constrained by the very limited (if any) context provided in a Data Warehouse (or Data Mart).

Data Mining: Data Mining tools analyze the data in a Data Warehouse (or Data Mart) to establish relationships, identify trends, and predict future trends.

Ontology: An information structure, rich in relationships, that provides a virtual representation of some real world environment (e.g., the context of a problem situation such as the management of a transport corridor, the loading of a cargo ship, the coordination of a military theater, the design of a building, and so on). The elements of an ontology include objects and their characteristics, different kinds of relationships among objects, and the concept of inheritance.

Collaborative Agents: Software modules that are capable of reasoning about events (i.e., changes in data received from external sources or as the result of internal activities) within the context of the information contained in the internal information model (i.e., ontology). The agents collaborate with each other and the human users as they monitor, interpret, analyze, evaluate, and plan alternative courses of action.

Security Contingency Planning Matrix:
Cues . Perception. Psychophysical Systems . Performance Criteria . Surety …. for Life-Quality and Environment

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Overview :

There are myriads of processes flowing in our world, all working towards a quality of life. There are key products to this process from the air we breathe, food we eat, shelter we build, the life about us, things we work at, the generation of power, to the money we make. The processing flows that maintain those products need to be steady and consistent to balance the ecology of all those forms of life within our environment.

We are familiar with the development sequence to plan-incorporate-finance-design-build-operate-manage. As interdisciplinary professionals we often assume this predictable, probable sequence of development from the good times. We react to damaging changes by trying to recover those same sequences we so carefully planned. Like insurance we patch up after the catastrophy in the same old way merely to wait for the same old thing to happen again. Today deliberate terrifying threats are changing that predictable process so now we need to *anticipate* those devastating uncertain events by planning actions to *counter those sporadic contingencies* ahead of time.

Enter the security contingency planning matrix. Consider a process *creating a product;* it may behave in a *usual or un-usual way*. There are cues that detect this change. Each *cue is a precursor to an unfolding event* in the process. There are predetermined key criteria to collaboratively respond to that precursor and to simultaneously *feedforward and feedback* for further cues to confirm both the precursors and unfolding events. Here we collaboratively decide actions to counter the contingent threat and-or breach in security of the process. *Security Shell* protection and vulnerability criteria progress both in the severity *to impair, impede or threaten* and in *the product, process or context*.

A planning matrix provides a framework for appropriate actions to progress as the events unfold in a real time context. *Columns follow the product back through the process to the context. Rows compare cues between a usual and unusual process*. *Cues trigger the contingency plan for collaborative decisions* as to the threat or breach for reaction, recovery or countermeasures. This ties in with an overall matrix management disussed in a previous paper (Ref.1). A 12 chart *Compendium of Psychophysical Systems* provides sensing Cues for perceptual responses, related environmental stimuli and design criteria.

Contingency criteria for cues are discussed as *heuristic sporadic models* of chance discovery rather than as predictable probability models of known events. People's sensory perceptions and automated sensor systems are linked by psychophysical methods. *Life-quality response criteria* are outlined as related to environmental stimuli in threshold, growth, optimum, enhanced, impeded, impaired, decay *ranges of performance*, according to the changes in *stimulus power*. We suggest ways to improve performance, vigilance, security, to set environmental standards and to assess the surety of security for gain and against loss.

Security Contingency Planning Matrix :

Our world has multitudes of **"processes" at work** that **"produce" many "products".** They range from the chemistry of life to the things people makre and do. We focus on those products that sustain our lives, stabilise a livable environment and maintain economically viable communities. In setting priorities we can ask how important is each product in its support of those objectives for life-quality. Immediately we find there is an interdependence of products and processes. Thus we **group dependent products and processes** and ask "what if ….. the … **"un-usual" happens from the "usual"** passage of life events? ", then, "**what needs to be done** about it?" This is a **Contingency Analysis** where one thing depends or is contingent upon another.

Contingency is the **chance that a sporadic event could happen**. In our case it is the **chance between the un-usual and usual being sensed** or detected from the prevailing cues. Now we **cascade the cues** with a decision tree approach by looking forward, backward and expanding the process events to find more relevant cues as to the changes happening in the usual processes. This is a unique investigative method in contrast to the customary controls which limit the cues to only probable events and causes. So planning for contingencies anticipates scenarios to a wide range of cues that could happen, sets up the "sensors" for sensing the changes, cascades the cues, establishes decision-making sequences for the **precursors to events that could follow**, then provides avenues for responsible decisive action to counter or accommodate those precursors.

Process and product improvements can be made by creating a better "un-usual event. In testing we vary parameters to get an optimum performance. In facility management we **change procedures to to improve the economy** of operations. In marketing we have samples and trials to find a better way to proceed. Some architects improve their design from their experience and client desires. Most of us are familiar with program evaluation review techniques PERT, critical path analysis CPA, and Gantt charts in decision-making. These are probable sequences of events and can be analyzed with probabilistic models. With contingency analysis these models would continuously change with the varying context so we **use heuristic models** of chance discovery to analyze the sporadic events. We **cascade the cues** rather than narrow the probable degrees of freedom.

Security seeks to **prevent change** and **identifies any vulnerability** to change in the "usual" product and process. It is nutured by ,management to ensure a probable predictable outcome in usual events. The question nowadays is how intrusive can the security be before it impedes the usual process and cues to its change.. Automatic controls regulate processes beyond a sustained capability of people's control. Automated controls add a programmed dimension. Expert system programs with the rudiments of heuristic control bring us closer contingency planning. However, trained human sensing of cues and decision-making remain a basic link for responsible action.

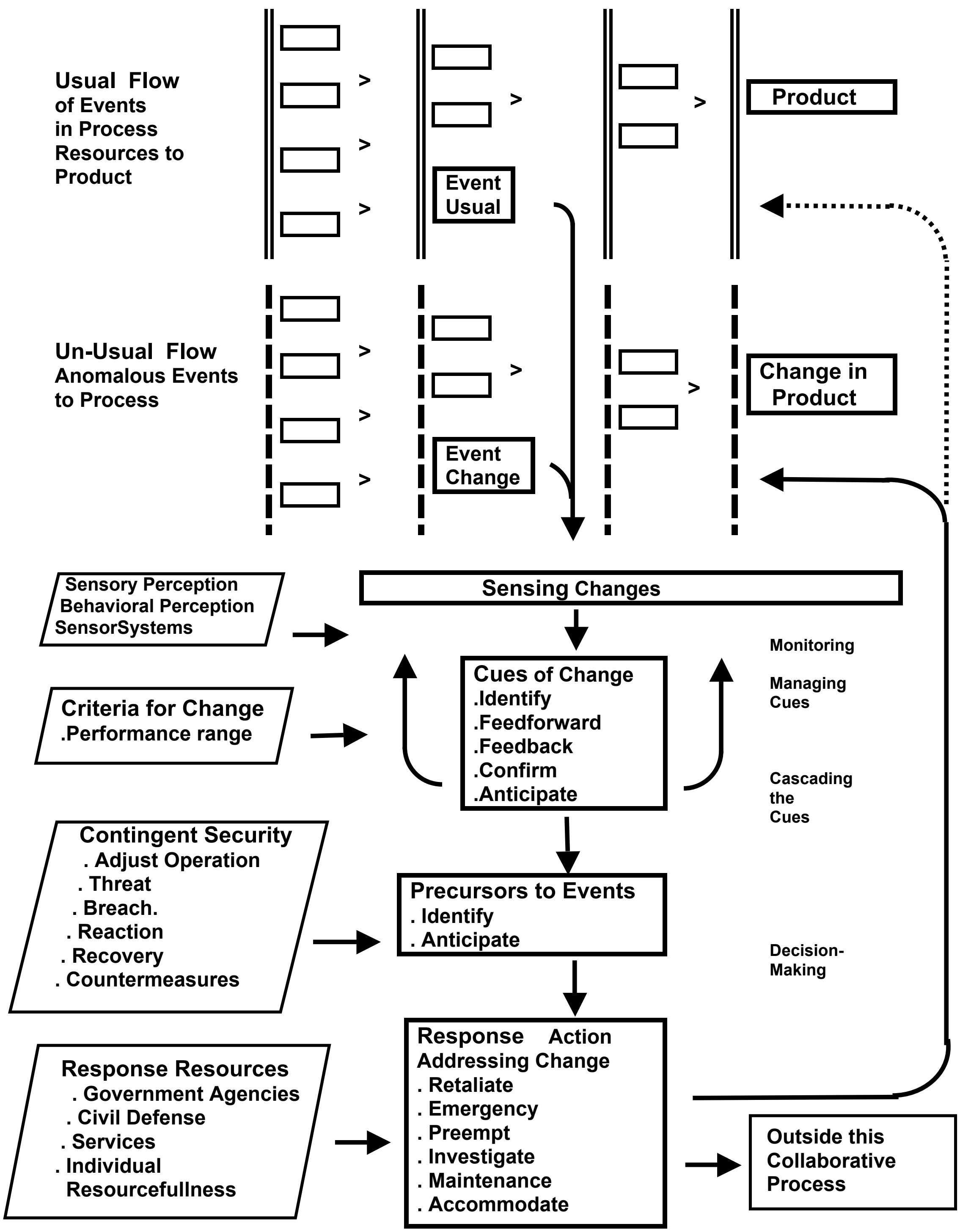
Security breaches and process malfunctions are traditionally treated as probable emergencies with alarms directed both inside and outside the process. With usual predictable hazard precursors this can be fine. However with unauthorized entry, sabotage, chemical spills, dangerous leaks,,….. an alarm must also provide information about the breach, what people should do and for only those affected. A classical problem is with an elevator, "in case of fire do not use the elevator"…. Well what do you do? I suggest **sequential directions** like, "fire, elevator stopped, go exit, stair down". Covert activity could well be responded covertly too by "silent alarm" with a documentation of the unfolding events. Burglar alarms on buildings are ineffective with so many false calls they tend to be ignored or the culprit gets away in long response times. **Silent alarms** have been installed in schools and banks for the staff to call for help without raising the anxiety of those around.

Security Contingency Planning Matrix

Security Shell Criteria

Protection – Vulnerability . . .

Criteria to	Context	Process	Product
Impair	*C*	*B*	*A*
Impede	*F*	*E*	*D*
Threaten	*I*	*H*	*G*



John F. Halldane Feb 2003

Context

Security alerts must be specifically focussed for only the **people or thing affected** and **for those trained to respond** in specific ways. Otherwise more harm can be done to those without knowledge of how to respond to designated dangers. A recent national "orange" security alert called for duct taping windows, but this cuts off indoor ventilation which with gas stoves can poison the occupants with carbon monoxide … a far greater hazard that did happen in the 1973 oil crisis to save energy. "Color" alerts have no meaning to the public and with no action to take it only raises public anxiety. Even bomb alerts in DC during the 70's meant bag searches and building evacuations, however we all understood the threat because the reasons were disclosed at a local security level to those immediately affected. Also a degree of alertness is meaningless without a specific context. This is because security breaches are contingencies until events unfold to become emergencies that are well programmed for a response.

Readiness is a preparedness to appropriately **respond to probable emergency** situations and to have a **"common sense" during contingencies**. This needs training in the general education of a community. We have all experienced fire drill, earthquake drill in California, tornado drill, hurricane preparations, …. but we are less ready with air raid drill, first aid, cardio-pulmonary resuscitation cpr, healthy lifestyle, home hazards, food and water contamination, …… In Singapore there is an "Emergency Handbook" by the Civil Defence Force. Contents of the well illustrated booklet are in the following box. The motto is "readiness is your only protection". There are frequent community and TV demonstrations and drills on civil defence readinesss from water rationing, fire ladder evacuations, rappelling down highrise housing flats, first aid, hazardous chemical spills, siren alarm tests, … Futher all males in Singapore do 2-3 years National Service. Unfortunately this puts them back in their higher education. In New Zealand we did Compulsory Military Training in camps during university breaks, weekends and night training workshops. Today I would advocate "**Compulsory Readiness Training"** for all civilians of voting age where they participate in appropriate programs together during school vacations, weekends or in recognized camps. Registration in a program would allow those participating citizens to be eligible for government services such as health benefits, civil service, social security benefits,…

Readiness in Civil Defence. . . . ***Readiness is your only protection***

Rescue :	**FIRST AID How to stop bleeding . 4 MAIN PRESSURE POINTS . Treating Fractures . Treating Burns and Scalds . CARDIO-PULMONARY RESUSCITATION . CHOKING obstructed Airway of a Conscious Adult . Obstructed Airway of an Unconscious Adult . Transporting Casualties Without a Stretcher . FIRE SAFETY What to do if a Fire Breaks Out . Operating a Fire Extinguisher . When You are Trapped. If Your Clothes Catch Fire .**
Tremors :	**WHAT TO DO IN AN EMERGENCY . When a Tremor Occurs . After the Tremor Stops .**
Survival :	**EMERGENCY PROCEDURES . Water Distribution . Food Rationing . Fuel Rationing . Blood Donation . STOCKPILING ESSENTIAL HOUSEHOLD ITEMS . Items to Stockpile**
Protection :	**PUBLIC WARNING SYSTEM . Public Warning Systems . Responding to an Alarm Signal . SHELTER PROTECTION . Public Shelter Procedures PREVENTING DAMAGE . Protection of Glass Surfaces . Removal of Objects . Defensive Precautions . Personal Safety**
Source :	Emergency Handbook…. Singapore Civil Defence Force 2001

. . . be READY . . . anticipate threats . . .
. . . cascade cues . . . identify precursors
. . . ***collaborate*** **. . . take appropriate action . . .**
. . . follow through

Security shells are the degrees that the product and process are **both protected and vulnerable to disruption**. For me, if the product blows up it is a "*Shell A*" catastrophe that irreversibly impairs the product. I rememeber when an electrician in a nuclear power plant caused a fire with a candle of all things; it caused I believe a "level 6" emergency!? then later they said a "level 9" was a reactor meltdown?? There were no comparative criteria for evaluating the severity of the situation so the "level" information was useless. Further the public had no idea whether it would lead to a Chernobyl like disaster in global radiation fallout. Our present Security Alert color code suffers the same way. Any **alert** must address the **specific threat to the process-product** for the **appropriate collaborative agents** to respond. May I suggest the following Security Shell approach based on severity criteria to impair, impede or threaten the product, process or context. Note that Shells A-F are in-progress emergency situations with action based on well tried probability models. Shells G-I are sporadic unpredictable contingency situations with behind the scene action based on "what if" trends in heuristic models.

Security Shell Criteria. . . ***for protection and vulnerability***

Shell	***A***	**Impaired Product :**	**Irreversible damage . hazardous condition . destroyed .**	**Probability : . . . Models**
Shell	***B***	**Impaired Process :**	**Irreversible stoppage . vitals inactive . resources out . facility closure .**	
Shell	***C***	**Impaired Context :**	**Irreversible damage to supporting context and collaboration . invasion .**	
Shell	***D***	**Impeded Product :**	**Reversible damage . strikes . delays .**	
Shell	***E***	**Impeded Process :**	**Reversible stoppage . breakdowns . walkouts . sabotage . supply faults . bypass components .**	
Shell	***F***	**Impeded Context :**	**Reversible damage to supporting context and collaboration . demonstrations . utility interruption**	
Shell	***G***	**Threatened Product :**	**Contingency to product impairment, impediment boycott . weather conditions .**	**Heuristic :**
Shell	***H***	**Threatened Process :**	**Contingency to process impairment, impediment . union dispute . sabotage . maintenance . safety .**	
Shell	***I***	**Threatened Context :**	**Contingency to context impairment, impediment war . depression .**	

John F Halldane March 2003

Performance of Life-Quality Processes :

Life-quality **responses depend on chemical reactions excited by the stimulus power** from their physical environment through their physiology. The ***chemical concentration*** **(c)** of an **active life ingredient** dissociates according to the environmental ***stimulus power*** **(P)**. A simplified model is expressed in the form $\mathbf{c^2 / (100\text{-}c) = P}$ in steady state, for any stimulus mode, such as for energy, heat, light, sound, acceleration,… By plotting the stimulus on a $\mathbf{\log_{10} P}$ **scale** the concentation c takes an ogival form as shown in the sensor and perceptual response chart following. This explains most of the basic responses of the sensory receptors, life processes, growth, metabolism, contamination,… from detectable conditions, optimum performance to impeding and impairing situations.

Neural processes in creatures and people behavior follow the ***changes in stimulus*** **Power _P** . In turn those **neural responses activate the sensory perceptions** in the brain for the visual, auditory, cutaneous, tactile, olfactory, gustatory, vertigo, kinesthesis, visceral sensory responses (Ref.2,10). By taking the "slope" of the ogival concentration to stimulus power $\Delta \mathbf{c} / \Delta \mathbf{P}$ we get a **perceptual response curve that peaks in performance**. This is illustrated in the sensor and perceptual response chart with examples for visual brightness, auditory loudness, metabolic warmness-coolness, air stuffiness and a generalized task performance. Note here there is an **optimum peak performance for certain stimulus ranges**. There must be sufficient stimulus to exceed the sensor threshold for detection. **Too much stimulus impedes**

performance by overloading the system. **Excessive stimulus impairs performance irreversibly** or by taking an exceedingly long time to recover. For instance it takes about 5 minutes to adapt to daylight from a dark room and about 20 minutes to dark adapt for night vision. This relationship between response and stimulus is termed **psychophysics**. A 12 chart "***Compendium of Psychophysical Systems***" has been attached to this paper for readers to understand these processes and to apply the principles in appropriate ways. A key part of the Security Contingency Planning Matrix is to sense the changes between the usual and un-usual process flows. Much of this is based on people's perception of the differences in cues. You need good visual, auditory, olfactory, gustatory, tactile,… perceptual conditions to do this, so the charts direct you in ways to allow for it.

Life-quality requires corresponding **environmental stimulus standards** to be based on ***optimum performance*** criteria. Pollution contamination strengths and safety conditions are generally based on epidemiology **death and handicap statistics that are impairment criteria** in legislation that **guarantees death or handicap**. Ethically society does not allow us to test people's responses to the point of impairment; we do not make them blind, deaf, numb, sick,… handicapped. Instead we are restricted to psychophysical tests that only **go to the point of impeding performance** so subjects can recover without harm. People were falling and getting crushed in fire escapes during egress so the National Bureau of Standards was asked to study ways to make them safer. You could not make subjects fall, so we flipped the question to ask what makes it easier to go down stairs without being impeded. Essentially we looked for cues for optimum performance then cues that would impede a person rapiding walking down stairs. This would then avoid impairment in falling and crushing.

avoid standards based on death and handicap statistics . .
. . . . . this guarantees death and handicaps

Optimum Response (R) criteria are about 16-28% of the Impeding Stimulus Power (P) criteria and about 50-60% of the Impeding Sensor Response (c) criteria. Power is the energy/time, chemical concentration flows, strength of the environmental stimulus. On the chart, sensor and perceptual responses, you will note this is generally true for all modes from the visual, auditory, metabolic, air quality to task performance.. It means that **legislated criteria for levels of contamination should be based on about 25% of the Impeding environmental levels** for optimum performance. Preferably we should take

The optimum levels directly; for example, **clarity in vision at about 60fL**. Unfortunately Occupational Safety and Health standards consider these as "comfort" and not safety, so we could propose glare at 200fL as an impeding limit for safety. The interesting one is with **carbon dioxide concentrations at about 1,000 ppm** where we found a new **"stuffy" response** became the **upper limit for optimum performance** (Ref. 15).

. . . adopt stimulus power standards for
optimum response **performance . . .**
. . . . about 25% of impeding stimulus power

Cues for the Changes in Life-Quality :

The **Compendium of Psychophysical Systems** defines a series of responses that we perceive, the related environmental stimuli, the psychophysical processes involved and design criteria for the applications. Perception depends on a **rapid change in the stimulus to which it *adapts*.** In time a bright room appears to dim as we "adjust" to the light, a loud sound becomes less noticed, pressing on skin numbs, an odor lessens its potency, a strong taste weakens, a hot day more comfortable, we get used to bumpy rides, handicapped adjust,… Security therefore needs optimum conditions to sense the changes in light patterns, sounds, posture, odor, taste, heat from the body, vibration, limits to our physiology. Recording events over time is extremely important in order to present them in a compressed timeframe to sense the longer term changes. It recharges our memory box. There is also a perceptual sampling in time between our sensory modes according to the dominance within a person's behavior. Simply you can not think of everything at once. In emergencies a warning sound is sensed before a flashing light because hearing does not depend on one's orientation in the environmental stimulus field. Security guards get drowsy with inactivity and need to experience a varying stimulus field to stay vigilant. Walking around helps, different monitor positions, counter work,… TV monitoring could well be programmed for changes in motion coupled with a complementary auditory tune and an immediate playback facility. Fire alarms should be coupled to a fire marshall public address to inform the occupants of the nature of the emergency and to remind them of what to do.

. . . understand our sensory responses . . . to surrounding stimuli . . .
. . . for the optimum perception of cues . . . in security planning

Sureness and Riskiness : Surety in Maintaining Performance :

Sureness and riskiness are complementary in maintaining performance. A surer management takes less risk in accommodating a loss or a gain in performance. ***Surety*** **is a security for gain and against loss** ; a responsibility to maintain the system for whatever it does and for repaying the debts that secure the system. Who then provides the surety and who the risk? To answer this we look for those who benefit in the usefulness of the product. Beforehand users need to **assure** producers a market will be made to **ensure** production through sales. A producer before the use of a product **assures** the product's usefulness with a guaranty and warrant of service. Now to cover that **assurance** the producer **insures** within their corporation to indemnify against loss. In turn that corporate indemnity is spread within **other sureties** as **insurance**. An indemnity is a protective security or compensation against future loss, damage or liability.

Indemnities can take many forms. The **assurance** in many communities, villages, kampungs, kibbutz, communes,… is **assumed in a self-sufficient self-reliant economy** where each member contibutes in their way their wealth in service, production and resources. Here outward trade becomes a barter of wealth in an equitable exchange. In fact it is the basis for global currency stability. Even feudal towns became vassal states for security and trade. With **venture capital assurance** is in future earnings from that enterprise in a growing economy, such as in a lease-back, lien or right-to-use share. In our other legal world everything is unfortunately **evaluated and equated in monetary terms as insurance,** with the rest left out as unpredictable, intangible or in acts of God. Insurance requires collateral surety as in property mortgages, bonds, stock. We are finding the security of insurance is becoming less reliable with the reality of economic recessions or depressions, riots, fraud, corruption and the vagaries of nature. The **trust in assurance is eroding**. For example ; floods, hurricanes,, earthquakes… have devastated communities beyond corporate insurance reserves, which now needs national emergency relief to compensate for reconstruction. The **insurance concept here is for replacement**, but to see the same buildings being damaged in the same way year after year, my contention is they **should be designed and built better** to avoid the problem causing the damage. Loan **mortgages have artificially overvalued land** to equate with the improved landuse value in **speculative development**. Foreclosures on defaulted loans have left families homeless and have collapsed banks in overvalued securities that they can not get rid of in depressed property markets. In Denver the 1988 depression created 35,000 foreclosures through unemployment. Islamic banking does not hold to this usury. Currency trading fluctuations without a balance of trade between countries projects risk in foreign investment. Devaluation can make it difficult to recover debt so we need to boost local economies to compensate. We have seen healthcare insurance rise precipitously with arbitrary fee increases, overvalued rents, fraud, untenable malpractice, all in a so called market economy. Our hope rests in trustworthy **re-assurance programs** where there is more understanding of the **sureness of product performance**.

Sensor and Perceptual Responses with Performance Criteria Related to Power of Environmental Stimuli for Life-Quality

Power P of Physical Environmental Stimulus to Log Scale Base 10 with Related Response Criteria

Sensor Response: c

Concentration c of forward-backward chemical reaction to Power P in dissociation form R(c) $c^2 / (100-c) = P$ in steady state.

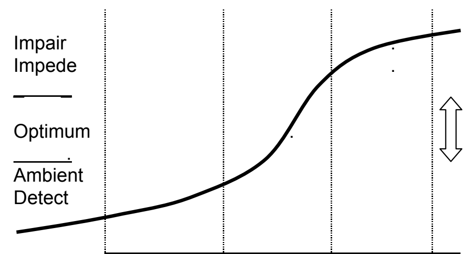
$c \propto P^{0.5}$ "Power Law".

- . sensory receptors . life process
- . growth-decay . metabolism
- . contamination . ogive
- . cumulative process
- . chemical reaction . adaptation

Scale c from "Overload" 100
"Impede" 80

Sensitive> Overload>
Detected> Saturated>

c: 100, 90 Impair, 80 Impede, 70 ____, 60, 50 Optimum, 40 ____, 30 Ambient, 20 Detect, 10, 0



Log10P: 0 1 2 3
c: 10 20 30 40 50 60 70 80 90

Stimulus Power : P

c	P	$\%P_{90}$	$Log_{10}P$
95	18+	560%	3.3
90	810	253%	2.9
80	320	100%	2.5
70	163	51%	2.2
60	90	28%	2.0
50	50	16%	1.7
40	27	8%	1.4
30	13	4%	1.1
20	5	2%	0.7
10	1.1	0.3%	0.05
0	0		

Scale P from "Impede" 100%

Perceptual Response: R

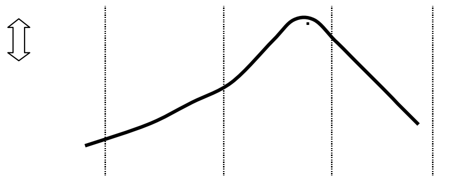
Life systemperception "senses" sensors based on a change in Concentration Δc to the changes in Stimulus Power ΔP and shifts in Sensor adaptation = "slope" of Concentration

$$R = P_1 \frac{\Delta c}{\Delta P} = P_1 \frac{(c_2 - c_1)}{(P_2 - P_1)}$$

- . neural response . perception
- . probability of detection

Threshold> Optimum Impede Impair>

R: 14, 12, 10, 8, 6, 4, 2, 0



Log10P: 0 1 2 3
c: 10 20 30 40 50 60 70 80 90

c	P_1	P_2	P_1 10/ΔP
90	810	18+	4.1
80	320	810	6.5
70	163	320	10.0
60	90	163	12.9
50	50	90	12.5
40	27	50	11.7
30	13	27	9.0
20	5	13	6.0
10	1.1	5	3.0
0	0	1.1	0

Performance Criteria :

Visual Brightness : B
Clearness follows Performance task.
Visibility follows Sensory response
Glariness follows Sensory response
Blindness irreversible $c \propto 95$
$c \propto P^{0.2}$ with light adaptation

Task Clarity [50-60]
Visible [50 - 70]
Glare Impede [80 >]
L(fL) 30 60 100 200 fL
c 50 60 70 80 c

Luminance : L(fL)
footLambert from surface

30	60	100	200	L(fL)
15	30	50	100%	%L
16	28	51	100%	%P
50	60	70	80	c

Auditory Loudness :
Speech Intelligibility Performance over ambient loudness.
Noisiness adaptation of Sensory response.
Deafness irreversible $c \propto 95$

Speech Intelligible [40-48]
Still [24]
Noise Criteria [40 - 80]
N (dBA) 10 30 40 80 dBA
c 24 40 48 80 c

Sound Pressure Level :
N(dBA) =Log in deciBel
"A" weighted for hearing pitch

10	30	40	80	100	dBA
24	40	48	80	95	c

Metabolic Warmess, Coolness :
Sensory response from Neutral
Warmness from Neutral
Coolness from Neutral
Heat Stroke $c \propto 87$ about 100-104 °F
Chilling $c \propto 88$ below 50 °F

Heat Exhaustion . Shivers [80-87]
[10 "Comfort" 60]
°F 75 Neutral to Warm 79 89 100
°F 75 Neutral to Cool 71 61 50
c 10 60 80 87 c

Air Temperature Difference from Neutral (T -75 °F)

0	4	14	25	ΔF_{75}
0	25	100	180	% ΔF_{75}
1	28	100	180	% P
10	60	80	87	c

Air Stuffiness: Air Quality. Pollution
Stuffiness follows Sensory response.
Drowsiness to Carbon Dioxide
Toxic Death $c \propto 90$

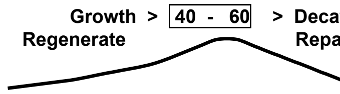
Stuffy 30 - [50]
Drowsy [50 - 80]
ppm 300 1000 7000 ppm
c 30 50 80 c

Carbon Dioxide : CO_2 ppm

300	1,000	7,000	14,000	ppm
4	14	100	200	%ppm
30	50	80	88	c

Task Performance : Economics . R
Aging : Fever. Maintenance. Repair
Train - Experience c improves. grows
Disease - Disuse c degenerates
Peaks when c is about 60

Growth > [40 - 60] > Decay
Regenerate Repair



P% 0.3 2 4 8 16 28 51 100
c 10 20 30 40 50 60 70 80 90

Stimulus Strength: P
Age : Time T
Forward reaction c grows
Backward reaction c decay

John F. Halldane Feb 2003

We ***ensure security***; that is we **make sure the surety is secure** for protection and against vulnerability. It is a responsible action by those who benefit and are affected by the product, process and context. You do not insure security by delegating your responsibility and you **can not insure against contingencies** that can not be predicted by probability. Our Judaic, Islamic and old testament Christian concepts judge a loss with a gain, a pound for a pound, a life for a life, steal the stealer,.. but also add a penalty or punishment beyond any means to recover that debt. No job, no savings, default on a loan payment, lose your property, lose your equity, pay a penalty too for the legal inconvenience, then become destitute hoping for a helping understanding community. Not much assurance in our security against no-growth speculation and insurgence! The legal concepts may be fine if you know the perpetrator of the loss but when it is in a general economic context or the nature of God then with whom do you insure? Right! ; the **surety of living is not insurable**. With wars about us many are asking for "insurance" against losses, predict a budget, predict probable losses,… it can not be done because war has unpredictable contingencies, a sporadic heuristic model of what if's. With no-growth scenarios, depreciating stocks, recessions, unemployment,… the threat of loan foreclosures is devastating the social structures of our communities. Yet speculators expect their pound of flesh, they raise rents, confiscate property, sell it for another spectulator's profit, evict, take any assets,… all with a legal blessing. They are the terrorist within and those **speculators in any judgemental society must share the risk of loss with everyone else**. This is why I have ***evolved a right-to-use property for a share in the business concept*** in financing development. For instance, here a landowner shares in the revenues as they are gained by the using enterprise. During construction and during depressions there are no dividends paid since there is no income from the business. This assurance by all parties ensures the security of financial capital. It is consistent with Islamic principles for an equitable distribution of wealth and a Christian goodness in mankind. These concepts are being demonstrated in freeway with towns development in SE Asia (Ref. 15,16) through urban revival in land-use value and owner-enterprise in order to **avoid future ghost towns** from overpriced land-own value **and speculative planning**.

. . . avoid speculation and future ghost towns . . .
. . . ensure an equitable distribution wealth *and loss*. . .
. . . all parties . . . should share the *surety* in . . .
. . . security both *for gain and against loss* .

Acknowledgement :

It is my pleasure to have the opportunity to contribute to the Focus Symposium on Collaborative Decision-Support Systems through the Collaborative Agent Design Research Center in San Luis Obispo, California.

I truly thank my colleague Dr Jens Pohl of CADRC for this participation.

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Compendium of Psychophysical Systems : . . . *follows in 12 Charts*

These are from the SEACEUM to be published:

People's perception of their environment: The assessment, simulation, analysis and design. John F. Halldane. ISI-SEACEUM-8, Sep 2002. Outlines a psychophysical approach to enquiry and design applications. Reviews 40 years of the author's search, testing, applications and consulting. Compedium of response-stimulus psychophysical systems in environmental design.

Compendium of Psychophysical Systems . . 1

John F. Halldane 1968, 1984, 1997, 2002

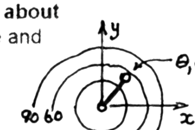
Psychophysical correlations of people's perception of their environment for and within a given stimulus context defined as a . .

- **Scenario of people's activity: the events: the occasion: things they are doing, tasks: . . .**
- **Setting for that activity: ambiance: enhancing environment: surround supporting activity: . . .**
- **Person's Polar (θ,Φ) space and form in time moving as a pole within a Cartesian (x,y,z) world.**
- **Person's ability to respond within their limits of their understanding, physiology, behavior**

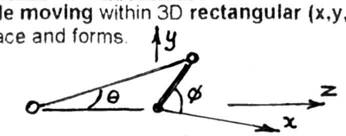
Physiological Responses in Sensory Perception . . .

- **Response Scenario in Polar World** : Person with their sensory receptors as a **Pole** in their **Polar (θ,Φ)** angular 2D world. **Activity scenario** supported and enhanced by stimulus setting about them.

Stimulus Setting as Polar World : **Polar (θ,Φ) setting about Pole** to sense space and form in time.



Distribution in Cartesian World : **Pole moving** within 3D **rectangular (x,y,z)** space and forms.



Design Criteria : **Coordinate systems transformed for person's perception.** 3D to 2D dimension People's senses are in different world from designer's.

- **Receptor Chemical Response** : Receptors respond as a chemical reaction to the stimulus that couples to neural pathway Concentration **C** changes in time from zero stimulus C_o towards C_s in steady state.
- **Receptor Adaptation** : Receptors take **time to change** concentration from adapted level ΔC_s. Forward *F* 'on' reaction faster than back *B* 'off'.

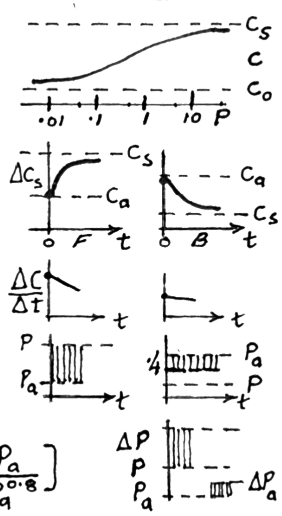
Stimulus Power : Stimulus Power Density **P** causes dissociation. Reaction coupled neural transmitter C_N

$$P = \frac{k[C_s - C_o]^2}{[1-(C_s-C_o)-C_N]}$$

$$C = C_s - C_o = [P/(P+k')]^{0.5} - P \approx k P^n$$

Transient Concentration : Driver is towards steady state C_s. Time "constant" depends on P

$$C_t = C_s - \Delta C_s \cdot e^{-fn[P].t}$$



Design Criteria : Reacts to **receptor sensitivity for steady state** ogive. Stimulus range logarithmic plot. Basis "power law" for used range.

Design Criteria : Response reduces in time by **adaptation** to steady stimulus. Senses "numb". Apparent task adaptation.

- **Neural and Sensory Response** : Perceptual responses and motor reflexes **R** relate to neural frequency **f** of discharge to brain. R varies as f.
- **Apparent Response** : Observed response **R** in **adapted** state for no task.
- **Relative Response** : Observe difference in response **ΔR** between difference in stimulus powers **Δ P** from change in adaptation ΔP_a for specified task or test.
- **Threshold Response** When relative ΔR_H **just noticed** . **H** subscript
- **Pattern Enhancement** : Pattern **step enhanced**; high side higher, low side lower
- **"Combined Response" Cues** : Overall perception of separate responses. **Cues identify**. Make each dominant by change, comparison, mindset on combined.

Change in Concentration : Neural frequency **f** relates to change in concentration **ΔC/Δt**

$$R = f = [C_s - C_{sa}] \cdot e^{-Con.t}$$

Change in Adaptation : Steady stimulation changes concentration level.

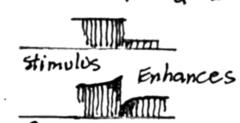
$$R_F \approx R_o [P^n - P_a^n]$$

Contrast in Stimulus Power : Step in pattern, progression

$$R = \Delta f \approx R_{Task} \left[\frac{\Delta P}{P^{0.8}} - \frac{\Delta P_a}{P_a^{0.8}} \right]$$

$$R_H \approx R_{Task} [\Delta P_H / P_a^{0.8}]$$

Neural Lateral Inhibition : Adjacent paths inhibit each other. $F_{\theta,\Phi}$ output from $f_{\theta,\Phi}$ input less surround inhibition f_i.



$f_\theta \downarrow \quad \downarrow f_i$

$F_\theta \downarrow \quad \downarrow F_i$

$$F_\theta = c_\theta f_\theta - \sum_i c_i f_i \frac{a}{\theta_i}$$

Neural Summation : Sum superimposed frequencies from stimuli of separate responses.

"color" Σ 3 receptors f_1 blue f_2 yellow f_3 red

Brightness $= f_1 + f_2 + f_3$ Hue $= f_1 + f_2 - f_3$ Saturation $= f_1 - f_2 + f_3$

Design Criteria : There must be a **change in stimulus** for a sensory response.

Basic **apparent response** to areas stimulated **without task**.

Relative task performance in **comparing difference in responses** to constrast in setting Task **to just notice** an event in a specified setting. Detection.

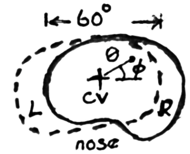
Design Criteria : Patterns **enhanced**. Reinforces "contrast".

Design Criteria : **Cues** in "color","glare","depth", "motion","odor","taste","timbre",. . .

John F. Halldane 1968, 1984, 1997, 2002

Visual Responses in Perception . . .

o **Field Response :**



o **Position :**
Polar field from center of vision.
Subtended 30° cone limit of detail.

o **Separation :**
Angular subtense between points.

$\Delta\theta$ (1. — 2.)

o **Area of Field :**
Solid angle subtended. θ^2 degree^2

$A_{\theta\chi} = \theta . \chi$

o **Texture :**
Pattern of fine color areas

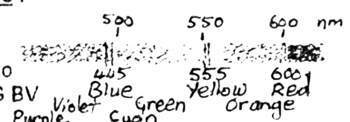
o **Contour :**
Continuity separating areas of different color

Δ Hue
Δ Value
Δ Chroma

o **Shape :**
Contour about an area

o **Polar Perspective :**
Contours of shapes curve to far points.

o **"Color" Response :**



o **Hue :**
Response attribute to spectral light. ROYG BV

o **White :**
Response attribute to white light.
Color without hue.

o **Brightness :**
Magnitude of color relates to Luminance optically

L ... $L_W + L_\lambda$

o **Grayness , Relative Brightness :**
Relative brightness a color to white in field.

o **Whiteness :**
Magnitude of white in a color relative to the brightness.

o **Pureness :**
Lack of white in color.

o **Matching, Threshold Color Difference :**
Compare to see if same, no contour seen.

Form Stimulus :

Location :
Pole in Cartesian space and form.

Subtense :
Angle subtended in arc to observer.

Surface Projection :
Solid area to observer ω steradian

$\theta . \chi = \omega = A_S / s^2 = \frac{A . \cos\alpha}{r^2}$

Fine Pattern :
Repetitive character of material.

Boundary of Change :
Continuity of chromatic change.

$\Delta L, \Delta L_\omega, \Delta L_\lambda$

Form :
Boundary about an area as seen.

Curvilinear Projection :
Polar projection of straight Cartesian lines.

Chromatic Stimuli :

Monochromatic Light :
Narrow spectral band at wavelength λ
Spectrometer incandescent source.

Achromatic Light :
White light of incandescent source.
Balance of complementary spectra.

Luminance :
Light power Lumen/steradian/m² = nit
foot-Lambert fL=cd/π.ft²=3.43 nit

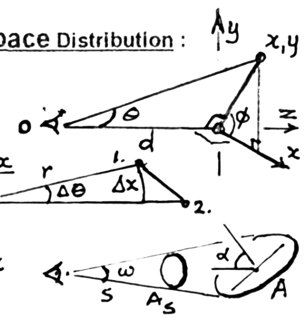
Grayscale :
Neutral Scale 0-10 Black to White

Achromatic Luminance :
White light component of luminance.

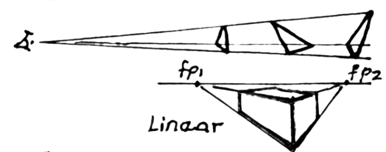
Saturation :
Degree towards monochromatic light.

Munsell Color Chart :
Reference chart with scales for Hue, Value, Chroma

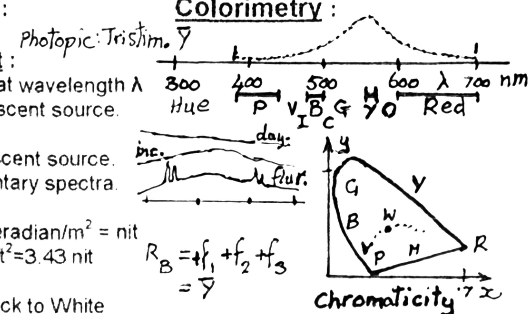
Space Distribution :



$\Delta\theta = \frac{\Delta x}{r}$



Colorimetry :



$R_B = +f_1 + f_2 + f_3 = \bar{y}$

$R_W = -f_1 + f_2 + f_3$

$\frac{L_W}{L_\lambda + L_W}$

$R_P = +f_1 - f_2 + f_3$

$\frac{L_\lambda}{L_\lambda + L_W}$

f_{peak} B Y O

Design Criteria :

Person at **Pole. Field 30°** cone
Binocular field.

Fineness. Acuity. **1'** threshold

"**Brightness glare**" Detection.
Motor responses.

Color patches 0.02-0.4 deg

Line description, sharp, blur,..

Outline. Depth cue. Recognise

Simulates visual field.
Drawing forms. Depth cue.

Design Criteria :

Visible spectrum "color"
Munsell **Hue**

Daylight. Incandescents
Balanced fluorescents
Photopic corrected spotmeter
Luminance photometry.
Retinal illumination.

Munsell **Value**

Cue for pureness and grayness

Munsell **Chroma**

Color **comparison to match or contrast patterns**.

Compendium of Psychophysical Systems . . 3

John F. Halldane 1968, 1984, 1997, 2002

Contour Responses :		Contrast Stimulus :	Process :	Design Criteria :
o **Hue Difference** :	Δ Hue	**Chromaticity Contrast** :	Hue shift as rotation about White , Saturation shift as radial from White on Chromaticity Diagram.	Colors define contour.
o **Pureness Difference** :	Δ Chroma	**Saturation Contrast** :		**Rendering by illuminant**.
o **Brightness Difference** :	Δ Value	**Luminance Contrast** :	1 fL, 1 mL, 3·2 nit; L, E, 1 fc, 11 lux; 100% Diffuse	**Task performance**. "**disability glare**" cue.
o **Texture Difference** : In fineness, shape, color, brightness		**Fine Pattern Contrast** : Materials, condition, surface...		Articulates surfaces. "**depth**" cue.
o **Apparent Brightness** : Field for difference task.		**Adapted Field** : Task surround	$R_a \approx R_o [L_a^{0.2} - L_o^{0.2}]$	Field **adaptation** for task.
o **Relative Brightness Difference** : Contour stronger with contrast and dark surround.		**Contrast in Field** : Change in luminance from adaptation a.	$\Delta R \approx \Delta R_{Task} \frac{\Delta L}{L_a^{0.8}}$	**Task performance.** More contrast at higher adaptation.
o Contour weakens with veiling field.		**Veiling Contrast** : Veil raises adaptation	$\Delta R \approx \Delta R_{Task} \frac{\Delta L}{[L_a + L_v]^{0.8}}$	Lamp **reflection in task gloss**. "**disability**" glare.
o **Brightness Enhancement** : Difference enhanced. Light lighter, dark darker.		**Neural Lateral Inhibition** : Adjacent areas mutuall inhibit. Boundary simultaneously reinforced.		**Contour-image enhanced**. Lines more pronounced.
o **Banding** : Eye fixation makes light band of mixed colors.		**Eye Fixation on Contrast** : Eye tremors **across** contrast makes light band, mixing color, band width movement nystagmus Δε	0·15° ΔΕ	**Band visible but not clear or sharp**. With white and complementaries white band.
o **Flare** : Spreading from a bright area. Blurs contour. Veils nearby area.		**Suffusion of Contrast** : Entoptic scatter of light in retina. Lateral illumination veils, nearby adaptation up	$L_{V\theta} \approx \frac{L \cdot A_L}{\theta^2}$	**Blurs contour**. Things nearby hard to see. Car headlights. "**veiling" glare nearby tasks**.
o **Threshold, Visibility** : Just noticed contour in task.		**Contrast to Just See** : Contrast follows adaptation.	$R_H \approx R_{Task} \frac{\Delta L}{L_a^{0.8}}$; 30-100 fL	**Detection**. Just see lighting. Old-current lighting criterion.
o **Clearness, Clarity** : Clearest **enhanced** contour. Best **brightness** difference for task. **No veil**. **No fixation** band. **No flare** of contour nor from surround.		**Contrast to See Well** : Good B-W contrast, no veiling, bright spot forms, surround contrasts to distract fixation, task away from bright areas. Snellen Chart in eye testing.	Visible, R_{Clear}, Band, Flare; 30-100 fL	**Lighting criteria to see form**. **Sharp B-W** or monochrome. **Pointillism** painting. Texture surround. Snellen Test. **Lighting from side no veil.**
o **Blur** : Contour of graded color, unfocussed, complementaries gray band.		**Contrast Gradient** : Luminous and chromatic gradient across contrast. Shadow of form.	Color mix over ΔE	Unfocussed, hazy, "depth"cue, shadow suggesting form.
o **Modified Shape** : Acute angles appear to open. Horizontal forms appear to sag. Visual field barrel distorted.		**Eye Optics on Form** : Polar field barrels the form from center of vision. Parallel lines close with distance.	needs camber up; needs tilt back	Compensate by **designing the opposite**, "correction". Use effect as "illusion".
o **Disparity** : Eye views different, slightly rotated polar perspective		**Binocular Rotated Forms** : Two rotated stereoscopic views from eyes superimposed in brain.	Left eye; Right eye	"depth" cue.

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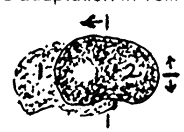
John F. Halldane 1968, 1984, 1997, 2002

o Areal Field Responses :

o **Areal Brightness :**
Apparent Brightness over field Area, photic- phototropic power driving motor responses by field quadrant.

o **Photic Areal Brightness :**
Contracts pupils, induces blink, raises adaptation in veil.

o **Phototropic Areal Brightness :**
Asymmetrical bright areas, involuntary eyemovement towards light.



o **Areal Flicker :**
Bright area pulses with undulating color at disturbing hallucinary slower frequency. Strong 8-15 Hz. 40-60% light modulation. Threshold CFF.

o **Flash :** Discrete flicker :

o **Pattern Flicker :**
Striped pattern loses shape, pulsates, waves, becomes unstable.

o **Apparent Image-After Image :**

Pre-Image		After-Image
hue	➡	hue fading +ve
hue	⇨	complementary -ve
hue	⇨	hue
hue	⇨	hue more saturated
white	➡	colors, black alternating
black	⇨	white fading

Areal Form Stimulus :

Stereo Luminance Change in Fixation :
Stereo-Area ω , power L , receptor density ρ , between fixations 1,2 , modified by lateral inhibition. Transform by Self-Inhibitive Context Diagram for θ
4-quadrant field drives reflexes. Contracts sphincter muscle around pupil.
2-quadrant opposite fields drive vertical-horizontal eyemovement. Asymmetrical power between fixations drives next eye saccade. Back-ve Image=0.4Forward+ve

Intermittent Lumination :
Pulsing luminous area "beats" with brain alpha rhythm 8-**13**-25 c/s.Hz. Critical Fusion Frequency above 15 Hz rising with Stereo Luminance to 40 Hz room range. Pulse period 0.2-**0.3**-**0.5**-1 sec.

Eye Saccade Over Striped Pattern :
Saccades over stripes becomes intermittent stimulus,.
Δθ 0.2-**0.5**-2 deg Stripe Separation
M_{on} 15-**50**-75 % Light On Modulation

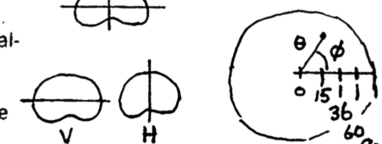
Sequential Chromatic Forms :

Pre-Stimulus		After-Stimulus
monochroma	➡	dark
monochroma	⇨	achroma
monochroma	⇨	monochroma
monochroma	⇨	complementary
achroma	➡	dark
achroma	⇨	achroma

Process :

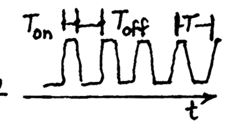
$$R_p \approx e_\theta[L_2^{0.2}-L_1^{0.2}].w_\theta . fn(f_{ij})$$

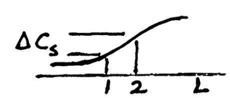
contrast area inhibit



$$f = \frac{1}{T}$$

$$m_{on} = \frac{T_{on}}{T}$$





$$R_F \propto [L_2^{0.2}-L_1^{0.2}] \quad +ve$$

$$R_B \propto 0.4[L_1^{0.2}-L_2^{0.2}] \quad -ve$$

Design Criteria :

Reflexes more powerful in central vision, with greater projected area on diagram, initial dark adaptation, high luminance.
Strains eye. Cue for "discomfort" "blinding" glare
Attraction eye towards light. First involuntary reflex then voluntary if interested. Distraction from task.
Occurs sun through leaves, fluorescent lighting at bad electrodes, under helicopter rotors, light through fans,..
Seisures in epileptics.
Attention. Emergency.

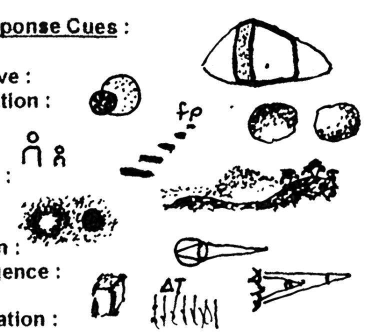
Contrasting stripes, textures, patterns unstable.
Barcode case.
Attention, gaudy design.

Stimulus conditions governed by patterns at each fixation or presentation and adaptation.

Avoid bright TV, computer screen, skylights in dark space.

o "Depth " Response Cues :

o **Polar Perspective :**
o **Shape Interposition :**
o **Shadow :**
o **Relative Size :**
o **Relative Motion :**
o **Visibility :**
o **Color :**
o **Accommodation :**
o **Ocular Convergence :**
o **Disparity :**
o **Auditory Reiteration :**



Distal Stimulus :

Distal Stimulus	Process	Design Criteria
Curvilinear space vanishes to far point.	Angular simulation.	Object Δθ less with distance.
Overlapping shape appears closer.	Interposition.	Articulate forms consistently.
Convex shadow below, concave above.	Light assumed from overhead.	Footlights reverse shapes.
Depth relates to size of recognised object.	People-head "constancy".	Sets "scale" of space.
Streaming from direction travel far point.		Close things move more.
Misty hazy air veils distal view.	Atmospheric attenuation..	Misty background.
Bright colors may appear closer.	Color affected by context.	Inconsistent depth cue.
Retinal focus for clear image 1-6 ft		Clearances over 2ft to see.
Binocular rotation onto object 1-60 ft		Monocular cues sufficient in
Binocular stereo superposition 1-60 ft		urban, architectural design.
Reverberation and echo indicate volume.	Time difference of sounds.	Quality for superimposed

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John F. Halldane 1968, 1984, 1997, 2002

"Glare" Response Cues :	Luminous Stimulus :	Corrective Process :	Design Criteria :
o **Task Glare** : Unclear contour differences, high adaptation, veiling, impede task.	**Contrast Insufficient in Task** : Insufficient contrast obscured by excessive adapting field, veiling.	**Light to side.** **No gloss** **Shield lamps.** Reduce contrast. **Vary task surround**.	**Glare impedes task.** **"disability glare"** IES Imagine task a mirror surface. Enhancement limit for **clarity**. Distract by **interesting surround**
o **Banding Glare** : Contour obscured by light band.	**Contrast Excessive, Phototropic** : Nystagmus bands modifying form.		
o **Flare Glare** : Contour obsured by spreading bright area.	**Suffusion of Contrast Excessive** : Scatter makes starlike form grading the contrast.	Avoid seeing bare lamps.	**"direct glare"** IES for lamp
o Nearby task obsured by spreading bright area.	**Suffusion Over Nearby Task Excessive** : Veils nearby area.	**No dark cavelike ceilings**, black backgrounds.	**"veiling glare"** IES for task. Enhancement limit for clarity.
o **Areal Brightness Glare** : Reflexes pupil, blink,squint, tear,strained. Glary, adaptation too high to see well.	**Photic Areal Luminance Excessive** : Pupil-sphincter contraction stressed. Adaptation raised.	No sudden or sustained bright areas. Daylighting **gradual gradient**.	Reduce spatial brightness. **Less "glary"**. Tint glass, glasses **"direct and blinding glare"** IES
o **Distraction Glare** : Eyes forced away from task by involuntary phototropism.	**Phototropic Areal Asymmetry Too High**: Areal luminance drives saccade away from task.	Balance stereo luminances about task. Bright areas over 10 deg	**Balance field.** **Avoid involuntary distractions** from task.
o **After Image Glare** : Superimposed after image annoyingly obscures task following image.	**Sequential Images Incompatible** : Bright +ve pattern initial fixation reverses to -ve image in following task fixation.	Avoid adapting to bright colored patterns.	**Grade adaptation**, bright areas to task as in daylighting. **"blinding glare"** IES
o **Flicker Glare** : Flicker mesmerises, hallucinary, seisure.	**Frequency Low,Contrast Mod. High**: Intermittent Lumination beats with brain.	Avoid alpha wave frequencies which are present when awake, relaxed, unattentive.	Frequencies **above CFF** for "relaxed" seeing.
o Pattern flicker disturbing, distracts from task.	**Striped Pattern Too Severe** : Saccade over contrasts too strong.	Avoid strongly modulated patterns, textures. **Use fine lines**, etchings.	Avoid flicker patterns. **Etching.**
o **Flash Glare** : Involuntary reflexes hazard to task.	**Sudden Lumination Affects Reflexes** : Blink, blinding adaptation, startle.	Reduce "emergency" levels	Cautionary threshold.
o **Motion Glare** : Streaming hard to follow. Distraction. Oculogyration upsets balance.	**Moving Field** : Fixation-saccade hard to track. Moving field induces opposite to balance.	Keep movement within eye saccade pace.	Eyes able to **follow movements**.
o **Avoidance Glare** : Blink. Close eyes. Duck. Shield eyes.	**Sudden Stereo Luminance Change** : Looming. Flashes. Unexpected movement.	Avoid or slow presentation time of stimulus.	Avoid situation. Allow time to anticipate.
o **"Eye Strain" Response Cues** :	**Eye Stress Stimulus-Response** :		
o **Accommodation Focus Strain** : Difficult for eye to focus on object.	**Contrast Form. Eye Ability Limit** : Blurred contour. Inability eye to focus.	Eye test Snellen Chart for corrective lenses	**Clear design** of contours, light. **Corrective lenses** eyeglasses
o **Pupil Contraction Strain** : Contraction insufficient.	**Sphincter Muscles Stressed** : Reflex diameter below adaptation.	Lower adaptation.	Less **light for clarity**. Tinted sunglasses.
o **Squint Strain** :View through eyelashes.	**Long High Adaptation.Dust** : Lashes filter	Avoid bright light, difficult task, dust, heat.	**Shaded** with even field.
o **Tired Eyes Strain** :Sluggish reflexes.	**Overworked Reflex Stress** :	Avoid holding concentrated focus.	**Vary visual tasks**. Wash
o **Tearing Strain** : Eye tears.	**Stress. Emotion** : Lacrimal gland secretes	Avoid too much close work.	**Vary distance. Interest** around
o **Red Eyes Strain** : Bloodshot eyes.	**Irritants,Overworked Eye Muscles** :	Avoid overworking, dust, irritants.	**Unpolluted environs**. Eyedrops
o **Eye Bags Strain** :	**Health Stress** :	Avoid being overtired.	Sleep. Health. Nutrition.

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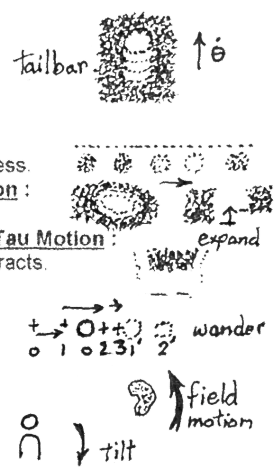
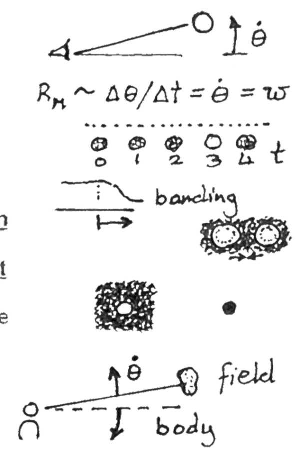
John F. Halldane 1968, 1984, 1997, 2002

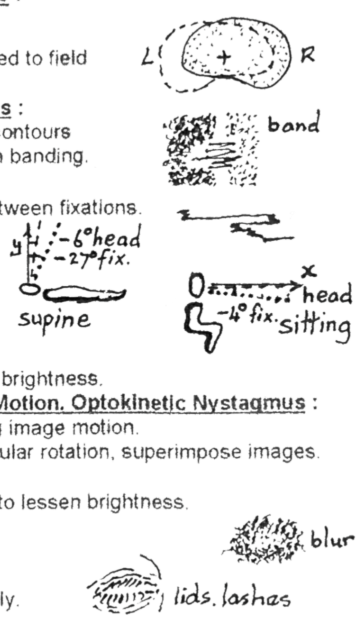
Motion Responses :	Movement in Stimulus :	Design Criteria :
Image Motion : Apparent motion of a shape in stationary field.	**Form Movement** : Distinct **3-10 °/s** in 4°,0.3s saccade. Blur 10-14°/s, Tailbar 14-21 °/s, Sheet **60-°/s** faster than nystagmus	See motion within fixation time
Area Progression, Phi Motion : Motion in direction of changing brightness.	**Areas Pulsed Progressively** : Luminous areas pulsed in order	Draw attention to direction or related feature. Theater front
Flash Image Expansion, Gamma Motion : Brightening shape appears to expand.	**Pulsed Luminous Form** : Luminous form pulsed. Suffusion.	Warning sign. Orange ball at pedestrian crossing. Advances
Flash Image Separation Contraction, Tau Motion : Opposed brightening shapes space contracts.	**Separation Pulsed LuminousForm** Separated luminous shapes pulsed.	Squeezes space between.
Isolated Image Motion . Autokinesis : Image moves about in featureless field with random fixation	**Stationary Forms Without Context** Luminous form against black or white ground. Phototropic afterimage	Night disorientation. Avoid fixation on visible form
Body Tilting Motion, Oculogyration : Proprioceptive response, body tilts contrary to field motion.	**Moving Visual Field** : Stationary reference in body so compensates to contrary.	Tilting, unbalancing effect. Clouds moving. Traffic below. Look down, field up, tilt forward



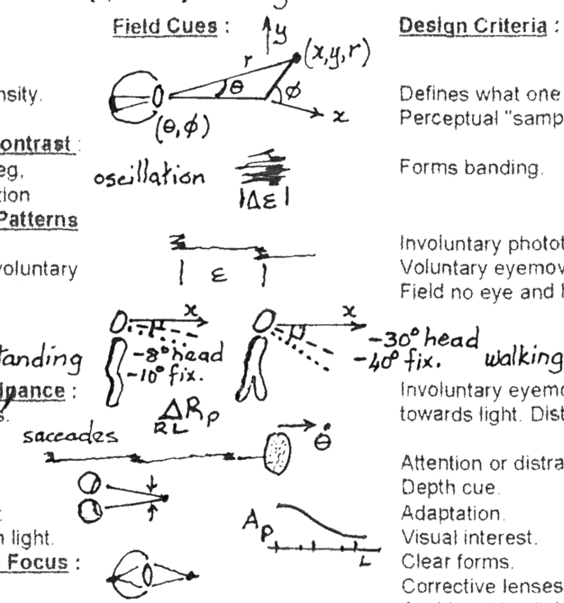
Spatial Distribution :



Ocular Motor Responses :	Ocular Motor Stimuli :	Design Criteria :
Fixation : Stationary period of eye related to field between saccades.	**Center Field** : Center greatest receptor density. Period 0.2-**0.3-0.5**-1.6 sec	Defines what one looks at. Perceptual "sampling" time.
Fixation Tremor, Nystagmus : Physiological tremor across contours during a fixation. Amplitude in banding.	**Reflex Across LuminousContrast** : Amplitude **Δε** 0.001-0.01deg. Frequency 30-70 Hz at fixation	Forms banding.
Saccade : Involuntary eyemovement between fixations.	**ContrastProgressiveFieldPatterns** Contrast between fixations Amplitude 0.2-4-7° to 30° voluntary	Involuntary phototropism Voluntary eyemovement.
Relaxed Fixation : Fixation position without field depends on body orientation.	**Relaxed Closed Eyes** : Close eyes, relax, open,see position.	Field no eye and head stress.
Phototropism : Eyemovement towards areal brightness.	**Asymmetrical Stereo Luminance** : Imbalance between fixations.	Involuntary eyemovement towards light. Distraction.
Saccade Following Image Motion, Optokinetic Nystagmus : Involuntary fixations following image motion.	**Movement of Form** : Eye tracking moving form.	Attention or distraction to task.
Ocular Convergence :Binocular rotation, superimpose images.	**Angular Distance** : 1-60 ft	Depth cue.
Pupil Area : Involuntary pupil contraction to lessen brightness.	**Field Adaptation, Interest** : Ciliary muscles contract with light.	Adaptation. Visual interest.
Accommodation : Ability to focus on images	**Clearness Form, Ability to Focus** : Contrast difference.	Clear forms. Corrective lenses.
Blink : Closing of eyelids momentarily.	**Physiological Irritants** : Washes eyeball. Startle reflex.	Avoid sudden light changes, eye contamination, dust....



Field Cues :



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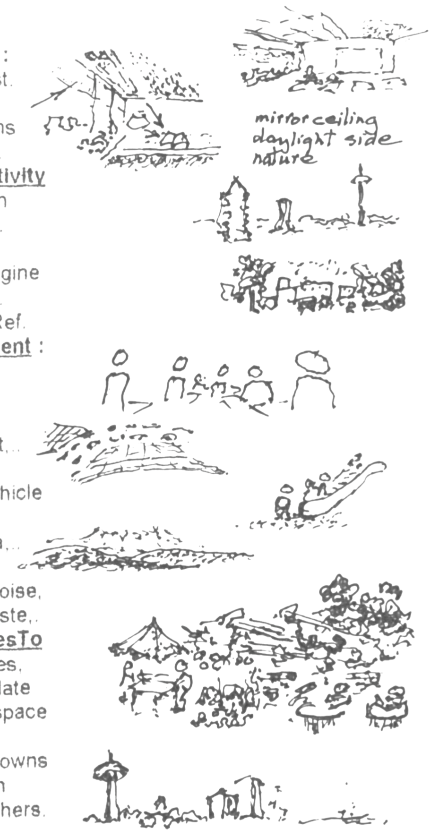
John F. Halldane 1968, 1984, 1997, 2002

Cognitive Responses :

- **Imaging Field** :
  Interesting for activity scenario.
- **Image Clearness** :
  Color, contours, areal field,.. all clear without glare, eyestrain.
- **Image Recognition** :
  See, recognise, scale, each image appropriate for activity. Highlight icons.
- **Relative Lightness, Grayness** :
  Grayness of area compared lightest in field.
- **Recognised Image Scaling, Size Constancy** :
  Apparent angular size constant as expected by polar perspective cues
- **Phobias** : Fear of . . .
  High places . . Acrophobia
  Closed in . . . . Claustrophobia
  Motion . . . . . . Kinephobia
  Darkness . . . Nyctophobia
  Open space . . Agoraphobia
- **Impersonal Space and Images to Identify With** :
  Surroundings that a person does not relate to, finds overpowering, threatening, loss of personal identity.
- **Personal Space** :
  Immediate personal things person identifies with, a friend to chat with, cat on lap, seat, table, books, mobiles, computer, canopy,... their things.
- **Skyward Buildings Theme**:
  Concept of icons rising skyward through a nature-urban base in urban design.
- **Vernacular Expression** :
  Design with nature theme.
  Living with nature.
  Humanising architecture.
  Humanising urban habitat.
  Blending peopleways with natureways.

Sensory Response Cues :

Setting Appropriate for Scenario :
Involuntary reflexes towards interest.
Contrast, Areas Support Tasks :
Chromatic light, contrast, areal forms appropriate without impeding tasks.
Setting Form Consistent with Activity
Forms, size, cues as expected. Icon separation over 6 deg for attraction.
Scaling White-Black Reference :
Select brightest area in setting, imagine blackest, scale brightness between. Compare Munsell White to match Ref.
Known Size for Distance Consistent :
Apparent angular size for distance consistent with depth cues.
Spatial Cues :
Looking down from building, aircraft,..
Confined personal space
Unsure balance in lift, escalator, vehicle
Scarey nights, difficult to see way.
Overpowering expanse, desert, sea,..
Inhuman Settings :
Soaring buildings, choking traffic, noise, bustling crowd, concrete jungle, waste,.
Things at Distance Person RelatesTo
Within distance to recognise features, see detail, touch, control,... they relate to. Define transition to impersonal space
Theme Highrise Urban Habitat :
To visually feature tall buildings in towns by separating their towers above an urban mantle by over 6 deg from others.



Vernacular Cues : living with nature humanising
Nature .... living things about us. tropical
Landuse ....right use of land. organic ways
Economy .... dual community-world
Conservation ....just-right minimal means
Community ....people being together
People-Places ....meetings to remember
Behavior Settings ....right for occasion
Aerial Places .... highrise experience
Heritage ....memorable things and settings
Systems Integrity ....images that work

Design Criteria :

Setting supporting activity.
Interesting setting.
Color rendered, **clear, easy to see images**.
No glare, strain.

Phototropic separation icons.
Natureway, green mantle base.
Grayness articulates the images. Should be consistent with setting. Light for highlight, dark for silhouette.
Scale polar perspective with known expected forms.
Human, **people scale**.

Be aware of people's fears and superstitions by accommodating in design.
Provide assuring familiar transition spaces and forms.
Needs **transition space-form** to "protect" person, recognise their identity.
Pesonal identity with their things and space for activity.
"My home" workstation.
Personal transition space-form.

Skyward suggests a special identity above others or a natureway base. Icons.

Rainshedding ....keeping dry in downpours
Sunshading ....keeping out sunshine
Daylighting ....everchanging light patterns
Transition Spaces ....places inbetween
Breezeway ....drying cooling airflow
Radiant Cooling ....shady damp cool place
Sun-Compatible ....working with the sun
Surface Texture .... form and depth
Mellow Aging .... nature's expression
Livable .... wellkept.clean. healthy.caring
. . . . welcome to our place and home

Compendium of Psychophysical Systems . . 8

John F. Halldane 1968, 1984, 1997, 2002

Auditory Responses in Perception . . .

- **Audio Behavior** Responses :

- **Audiotropic Orientation. Sound Direction** :
  Lateral direction sound to observer. Cue difference loudness between ears. Reflex LR. No tell front-back.
- **Audio Arousal** :
  Startle, flitch. Beta waves 13-30 Hz on brain in arousa l.
- **Audio Relaxation** :
  Sleepiness, drowsy. Alpha waves 8-13Hz
  Theta 4-7Hz light.. Delta 0.5-4 Hz deep sleep.

- **"Tone" Response** :

- **Pitch** :
  Tone vibration attribute, high-low related to frequency.
  Mel Scale to 1 kHz, 1000 **Mel.**
  Bark Scale to 500 Hz, 5 **Bark**
  "note", "hum", "do-re-mi-fa-sol-la-ti-do' "

- **Harshness. Noise** :
  Pitchless sound, harsh not mellow.
  "Pink Noise" even loudness over audible tones, the "siss", then "hum", "drone" for low pitch harshness.

- **Loudness** :
  Magnitude of tone relates spectrally to an A weighted Sound Pressure Level; **SPL** with base as threshold of hearing p_0.
  Sone for pure tones, relates to **Phon** at 1 kHz.

- **Ambient Pink Noise for Task** :
  Background noise setting adaptation for tasks, without impeding the task. Theshold of **"annoyance"**.
  Preferred Noise Criterion. **PNC(Noy)**

- **Pureness** :
  Harmonic. Lack of harshness in a tone.
  Loudness without noise.
  Scale with square wave harshness.

Sound Stimulus :

Binaural Loudness Difference :
Difference in sound pressure level N(dbA) between ears $N_L - N_R$.
Sudden Sound :
Bang, clapping, explosion,.. interest.
Quiet, Monotonous Sound :
Even voice, drone, waves,...

Audible Sound Stimulus :

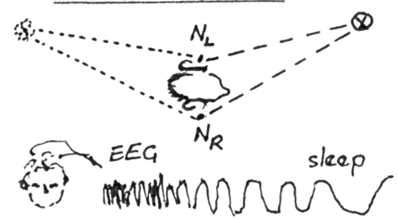
Monospectral Sound Frequency :
Sinusoidal frequency, **f**, Hertz Hz=c/s
Audible 20-10,000-20,000 Hz
Speech 300-600-1200-2400 Hz
Octave = **2. f** Diatonic Scale in music

Continuous Broad Band Sound :
Broad spectral sound pressure level,
"White Noise" as unweighted **dBC** , then **"Pink"** A weighted, **dBA** in Octave Band **f,2f,4f.** and 1/3 Octave Bands
Weighted Sound Pressure Level :
Unweighted C Scale, Sound Pressure Level, N(Bel) = $Log_{10}[P/P_0]$ power
=$2Log_{10}[p/p_0]$ pressure
N(deciBel) = $20Log_{10}[p/p_0]$ = **dBC**
"A" weighted for spectral hearing sensitivity **dBA**, for Phon Scale at1kHz
Background Sound Pressure Level :
Background Noise Criteria based on dBC, then related to Noise Criterion Curves for Noy Scale

$$PNL = N_{Noy}(dBC) = 40 + 33.3 Log_{10} R_{Noy}$$

Sinusoidal Component of Sound :
Pure sine waveform without clouding harmonics and noise. Compare with harsh square wave and pulse wave at same frequency and power.

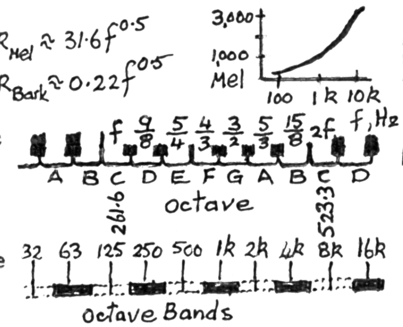
Acoustic Distribution :



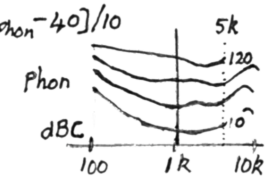
Audiometry. Acoustics :

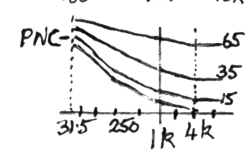
$R_{Mel} \approx 31.6 f^{0.5}$

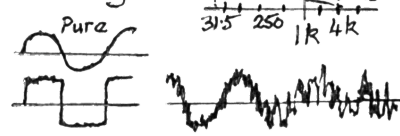
$R_{Bark} \approx 0.22 f^{0.5}$



$R_{Sone} \approx 2^{[N_{Phon} - 40]/10}$







Design Criteria :

Cue for location source. Lift lobby confusion. Need visual cue. Stage player to amplified. Sounds interesting, "music", activity. Emergency signal.

Quiet neighborhoods for sleeping, rest.

Design Criteria :

Audible spectrum "tone"
Music keynotes.
"Pure Tone" with tuning fork.

keynotes

Auditory adaptation.
Ambient background.
"Toneless Sound"

In acoustics use unweighted N(dBC) scale.
For audition use ear weighted N(dBA) scale on sound level meter.

Sets auditory adaptation. Part of concept for noise as unwanted sound.
Noise Criterion Curves.

Pure tone, oscillator, tuning fork, signal generator.

Compendium of Psychophysical Systems . . 9

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o Timbre Responses :

o **Progressive Tones :**
Music,note,chord,scale,phrase,passage,..
Tempo. speed, rhythm. Metre. beat

Scale											
: major	C	D		E	F	G		A		B	C
wholetone	C	D		E	F#	G#		A#			C
harmonic minor	C	D	D#		F	G	G#			B	C

o **Warble. Drumming. Burst. Flicker. Tone :**
Warble a waving tone beyond sampling time 0.3-1 sec .
Drumming a low pitch beat beyond 0.3-1 sec sampling..
Burst, loud toneless energy over perceptual sampling time 0.2 sec. with task impedance over 0.5-1 sec
Flicker arousal disturbing 0.05-0.08 sec Beta wave.
Flicker threshold when a tone, period 0.05 sec

o **Echo :**
Distinct tone progression repeated beyond perceptual sampling time 0.05 sec

o **Repetition :**
Passage repeated in time at lower loudness to enhance timbre with consistent overlayed tones. "Lively-Dead" space with high-low repetition.

o **Clearness. Articulation :**
Clear passages in note timbre, speech.
Threshold task interference, intelligibility, understanding.
Community ratings; acceptable, annoyance, complaints, group appeals, legislation.

o **Presence :**
Proximity observer to sound source. Feedback cue from repetition indicates what other hear.Spacious echo.
Loudness above ambience depth cue.

o **Doppler :**
Sound advancing to observer v_{to} higher pitch f_{to} and rising loudness.. receding from v_{fro} lower pitch falling.

o **Exposure. Hearing Loss :**
Long term hearing damage by acoustic energy, acoustic power over time.
Hearing loss with age.

Sequential Sound Stimuli :

Successive Notes :

	[1] o	[1/2]	[1/4]	[1/8]	[1/16]
Note Period :	semibrieve .	minim	crotchet .	quaver .	semiquaver
Frequency :	0.6-0.8 /s		**2.4-3.3** /s		9.4-13 /sec
Rests :					
Time Signature :	**2/4** two-step	**3/4** waltz	**4/4** quarter time	quarter time	march,foxtrot

Intermittent Sound :
Oscillating sound less than 1-3.3 Hz
Rhythmic sound repeated less 1-3.3 Hz
Impulse noise above ambient.
keep Peak dBC < 20 dBC + Ambientt
Clacking 13-20 Hz, bad 50%Mod.
Critical Fusion Frequency about 20 Hz.

Path Difference of Sound :
Repeat period over 0.05 s, v=1100 ft/s for path difference 55 ft, 17 m

Reverberation :
Time decaying reflections in space for sound field. Reverberation Time = Time sound to drop 60 dBC

Ambient Sound. Noise Criterion :
Background unobtrusive. Sounds to hear about 7-8 dBA above ambient dBA
Ambient octave band dBC below Noise Criterion Curve, NC, value for activity.

Auditory Spatial Cues :
Precise sound closer.
Supportive reverberation. Echo in large enclosure. Anechoic isolation within.

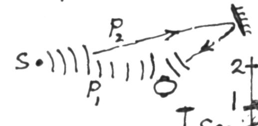
Passby Sound :
Moving sound to and fro with observer.
Velocity sound v_s = 1100 ft/s

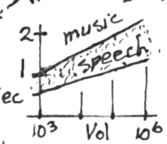
Acoustic Power Over Time. Energy :
Sustained sound pressure levels damages the auditory system.
Relates to occupational safety and health, OSHA Standards.
Maximum permissible exposure time per day for a SPL dBA

Acoustic Distribution :

$m = \frac{T_{on}}{T_{cycle}}$

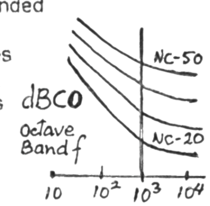
f_o))) ((·f $\Delta f = f_o - f$ beat

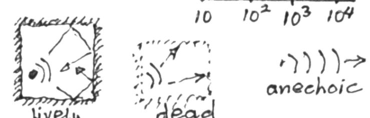




NC- recommended

NC	
50	sports
40-65	factories
40-50	offices
25-45	schools
25-35	home
15-25	halls





$f_{to} = f v_s / (v_s - v_{to})$

$f_{fro} = f v_s / (v_s + v_{fro})$

8	hour/day	90 dBA
4		95
2		100
1		105
½		110
¼	or less	115

Design Criteria :

Music for the occasion, place.
Empathy between contributions of instrument, player, audience, space.

Detection. "Beat" frequency in unbalanced system. Musician's quaver, singer's trill.
Impact sounds, hammers, guns, pile drivers, metalwork.
Clacking unbalanced machines
Humming of equipment.
Room acoustic reflection limits intelligibility. Cue for openness, spaciousness.
Ambience. Actor's cue for audience presence,stagefright audience absorption.Music tonal overlays

Clear, enhanced for task and community acceptance.
Continuous broad ambient for adaptation to hear task well.
No intrusive background.

Singing in bath syndrome.
Player stagefright with full audience absorbing sound, practice in reverberant hall.

Hazard cue, approaching traffic passby vehicle.

OSHA Standards for occupational safety.

Cutaneous Skin Responses in Perception . . .

o **Dermal Heat Loss Responses** :
Sensible heat transfer to air. Thermal radiation on skin. Latent heat in sweat evaporation, drip. Air flow. Conducted heat in skin-surface contact. Bathing water. Skin reddening hot. Goosebumps cold, flesh papilla.

o **Threshold. Adaptation. Neutral. "Comfort"** :
Just noticed, threshold cutaneous response of dominant warmness, coolness, wetness, dryness ...
Women 1°CDB lower than men.
Avoid condensation water vapor, formation fungus mould... all surfaces temperatures must be above air dewpoint θ °CDP.
Electrostatic shock dry air below 30%RH.

o **Warmness** :
Lower rate dermal heat loss in specific sensitive areas to exposure. Face, neck, hands, feet, back, head, ..
Relaxing in winter.
Feet warmer than head to 6°C, 11°F gradient.
Heatstroke when body gains heat, fatal.

o **Coolness** :
Higher rate dermal heat loss in specific sensitive areas to exposure. Face, hands, feet,.. Relaxing in summer.
Shock cold blast over- 5°C, -10°F air temp. diff.
Shivers. Goosebumps. Hyperthermia.

o **Wetness** :
Sweat from skin pores form droplets, then film to drip, clammy clothing.
Dehydration.
Sweat freezes subzero temperatures. Ices hair.

o **Dryness** :
Sweat evaporates too fast from pores, dries leaving salts on skin, itches, wrinkles. Electrostatic charges.

o **Stiffness:**
Mucles in neck, shoulders, legs,.. stiff, painful.

o **Burning.:**
Skin burn from ultraviolet radiation...surface sunburn.
Singe-burn by contact with hot liquid gas or solid.
Cooking within from microwave radiation.

o **Freezing** :
Frostbite freezes water, kills cells, gangrene spreads.
Amputation, cutting out of parts.

Dermal-Metabolic Stimulus :
Skin temperature **32°C , 90°F**. Sunshine
Sweat Rate, Humidity Ratio. Breeze.
Clothing-posture, insulation.

"Comfort" Conditions :
Ambient indoor air psychrometric condition of adaptation.
Dry Bulb 20-**24-26°CDB**, 68-**75-78°FDB**
Relative Humidity: 20-**30-50-70**-75 **%RH**
Humidity Ratio: 0.005- **0.010-0.012 HR**
Wind cools -0.2°Cair for 1.5m/s wind.
Radiation heats +0.7°Cair/ +1°C environ
Radiation cools -0.5°Cair/ -1°C environ

Lowered Rate of Heat Loss :
Dermal temperature gradient lowered
Higher air temperature, humidity, radiation, clothing, sauna, desert wind,..
Maximum dry air temp . **40°C, 104°F**
Maximum skin temperature **32°C , 90°F**

Raised Rate of Heat Loss :
Dermal temperature gradient raised.
Lower air temperature, humidity, radiation, clothing, ice pool, snow wind,
Increase metabolism by work, activity.

Raised Humidity. Lower Heat Loss :
Higher humidity and activity increases sweat for latent cooling by evaporation.
Air movement helps evaporation.

Low Humidity. Higher Heat Loss :
Low humidity and activity lowers sweat, evaporates fast, drying skin.

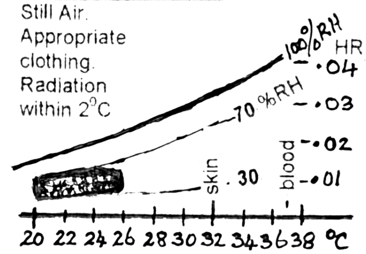
Muscles in Cool Draft :
Cooler air movement effects muscles.
In direct wind, breeze, airjet.

Exposure Heat :
Sun exposure high UV. Peels, renews.
Oxidation of skin, often irreversible.
Microwaves heat flesh within.

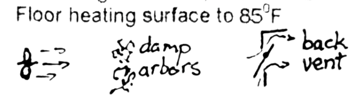
Exposure Cold :
Ice destroys cells damaging circulation.

Thermal Distribution :
Metabolism . oxidised carbohydrate
[CHO]+O_2 >Heat+CO_2+H_2O+
Blood **37°C,98°F** hypothalamus
Hyperthermia above, hyper- below

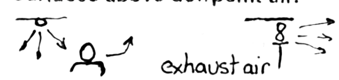
Psychrometric Chart :
Still Air.
Appropriate clothing.
Radiation within 2°C



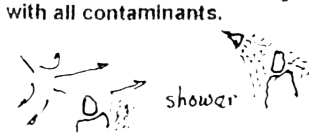
Radiant heaters over 10ft of head, hot ceilings to 100°F, wall to 110°F
Floor heating surface to 85°F



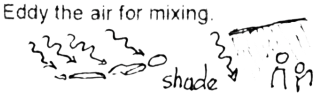
Fans, velocity > 1m/s raises paper.
Surfaces above dewpoint air.



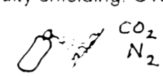
Exhaust moisture in moving air with all contaminants.



Eddy the air for mixing.



Faulty shielding. Over 1 GHz



Design Criteria :
Heat energy from food digestion-lung respiration chemistry to blood flow to body heat loss in environment.

"Comfort" air conditioning.
Utility energy savings adjust thermostat summer-winter, appropriare clothing, open windows, through ventilation, fans. sunshine heating, daylight lights off, plant arbors for cool shade,exhaust heat,..

Working hard, sport,...
Warm drinks, food,..
Warming by open fire, sunsitting, warm clothing, warm wind, warm tools,...
Rest, sedentary, relaxed,...
Night clear sky radiation, cool damp plant arbors, grass, sunshading, white surfaces, light clothing, breezes.

Air conditioning jets downward over people in humid tropics.
Drink water. Potassium salt replacement.
Still air to reduce evaporation.
Skin moisturisers. Bathing.
Drink water.

Avoid drafts all time. Exercise.
Cover affected parts of body.

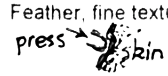
Sunshade for UV, clothing.
Cooking, thermal processing.
Microwave ovens, transmitters
Appropriate clothing, gloves...
Compressed gas expansion..
Winter conditions, snow, ice.

Tactile Skin Responses in Perception . . .

o **Touch Responses** :
o **Tickle** : Excited nerves to microvibration. No press.
o **Pressiness. Squeeziness. Numbness** :
Feeling of skin compression. Adaptation in time to numb
o **Slipperiness** : Feeling of resistance to skin slipping, slip
o **Sticky. Clingy** : Object holding to observer.
o **Massage** : Kneading pummeling skin.
o **Roughness. Smoothness** :
Press and slip pattern contours, rough-smooth.
o **Hardness. Stiffness. Softness** :
Give to pressing, supporting, ... for behaviour.
o **Hold, Posture** :
Skin-body keeping contact with surface-object.
Pressiness adapts with feeling of losing hold.
Roughness, hardness cues needed. Support for posture, walk, rest, sleep,.... task tools to handle, lift,...

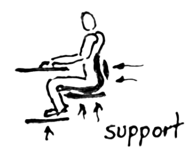
Contact Stimulus :
Light Stroking Over Skin : Fine fibers
Pressure Change On Skin :
Pressing on skin area.
Rubbing Friction Along Skin :
Adherence to Surface :
Press, Slide, Rub, Knead, Beat Skin :
Texture of Object to Skin :
Surface pattern contrasts
Give Pattern with Pressure :
Deformation object-skin with pressing.
Grip. Support for Task :
Configuration to match skin-object relationship, for pressure distribution, texture, deformation,...

Process :
Feather, fine texture, breeze,..



Reduced by sweat, water,oil,...
Gel, suction, electrostatic,..

Glass paper, concrete, wood, carpet, fur, wool,
Hard no give metal, ..to carpet pile
Soft give cushions, blankets, fabric,



Design Criteria :
For pleasure or annoyance.
Change in pressure for sustained response.
Balance, hold cue
Nuisance, plastic, paper,...
Tone skin, muscles
Appropriate for task, smooth to hold, rough avoid slip,...
Test by using.. chairs, clothing, beds,..

Ergonomics, economy in movement, forces, time, effectiveness,... for task operations.

Olfactory Responses in Perception . . .

o **"Odor" Responses** :

			Smell Reference Stimuli :
Fragrant	**Aromatic**	**Camphor.**	Camphor, lavender, moth balls, lemon, vanilla, hexochloroethane,...
	Musky	**Woody**	Musk, wood, amber, ambrosial, xylene, pentadecanolactone,...
	Floral	**Rose**	Roses, flower oil,...
	Pepperminty	**"Musty"**	Pepper-mint, alcohol 1-menthol, civet,
Ethereal	**Burnt**		Ether, resin, fruit, benzine, diethyl ether,...
Pungent	**Acid**	**"Pissy"**	Vinegar, acetic acid, sulfur dioxide, urine, ammonia,...
Putrid	**Goaty**	**Caprylic**	Hydrogen sulfide, bad eggs, chlorine, bromine,"gas"butyl mercaptan,...

Nasal Receptors :

o **Aroma** : Activity odor, scent for occasion, perfume.
o **Dominant Odor. Masking** : Change to agreeable odor.
o **Odorness** : hint.delicate. light.savor.heavy.overpower

Smells Compatible with Activity : Smells mix for characteristic odor.
Masking Smells : Air fresheners. Reodorants.
Concentrations of Smell Mix : Adaptation to smell concentration.

Design Criteria :
Odors are mixtures of these components.
Depends on dominance and adaptation.

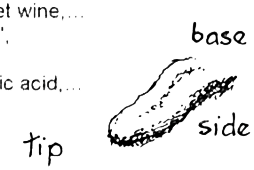
Agreeable odor for occasion.
Dominant odor compatible.
Strength of odor.

Gustatory Responses in Perception . . .

o **"Flavor". Gust Response** :

		Tongue sense	Taste Reference Stimuli :
Sweet	**Sugary**	Tip	Sugar, honey, saccharin, sucrose, glycerine, sweet wine,...
Bitter	**Malty. Oily**	Base	Olive oil, beer, hops, malt, alcohol, vermouth, "pill",
Salty		Frontal Sides	Salt, sodium chloride, seasoning, seawater, ...
Sour	**Acidy**	Basal Sides	Vinegar, acetic acid, lemon, citric acid, hydrochloric acid,...
Flavorless	Water. Neutral		Tasteless. Water is the diluter.

Tongue Receptors :



Odor Masking of Flavor : Odor can overpower flavor.
Gustiness. Tastiness : hint. savor. spicy. hot. burning

Smell can Dominate Taste :
Concentrations of Taste Mix :

Design Criteria :
Flavor for cuisine, occasion.
Odor of food, wine, room,... flowers, incense, wood,mints.. can enhance flavor,
Odor ambient can enhance.
Savor for cuisine.

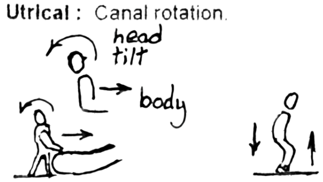
Motion Responses in Perception . . .

o **Vertigo Responses** :
o **Whirling** : Feeling of rotation of head in space.
o **Tilting Head** : Head tilt relative to body motion.
Balance, motion threshold standing.

Tilt Backward....	**Forward Motion.**	Sitting
Tilt Forward.......	**Slowing Motion.**	Sitting
Tilt Forward.......	**Backward Jerk.**	Standing
Tilt Backward.....	**Forward Motion.**	Standing
Tilt Sideways....	**Swaying.**	Sitting
Upward Motion ...		Standing
Downward Motion ...		Standing

Head Movement Stimulus :
Head- Space Horizontal Rotation :
Rotation in Horizontal Movement :
Forward Acceleration 0.6 f/ s^2 0.2 m/s^2
Backward Acceleration 2.6 f/ s^2 0.8 m/s^2
Forward Acceleration 0.6 f/ s^2 0.2 m/s^2
Forward Deceleration 2.6 f/ s^2 0.8 m/s^2
Impulse Velocity 0.1-0.3 f/s 0.03-0.1m/s
Forw. Accel. 0.01 G 0.3 f/ s^2 0.09 m/s^2
Oscillation 0.01 G 0.3 f/ s^2 0.09 m/s^2
Linear up 0.01 G 0.3 f/ s^2 0.09 m/s^2
Linear down 0.01 G 0.3 f/ s^2 0.09 m/s^2

Vestibular. Otolith Organs :
Semicircular canals sense rotation.
Utrical : Canal rotation.



Saccule: Vertical acceleration

Design Criteria :
Circular stairways. Spin

Jerk..car movement
Moving walkways
1.5 f/s 0.5 m/s

Lift high velocity...
Traction 0.1 G Braking 0.5 G

o **Kinesthesis Response** :
o **Kinesthetic Motion** : Feeling from strain in muscles.
o **Numbness** : No feeling of motion.

Sematic Motor System Stimuli :
Body Movement Stress :
Under or Over Stressed :

Proprioceptors :
Working skelital muscles, tendons
Sensory adaptation.

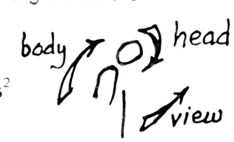
Design Criteria :
Working, exercise,...
Need body movement.

o **Visual Cues to Motion** :
o **Motion Object in Field** : Field considered stationary.
o **Motion Object in Dark or Ganzfeld . Autokinesis** :
o **Eye Follows Object : Optokinetic Nystagmus** :
o **Motion in Flashes ; Phi** :
o **Expanding -Contracting Motion. Gamma. Tau** :
o **Tilting Contrary to Image Motion. Oculogyration** :

Moving Light Pattern Stimulus:
Velocity > 0.1 deg/s **Subtense** >1 min
Eye Wandering : 3-4 deg
Eye Tracks Movement : 1 deg/s
Luminated Sequence :
Area Luminance Increase-decreases
Moving Field Presumed Stationary :

Luminance > 0.3 nit 0.1 fL
at 0.2-0.3 deg/s after 9 s

0.1 deg/ s^2



Blur over 10-14 deg/s
Fixation pattern with eyes.
Conveyor movement.
Flashing lamp sequence
Flashing ball. Dimming lights.
Tilt looking cloud past skylight

o **Auditory Cues to Motion** :
o **Timbre Related to Motion** :
Moan wind. Rattle lift. Doppler to-fro. Receding loudness
o **Ear Pressure** : Pressure in ears with descent.

Moving Sound Stimuli :
Related Moving Sound :
Air eddy. Moving, passby equipment.
Ear Pressure Change :Down 3-1.5 m/s

Distinctive noise 50-5,000 Hz
Above adaptation ambient 6-7 dBA
0.005-0.008 p/m^2 , 53 dBC/s

Lift gear, guides,.. Passby cars
Wind round buildings. Plays.
Lift down in tall building.

Visceral Responses in Perception . . .

o **Cues to Visceral Responses** :
o **Wellness** : Feeling good about one's body.
o **Sickness. Nausea** : Sickness from stomach.
o **Stuffy** : Drowsy, still, unfresh feeling to spatial air.
o **Headachy** : Pain in head, throbbing, hard to think.
o **Sleepy** : Dossy, nodding head. Hard to attend to task.
o **Irritation** : Itchy skin. Sore eyes. Acidy, pungent fumes.
o **Sweating** : Wetness of skin.
o **Pain** : Body suffering or distress.
o **Reflexes** : Pupil contraction. Blinking. Eyemovements.

Physiological. Organic Stimuli :
Healthy, adjusted body.
Wavy body movement. Putrid smells.
Carbon Dioxide : **CO_2 over 1000 ppm**
Carbon Monoxide : **CO over 1.7 ppm**
Hydrocarbons : **[HC] over 1.1 ppm**
Formaldehyde : **H_2CO over 0.2 ppm**
Impeded Heat Loss. Fever. Anxiety :
Excessive sensory stimulation.
Tearing. Blush. Scratching. Posture.

Autonomic System :
Regulation appropriate.
Involuntary rejection of food, vomit.
Breathing harder. Part O_2 exchange
Toxic to blood hemoglobin HbO_2
Acts as an anesthetic.
Chemical action.
Hypothalamic temperature.

Jumpy. Withdrawn.

Design Criteria :
Healthy.
Motion sickness. Putrid odor
Exhaust criterion indoor air
Intake criterion indoor air.
Exhaust air flow.
Exhaust air. Glues in carpet....
Air movement. Psychrometrics
Safety. Protection.
Allergies allowed for.
Avoid pollution-contamination.

A Naval Perspective on
Intelligent Procurement
… during Rapid Transformation

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Abstract

Changing global threats, including terrorism and the increased availability of weapons of mass destruction, challenge Allied military forces to respond rapidly and effectively to highly dynamic geo-political and economic environments. As evidenced over the past 12 years it is not easy, requiring significant coordination and potential redirection or reassignment of priorities and assets. Success is contingent on getting information to decision-makers, while ensuring interoperability, a common focus, and a common sense of purpose. Successful counter-threat operations require a robust and responsive procurement process, which ensures that the right platform or asset, is at the right location, at the right time. Therefore, responsible organizations must accurately assess the threat, determine the resources required, and develop and execute plans that will neutralize that threat. The U.S. Navy must overcome the natural limitations of a lengthy and complex procurement process, encumbered by numerous stovepipe organizations and decision-makers attempting to obtain the material, systems and equipment required to meet, neutralize, and if necessary, defeat these threats. Collectively, we must remain focused on achieving the desired outcome.

At the center of this challenge is the need to provide more detailed information and to effectively integrate data, information, and decision-makers from multiple disciplines and communities. Modern information management techniques and capabilities provide the opportunity to enhance decisions, maximize resources, and yield satisfactory results.

This paper discusses the need for an effective responsive procurement process to support rapid Military Operations during periods of transformation. The valuable lessons of history provide insight on how to meet the future challenges of global and regional instability.

Keywords

Decision support, logistics network, transportation, inventory management, just-in-time, procurement, assets, resources, responsibility, authority, assessment.

Disclaimer

The views expressed in this paper are those of the author, except as noted; and do not necessarily represent the official position of the U.S. Government, U.S. Department of Defense, U.S. Navy, or the Commander, U.S. Pacific Fleet.

Introduction

"The Navy exists to defend our Nation – it has no other purpose. It serves as a shield in peace as well as in war; for, in final analysis, diplomacy rests upon the deployment and use of military force." (Rickover)

Geo-political and religious ideologies; or economic conditions and pressures provide the basis for both human and armed conflict. Armed conflicts are often the result of failed human negotiations. When military actions are required, successful plans must be developed and executed in order to achieve State objectives. Challenges exist when military planners must predict: global threats, platform or force structure, personnel requirements, desired research and development initiatives, and resource requirements to support unit operations and maintenance. Within the U.S. Department of the Navy this effort requires a complex balance of future capability with the need to go *Forward ...From the Sea* anytime, anywhere. Since the 1980s the U.S. has recognized the value of unified military forces. Additionally, Twentieth Century conflicts and wars have validated the need for coalition force interoperability and effective operation plans.

Traditionally, procurement has been viewed as the acquisition or purchase of ships, submarines, aircraft and their parts support. In the following pages, I will focus on the need to **obtain** the right resources, at the right time, at the right location while incorporating technology into our next generation of assets or resources. Critical to decision support and maximizing resource use is the availability of information, to the right decision maker, at the right time; with the recognition that organizations should be provided the necessary authority to carry out their assigned responsibilities. Finally, the valuable lessons of history provide insight on how to meet current and future challenges to global and regional stability.

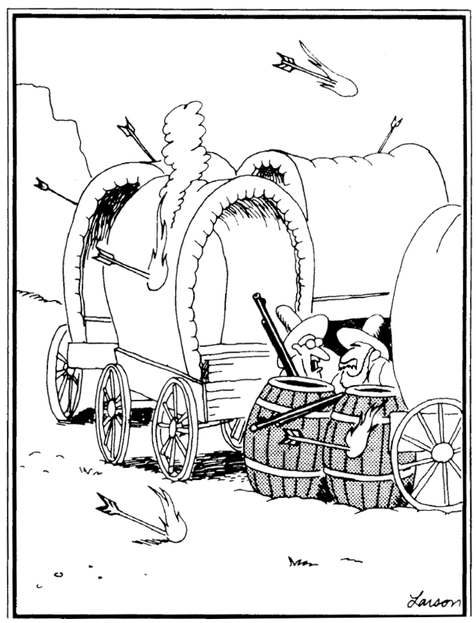
The Challenge

"The security environment in which we live is dynamic and uncertain, replete with a host of threats and challenges that have the potential to grow more deadly."
President Clinton, National Security Strategy, 1999

Since the end of the *Cold War,* the U.S. Department of the Navy has developed strategic plans based on the assumption that the United States will not have a Naval peer for the next two decades. This assumption recognizes that Maritime Forces will need to maintain a forward presence in the Middle East, Asia, Europe, and the Americas. The U.S. Navy and our maritime allies must continue to dominate the globe's oceans to dissuade regional powers from aggressive actions, while being prepared to engage in a full spectrum of Military Operations Other than War (MOOTW). The "on scene" presence of Allied Naval Forces in the Persian Gulf on September 11, 2001 provided ample evidence that maritime superiority was essential in providing rapid response options. As coalitions, allegiances, and security agreements change the need for a strong independent naval force remains paramount.

In order to meet this challenge we must be able to sustain a long-term, forward deployed presence. (Natter 2000) Within the Pacific Fleet this means supporting deployed forces through the discipline of sea-based logistics with a full spectrum of battle force replenishment, operational logistics, weapons handling, from logistics bases over 14,000 nautical miles away.

With this background of dynamic and asymmetric missions, and the *Tyranny of Distance,* it is important that we recognize that time may not be an ally. Likewise we must acknowledge and consider the important role our global allies play in meeting current and future threats. Success requires us to know what we want or need, why we need it, where we need it, and when we need it. Once this is known we can develop plans to meet dynamic and asymmetric missions and responsibilities. Figure 1 depicts, the importance of recognizing that our resource needs may change as our situation changes.



Hey! They're lighting their arrows!! … Can they DO that?

Fig. 1: The changing environment

Historical Perspective -

At the start of the American Revolution our Founding Fathers recognized the need for a strong navy to limit England's ability to re-supply her forward deployed army. The continental navy was formed from converted merchant vessels, and captured enemy ships of war. At the end of the revolution the U.S. Navy was virtually disestablished. During the American Civil War the value of a strong naval force was again recognized and by 1863 the U.S. Navy had become one of the most effective sea powers in the world. After the Civil War the U.S. once again allowed the navy to dwindle in numbers and effectiveness, and by 1880 the navy lacked the marine engineering, naval architecture, and ordnance skills necessary to remain a powerful maritime force. (Rickover 1974) At the end of World War I, the war to end all wars, U.S. decision makers saw little value in maintaining or modernizing the fleet, and by 1940 most of the fleet assets were aging and lacked the benefits of advancing technology. By December 1941 the U.S. Pacific Fleet had six Aircraft Carriers, and nine Battleships, with numerous other battle Cruisers and Destroyers. (Fahey 1944)

On December 7th, 1941, eight of the nine Battleships were in Pearl Harbor, all were damaged with *Oklahoma and Arizona* sinking and never returning to active service. In February 1942 the Carrier *Langley* was sunk south of Tjilatjap. During the Battle of Coral Sea (April 28th - May 8th 1942) Japanese and American Carriers engaged in the first battle fought entirely with aircraft; marking the first time that naval forces clashed without seeing one another. On May 8th the carrier *Lexington* was sunk and the *Yorktown* was heavily damaged, with estimates that it would take 90 days to repair her flight deck, interior, and structural damage. That morning *Yorktown* departed Coral Sea proceeding to Pearl Harbor at 7.5 knots.

During the 1920s Naval Intelligence officials recognized that rising Japanese militarism represented a threat to U.S. interests in the Pacific, and therefore sent U.S. Naval Officers to Japan to learn the language and collect information on Japanese ships and aircraft. At the same time the U.S. Navy began a dedicated effort to collect intelligence information by breaking Japanese radio codes. By May 1942 a key Japanese code had been broken and *information* confirmed that a Japanese Task Force of four Heavy Carriers, two light Carriers, 11 Battleships, 333 aircraft, 52 Cruisers and Destroyers and 16 submarines was heading toward Midway Island in the Northern Pacific. (NIP 2001, 2002)

Armed with this *knowledge* Admiral Chester W. Nimitz, Commander-in-Chief U.S. Pacific Fleet determined that U.S. Naval Forces must stop the Japanese before reaching Midway. He also knew that since *Lexington* sank at Coral Sea and *Saratoga* was on the West Coast, unable to reach Midway in time, he needed *Yorktown* to join *Hornet* and *Enterprise* to engage the enemy at Midway. Nimitz concluded, from radio reports prior to *Yorktown'*s arrival at Pearl, that the original 90 day repair estimates were unrealistic. "In 90 days the Pearl Harbor yard could make her good as new." That was out of the question now and unnecessary. It would take much *less time* to make her *battleworthy*. She had propulsion, her elevators were working, and her wooden flight deck had been repaired during the transit. Her bomb-damaged compartments could be temporarily braced and timbered. It was necessary to patch her hull, only well enough to keep fish out for a few days more. On May 27th *Yorktown* proceeded directly into Drydock 1 and before the water was completely drained, Nimitz and the inspection party were examining her hull for structural integrity. He informed, Lcdr Pfingstad, the shipyard's hull expert that *Yorktown* must be back to sea in three days. Within an hour 1400 shipyard workers started working around the clock. Three days later she was heading toward Midway. (Potter 1981)

June 4 - 7 *Yorktown, Hornet*, and *Enterprise* loaded with 348 aircraft joined 24 Cruisers and Destroyers, and 19 submarines in defeating a far superior force at Midway. *Yorktown* eventually sank at 0701 on June 7th with her battle flags still flying from battle damage, in what is considered the U.S. Navy's greatest Naval victory. (American Fighting Ships)

Balance – Requirements to Resources

Threats

Admiral Nimitz had a clear *understanding* of the threat. His ability to obtain accurate and timely threat *information* gave him an advantage that proved to be a force multiplier. His *knowledge* and *understanding* enabled him to develop a successful plan of action. The success at Midway validated the *Yorktown* repair decisions Nimitz made.

Post-911 analysis indicates that prior to September 11th, 2001, there were numerous indications that terrorist units were planning attacks. The difficulty was validating the *information*, assessing the options, and developing plans to defend against the attacks. The simplicity of a homicide attack makes defense a formidable challenge, yet the threat remains real and must be neutralized.

Nimitz had the advantage of focusing on a narrow target and threat, the Japanese; today we are challenged to deal with more than one threat, and to accurately assess future threats. Effective threat assessment is more important today than ever and, to be successful, must be a shared responsibility of allied nations. Accurate and timely intelligence *information* is critical to evaluating the threat and building successful plans.

Plans

Plans should be based on a firm *knowledge* of the threat and available resources, they must be executable; they must be dynamic. Plans should be modified as new information becomes available, or as new capabilities or resources are delivered. In order to be effective they should be tested through experiment, simulation, and exercise.

Prior to World War II, submarines and battleships were the primary maritime weapons of choice. The vulnerability of large outdated battleships was documented at Pearl Harbor and the value of aircraft became obvious. Admiral Yamamoto *understood* the value of aircraft to his objective and exercised his plans prior to December 7th, 1941.

Subsequent to Pearl Harbor overall PACFLT force levels were much less than those of Japan. Recognizing this fact, the Navy developed a stealth-over-strength strategy in the early years of the war. Using carrier-based aircraft and the technological advantage of radar, U.S. forces could engage the enemy without ever being visually sighted by the Japanese forces. This provided the U.S. with the ability to continue to fight while America's industrial capability surged to meet the demand for new ships, aircraft, and capability.

After Coral Sea, Nimitz *decided* to send his slow inefficient battleships to the west coast and rely on air power from land based airfields and carriers to conduct strike operations. Additionally, he realized that Japanese aircraft were superior to U.S. carrier based aircraft; we needed better fighters and torpedo planes. Better aircraft were not available, therefore, Midway battle plans needed to offset an overwhelming Japanese advantage. Midway plans were modified to provide U.S. fighter aircraft with a tactical advantage by flying combat air patrols at 20,000 feet instead of 10,000. This allowed fighters to "drop in" on the heavier Japanese bombers and shoot them down before they reached their target. Finally, Nimitz recognized that time was a resource that he had very little of, and his plans considered that observation.

The Resources - Force structure

Throughout history the U.S. Navy has never had an appropriate force structure. In 1942 construction of five new Battleships, authorized in September 1940, was stopped. The Navy's shipbuilding program changed focus to modern light carriers, with many being commissioned within two years of keel laying. A total of 20 carriers were commissioned in the active Navy from December 1942 to late 1944, some were modified from their original design as requirements and capabilities changed. (Fahey 1944)

History has shown that we cannot wait 10 years to deliver major weapons systems therefore, we must figure out how to bring systems on line faster. Vice Admiral Cebrowski pointed out in April 2002 during congressional testimony; that change does not have to take this long, the proof is in our history. As an example, our Polaris missile program received the go-a-head in November 1956. Just 48 months later, the U.S.S. George Washington – our first Polaris missile submarine made its first patrol. (HASC Wolfwitz 2002).

Nuclear arms reduction agreements and reduced nuclear "first-strike" threat has eliminated the need for two SSBN submarines in the U.S. Navy inventory and made them available for other requirements. Based on a changing threat the U.S. is modifying these submarines to carry tactical cruise missiles from a submerged "stealth" platform. Therefore, we have used what forces were available to achieve our desired objective. Manufacture lead times and changing threats will undoubtedly leave decision-makers short of the resources they desire or require.

Since June 1942, naval battle plans have centered on the carrier. Recent global tensions have usually caused U.S. decision-makers to ask "where is the carrier?", perpetuating the need for attack from the air. Over the past 12 years hostilities and military actions have highlighted the value B-2, F-117, and cruise missiles in continuing to provide *over-the-horizon* "stealth" capabilities to battle planners. Technology now provides us with an opportunity to once again assess our force requirements to achieve success. The recent Iraqi war provides an example of how proper information, flexibility, and capability; can be used to modify U.S. plans by initially attacking Baghdad with Tomahawk missiles vice air bombardment. The use of Tomahawks instead of manned aircraft provided a level of safety to pilots, particularly when the threat of anti-aircraft missiles could not be confirmed. It should also be noted that the *absence of information* (uncertain Iraqi anti-aircraft capability) did not preclude a decision from being made or from action being taken.

Lessons Learned

"*... the Navy misreads the lessons of past wars. It congratulates itself upon the victories ... it does not ask the question: How well did we do compared to how well we should have done?"* **(Rickover)**

Throughout history there have been hostilities, wars and conflicts. They appear to be inevitable, however, rapid effective responses can minimize their negative affects.

I. Flexibility and Creativity are Invaluable Capabilities

In the 1700s an inexperienced navy captured merchant ships and reconfigured them as war ships. During World War II ships under construction were reconfigured or modified to enable them to perform new missions. In the late 1950s an existing SSN was separated and a missile section was "sandwiched" between the control and engineering spaces to provide a stealth strategic deterrent asset. The engineering plants on modern combatants are not only common to other ships but aircraft as well. Finally, the Navy's F/A-18 aircraft have been designed and reconfigured to allow a single airframe to perform the missions of fighter, attack aircraft, and refueling tanker. These examples show how creativity and flexibility provide the opportunity to maximize the utility and mission capability of all available resources and minimize the time required to deliver the resources required to meet operational plans. During RIMPAC 2000, a major fleet exercise that takes place every other year with nations around the Pacific Ocean rim, the Royal Australian Navy's (RAN) *Collins Class* submarine demonstrated the exceptional capabilities of this conventional-powered submarine. Joint and allied operations provide opportunities to share operational concepts, the potential for the collaborative use of resources, and the possibility of joint or combined procurement initiatives.

II. Information, Knowledge, Understanding are Necessary for Good Decisions

At the beginning of World War II a naval officer from the Bureau of Ordnance visited Professor Albert Einstein to demonstrate a new technology torpedo. Professor Einstein informed him after a brief review, that the exploder mechanism had a design flaw that would preclude the firing pin from performing properly. The next day Einstein provided a sketch of a design modification that would allow the exploder mechanism to perform properly. Unfortunately, it was not until 1944, long after the major and significant naval battles of the Pacific were over, that the torpedo firing pin problem identified by Dr. Einstein was corrected. (Crenshaw 1995) Although a naval officer within the Navy's ordnance bureau had the *information* and *knowledge* of the exploder mechanism fault it is not clear that he had the *understanding* of the effects of the fault or the *authority* to ensure that the design modifications were included in actual production runs.

As previously stated, information, knowledge, and understanding are critical to successful operations. Admiral Nimitz knew: what was needed, why it was needed, when it was needed, and where it was needed. He had the *information, knowledge*, *understanding* necessary to make an informed *decision*; and he had the *authority* to effect his decision. The outcome at Midway validated his decisions.

III. Responsibility, Authority, and Accountability Roles Must be Intelligent

Responsibility, authority, and accountability are also necessary components in the decision-making equation. As the faulty torpedo exploder example points out, having the necessary information, knowledge, and understanding may not ensure that the right decisions are made. The decision to not modify the exploder at the start of World War II may have contributed to the unnecessary death of numerous sailors and marines. Unfortunately, no amount of accountability will restore life to those that died.

Similarly, having the responsibility and being held accountable may not ensure the appropriate decision-maker has the requisite authority to carry out that responsibility or that the right decision is made. On February 1st, 1941 Admiral Husband E. Kimmel relieved Admiral James O. Richardson as Commander-in-Chief U.S. Pacific Forces, after President Roosevelt removed Richardson for protesting the vulnerability of the Fleet at Pearl Harbor. On 31 December 1941, 24 days after the attack on Pearl Harbor, Nimitz relieved Kimmel as Commander-in-Chief U.S. Pacific Fleet and Pacific Ocean Areas. Twenty-twenty hindsight shows the level of understanding of Pearl Harbor's vulnerability that Richardson possessed prior to December 7th, 1941. Unfortunately, the decision to ignore Richardson and replace him early in 1941 may have contributed to the loss of life at Pearl Harbor and an inability to detect and neutralize a surprise attack. Blurred lines of responsibility and authority have continued into the 21st Century. Fareed Zakaria in a Newsweek article observed a weakness in U.S. intelligence assessment prior to 911: "No one person at the FBI had responsibility for strategic analysis, connecting the dots" (Zakaria 2002)

Solutions

"The significant problems we face cannot be solved with the same level of thinking that created them." Albert Einstein

I. Intelligent Use of Assets

Future procurement actions must recognize the need to maintain flexibility in the purchase of our capital assets. We must also build a process that encourages flexibility in our thinking and creativity in asset use. This may require us to look beyond our own shores. If we are to continue to be successful in naval and military operations we must maximize the utility and mission capability of all available resources and build plans to exploit those capabilities.

II. Intelligent Information Management

In an environment of increased threats and limited resources it is essential to bring together information from the numerous stakeholders and legacy systems. In May 2002, Michael Isikoff observed "So much intelligence comes in, rumor, hearsay, disinformation, so little of it more than trash: once in a blue moon an agent-prospector may get lucky. But even then an agent's warning is likely to be dismissed as "chatter" …there's always too much information" (Isikoff) The Defense Reform Initiative Directive #47 identified the need to operate in a shared electronic data environment. The final report identified the need to effectively integrate knowledge-based solutions and the seamless exchange of information. (Hambre 1999)

During World War II Admiral Chester W. Nimitz posted a sign on his office asking three questions: Is the proposal likely to succeed? What might be the consequence of failure? Is it in the realm of practicability of materials and supplies? His decisions and orders in 1942 were indicative of a solid assessment of the threat, the *knowledge* of the situation, the *confidence* in the personnel assigned the execution responsibility, and a clear *understanding* of the consequences of failure at Midway. He evaluated his options, developed a plan that was likely to succeed, understood the consequences of failure, and determined that supplies and material were available. Nimitz was committed to success because of the k*nowledge* that there was no more time and that he had all the resources available. The bedrock of his decision was *accurate and timely information*.

The near term solution to today's "information overload" may rest with the creation of human-computer partnerships. Dr. Jens Pohl has highlighted the importance of creating a decision support environment where computers can focus on the functions that they perform best, and humans can collaborate in the decision process with the requisite knowledge. Better decisions can be made once a human-computer partnership has been established and organizations have progressed to an environment of Business Intelligence bringing together effective, computer-assisted (agent), information management and knowledge building. (Pohl 2001) Business Intelligence should be capable of integrating disparate information systems in a common environment. The world's military and para-military organizations could benefit from a collaboration effort that brings computers, humans, and information sources together, in order to facilitate better decisions information needs to be available to all appropriate organizations and individuals.

III. Intelligent Organizational Structure

Transformation and interoperability have been complicated by delays, stovepiped special interests, and a lack of commitment. The solution rests on eliminating redundancy, streamlining roles and responsibilities, and ensuring that all the appropriate stakeholders are included in the decision process and organizational structure. This focus is not limited to the U.S. Navy or the U.S. Government but should include our global partners. The challenge is formidable but can be achieved through intelligent information management.

IV. Commitment

In March 2003 while preparing to make the decision to commit U.S. Military forces to an attack on Iraq, George W. Bush brought together most of the concepts and observations presented in this paper. Prior to his final decision he asked his military leaders two questions: Do you have the resources you need? Are you prepared to execute your war plans? When all **appropriate** military personnel responded in the affirmative, he committed to commence the attack on Iraq and **authorized** them to proceed and allowed them to do their job.

Knowledge and understanding in the hands of the appropriate decision-maker enable us to use our resources and assets intelligently. However, without the solid foundation of timely and accurate information, understanding and a commitment to proceed are difficult to obtain.

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Section 2:

Collaboration Principles and Tools

Understanding and Applying the Cognitive Foundation of Effective Collaboration

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Abstract

Knowledge is central to collaboration and teamwork. Teams whose members know what they need to know can work together effectively. Those that do not are prone to various kinds of predictable errors, with the type of error dependent on the type of knowledge deficiency.

Our analysis of cognitive foundations for collaboration organizes collaboration knowledge into twelve major categories. The first six of these address the mostly non-real time knowledge that team members acquire as they organize for their tasks and get to know one another over time. These are understanding team goals, the plan, dependencies (task and situation interaction models), each other, team business rules, and task work methods. The second six address the knowledge needed to carry out the team work. These are understanding what others are doing, the external situation, task progress, areas of agreement or disagreement within the team, extent that the plan will still work, and decision factors.

Three important applications of this framework are an expert system to help teams diagnose and fix collaboration problems, a methodology for objective evaluation of the contribution of new technologies and processes to effective collaboration, and a knowledge basis for allocating functions among human and computer agent members of a team.

Keywords

collaboration, effectiveness, knowledge, teamwork, agents, metrics, evaluation

Introduction

Collaboration and action coordination are closely coupled activities in which team members work together to produce a product or carry out an action. Collaboration focuses on the problem solving aspects of group work. It is defined here to be "the mental aspects of group problem solving for the purpose of achieving a shared understanding, making a decision, or creating a product." In contrast, action coordination refers to the synchronized actions that people take in pursuit of common goals.

Collaboration and coordinated actions can provide many benefits (Evidence Based Research, 2001). Often the biggest payoff from collaboration arises when the team is evaluating a situation, creating an intellectual product, making recommendations, or reaching a decision. Here, team members leverage each others' perspectives to generate:

- More views on what is happening, the reasons for these occurrences, and their possible impact on the team mission
- More possible actions to take in response to the situation
- More criteria to consider when evaluating the desirability of these actions
- More possible consequences of the alternatives being considered

Unfortunately, people do not always work together effectively. The team may create products that customers don't use, and individual team members may be missing deadlines or complaining about having to do others' work or having to attend meeting they feel are a waste of time.

An understanding of the knowledge basis of collaboration and teamwork can explain fundamental causes of these problems. It can describe what's occurring "under the hood" when people work together to achieve their shared understandings, make a group decision, create such intellectual products as situation assessments, courses of action, plans, analyses, and recommendations, or carry out a coordinated action. This understanding has many practical benefits. This paper describes three of these: an expert system to help diagnose and fix collaboration problems, an evaluation methodology able to explain the reasons for effective and ineffective team behaviors, and an improved rationale for partitioning team functions among human and computer agents.

The Knowledge Basis of Collaboration

Our focus on team knowledge and understandings is motivated by the foundational role of knowledge when people work together, as reflected by the following fundamental tenants:

1. Knowledge is central to collaboration and teamwork. Teams whose members know what they need to know can work together effectively. Those that do not are prone to various kinds of predictable errors, with the type of error dependent on the type of knowledge deficiency

2. Knowledge must be distributed among members of a team. Everybody does not need to know everything for a team to be effective. But every team member does need to know how to get the knowledge he or she needs.

3. Individuals need to know about both "taskwork" and teamwork. Taskwork knowledge is what team members need to carry out their tasks alone. Teamwork knowledge is what team members need to know to work together effectively

4. The collaborative dialog helps generate the needed teamwork and taskwork knowledge. Team members exchange ideas to put in place the knowledge and understandings that team members must have for the team to achieve its mission.

Our overview diagram of collaboration mechanisms (Figure 1) emphasizes this primary importance of knowledge to collaboration. As shown in this figure, team members' knowledge and understandings support many different kinds of team activities (Wegner, 1987). Figure 1 includes three of these: team set up and adjustment, group problem solving, and synchronize and act. Team set up activities usually occur earlier and "synchronize and act" later, but in most teams these activities re-occur as long as the team continues. Thus, most teams will revisit objectives, roles, and tasks as they solve problems and act together and discover need for clarification (Katzenbach, 1993).

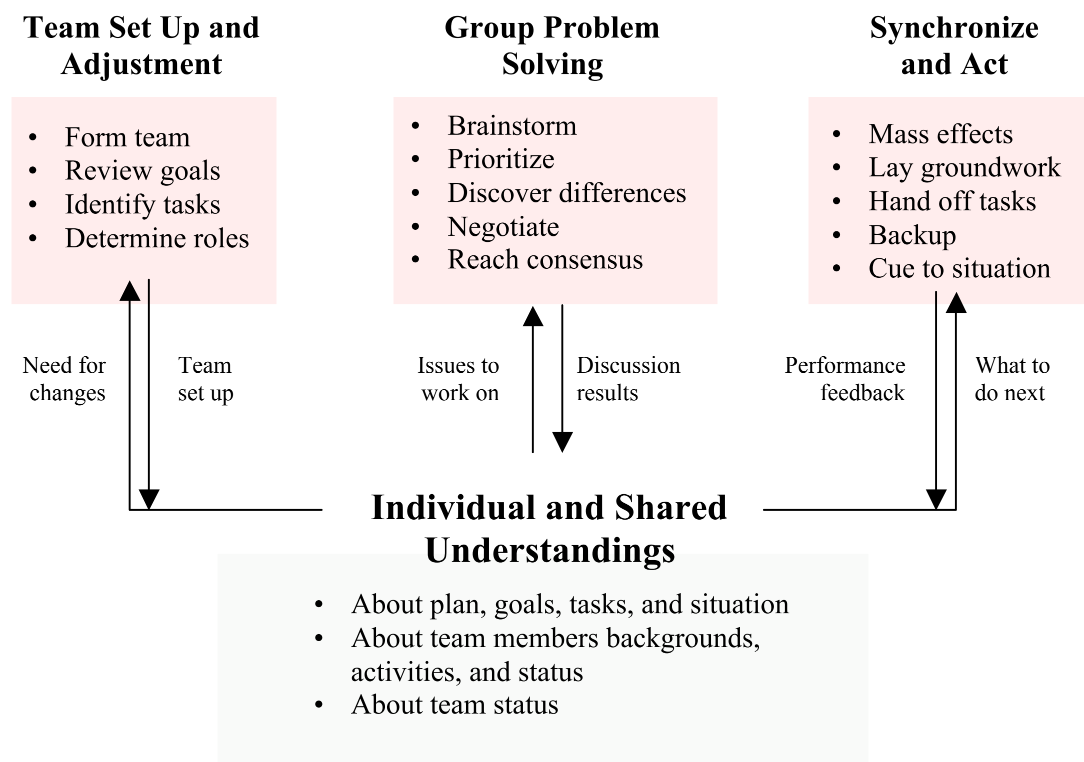

Figure 1. Building Blocks of Collaboration and Coordination

The two way arrows in Figure 1 emphasize that the knowledge both enables and is enabled by the activities in the three upper boxes. Teams cannot carry out their tasks and work together effectively if they do not have the necessary knowledge. But because teams acquire the knowledge they need to do subsequent tasks by carrying out earlier tasks, they can't acquire the knowledge they need for future tasks if they fail in earlier ones. Thus, team failure can feed on itself, with early difficulties impeding task progress, which in turn impedes obtaining the knowledge required to continue working together in future tasks.

Understanding the specifics of the enabling collaboration knowledge is the foundation to the three applications discussed later in this paper. It provides the organizing principle for the Collaboration Advisor Tool that diagnoses collaboration problems and suggests remedies, provides the framework for creating a cause-effect audit trail when evaluating the impact of new technologies, processes, or organizations on collaboration, and motivates the partition of functions among human and computer agents.

Our analysis of cognitive foundations for collaboration has organized collaboration knowledge into twelve major categories, our "knowledge enablers." This organization draws on EBR's case analyses of collaboration problems, on the collaboration research literature, and on theories of situation understanding, decision making, and command and control. We also use this categorization because it maps easily into the different classes of commonly observed collaboration problems.

The following briefly describes each of these categories. The first six of these address the mostly non-real time knowledge that team members acquire as they organize for their tasks and get to know one another over time. This knowledge changes relatively slowly over time. The second six categories are the time sensitive understandings of team and task status and prospects at each instant of time. These understandings can change rapidly.

1. Goal understanding encompasses understanding team mission, the goals of the client, the criteria for evaluating team success and achievement of commander goals, and the criteria for evaluating task progress. Understanding of team objectives includes understanding both the explicit and implied goals of the team, taking into account the cultural norms of the tasking authority.

2. Understanding of roles, tasks, and schedule is the "surface" understanding of the plan. Project plans usually decompose the team's work into separate tasks, assign these tasks to individuals or groups of people, and then specify a schedule. The plans may specify team member responsibilities, to include both fixed and context dependent leadership roles, principal task performers, and task backups.

3. Understanding of relationships and dependencies is the "deeper" understanding required to project success and make adjustments between tasks, resources, time, information, and the situation. The dependencies important to understand are the temporal, spatial, and causal (logical) relationships between separate tasks and between tasks and goals, information, resources, and the external situation.

4. Understanding of team members' backgrounds and capabilities ("familiarity" in Table 2) includes knowing other team members' values/decision criteria, to predict what they will decide; mental models, to predict what they will project; motivation, to predict their level of interest and engagement; capabilities and knowledge, to understand what they can do.

5. Understanding of team "business rules" includes both formal and unspoken rules by which team members work together. These are the rules for talking, listening, brainstorming, and hearing outside perspectives at meetings; (2) critiquing and editing; (3) offering/asking for help and information, (4) providing performance feedback, (5) setting up meeting (how to schedule, who to invite), (6) and cc'ing and broadcasting.

6. Task knowledge is the knowledge team members need to do their individual tasks. No matter how effective their teamwork is, teams cannot be successful if the individual team members lack the skills and knowledge to carry out their parts of the job. Task knowledge includes knowing how to perform assigned tasks, how to find and access documented information, how to use support tools, and how to find and access people with needed knowledge.

7. Activity awareness is knowing what others are doing and how busy others are, their level of engagement, if they are getting behind or over their heads, and if they need help with their workload.

8. Understanding of the external situation is appreciation of everything outside of the team that can impact its work. In military operations it includes the actions of the adversary. In business it may include the actions of competitors and the preferences of customers. Understanding the external situation includes knowing who the significant players are and knowing their status, capabilities, strengths, weaknesses, behaviors objectives, and plans.

9. Task assessment is determination of what tasks are being worked on and by whom, the status of these tasks, comparison of this status with the status called for by the plan, and judgment of the adequacy of available information and resources. It includes an assessment of progress and prospects for task success, including an estimate of whether a task needs help and an estimate of whether required resources and information are available.

10. Mutual understanding addresses the extent to which team members know how well they understand each other. It includes the extent to which team members are aware of where and why they agree or disagree about team goals, team progress, the external situation, and all the other team knowledge enablers.

11. Plan assessment is an estimate of whether the current team, processes, plans, and resources will still enable the team to achieve its objectives. It builds on and integrates assessments of team activities, task progress, the external situation, and degree of mutual understanding. Unlike a task assessment, which focuses on how well individual tasks are progressing, plan assessment considers all current factors and projections into the future to estimate the need for plan adjustments.

12. Understanding of decision drivers includes grasping all of the factors that must be considered when making a decision. These include knowing what can impact the effectiveness of a decision, and also knowing the factors that constrain the decision or can impact how the decision should be made. These include understanding the extent that a change in plan will confuse or disorient others; appreciation of appropriate decision strategy/ e.g., RPD, deliberative (Zsambok, 1993), insights into methods for handling uncertainty; and knowledge of time available and of decision trigger points/events.

Application 1: Collaboration Advisor Tool

The Collaboration Advisor Tool is a team self-help diagnosis and recommendation expert system. It diagnoses the underlying reasons for team difficulties in terms of the twelve knowledge enablers, lists warning signs for future problems in the knowledge areas of greatest concern, and suggests processes and tools to alleviate these problems. It also provides a "team view" to summarize and compare team member perspectives.

Diagnosis. Figure 2 is an overview of the tool's logical structure for diagnosing knowledge inadequacies. The four blocks at the top represent the product development flow, from information to team knowledge, to team behaviors, and to products. The bottom set of blocks are the issues the collaboration advisor tool considers when making its diagnoses. These are knowledge risks, knowledge importance multipliers, and behavioral symptoms of knowledge problems.

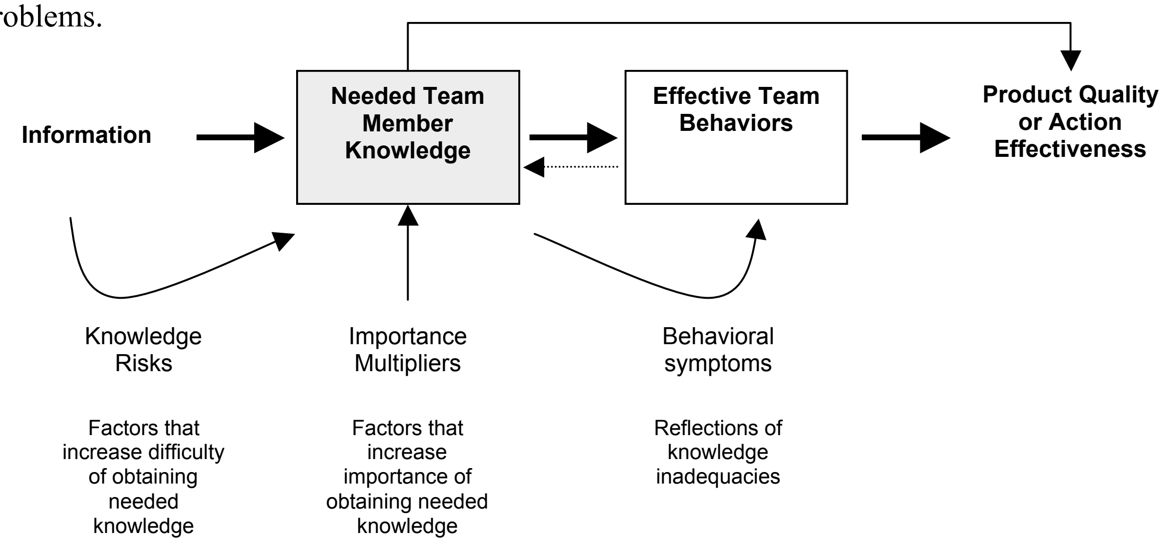

Figure 2. Factors Impacting Collaboration Advisor Diagnoses

The tool knowledge base has separate sections for diagnosis and for remedy suggestions. Table 2 illustrates some of the knowledge risks, importance multipliers, and behavioral symptoms useful in diagnosing team problems in goal understanding.

The knowledge base has similar entries for each of the knowledge enablers. Because a risk, multiplier, or symptom usually applies to more than a single knowledge category, the tool uses evidential reasoning in diagnosing team problems and assigning a level of concern for each of the knowledge areas. For example, in assigning a level of concern for a risk, the advisor tool considers the degree of risk a particular issue imposes for each of the knowledge areas, the number of knowledge areas it impacts, and the overall level of current concern for each knowledge area it can affect.

Knowledge Base Category	*Examples of Knowledge Base Elements*
Risks: Makes obtaining needed knowledge more difficult	• Customer goals and expectations are not clearly stated • The team has multiple competing/conflicting goals • Some team members are unfamiliar with a customer's business area or culture • Criteria for determining mission success or product quality are unclear • Criteria for determining task progress or reaching milestones are unclear
Multipliers: Makes having the knowledge more important	• Anomalous unanticipated situations are likely to arise • Timely clarification or feedback is not readily available
Symptoms: Indicators gaps in needed knowledge	• People act in ways which the leader or sponsor believe are inconsistent with intent • Team members argue or disagree about what achievements constitute success • Team members propose actions which if successful would be inconsistent with intent

Table 1. Illustrative Knowledge Base Entries for Diagnosing Gaps in Goal Understandings

Advisor remedy suggestions. Once it makes its diagnosis, the tool suggests tool and process remedies for team areas of concern. It makes a "canned" suggestion for each of the enabler areas, and makes additional specific recommendations for each of the team risks that the tool identifies as significant.

As an example, the general advice for concerns about team goal understanding is:

> "The most direct way to understand explicit team goals are briefings and documents stating these goals, as in written plans and requirements traceability documents. Interactions with leaders (e.g., military commanders) and clients help convey both explicit and implicit goals, especially when non-verbal cues may be communicated. Knowing the leaders, clients, and their cultures helps people understand implicit goals. Group discussions of specific success criteria, especially in terms of the properties of desired team products, contribute to goal understanding."

Continuing the example, the specific suggestions that the tool makes for the risk (see Table 1) "The team has multiple competing/conflicting goals" is:

1. Identify possible obstacles or challenges to meeting plan goals
2. Analyze goal and task conflicts to determine how the conflicts can be mitigated or how goal achievement can be modified to reduce conflicts.
3. Discuss with customers, stakeholders, and team members the desirability of various possible goal trade-offs
4. Develop consensus of team members on customer requirements, goals, and expectations

5. Publish customer requirements and team consensus on goals and expectations

Team View. The collaboration advisor can collect the perspectives of team function from each team member, and create a consolidated team view. This view points out areas of agreement and disagreement within the team, and in each area displays the number of team members with each perspective. Issues summarized in the team view are the knowledge areas of greatest concern, team risk areas, and team behavioral symptoms.

Application 2: Collaboration Evaluation

Collaboration evaluation has two principal goals. First, it seeks to quantify changes in team performance, in order to determine the extent to which a new technology, process, or organization improves team effectiveness. Second, it seeks to explain the reasons for changes in effectiveness. The paper "Objective Metrics for Evaluation of Collaborating Teams" (Noble, 2003) and the handbook "Command Performance Assessment System" (Kirzl et al. 2003) describe methods of objectively evaluating team performance. This paper focuses on the key role of team knowledge in explaining the reasons for changes in effectiveness; e.g., in creating an impact audit trail.

An objective evaluation, which quantifies the change in team performance, is an important part of an evaluation. Usually, however, a sponsor desires to understand not only how much team performance is improving, but also wants to understand the reasons for the improvement. Understanding the changes to team understandings and knowledge is an important part of the improvement audit trail.

Explanatory audit trails can identify the reasons for changes in team performance. Figure 3 outlines the audit trail components: the information presentation and communication tools, the team knowledge, the team behaviors, and actions and products. The team knowledge is the twelve enabler categories previously discussed. The critical behaviors measure the extent to which the team coordinates and adapts well. The audit trail framework organizes the critical team behaviors into nine categories. The first three of these concern how well the team coordinates and synchronizes its tasks. The next four categories concern how well the team manages and handles information. The last two categories address a team's ability to change when needed.

This audit trail enables team evaluators to tell a causal story explaining why a new technology, process, or organization improves team performance. For example, a spatially distributed team may produce a product more efficiently when a tool that helps them be more aware of each others' activities is introduced. The overall performance metrics might show that the team is now creating a better product (as measured using the product metrics) faster and with fewer person hours. The behavioral metrics might then document that team members have reduced performing unnecessarily redundant tasks and members spend less time waiting for team members to finish precursor tasks. The knowledge metrics might document that team members are much more aware of what each other is doing, thus enabling the improved coordination. An analysis of the new information technology confirms that its displays are designed to help people know what others are working on.

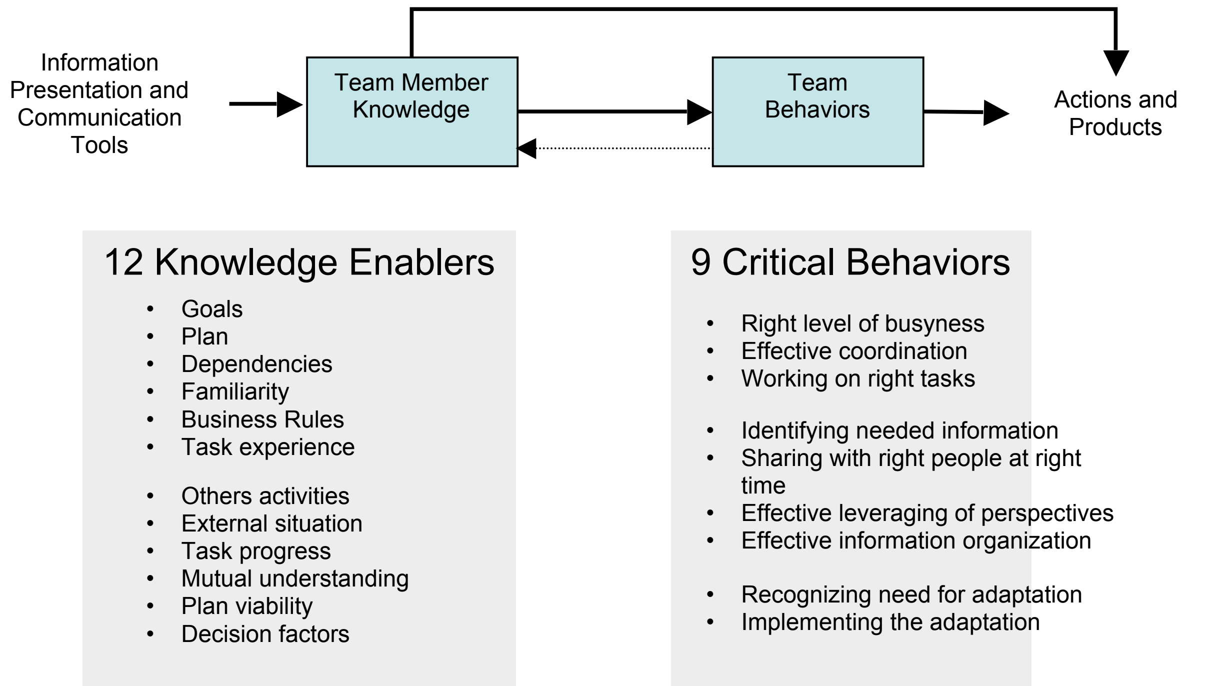

Figure 3. Elements of the Evaluation Audit Trail

In order to document this story, evaluators need to measure each of the steps in the audit trail. They need to measure the properties of the tool, process, or organization that could plausibly impact knowledge. Then they need to measure the knowledge itself to show how much it changed. Next, they need to measure the behaviors, and finally, they need to measure the products. The evaluation handbook (Kirzl et al. 2003) describes each of these steps. This paper reviews the first two steps: measurement of the environment properties that can impact knowledge, and measurement of the knowledge itself.

Risks to knowledge. As described in that handbook, the link between the supporting infrastructure (tools, processes, and organization) and knowledge are various risks to knowledge. These risks are task, team, and environmental factors that increase the difficulty of obtaining the knowledge needed for effective performance. Table 2 provides examples, selected from the more extensive set in the handbook, for how some illustrative tool and tool services can impact some knowledge risks. The left column of the table lists illustrative tool services. The middle column lists knowledge risks that the tool service reduces. The right column references one or two of the knowledge enablers affected by that risk.

Tool and Tool Service	***Knowledge / Understanding Risk***	***Key Knowledge Areas Impacted***
Applications that enable team member's input (new material, comments) in near-real time	It is difficult to see other people do their jobs	Activity Awareness
	It is difficult to link team products to the people who did them	Familiarity, Mutual Understanding
Monitors for watching others work	It is difficult to see other people do their jobs	Activity Awareness
	Team members are sometimes assigned to tasks based on title rather than skill	Task Knowledge
Monitors focusing on external situation changes	It is a difficult environment in which to discover problems early	External Situation
	There are significant time lags between taking an action and knowing the result	External Situation, Decision Drivers
	It is hard to see quickly the changes people make to either the situation or to team products	Activity Awareness, External Situation

Table 2. Example of Tools and Services that Reduce Knowledge Risks

Measuring changes to critical team knowledge. Changes to team knowledge may be measured by asking people questions that they need the knowledge to answer. Alternatively, this knowledge can be inferred from overhead team statements or behaviors. The latter is especially important in environments where team participants cannot be disturbed to answer questions.

The first method of measuring knowledge is to ask the team participants questions. The handbook suggests questions for each of the twelve knowledge categories. Example questions for "familiarity" (knowledge about others on team) are:

1. Who on the team are most knowledgeable about y?
2. Who has experience in subject y?
3. What is person z likely to think about y?
4. What is he most likely to do in situation y?
5. What are the conditions under which y is likely to need help with task z?

The second way of measuring knowledge is to infer it from overheard statements and team member behaviors. These behaviors and overheard statements are the knowledge deficiency symptoms, and are the same ones that the collaboration advisor tool uses to help diagnose gaps and deficiencies in each of the knowledge categories.

Table 3 lists five symptoms extracted from a more comprehensive table in the evaluation handbook. The first three of these were also shown in Table 1. The second column notes the data to be collected at each observed instance of a symptom. The third column scores how often the symptoms are observed, a count used to weight its significance.

Each of the symptoms in the table can be a sign of poor understanding of goals. Unfortunately, as previously discussed with respect to the collaboration advisor tool, most symptoms are ambiguous. The fourth symptom can also imply poor understanding of the plan or relationships.

The fifth can imply poor understanding of decision factors. Therefore, inference of the knowledge from symptoms requires evidential reasoning. In fact, because this is the same evidential reasoning that the collaboration advisor tool performs, that tool can be a significant support in documenting team member knowledge, and thus in creating the evaluation audit trail.

Symptom	***Data to be Collected***	***Scoring***
People act in ways which the leader or sponsor believe are inconsistent with intent	Questionnaire or record leader feedback to staff	# of inconsistent actions per time period
Team members argue or disagree about what achievements constitute success	Record disagreements	# of disagreements/time period
Team members propose actions which if successful would be inconsistent with intent	Record actions. SME determine inconsistencies	Ratio of # of inconsistent actions to total actions
Sometimes team members pursue their own objectives rather than support team needs	Questionnaire	# of occurrences per time period
Team members state that some past team decision or orders contradicted overall intent	Questionnaire	# of occurrences

Table 3. Example of Handbook Table for Symptoms of Poor Goal Understanding

Application 3: Agent Functional Allocation

In “mixed initiative” human-computer systems, people and computers work together to solve a problem and achieve a goal. Designers of such systems are admonished to “task computers with work computers do best, and to task people with work that they do best.”

Though the line between what computers do well and what people do well continues to shift as technology improves, it is agreed that today computers are best at arithmetic, data storage, data sharing, and reasoning confined to well structured problems. They can accomplish these tasks quickly and reliably. In contrast, people need to be entrusted with any task that requires “common sense reasoning” based on people’s experience interacting with the world and with each other. Computers have particular difficulty when reasoning requires an understanding of societal norms, values, and conventions or when reasoning requires the computer to input from unstructured perceptional cues (interpreting a movie), such as natural language comprehension and scene interpretation.

Table 4 applies these general guidelines specifically to collaboration. It describes for each of the twelve collaboration knowledge categories those parts of the knowledge and understanding that computers address and the knowledge and understandings which given current levels of computer intelligence, should be reserved for people. Functional allocation then follow from the knowledge assignments. Functions who success requires knowledge in the “human strength” column should be assigned to people. Those that need only knowledge in the "computer strength" column are good candidates for assignment to computers.

Knowledge Category	***Computer Strength***	***Human Strength***
Goal Understanding	Explicit goals associated with concrete measurable objectives	Goals implied by cultural norms
Understanding of roles, tasks, and schedule	Knowledge of plan and schedule, as recorded in planning documents Formally specified team roles	Knowledge of backup and default team member roles based on knowledge of team members character and past experiences Extent that a schedule can slip without violating unstated "real" goals
Understanding of relationships and dependencies	Physical relationships among entities, especially time-distance relationships	Relationships that depend on understanding human behaviors and motivation
Understanding of team members' backgrounds and capabilities	Credentials, as expressed in defined ontology Extraction of backgrounds by review of topics in documents written	Team members' values and character, as needed to predict action in unusual circumstances
Understanding of team "business rules"	Rules for informing others, for accepting edits, and enforcing formal permissions	Understanding the reasons for rules, in order to know when it's appropriate to modify
Task knowledge	Routine and standardized tasks reducible to algorithm or formula. Retrieval of documents and written information	Tasks requiring imagination and creativity Elicitation of information from people Tasks requiring understanding of implicit human values
Activity awareness	Tasks people are working on, as implied by documents they are accessing and people they are interacting with through computers	Tasks people are working on, as inferred by watching them work. Level of engagement in tasks, as inferred from body language and other non verbal cues
Understanding of the external situation	The locations and identity of situation participants, as inferred from reports	The motivations, goals and plans of situation participants, as inferred from current and past experiences
Task assessment	Task progress, as inferred from development of computer readable documents Needed resources and information, as specified in written plan	Task assessment as inferred from verbal reports and inspections of product Estimates of difficulties from non-verbal cues and familiarity with team members
Mutual awareness of team member understandings	Facts in distributed data/knowledge bases Consistency of facts, based on literal interpretations	Extent of agreement/disagreement based on behaviors and on past knowledge of people's goals, values, and behavioral styles

Plan assessment	Extent plan will work, based on recorded task progress and resource/information inventories and on formal mathematical models of task dependencies and resources	Extent plan will work based on observed or verbally reported task progress Projections that depend on forecasting human behaviors
Understanding of decision drivers	Knowledge of planned and standard actions, of schedules time available to make decision, and of specified sub-goals	Knowledge of how human team members and adversaries may react to plan changes Identification of unstated action constraints based on societal and client values

Table 4. Knowledge Most Conveniently and Reliably Allocated to People or Computers

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Observations of Improved Collaboration Among Global Patient Movement Planners

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Abstract

For the United States military forces, Booz Allen designed and implemented a web-based patient regulating, movement planning and tracking system called $TRAC^2ES$[1]. During the implementation and fielding of this system, we noticed a dramatic improvement in collaborative decision-making among patient movement planners. While this was not the primary objective of fielding $TRAC^2ES$, it has proven a welcome benefit. This paper explores the causes of collaboration improvement brought about by the system and how lesson-learned might be applied to other business situations requiring collaboration among the participants.

Before the implementation of $TRAC^2ES$, the patient movement process was possible, but fraught with incomplete or conflicting information. Hand-offs between movement planners were often abrupt or incomplete. While movement planners worked very diligently to avoid harm to any patient, there was a constant need to adjust to surprises, if not near catastrophes. Receiving hospitals had no warning until the morning the patient was in-bound.

The collaborative decision-making success of $TRAC^2ES$ can be attributed to three primary factors addressed in this paper:

- Adapting information flow to business process
- Adjusting decision cycles to workflow cycles
- Providing a decision support tool that allows each party in the process to understand the impact of his or her own actions on the overall process

$TRAC^2ES$ has now been in operation for two years. It has supported military operations and military families throughout the world, providing safe and reliable transit for not only U S, but also international patients. Planners and hospitals, alike, have visibility for several days in advance to assure that resources are fully available and prepared to provide smooth, responsive and safe transit for patients, anywhere in the world.
The lessons learned for $TRAC^2ES$ have clear implications for broader supply chain application. Horizontal collaboration among supply chain partners at the tactical and strategic level may be vastly improved with similar approaches.

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1 *TRANSCOM (US Transportation Command) Regulating And Command and Control Evacuation System – a system designed to collect information, plan, route, and schedule movement, and track progress of movement for military or military family member patients, requiring movement from one area of the world to another for medical treatment not available in their original location.*

Key Words

Decision support system; collaborative process, flow, sharing, fit.

Introduction

U.S. military patients are often moved to locations where better medical care can be provided. A casualty occurring in Afghanistan or Iraq, for example, is provided emergency and life-saving treatment there. However, once stabilized, this patient is transported to U S military medical facilities in Europe, and possibly to the U S for more definitive care. In the case that the casualty travels to the U S for ultimate treatment, at least three movement planners and three medical facilities, spanning half the globe and a dozen time zones, must collaborate to facilitate this patient's successful (and uneventful) move to the hospital that will provide definitive and restorative care. Meanwhile, these planners are performing similar tasks for hundreds of patients each week. For example:

- An airman's child injured in an intramural sporting event in Italy may require restorative care available to the service member's family only in San Antonio, Texas.
- A sailor, injured aboard ship in the western Pacific, must be returned to San Diego, California for vital treatment.
- A soldier burned badly in an automobile accident in California requires specialized burn treatment available at Brooke Army Medical Center in San Antonio, Texas.

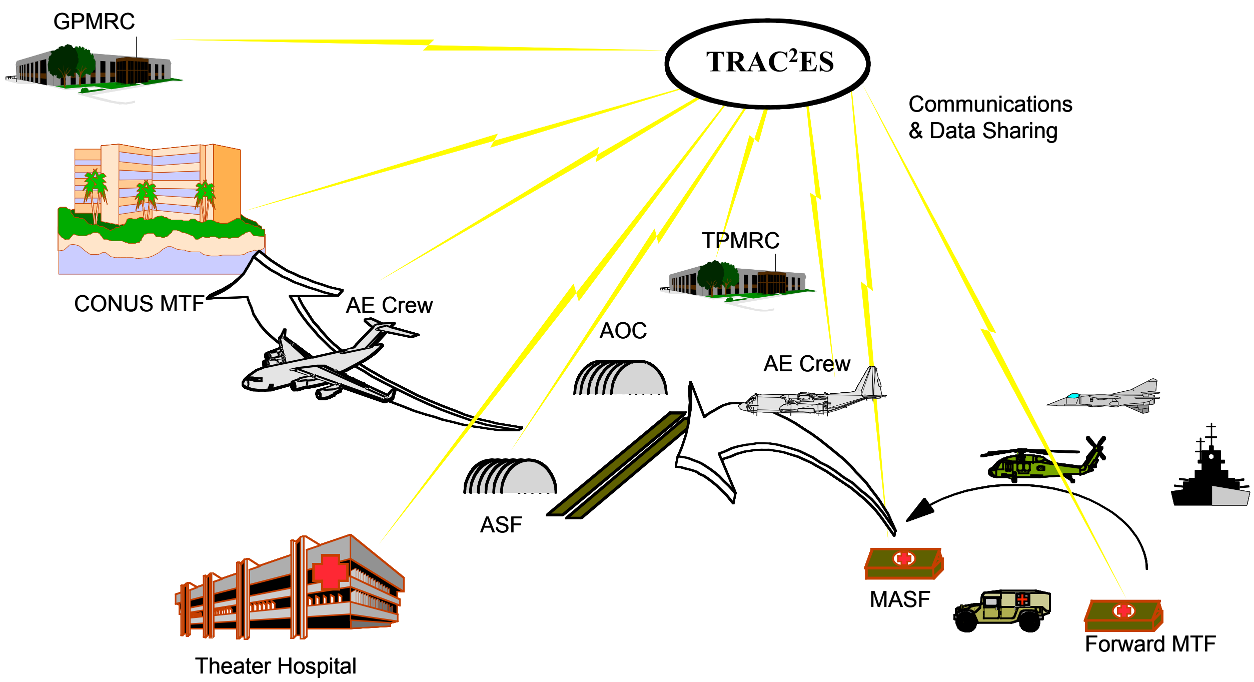
A vast network of military hospitals and patient movement specialists exists around the world to provide medical care for the U. S. military services members and their families, and to move them to any location within that network which can provide the specific care needed, when necessary.

Patient movement specialists work closely with U. S. Transportation Command to both plan dedicated patient movement aircraft missions and to take advantage of opportune aircraft missions to quickly and safely move patients to the required destination.

Substantial collaboration is required among worldwide participants to make this process work smoothly. Lessons learned from Operation Desert Storm, the first Gulf War, suggested that this collaboration was ineffective and led to considerable confusion. While no patient failed to obtain satisfactory treatment, patients were frequently routed incorrectly, arriving unexpectedly at unprepared locations. Tracking patients whereabouts, once evacuated from the combat zone, became a painstaking process of telephoning multiple hospitals to inquire if they were treating the specific patient. Each participant in the patient movement network was performing his or her job with exceptional skill and efficiency in a local context, but without knowledge of the impact of his or her action on the total system. Lesson's learned pointed out the need to both streamline the patient movement business process and to create a tool to facilitate the process and aid in crucial decision-making. That tool is TRAC^{2}ES (see footnote 1).

Exhibit 1 describes a high level patient movement process and the coordination required to accomplish the movement of a battlefield casualty to a definitive or restorative care medical treatment facility (MTF) in the continental United States (CONUS)

Exhibit 1 – Patient Movement Flow from Battlefield to CONUS MTF



Acronym Decoder

AE – Aeromedical Evacuation AOC – Air Operations Center ASF – Aeromedical Staging Facility CONUS – Continental United States GPMRC – Global Patient Movement & Requirements Center	MASF – Mobile Aeromedical Staging Facility MTF – Medical Treatment Facility TPMRC – Global Patient Movement & Requirements Center

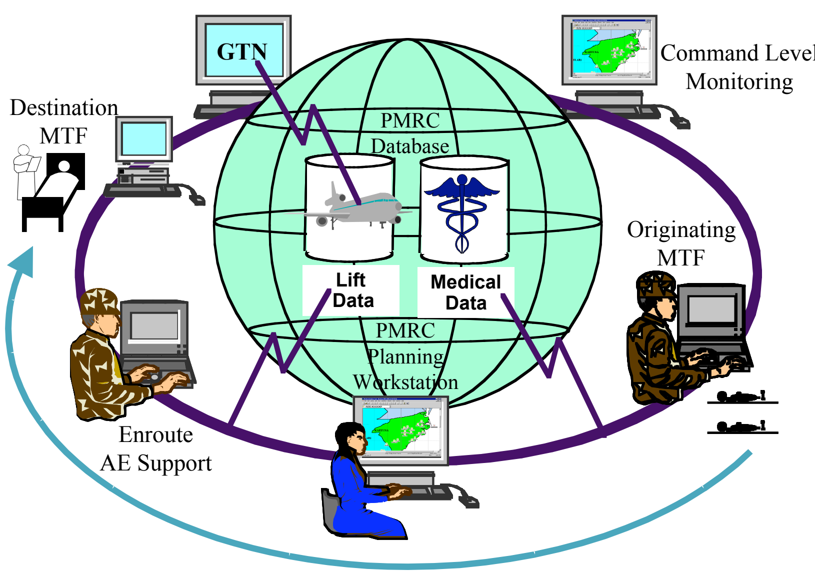
The patient may be moved by air or ground ambulance from the battlefield to a forward deployed medical treatment facility (MTF). These MTF's are quite capable, but have limited capacity and must quickly treat and evacuate patients to be prepared for the next wave of casualties. The patient receives resuscitative care and intensive care as needed until stable enough to be transported. The forward MTF requests movement of the patient, describes care required, and establishes a ready to move date.

A TPMRC (Theater Patient Movement Requirements Center) coordinates the movement of all patients in its area of responsibility. It provides itineraries for each patient and crew, manifests for each aircraft mission that will carry patients, instructions and patient information for both origination and destination hospitals, as well as for en route medical crews, called Aeromedical Evacuation (AE) Crews.

In the forward areas, the patient will be delivered via ambulance, at the appointed time, to a Mobile Aeromedical Staging Facility (MASF) to rendezvous with the aircraft. The complete move may involve multiple stops. From locations that are very distant, the patient will be flown to an intermediate location where adequate care is available, such as the Landstuhl Army Medical Center in Germany, or the Tripler Army Medical Center in Hawaii. Ultimately the patient is flown to a CONUS MTF with the availability of appropriate care, and when possible, close to the patient's family. Aeromedial Staging Facilities (ASF) are located at the major hubs to facilitate transfer of patients from one aircraft mission to another en route to final destinations

Exhibit 2 depicts the information sharing which must take place throughout a patient's itinerary. In addition to routing and patient care information, knowledge of the patient's location and movement progress is also essential. In the age of instant communication, embedded reporters, and images beamed by satellite phone to our television sets, families may see their loved ones injured on the battlefield before the battlefield commanders are even able to have a full accounting of the unit's casualty status. The ability for the military commanders to properly inform family members of their loved one's status, and reassure them that they are being cared for properly, is greatly facilitated by quickly available and accurate information about patient's condition, current location and planned itinerary.

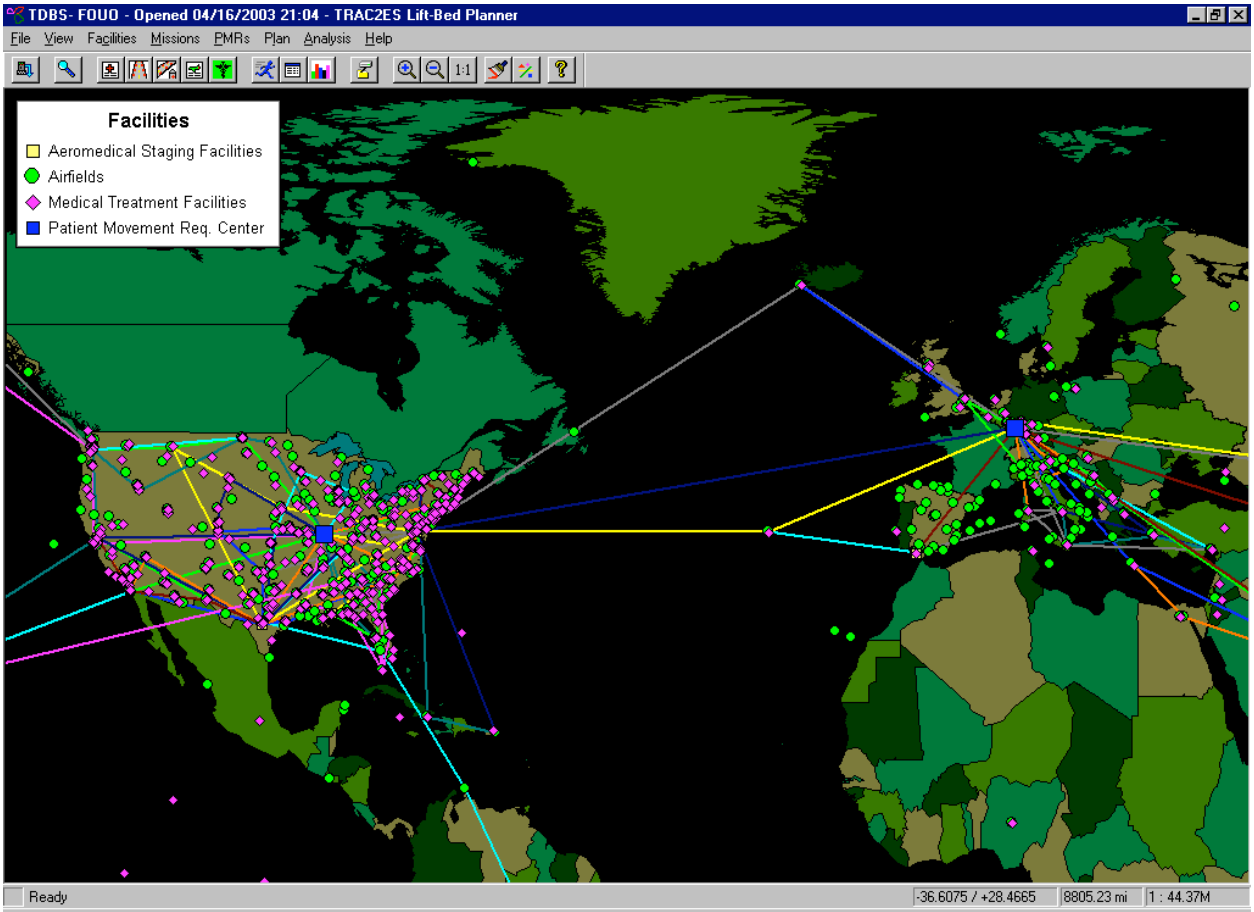
Exhibit 2 – Patient Movement Information Network



Each participant in the process needs the ability to both give and receive timely information that contributes to the swift and uncomplicated delivery of the patient to his or her ultimate destination.

The process is further challenged by the complexity of the worldwide patient movement network. Exhibit 3 illustrates that this network must be capable of responding to illness and injury wherever service members and their families may be located.

Exhibit 3 – Global Patient Movement Network



The network includes hundreds of MTFs, as well as aircraft missions, serving millions of beneficiaries. This involves hundreds of patient moves each week, even when no conflict is in progress. In major conflicts, or man-made or natural disasters, the numbers of casualties can peak to thousands per day.

Even if the capacity exists in terms of hospital beds, aircraft and crews, a task of this magnitude cannot be accomplished successfully without effective collaboration among the patient movement network participants.

The Collaborative Process

What do we mean by collaboration? How do we measure it? How do we improve it? We will not attempt to answer all of these questions, here; however, they are important questions to consider. Too often, technology is the only solution considered to enhance collaboration. Electronic whiteboards, application sharing, instant messaging and other technologies are helpful in some situations, but not all.

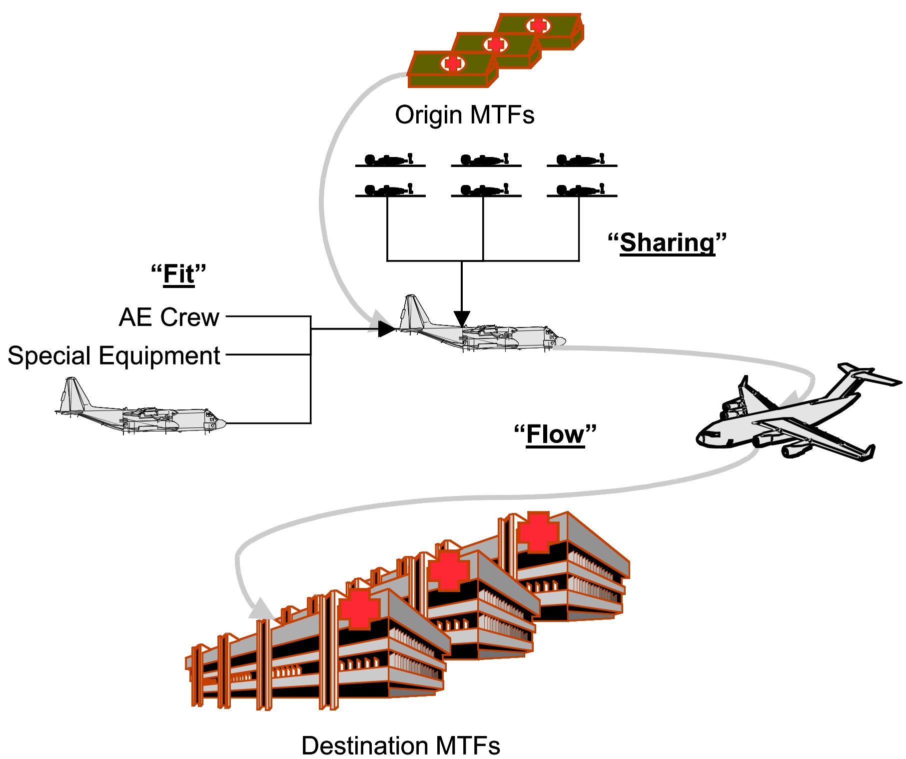
In the patient movement process, collaborators frequently act independently in the system. However, there are dependencies that they must manage in order to coordinate a patient's move. Understanding these dependencies, related decisions and timing of actions are key elements of collaboration.

According to the Center for Coordination Science at Massachusetts Institute of Technology, three basic types of dependencies exist to facilitate coordination.[2] The types suggested are as follows:

- Flow – when one activity creates a resource that is used by another activity
- Sharing – when multiple activities use the same resource
- Fit – when multiple activities produce a single resource

The collaborative processes that combine to move patients include all three. Exhibit 4 describes several of these processes as examples of flow, sharing, and fit coordination instances in patient movement.

Exhibit 4 – Coordination For Patient Movement.



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[2] *Malone, T.W., et al; Tools for inventing organizations: Toward a handbook for organizational processes; Management Science 45(3) March, 1999.*

Patient movement is inherently a “flow” process. Originating MTFs prepare patients to move and present the patients to the transportation network to be moved. One aircraft mission transports the patients to a staging facility to await another aircraft mission to continue each patient’s itinerary, until the patient ultimately reaches his or her destination. Information to support these activities includes the availability and schedule of resources. Decisions include aircraft mission schedules and manifests, as well as patient itineraries.

At the same time multiple patients “share” an aircraft mission as well as MTF capacity. Information to support sharing includes availability of litter or seat space on aircraft and beds in MTFs, but must also include patient priority in order to adjudicate conflicting needs for the same resources. Currently, patients are identified as “urgent”, “priority”, or “routine” for patient movement purposes.

In order for an MTF bed or aircraft litter to be usable by a patient, several important resources must “fit” together. The aircraft must be ready to fly, and it must have both a flying crew and a medical crew to care for the patients en route. In addition, special equipment or services for certain patients must be available, such as ventilators, special medications or special meals. The MTF bed must be supported with appropriate staff having the specialty appropriate to the patient’s need. Information to support these activities include aircraft and crew availability, patient condition and special requirements, and MTF bed and staff status.

To establish who needs what information, when, it is important to understand the relationships of the patient, at each stage of movement to the collaborator involved. Time scale is also critical in order to grasp the responsiveness and timeliness of actions necessary. Exhibit 5 describes these relationships.

Dots on the graphic represent the patient. Vertical arrows represent the patient moving from location to location listed on the left site of the table. Horizontal arrows represent the patient remaining for treatment at the location shown to the left. Above the table, gray-shaded shapes indicate the span of control of the patient movement requirements centers (PMRCs) that control patient movement for their region of responsibility. For example, the theater (T)PMRC moves the patient out of Iraq to Kuwait, then from Kuwait to Europe. The European (E) PMRC will monitor the inbound patient, then manages the outbound move to CONUS. The Global (G) PMRC monitors the inbound movement to CONUS, then manages onward movement to final destination. All have end-to-end visibility of the patient from origin to destination. Listed across the bottom of Exhibit 4 are the many other entities that must also share information about patients and aircraft missions to successfully accomplish each patient move.

Exhibit 5 – Collaborative Participants Interaction With Patient Over Time

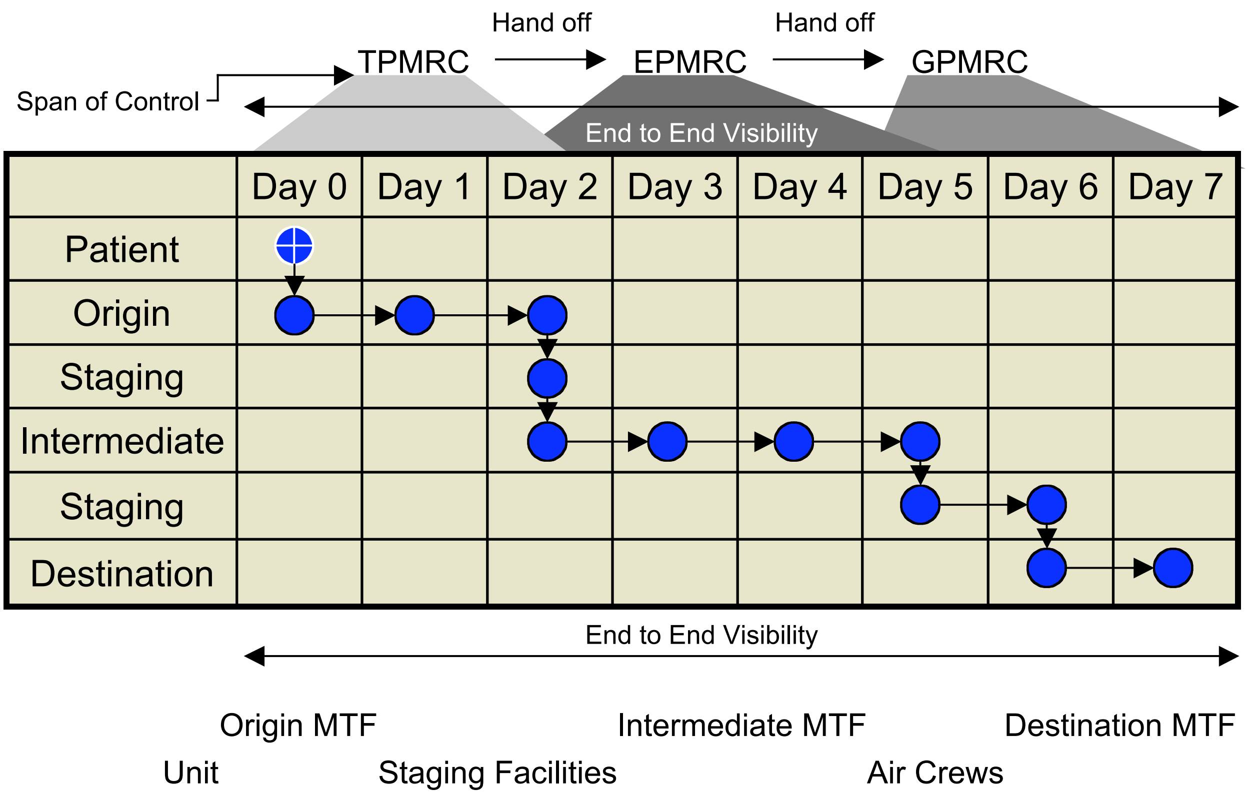

Exhibit 6 describes the minimum input and output information required or available for each collaborator in the process, and decisions made by each.

Exhibit 6 – Input, Output And Decisions Required For Each Collaborator In The Patient Movement Process

Collaborator	Required Input	Available Output	Decisions
Command Structure Original Unit	Status Location Plan of Movement	N/A	Patient Ready Date
Originating MTF	Patient departure time Scheduled mission Movement status	Patient condition Patient demographics Patient Ready Date	Patient Ready Date
Staging Facility	Mission manifest Mission schedule Special needs Patient condition/status	Staging capacity Patient location	Logistics per mission Beds Ground transport In/outbound mission Mission schedule
Operations Teams	Mission manifest Mission schedule Special needs	Available resources Time needed prepare	Litter / seat configuration Special needs

Flight Medical Crew	Patient status/condition Mission manifest Mission schedule Special needs	Post mission debrief Patient status Patient location Equipment status	Adequacy of resources Suitability of mission for patient
PMRCs	Patient condition, location, ready date Patient care needs Mission status Mission schedule	Beds available Patient location	Treatment plan Resource allocation
Destination Facility	Patient arrival schedule Patient status Patient condition	Beds available Patient location	Treatment plan Resource allocation

Building TRAC^{2}ES to Facilitate Collaboration

TRAC^{2}ES was designed as a web-based tool with global access via the internet. Anyone with an appropriate account and access to the internet may use the system. Access in forward combat areas is further facilitated by a "thick" client application that allows users to send and receive information with intermittent transmissions via radio or satellite telephone, similar to e-mail. Data structures, screens and reports in TRAC^{2}ES are designed around each type of collaborator's needs.

As soon as a patient is reported for movement and a "ready" date is established, planning for the entire trip may begin. Flight nurses screen the patient records to assure that all needed information is included, such as special treatment, medication, equipment, or limitations. Crews study their mission manifest and plan the treatment they will carry out during the mission, as well as actions required at each stop. Mission schedulers review TRAC^{2}ES generated patient itineraries and mission manifests, and observe any patients in an "unplanned" status to determine what adjustments must be made to allow the patient to move to destination.

TRAC^{2}ES was carefully designed with the business processes of patient movement in mind, yet collaboration among participants was not specifically or explicitly addressed. Once placed in service, TRAC^{2}ES has proven to facilitate collaboration extremely well. Why?

Adapting information flow to business process. As previously discussed, the TRAC^{2}ES design carefully considered the roles and responsibilities of several categories of users. Reports and information queries were designed to best support each role. However, the tool is actually capable of performing more powerful functions than we allow. For example, using a tool in TRAC^{2}ES called the lift-bed planner, it would be possible for any one of the PMRCs to route and schedule the entire patient move from end-to-end. However, using this capability was not always deemed in the best interest of the patient hand-off process. The management and hand-off of patients from one PMRC to another is subject to many variations in schedule conditions over the total period of the patient's move. Aircraft missions scheduled in advance are subject to frequent change, based on weather, aircraft condition, crew availability, and other factors. A patient's condition may change, requiring additional days of treatment in an MTF before moving. The patient movement planners established business rules that they collectively felt more comfortable with. While some of these rules restricted the use of the tool, the rules actually facilitated collaboration.

Managing the collaboration of the "flow" of a patient is a very dynamic process, in the sense that planners must be able to quickly react to changes in resource availability or patient condition. While information exists to plan the move of a patient over a five to seven day planning horizon as shown in Exhibit 4, the information is perishable. Understanding this, patient movement planners wanted to retain as much flexibility as possible to quickly adjust to changing conditions, with least disruption to the patient. They chose to allow end-to-end planning only when it was possible to assign a patient to an existing mission in another PMRCs area of responsibility. If a new mission was required, the originating planner was allowed to plan only on existing missions in the direction the patient needs to travel, then terminate the itinerary as a partially planned mission. Within TRAC^{2}ES, a partially planned patient is called to the attention of the next planner to complete the transaction, as soon as possible. Next, we address how timing of these transactions also plays a role.

Adjusting decision cycles to workflow cycles. Exhibit 4 also serves to illustrate the impact of time on the patient movement process. While patient movement is often urgent, requiring rapid response to a request to move a patient in order to save a life, the total life cycle of a patient move unfolds over many days. Getting a patient to the first medical care available is best done within the "golden hour". That is, a seriously injured patient on the battlefield, who gets care within a very short time after being injured, has a much better chance for survival and uncomplicated recovery.

Once that initial care has been provided and the patient has been stabilized, a more deliberate movement process takes the patient to increasingly more capable medical facilities. The process takes days, if for no other reason than the distance the patient must travel. Long distance air travel is not conducive to the healing process.

The fact that a patient move from a distant overseas location takes several days facilitates the collaborative process, because it allows lead time for planning and executing actions to support the patient's move – provided that this information can be easily shared. First, the planning process generally begins at least a day before the patient actually begins to move (after initial entry into the first MTF). With TRAC^{2}ES, everyone who needs to interact with this patient can immediately see what the patient's itinerary will be. If anyone has a reason that this move will be troublesome, they have the ability to signal the original planner about the potential problem. For example, U. S. East coast weather may not look good for the planned arrival at, say, Andrews Air Force base. Hurricane Edna is moving up the East Coast and will most likely impact the Washington D.C. area on the scheduled day of arrival. At that point, a decision may be made to delay the patient's trip or to move the patient only as far as the intermediate MTF and have the patient remain there for an extra day. A change to the plan quickly alerts everyone in the network to the new plan and allows each to evaluate the impact.

Providing a decision support tool that allows each party in the process to understand the impact of his or her own actions on the overall process. Too often, networks of people, working to accomplish a common goal, lack the information to successfully contribute to the best solution. Without visibility of the status of the network, the Theater planner may be tempted to move his patients out on the next flight departing. From his perspective, he is doing a good job by sending the patients as soon as possible. However, he may be unaware that he is sending them into a situation that will only cause them to delay, elsewhere in the network. With TRAC^{2}ES, the planner can see the impact of his decision, immediately. TRAC^{2}ES lift-bed planner screens will show the planner the patient will end up in an incompletely planned mode, having to stop short of his destination, or that the patient must remain overnight en route. Rather than send the patients today, TRAC^{2}ES will suggest a mission that leaves tomorrow and easily connects with another mission for the next leg of the patient's journey. If the planner forces the move today, he will see that the patient must remain overnight at the next stop, in order to await the mission that carries the patient to final destination. In some cases, move today will still be the best decision to make, but the planner can make that judgment with full knowledge of the impact on the total system.

Implications:

Collaboration efforts often focus only on the information sharing process, itself. The TRAC^{2}ES case illustrates the importance to understand the business process, decisions to be made, nature of dependencies and timing. Patient movement is a unique instance of a supply chain operation. Lessons learned in TRAC^{2}ES have broader implications to supply chains in general.

Many supply chain business processes are driven by metrics that do not facilitate collaboration among all entities in the supply chain. For example, fill rate or delivery time metrics do not always measure success in an extended supply chain. These can lead to sub optimal solutions, when no clear understanding of the bigger picture is available to independent operators in the distribution network.

Visibility of the supply chain is helpful, but not sufficient. Knowing where everything is located at any given moment is useful, but does not preclude inappropriate actions or decisions. Visibility systems are generally used to troubleshoot and fix problems in the supply chain, but do nothing to preclude them. Supply chain management and planning tools are needed to plan and direct actions in the supply chain that accomplish the intended results, provide clear feedback to collaborators, as well as provide an understanding of the impact of any collaborator's action in the total supply chain.

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Connecting the Dots: War Room Team-Based Analysis

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Abstract

War Room Team-Based Analysis provides a new analytical paradigm for rapidly discerning trends and detecting anomalies thus leading to knowledge discovery. It furnishes a quick and low cost capability to "connect the dots". This is achieved through the custom integration of "off the shelf" tools that are configured to mirror the analytical process and facilitate the flow of information. War Room Team-Based Analysis is based on two premises. The first is that collaborative teams of domain subject mater analysts working in conjunction with information technologists can often best accomplish complex analytical tasks. Tool experts focus on configuring the tools for the collection, processing and formatting of the data. Powerful tools, which the typical analyst does not have the IT skill set to utilize, can thus be incorporated. The analysts on the team are able to focus more on the actual analysis and less on the collection and filtering of information. Through iterative interactions of analysis and IT an optimized tool suite can be quickly developed and fielded. The second premise is that in a team-based setting, not one tool or technology will satisfy all the analytical needs. Complex analytical processes or decisions require multiple tools to facilitate information flow. So the IT component of the team works closely with the analysts to configure and integrate the optimal tool suite to support the analytical effort. Effective collaboration includes the mix of people, tools and process. This approach has produced dramatic results for both government and commercial applications including intelligence, counterintelligence, counter terrorism, competitive intelligence, and market research and investment decision-making.

Keywords

War room, team-based analysis, decision support, operations centers

Not Connecting the Dots

Senior decision-makers must receive timely awareness of rapidly changing events in order to operate successfully within today's "information age." Executives are faced with shorter cycles for making increasingly important decisions. To support decisions, staffs have become gatherers of data to the point that they are often inundated by facts and figures. They have great difficulty separating the "wheat" from the "chaff" to determine what is important and to manage this deluge of data. Senior officials and their support staff often suffer from an inability to display complex relationships and linkages associated with planning, information and intelligence. The serial display of this information has often proved inadequate for comprehending complex activities, programs and processes. There is difficulty in articulating plans and generating support.

After the horrendous events of 9/11, there has been a great deal of investigation and introspection as to why numerous agencies with myriads of databases did not provide enough forewarning of the tragic events to come. It should be noted that there are a number of other recent major analytical failures in both government and industry. Some other failures to "connect the dots" include: not solving the anthrax case, the inability of investors to foresee the dot.com crash, and the failure by the scores of financial analysts, auditors, and business journalists to provide advance warning of the collapse of Enron.

The arrival of the information age, coupled with a rapidly changing environment, significantly increases the challenge to the government and corporations in analyzing disparate and unstructured data. There are a number of things that make this so. The first part of the challenge is due to the sheer volume of data potentially available through various sources, most notably the World Wide Web. The paradigm for most analytical activity (whether it is in the world of commerce or government) is based on the research activities of individual analysts. Typically, an analyst establishes a hypothesis, goes on the Web using a favorite search engine, or searches through an Open Source or proprietary database, either substantiating or detracting from the original premise. The more adept researcher may use a spreadsheet or other available tool to record and plot data. The reality is the analyst often spends much more time collecting, sorting, and filtering data than actually "thinking" and analyzing. Moreover, even a very efficient analyst will access only a fraction of the available information and may never see a key indicator.

In larger efforts, analysts may be part of an overall team or task force assigned to maintain awareness of an issue or region, or develop specific information to support decisionmaking. The team may meet to share findings and ideas, but most of the information has been developed through individual analytical efforts. This model of analysis is proving to be inefficient, particularly in critical, time-sensitive environments. Finally, the information age provides search, data management, and analysis tools with previously unimagined power. As such, current approaches to implementing these tools all too often fall far short of expectations.

Government, commercial organizations, political and advocacy campaigns have set up "war rooms" as a means to handle and enhance decisionmaking and planning. There have been, however, many failures often leading to the development of a "hi-tech" glitzy facility used merely to present PowerPoint briefings. There have also been some noted successes from which worthwhile lessons have been learned and can be applied to future war room developmental efforts.

For the past decade, my associates and I have been involved in designing and implementing war rooms for a number of applications including: strategic planning, investment decisionmaking, government intelligence and counter terrorism, corporate competitive intelligence, mergers and acquisition, defense acqusition planning, and for bid and proposals. This paper provides case studies and the associated lessons learned from the war room experiences that I consider to be of the most importance in shaping my thinking for war room design and implementation. It is hoped that this will aid in advancing the "art and science" of developing war rooms and their use. In order to meet the urgent needs of today, in both a timely and cost effective manner, we are promoting the War Room Team-Based Analytical approach as one viable option in helping analysts to connect the dots.

War Room Fundamentals

A war room is a very focused, intense effort to organize complex programs, to develop program and strategic plans, and to visualize and assimilate data and linkages between information that impact multidimensional plans. The war room enables a collaborative team to break down complex programs and information processes into comprehensible parts, to promote structured dialogue and brainstorming, to comprehend program intricacies, and to establish program concepts quickly.

War Rooms can be vary from glitzy "hi-tech" rooms in which computer generated information is conveyed through hi-resolution displays to a "low-tech" approach utilizing foam boards, or magnetic white boards. They can be optimized for the specific needs, applications and budget of the organization. There are variations on this approach and we have developed a war room typology consisting of the following varieties:

- Analog (low tech, paper based; map logic flow and represent on paper or boards)
- Digital (embed displays and integrate decision support software and tools into facility)
- Virtual (Web-based portal system; provide downloadable template of process; provide digital content and information feeds)
- Hybrid – combinations of these war room types.

Our approach to the development of a war room is rooted in a bottom-up approach starting with process analysis and ending with the application of the appropriate war room structure. The first and most important step in developing a war room is to capture and then map the information flow and the process through which the functions and activities are to be carried out and the specific tasks that will need to be performed. This is accomplished by displaying this information flow within an analog war room framework.

Typically a core team develops the first "straw man" logic flow for the war room. They may have used input from a combination of primary and secondary sources including a literature review and Internet search; surveys and interviews with key officials and outside experts. After this initial process is mapped out on the walls of the room, other knowledgeable people and experts are invited and "walked" through the room. Their advice on correcting specific "logic train" flaws and enhancing the process can be easily captured and then displayed in the room. After obtaining the input from many knowledgeable sources, the end result is a very robust war room, reflecting a clear and logical information process. This in essence becomes the analog war room, and it in itself, may suffice for certain applications and uses.

The next phase of the development involves the infusion of information technology into the war room facility. This involves the selection of specific software tools and appropriate hardware and display systems which transforms the information flow captured on paper and displayed on the walls of the analog war room into a digital format, thus creating the digital war room. The basic approach is to use off the shelf software tools that are then integrated together using an open architecture approach. This allows the war room team to choose the specific tools that are needed as well as upgrade or change these tools as the state of the art advances. The tools selected will perform tasks such as automated text retrieval, data mining, decision modeling, data visualization, data storage and linking.

It has been our experience that the best war rooms are in fact hybrids, integrating computer generated information on displays with some static boards. Innovations such as electronic whiteboards have also proved to be very useful tools.

Case Studies

We will now explore 4 case studies and discuss the lessons learned from each of these very different war room applications.

War Room Case Study 1. Counterproliferation Investment War Room

In the mid 1990s there was an effort undertaken throughout much of the Intelligence Community and the Department of Defense to come up with the technical means to assist in countering the proliferation of weapons of mass destruction (WMD). DARPA was experiencing great uncertainty as to where they could best put their resources and key talent to support the counterproliferation effort. It was particularly difficult since numerous other agencies were engaged in similar and often duplicated efforts. DARPA decided to set up an investment decision war room to help guide their funding and project management. Panels were placed around the walls within a conference room, which was dedicated for this effort. A logic flow was mapped out and displayed across these panels. Sections of the wall included:

- Threat (descriptions detailing how weapons of mass destruction were or could be proliferated)
- Need/Requirements (capabilities needed in order to thwart the proliferation).
- Concepts of Employment (Approaches, techniques in which to achieve the capabilities to hinder the proliferation.)
- Operational Performance Characteristics (The performance levels needed for the concepts of employment to prove effective; such as speed, sensor range, duration, etc.)

- Technological Requirements (The technology needed to achieve the performance characteristics.)
- Open Source Intelligence (Information on where and who is working to achieve these technologies capable of achieving the performance characteristics.)
- Leveraging Strategy (How DARPA can leverage research and technology developments conducted elsewhere into their counterproliferation program.)
- Funding and Investment Strategy (Determining the costs associated with leveraging the technology, and grouping and consolidating into program elements and into an overall investment program.)

The information from each section was color coded and linked to the subsequent section so that individuals could follow the logic train from a specific threat all the way around to the investment strategy associated with countering that threat. A link analysis software tool called Netmap™ was used to link all the information, enabling the information to be somewhat portable, facilitating briefings outside of the war room.

An initial straw man framework for this investment strategy was presented in the war room on the various panels. Numerous project managers and senior decision-makers from within DARPA and other government agencies were walked through the war room. Initially many gaps and flaws were found and pointed out by the individuals who toured the room. Their input and views were captured and inserted within the room. Over time as more "knowledgeable individuals" and key counterproliferation experts were walked through the room, the war room became increasingly detailed and sound analytically. Eventually it enabled DARPA's Counterproliferation Program Manager to produce a very coherent investment strategy whose logic could be readily displayed and advocated to key decisionmakers.

War Room Case Study 2. Advocacy Campaign War Room

A major public utilities company was engaged in a fight for its survival. For years it was able to take for granted that its captive market, with no competition, would continue to fund its very large nuclear infrastructure. Environmental concerns coupled with a desire by consumers for more options had dramatically altered the business and political landscape. The company's leadership believed that they could not prevent the move towards deregulation, but if they could slow its pace by about two years, then that would give the company enough "breathing room" to refocus and to better compete in the new marketplace. The CEO desired a strategy and advocacy war room in which his team could plan, implement and wage his advocacy campaign to forestall the pace of deregulation. It would serve to monitor and track the competitors and opposition coalition trying to cram deregulation legislation through the state legislature and the US Congress.

Because of the importance placed on the effort, a major conference facility was dedicated to this effort. It was a secure facility that featured magnetic white boards that wrapped around all the walls. The company's war room team had tried to assemble some informational boards that looked at their competitors/opposition's strengths and weaknesses. They were however having great difficulty in putting the information in any meaningful context that impacted decisions and actions. This author's team was brought in to develop a new design, approach and implementation plan for the war room to assist in the advocacy campaign.

Placed in the center of the war room, which was clearly visible to someone when they first entered was a process board. Utilizing magnetic panels which had graphics and wording displayed on the front side, the process board captured the legislative process through which deregulation laws would be enacted. On the top was the state legislative process, and on the bottom was the federal process. Our team worked with the corporate lobbyists and campaign team experts to fully capture and present these processes. The process depicted how the legislation would be initially introduced, what outside groups would be interacting with various legislators, and what committees the legislation have to proceed through. It eventually wound its way to the chief executive to sign. The panels included the sequential steps in order to navigate through the legislative process. The team identified the best possible scenario to forestall or delay the legislation from working its way through the process to enactment. Dotted lines revealed certain pathways that displayed how this scenario would occur. There were also alternative routes or pathways in which to delay this legislation. A worst case scenario was also captured and displayed showing how deregulation legislation could be pushed through in record time. This came to represent the optimal scenario for the competitor and its allies. Several different scenarios were postulated, including optimal, worse case and mixed results.

Another board on the side of the war room displayed the various scenarios with supporting data. The middle process boards identified critical junctures along each of the scenario's dotted line. These were the critical points where a decision or action had to be made for the scenario to ensue. Another sideboard was used to describe what strategy and tactics could be used to influence decisionmakers at these critical junctures. These were examined from both the utility's and its allies' perception, as well as from the standpoint of their competitor and its partners. Another sideboard described the intelligence required to support the decisions and actions needed for these strategies and tactics. An intelligence collection plan was built around these actions. A tactics action board was used to track and monitor each development as it occurred during the legislative process.

A status monitoring board was also used to track the actions of the key corporate players needed to support the decisions and actions. Initially names with stop light type displays (red - in trouble, yellow – warning, green – everything going well) were set in place. The team members and others in the company resented having their names so boldly shown next to the status display. These displays were soon removed. Outside of this, all the other elements of the war room worked quite well, and the Corporate CEO gave credit to the war room for helping to delay some of the pace of deregulation at the state and national level.

War Room Case Study 3. Telecommunications Competitive Intelligence War Room

A competitive intelligence (CI) unit for a telecommunications giant was struggling to find in-house consumers for its reporting and work products. Like many government and commercial intelligence organizations, often there is a "disconnect" between the provision of intelligence, and its real value to core decisionmaking activities impacting the organization. This corporation's CI manager thought a war room might help elevate the use and importance placed on competitive intelligence by senior decisionmakers.

The war room effort began with an initiative to identify what were some of the key decision activities and processes, which could benefit from decision support furnished through a war room in which competitive intelligence would also be funneled. In addition to reviewing a number of internal documents, some 16 key executives were interviewed from various organizations within the company. Six core decisionmaking processes emerged which were considered essential to the corporation's success. These included:

1. Alliance Management (i.e. the selection of partners to fill customer or the corporation's needs and/or to enhance its overall competitiveness).
2. Sales Solution/Selling Training (i.e. understanding customer needs and market segment, benchmark the corporation against the competitor solutions, determine competitor sales strategy and the company's optimal sales strategy, and counter-strategy. Also provide visualized logic train to lead the potential customer to the corporation's solution).
3. Mergers & Acquisition (i.e. the selection of candidate companies to acquire; and the provision to support due diligence and negotiation).
4. Bid & Proposal (i.e. understanding the criteria and other factors in which the customer will be utilizing in its selection, determining how competitors will respond, and supporting the corporation's "win" strategy.)
5. Technology Assessment (i.e. the determination of which technologies can address specific customer needs, and how these can be best acquired by the corporation).
6. Scenario Planning (i.e. determining likely future market dynamics and opportunities; how competitors are likely to respond; and how the corporation can best position itself in this postulated environment).

The next step involved the mapping of each of the six decision processes to include capturing the information flow; the identification of decision support tools which could facilitate that flow; and the description of what activity would occur within the war room.

The war room processes for this effort encompassed the use of five tools as part of its tool suite. The tools included *Copernic 2000 Pro™, DOORS™, Netmap™*, *Decide-Now™, and Inspiration™*. These five tools provided the core functions of competitive intelligence collection and analysis needed to support the six decision processes. These functions included:

- Being able to plan and manage intelligence support for the decision
- Collecting the intelligence
- Being able to sort and store the intelligence, information and data collected
- Visualizing and displaying the information, enhancing its comprehension and conveyance to others.
- Analyzing the information, thus deducing important findings
- Making evaluations of different options and choices
- Providing recommendations to the decision-makers

The various tools were configured and integrated into one tool suite, enabling the output of one tool to flow as seamless as possible into the next tool. The tool suite was replicated and housed in several different conference facilities that became functional war rooms.

It is important to understand that these tools and processes did not automate, eliminate or significantly reduce the human *analytical* involvement in the decision-making process. Rather, they served to enhance and augment the analyst's abilities. These tools did take some time and energy to learn how to use effectively. This required practice and experimentation in addition to classroom training. There was a sharp learning curve so that after several weeks of practice and use in some initial projects, the CI staff became adept at their use. Their effectiveness increased greatly and the teams became more efficient in future analytical endeavors. Whereas without this tool suite CI would typically involve "bits and pieces" of overall support to a decision, this war room tool suite enabled total support for the "lifecycle" of a decision, from defining the problem to implementing the solution.

Analytical Transformation

Evidence Based Research, Inc. (EBR) is currently involved in developing an approach that integrates high-end commercial software tools, modern hardware, and a new analytical paradigm. This paradigm is predicated on close collaboration between analysts and information technologists supported by current, off-the-shelf technology to provide real operational capability within a short time period. This rapid prototyping approach yields real results quickly, with the ability to provide increased capability and fidelity over time.

The Team-Based War Room Analytical approach is based on the premise that information technologists working in tandem with domain subject-matter experts can together develop a highly effective system within a rapid prototyping environment. Success in the team-based approach involves having information technology experts as part of the team who focus on the collection, processing, and formatting of the data. Thus, powerful tools, which the typical analyst does not have the IT skill set to master, can be utilized. Real-world analytical practicality can also be instilled with the IT staff by the subject matter analysts. This ongoing iterative process of IT and analytical team members working in concert helps to ensure a pragmatic and time-effective solution. A great body of research into collaboration has shown that the benefit of a sum total derived from an analytical team working together far outweighs the outcome derived from analysts working separately.

Typically in the team-based setting, not one tool or technology will satisfy all the analysts' needs. Complex processes or decisions require multiple tools to facilitate information flow. As such, the IT component of the team works closely with the analysts to configure and integrate the optimal tool suite to support the analytical effort. Effective collaboration includes the mix of people, tools, and process. There is also an iterative process between analysis and engineering. Improvements in one impact the other, and like the "Yin" and "Yang" must be managed in concert.

The War Room approach is to rapidly provide a seamless-as-possible flow of information between tools. These tools are off-the-shelf and commercially available so that a plug-and-play capability is achieved. The War Rooms will not become obsolete if technology evolves or the client's requirements change. New tools can be added and exchanged. The War Room can also incorporate current analytical tools in use by a client.

The Team-Based War Room approach provides transformation in analysis so that analysts ultimately spend a lot less time on the collection and processing of information, and devote much more time to the actual analysis.

War Room Case Study 5 - Market Dynamics War Room

Evidence Based Research, Inc. (EBR) is active in supporting several clients in War Room Team-Based Analysis. Current War Room applications include technology assessments and forecasting, competitive intelligence/market research, counterintelligence, and counter terrorism.

One War Room project enables analysts to effectively track, monitor, and forecast the market dynamics within a key technology sector. Knowledge of the key players, by both product and geographical segmentation, is essential to accomplish this task. The client's analysts also need to be able to determine who may dramatically alter and shape the future environment. Discerning emerging technologies, and being able to identify who the first movers and early adopters are is also critical to performing this effort.

The project consisted of a series of sequential tasks in which the output of the proceeding task served as input into the subsequent task. The first task involved the development of generic market space characteristics, attributes, and metrics that could be used to measure and evaluate activity in all the relevant market sectors. This required the ability to identify and describe the key industry market characteristics. These characteristics comprise the activity and dynamics shaping and influencing the industry for which the analysts need to know in order to support the key decisions within the organization. This involves not only the determination of the market characteristics but also the associated metrics which enable an analyst to determine, weigh, and evaluate the status and situation of the given characteristic within the market place.

The second task involved determining the flow of information that would ultimately address the relevant market space characteristics and attributes and then "feed" the metrics in order to evaluate market activity. This involves identifying the types of collection activity including the use of search engines, intelligent agents, surveys and associated techniques, as well as the identification of informational sources that could be used to mine information that would "feed" the analytical tools used to address the metrics.

The third task consisted of the infusion of information technology. This involved the selection of specific tools, hardware, and software which transformed the information flow captured on paper into a digital format. The system needed to be able to perform the following basic functions:

1. Capture and collect data from varying sources;
2. Exploit information only available in what is being called the "Invisible Web";
3. Structure and store the data so it is useful to analysis tools; and
4. Port the data seamlessly to various analysis and visualization tools.

This basic "modular" approach used off-the-shelf software tools that are then integrated together using an open architecture. This allowed the selection of specific tools that are needed as well as the ability to upgrade or change these tools as the state of the art advances.

The fourth task involved the actual collection and processing of information on the market utilizing the tool suite. The fifth and last task involved an evaluation of the War Room's capability and utility. Several test case studies on real-world open source "live" data were conducted to determine whether the system could provide unique insight and enhancements over traditional modes of analysis.

Beyond approaching the project with certain technologies, it is important to create an environment in which team-based collaboration is easily fostered. The EBR team used a medium-sized room, in which several work stations were placed on one central table in the middle of the room. At the far end of the room, multiple screens were used to simultaneously display data and information. By using multiple screens, analysts were able to use several tools at one time, and simultaneously see the results in front of them. Other analysts in the room often joined the discussion, which provided added benefit for everyone on the team. Likewise, with several people working in one room, it was easy to ask questions or to listen to other problems in the room, and to learn from others quickly. Analysts working alone in a separate office all day are somewhat compartmentalized from this type of group-discovery, and are not able to benefit from a "circular" learning environment.

Using the War Room team-based method, we were able to come to some relatively quick decisions on market space, key players, and where the market was headed in a particular country. Our analysts had no previous knowledge of the subject going into the study, thus the team started at "zero" and had to learn quickly as they went along. In many ways, the team was successful because the analysts were using integrated tools. While one particular tool can be powerful for giving an analyst insight into a particular problem, it often only solves part of the real problem that's at hand. For this project, we used data extraction tools to pull the data that was relevant. This parsed data went into customized databases that our team developers created in-house. By having a relevant sub-set of information, we were able to create an organization and alliance database that was focused to the particular needs of our client.

Once the customized data was collected, we employed other off-the-shelf tools to perform link analysis and to display financial information data within a three-dimensional model. Single tools are often powerful, but are more useful when used in conjunction with other programs, to essentially create a "larger picture" of the situation. For this project, our developer created a Web interface on which all the data was stored. Information could quickly be found about a particular organization, allowing the analyst to drill down to specific types of information quickly. From this same interface, the analyst was able to launch the other analytical tools to continue to work on the problem in a more focused environment.

Using this approach, the time of which it takes an analyst to "get smart" on a topic is drastically reduced. Open source Web research is very broad, and it is often difficult to find a lot of relevant information quickly. By providing an interface with data that is specific to the problem at hand, analysts for our client were more successful at drawing conclusions and making relationships, while drastically cutting the time at which it took them to do so. In one instance, we gave them a case study with all of the relevant information. Even after being presented with many of the details, the client's analyst was not able to replicate our results simply by searching on the open Web.

Lessons Learned and the Way Forward

Our experiences as revealed in these case studies highlight that a War Room is not just simply the tools and technology that exist within its confines. It is the people, their interactions, and the total process, which is core to its character and attributes. War Room design is an art and science, and we learn more from each development and implementation. Truly effective War Rooms provide a structured and disciplined approach to analysis and decisionmaking. It is the team-based approach which generates the real success for the War Room.

There were some important lessons learned from these case studies, that should be incorporated when thinking about the design and planning of future War Rooms.

- The War Room is process driven. Understanding the client's needs and then capturing and mapping the analytical process and logic flow is key to its success. Selection of tools and hardware come after the process is clearly understood.

- The War Room is not a one-person tool or operation. Its real utility is as a facility to enable team-based thinking and decisionmaking. Much of its benefit is serving as a means for others to quickly gain comprehension and to develop a common frame of reference. It can also serve as an effective tool for team brainstorming.
- Establishing a team comprised of both domain subject matter analysts and information technologists is key to War Room effectiveness. The IT experts integrate custom-built databases with cutting edge software that aid the automation of data collection and processing. This leaves the analysts with more time to focus on data integration and analysis.
- A high degree of information density and lots of dimensionality are incorporated in the War Room utilizing advanced visualization techniques. These also include link analysis capabilities showing key relationships and interactions.

As we move into the future we are developing additional analytical capabilities. These enable visualization of aggregate data, showing activity over a period of time, and would also include a "drill down" functionality to enable the analyst to see details of individual events or view only a subset of the overall data to discern different patterns and trends. We are also incorporating predictive modeling tools and capabilities, some of which require human analytical "eyeballing", but other tools which will automatically detect anomalies and pattern shifts, and then alert analysts to these findings.

The War Room does not in itself guarantee success of a project, program, or activity. It is, however, a highly effective tool for team based collaboration, in which people can use to control and act on information.

A Capability Maturity Model-Based Approach to the Measurement of Shared Situational Awareness

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Abstract:

The very nature of warfare is changing drastically as it becomes technologically complex and dependent on distributed and interconnected systems. A virtual networked environment allows information to be more easily shared, fostering parallel processing and more collaborative interactions with the expected result being a more agile and responsive organization. However, applying useful, reliable metrics to measure organizational performance presents an analytic challenge. Performance improvements such as increased responsiveness and efficiency are measured in the context of Situation Awareness (SA), which is having the right information at the right time, which is analogous to the construct of Knowledge Management (KM). Hence, the framework of a KM Capability Maturity Model is a useful process for the measurement of SA. This paper offers five levels of Shared Situational Awareness that can provide the basis for the metrics that guides an organization in implementing a series of increasingly sophisticated practices and activities for developing and motivating its workforce and which can have a significant impact on individual, team, unit, and organizational performance. The measurement is then applied to a network centric warfare environment in order to determine the impact that differences in the values of individual team members have on the effectiveness of their teams.

Keywords:

Capability Maturity Model, Knowledge Management, Situation Awareness

1 Introduction

The very nature of warfare is changing drastically as it becomes technologically complex and dependent on distributed and interconnected systems. Information technology allows some fundamental rethinking. For example a virtual environment allows parallel processing and interactions. Emerging technologies for decision aids like intelligent agents, data mining and complex modelling offer the potential for large volumes of data to be collected, processed, and displayed without overloading users. Correlated data becomes information that is converted into situational awareness, which results in knowledge. The ability to approach total situation awareness and prevent the adversary from achieving it, results in a situation in which one side has achieved dominant battlespace knowledge. (Alberts 1995) Knowledge used to predict the consequences of actions leads to understanding. (Cooper 1995)

The expected result of being able to do things without the barriers of time or space should be a more agile and responsive organization. More fundamentally, information should be more easily shared and the network should foster collaboration. However, the analytic space is not clearly bounded. The challenge in the analysis process is that network centric warfare explicitly involves the human component and the other issues that arise from the complex interactions of distributed teams. These teams create a multi-dimensional analytic space that includes tightly connected interactions between platforms, systems and people. Often these interactions are subjective and therefore measures of effectiveness are impacted by elements such as organizational development and culture; morale, doctrine, training and experience.

Knowledge Management (KM) is a discipline that provides the strategy, process and technology that is comparable to the concept of situation awareness (SA). This implies the potential for the use of KM metrics such as the Capability Maturity Model (CMM). Because CMM is part of a larger framework that supports the organization's process improvement that means the CMM framework can also be extended to improve shared SA.

2 Discussion

Like Situation Awareness, the discipline of KM crosses diverse domains such as organizational development, business management, cognitive science, psychology and philosophy. However, unlike SA, because of its orientation to computer sciences KM has coevolved with the process maturity framework of the highly successful Capability Maturity Model for Software (SW-CMM). The Software CMM has been used by software organizations around the world as a foundation for a model of best practices for managing and developing an organization's workforce and for guiding dramatic improvements in their ability to improve productivity and quality. To take this well accepted process further, the People CMM (P-CMM) was introduced to help organizations characterize the maturity of their workforce practices, establish a program of continuous workforce development, set priorities for improvement actions, integrate workforce development with process improvement, and establish a culture of excellence. (Curtis 2002)

KM can be viewed as the process that leverages information and expertise to more effectively solve problems and make decisions. KM has been defined as the fluid mix of framed experience, values, contextual and actionable information, and expert insight that provides a framework for evaluating new experiences and information. (Harigopal 2001). Empowering the right people with the right knowledge and appropriate learning ability, at the right time is a key requirement for a KM-focused organization.

No single accepted theory of SA has emerged. However, the articulated behaviors that such a theory should account for are (1) considering and selecting goals dynamically, (2) attending to the critical cues at the appropriate times to determine if the plans generated and executed to achieve the chosen goals are effective, and (3) predicting future states of the system to support goal creation and abandonment. (Klein 1989) In such a theory, situation awareness is a *state of knowledge* that directly relates the elements of a dynamic environment to the operator's target goals. (Bass 1996) Although separate from the processes of decision-making and performance, situation awareness is intricately associated with them. (Endsley 1995) The generally agreed upon definition of SA is "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future".(Endsley 1988)

SA is having the right information at the right time, or more simply put, actionable information, which is analogous to the construct of KM. More succinctly, SA = KM.
The usefulness of this equality is the compelling benefit of applying to SA a relatively rigorous, credible, Department of Defense sponsored engineering process like the Capability Maturity Model, which has widespread use and has been successfully applied to KM.

2.1 Shared Situation Awareness

Individuals, organizations and teams can each be regarded as an independent cognitive system. Where individuals collaborate inter/intra organizations, more often in a ubiquitous and virtual workspace, they aggregate their cognition into shared situation awareness. Multiple channels permit the storage and mining of information that can be discovered, acquired, shared and leveraged by the members of a group. First, individuals develop their independent SA. Next, the second element of the process is the effective *communication* of individual perceptions to the other members of the group, for the purpose of consensus building. A prerequisite for effective communication is a *common ground* of shared knowledge, beliefs, and assumptions. (Perla 2000) Typically, building this common ground will require some familiarity among team members, based on common cultural backgrounds or experiences, either implicit or more explicitly inculcated through training and education. As Klimoski and Mohammed observe, "There can be. . . multiple mental models co-existing among team members at a given point. . . .These models need not be identical, but they do have to overlap sufficiently to make it possible to perform the mission." (Klimoski 1994) The measure of group effectiveness is the degree to which the different individual mental models of the situation are integrated into a common operational picture.

2.2 Congruent Cognitive Environments

Cognitive models in SA and KM are congruent. SA relies on learning the important cues to look out for, and what they mean which results in a dynamic mental model of an individual's operating environment and their place in it. This model is fashioned through a situation assessment process consisting of four interwoven sub processes: perception, comprehension, projection, and prediction. (Perla 2000) The resulting mental model is inherently subjective, based on integrating acquired information with each individual's structural and situational factors. The value added in a KM-focused organization is the ability to sense and respond to rapidly changing requirements. The organization is becomes an adaptive system responding to unanticipated events in an unpredictable environment. (Haekel 1999)

Although the impact of situation awareness on operators in complex systems has been recognized, according to the literature there is no clearly understandable, generally accepted, and objective way to measure situational awareness. Situation awareness has been characterized as the operator's *perception* of the elements within the environment, the *comprehension* of the elements' meanings, and the *projection* of their status in the future. Situation awareness is a *state of knowledge*, which directly relates the elements of a dynamic environment to the operator's target goals, in contrast to the process of achieving that state which is called situation assessment, and is separate from the notions of decision-making processes.(Endsley 1995)

Clearly, operating complex systems successfully depends upon knowing not only what tasks to perform and how to perform them, but also when to do so. To become proficient, an operator of a complex system must know several types of knowledge: declarative knowledge (i.e., what to do), procedural knowledge (i.e., how to do it), and operational skill (i.e., when to do it). (Chu 1995) A cognizant KM-focused organization is characterized as being able to leverage knowledge and learning. Critical success factors include the ability to make decisions under conditions of uncertainty. There is an emphasis on context and self-synchronization, which fosters an environment conducive to tacit information exchange.(Harigopal 2001) Tacit knowledge unlike implicit knowledge cannot be readily converted into explicit knowledge, but is the knowledge that cannot be expressed in words or pictures, but is transferred by observation. In a collocated environment, face-to-face communication includes both verbal and important tacit information exchange, which clearly becomes more of a challenge to shared SA in a distributed or virtual environment.

2.3 Measurement techniques

Several methods of testing situation awareness have been documented (Endsley, 1995; Adams, Tenney & Pew, 1995). These methods are inherently subjective, and are thus potentially iatrogenic which can bias the results. On the other hand, SA is a representation of a real operational environment, therefore their "quality" is the degree to which they accurately reflect an objective assessment of that reality. Unfortunately, making such assessments is challenging.

Several complex techniques exist which attempt to determine or model the subject's knowledge of the situation at different times throughout simulation runs. The difference in knowledge-based and performance-based techniques of evaluating situation awareness is about taking measurements at different points in the process of user cognition. Performance-based measurements have been determined to ascertain the timing and substance of a user's reaction to realistic situations, while knowledge based techniques are more accurate for providing a detailed, theoretical assessment of the subject's situation awareness. (Pritchett 1996) Within the context of systems, the effectiveness of SA must be based on whether the user will be provided with sufficient SA to perform the correct actions, which performance-based techniques measure directly, while knowledge-based measurement techniques only make reasonable guesses about the likely user's actions given their knowledge state. Performance-based measurement works well in time-critical situations to find the real-time response, rather than planned or thought-through response. (Johnson 1995) While performance-based measurement is complementary to knowledge-based measurement in the human factors analysis, performance-based measurement illustrates the inter-relationship between the user's knowledge and results in ascertaining the performance of the entire system, and illuminating areas of situation awareness that are deficient.

The Headquarters Effectiveness Assessment Tool (HEAT) has proven to be an effective and robust method of evaluating Command and Control effectiveness and has been used in over 200 military exercises and experiments over the past 20 years. HEAT is based on the theory that there is a direct path from understanding to making a decision, which leads to a conclusion that the time metric is valuable when comparing an observed process with a baseline process. HEAT also uses coherence metrics measure the staff's cognitive coherence and alignment, which include:

- Similarity of interpretation of commander's intent among team members
- Number of centers of gravity that all team members identify; number that some but not all team members identify
- Accuracy of team member's knowledge of roles and responsibilities of other team members.

The biases of this modelling paradigm while emphasizing the high-intensity quick-reaction aspects of battle command potentially minimize assessing the longer time-span processes of preparation and readiness that impact SA. (Builder 1999)

The legacy of SA metrics clearly trends in the direction of measuring SA in the context of process improvement.

2.4 Capability Maturity Model

The People Capability Maturity Model^{SM} (P-CMM^{SM}) adapts the maturity framework of the Capability Maturity Model^{SM} for Software (CMM^{SM}) to attract, develop, motivate, organize, and retain the talent needed to continuously improve software development capability. However, P-CMM can also be used by any kind of organization as a guide for improving their people-related and work-force practices. Evidence to date suggests that the predictability, effectiveness and control of process improve as the organization moves up these five levels.

Based on the best current practices in the fields such as human resources and organizational development, the P-CMM helps organizations to characterize the maturity of their work-force practices, guide a program of continuous work-force development, set priorities for immediate actions, integrate work-force development with process improvement, and establish a culture of excellence. It facilitates the evolutionary improvement path from ad hoc, inconsistently performed practices, to a mature, disciplined development of the knowledge, skills, and motivation of the work force. The P-CMM consists of five maturity levels that institutionalize a level of capability for nurturing the talent within the organization, developing effective teams, and successfully managing the people assets of the organization. The benefit of People CMM to the notion of SA is that the People CMM guides an organization in implementing a series of increasingly sophisticated practices and activities for developing and motivating its workforce which can have a significant impact on individual, team, unit, and organizational performance.

Level	Focus	Organization	Process
5 Optimizing	Continuously improve and align personal, workgroup, and organizational capability	Continuous Workforce innovation Organizational performance alignment Continuous capability improvement	Continuously improving process Effective change management Zero defects/Six Sigma
4 Predictable	Empower and integrate workforce competencies and manage performance quantitatively	Mentoring Organizational Performance Management Empowered Workgroups	Quality control Quantitative process management
3 Defined	Develop workforce competencies and workgroups, and align with strategy	Participatory culture Workgroup development Competency-based practices Career development Competency development Workforce planning Competency analysis	Standard, consistent stable, repeatable process Intergroup coordination Training program Organization process definition Organization process focus
2 Repeatable	Managers take responsibility for managing and developing their people	Compensation Training and development Performance management Work environment Communication and coordination Staffing	Documented Enforced Trained Measured Able to improve
1 Initial	Workforce practices applied without analysis of impact		

Figure 1: Five Capability Maturity Levels

2.4.1 Level 1: The Initial Level

At the initial level, the organization typically does not provide a stable environment. During a crisis, planned procedures are abandoned. Success depends entirely on having an exceptional leader. Even a strong tactics, techniques and procedures (TTP) cannot overcome the instability created by a dysfunctional organization. Capabilities of Level 1 organizations are typically unpredictable because the process is ad hoc and occasionally chaotic. Few processes are defined. Performance depends on the capabilities of individuals and varies with their innate skills, knowledge, and motivations, which mean that performance can be predicted only by individual rather than organizational capability. This is the lowest level of data fusion inasmuch it doesn’t exist. Without any data fusion, SA is based on the manual correlation and/or aggregation of linked track data. This would also correspond to the lowest level of individual SA, which is the fundamental perception of important information. Challenges to the cognitive process or shortcomings in the system can often result in errors in perception of needed information. (Endsley 2000)

2.4.2 Level 2: The Repeatable Level

Policies and procedures are established and institutionalized. Planning and managing new tasks are based on experience with similar projects, which allow organizations to repeat successful practices developed on earlier tasks. An effective organization’s process is practiced, documented, enforced, trained, measured, and able to improve. Problems in meeting goals and performance standards are identified when they arise. Level 2 organizations can be summarized as disciplined because planning and execution of the mission is stable and earlier successes can be repeated. The key process areas at Level 2 focus on instilling basic discipline into workforce activities. From the standpoint of data fusion the focus is individual objects. SA as a construct is still fundamentally about basic perceptions of important information.

2.4.3 Level 3: The Defined Level

The Level 3 organization exploits effective policies and procedures that are well documented and integrated into a coherent whole. There is a dedicated component organization that has been institutionalized and is responsible for the organization's process activities, i.e. quality control/analysis. An organization-wide training program is implemented to ensure that the staff and managers have the knowledge and skills required to fulfill their assigned roles. A well-defined process can be characterized as including readiness criteria, inputs, standards, and procedures for performing the work, verification mechanisms (such as peer reviews), outputs, and completion criteria. Because the process is well defined, management has good insight into the level of performance that is based on a common, organization-wide understanding of activities, roles, and responsibilities. The key process areas at Level 3 are knowledge and skills analysis, workforce planning, competency development, career development, competency-based practices, and participatory culture. Data fusion is devoted to organizing the hypothesized objects into a big picture of what is happening. The big picture is described in terms of groups or organizations of objects so that decisions can be made by decision makers about how to use friendly organizations. SA goes beyond perception and encompasses the combining, interpreting, storing and retention of information. At this level of SA, operationally relevant *meaning* and *significance* of the Level 2 data is being considered.

2.4.4 Level 4: The Predictable Level

The organization sets quality goals that are measured as part of an organizational measurement program. Processes are instrumented with well-defined and consistent measurements. Organizational control over performance is by narrowing the variation in performance to fall within acceptable quantitative boundaries. Meaningful variations in process performance can be distinguished from random fluctuations. The performance of Level 4 organizations is predictable because performance is measured and operates within measurable limits. These measurements permit an organization to predict trends in process quality and when the quantitative bounds of these limits are exceeded, action is taken to correct the situation. The key process areas at Level 4 focus on mentoring, team building, team-based practices, organizational competency management, and organizational performance alignment. At this level the data fusion is more about the situation and what is known from enemy doctrine and objectives to predict the strength and vulnerabilities for the threat and friendly forces. Almost at the highest level of SA, there is some capability to forecast future situation and events. Given a high level of understanding of the situation future events and their implications permit timely decision-making.

2.4.5 Level 5: The Optimizing Level

At Level 5 the organization is focused on continuous process improvement. The organization identifies weaknesses and strengths proactively, with the goal of preventing the occurrence of negative performance. Innovations that exploit best practices are identified and transferred throughout the organization. Level 5 organizations analyze defects to determine their causes. Level 5 organizations are continuously striving to improve the range of their process capability, thereby improving their performance. Improvement occurs both by incremental advancements in the existing process and by the introduction of innovations. The key process areas at Level 5 address continuous improvement for personal competency development, coaching, and workforce innovation. The fusion process at this level examines what is unknown in the context of the situation and threat and then develops options for collecting the information.

At the highest level of SA, relying more on tacit communications, organizations are self-synchronized and are heavily dependent on future predictions. SA becomes adaptive to different cognitive strategies in response to the dynamic aspects of real-world changes, which create a constantly changing situational awareness. (Endsley 2000)

While no particular style of organizational structure dominates high maturity organizations; matrix, functional, product, and customer group structures are the most common. However, high maturity organizations are characterized by:

- Establishing a program of continuous workforce development with process improvement, leading a culture of excellence.
- Avoiding workforce practices that its employees are unprepared to implement effectively.
- Readily available and easily accessible process documentation
- Limiting detailed standards, procedures, and checklists to tasks and not process
- Performing inspections emphasizing data collection
- Using control charts and other statistically rigorous methods for monitoring process
- Recognizing the importance of competent people.
- Requiring training in technical skills, management skills, and relevant application domains; including training in interpersonal skills, team building, and negotiating skills

2.5 Empirical data

Evidence to date suggests that the predictability, effectiveness and control of process improve as the organization moves up the five levels of CMM. (Harigopal 2001) The major challenge to transformation in the Department of Defense is not technological, but organizational. As rapid advances in information technology enable network centric warfare to move from concept to the battlesphere, traditional metrics of "warhead on forehead" need to be updated. Performance improvements such as increased responsiveness and efficiency need to be measured in the context of SA and KM which are fundamental to guiding process improvements in the storing, organizing and processing of information. A CMM is a framework for process improvement that can support the measurement of SA.

"Operation Enduring Freedom" is an example of a military use of virtual teams. The planning of Operation Enduring Freedom was conducted in Florida while, concurrently, the execution of these plans was in Afghanistan. Critical to the operation was the maintenance of shared situational awareness. Networking software allowed U.S. planners to coordinate nearly nonstop missions over Afghan skies using planes from Central Asian airstrips, aircraft carriers at sea, and bases as far away as the United States.

Following in the wake of those applied concepts, Millennium Challenge 2002 (MC02) which was conducted July - Aug 2002, was the Department of Defense's premier joint integrating event, bringing together both live field exercises and computer simulations. The key objective of the MC02 experiment was improved interoperability among military services by being able to communicate more rapidly and efficiently in a joint environment. Specifically, MCO2 focused on the ability of the entire force to share a common picture of the battlefield and the intents of the commander. Central to that ability to communicate across the forces, individual workstations were set up at several locations throughout the United States. Those stations, which were utilized by as many as 700 people at any one time, included a high-speed computer backbone featuring collaborative capabilities that allowed the forces to share information, time lines, graphics and maps throughout the entire experiment. The MC02 data, that was collected, was intended to help researchers develop a clearer understanding of the complex and critically important relationships between the composition of a fully netted force and organizational success. Controlling for known factors that affect team effectiveness; the impact that differences in the values of individual team members on the effectiveness of their teams was investigated. The assessment of how effective the teams performed was based on the Situational Awareness Maturity Model specifically developed for this research. In effect, Situation Awareness, as a dependent variable was an integral part of MC02. Ad hoc virtual teams were categorized in terms of their relative effectiveness by trained observers using the descriptions of the five levels of Situational Awareness found in Figure 2.

A general limitation of the study of distributed and networked teams has been a reliance on respondent self-administered measures of perceived effectiveness. While a detailed analysis of the MC02 results is a separate topic for discussion, clearly the CMM framework proved to be a useful instrument for the measurement of team effectiveness and countered the aforementioned limitation by using a subjective measure of effectiveness as assessed by independent non-participant observers.

The MC02 study attempted to fill a gap in understanding the impact of individual values on the effectiveness of collaboration among distributed and networked teams. Based on the attributes and characteristics of successful teams, there are a wide range of management choices. While connectivity and tools provide the infrastructure for collaboration, business processes and organizational values ultimately determine the effectiveness of collaboration.

Level	Focus	Process
5 Optimizing	Agent based communication; establishing a process for adapting processes to support operational contingencies; establish knowledge delivery mechanism to provide knowledge to strategic partners; process optimization	Evaluation of performance and effectiveness on a continuous basis Identify adjustments and potential improvement to the fusion process Determine source specific data requirements for processing Recommend allocation and direction of resources in support of the mission Understand mission, opportunities and risks, adversary's capabilities and limitations, analysis of possible outcomes, and adversary's intent
4 Predictable	Concepts embedded in data translated into a common ontology; data mining for patterns and relationships; presentation of knowledge based upon the user's learning profile; network of multiple portals enables the real-time aggregation of disparate knowledge	Estimate capabilities, i.e. number and location Predict enemy intent based on actions, communications and enemy doctrine Identify threat opportunities - ID of potential opportunities for enemy threat Assess from multi-perspectives Analyze prediction of offensive/defensive results of hypothesized engagements Understand mission, opportunities and risks, adversary's capabilities and limitations, analysis of possible outcomes
3 Defined	Data is aggregated in a central data base; data from multiple operational systems can be extracted on demand; richer artifacts of the process are stored and organized; data presentation includes summaries and analysis; collaborative tools capture the timeliness, breadth and depth of subject matter experts	Estimate relationships among aggregated objects including events/activities Interpret within context weather, terrain and other environmental considerations Assessment from a multi-perspective (i.e. Blue, Red & White viewpoints) Understand mission, opportunities and risks, adversary's capabilities and limitations
2 Repeatable	Data repository mechanism provided to capture individual input and retrieve data; forum provided for distributed collaboration	Focus on individual objects Associate sensor outputs w/specific known objects or initiate new objects Use sensor data to refine the best estimates of current positions for each hypothesized object. Understand mission, opportunities and risks
Initial	Limited collaboration, data fusion or correlation	Align data with respect to time/space Relate newly received observations to existing track Comprehend basic classification of emitters, platforms, etc. Understand mission

Figure 2: Five Capability Maturity Levels for Situational Awareness

At the core of the CMM process is a CMM-Based Assessment, which is an on-site investigation conducted by a trained assessment team. A CMM-Based Assessment is a diagnostic tool designed to identify strengths and weaknesses in workforce practices against a community standard. Additionally the assessment can be used to set priorities for improvement needs so that the organization can concentrate its attention and resources on a vital few improvement actions. A CMM-Based Assessment consists of phased activities that can be tailored depending on the objectives and scope of a particular assessment. Thus, for any future CMM-Based Assessment, the Situational Awareness Capability Maturity Model is a proven tool for measuring effectiveness.

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JMPS
Expeditionary Support Of Sea Basing

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Abstract

The Chief of Naval Operations described in "Sea Power 21," a broadened naval strategy that will fully integrate U.S. naval forces into joint operations against adversaries. One of the components of Sea Power 21 is Sea Basing, which is the projection of the sovereignty of the United States globally while providing Joint Force Commanders with vital command and control, fire support, and logistics from the sea, thereby minimizing vulnerable assets ashore. The mission planning systems of the future must enable distributed, collaborative planning efforts that are executed simultaneously and shared among participating mission planners at all levels to fully support the Sea Basing concept. Because of the Sea Basing concept, logistics will be a key factor in the mission planning and mission execution processes. This paper describes how the JMPS EXP System will automate and expedite the various naval planning functions and products, including logistics, to support the Sea Basing and Sea Power 21 concepts.

Introduction

In "Sea Power 21," the Chief of Naval Operations described a broadened naval strategy that will fully integrate U.S. naval forces into joint operations against adversaries. The Navy is being tasked to ensure prompt access and freedom of maneuver for joint forces moving from the sea to objectives deep inland. However, adversaries will strive to interdict air and sea lines of communication, render debarkation points unusable, and delaying or denying political access. Thus, Battlespace control near land is essential.

As technological advances drive the development, and fielding of state-of-the-art military equipment, weapons, weapons systems and platforms to provide maximum advantage to our military forces, so too must mission planning capabilities evolve to employ those assets to greatest advantage. The mission planning systems of the future must enable distributed, collaborative planning efforts to be executed simultaneously and shared among participating entities at all levels. The Joint Mission Planning System- Expeditionary (JMPS EXP) will be the preeminent joint mission planning system of the future.

JMPS EXP will transform the Naval expeditionary forces' planning process by linking together, in ways not previously possible, the means of acquiring, processing, disseminating and using information to increase the speed and the fidelity of the planning process.

JMPS EXP leverages and integrates with the Joint Mission Planning System (JMPS) architecture, a Navy-Air Force co-develop program of record for world-class aviation-centric joint mission planning capabilities. JMPS seamlessly integrates mission planning for all air platforms in every service. This synergy between JMPS and JMPS EXP provides significant savings in developmental costs through extensive reuse of JMPS component based architecture, development infrastructure and technical advancements.

JMPS EXP will become a core element in the Navy and Marine Corps Teams' transformation. JMPS EXP leap-ahead technology supports new operational warfighting concepts embodied in Expeditionary Maneuver Warfare and sea-based operations and provides the flexibility and adaptability needed to support Sea Power 21, specifically Sea Basing. Logistics is a critical element in Sea Basing and thus in the mission planning process. JMPS EXP capabilities will support other advanced warfighting technologies to form an integrated array that provides the Navy and Marine Corps Team with the versatility needed to confront different threats and environments and accomplish planning and dynamic replanning for multiple, disparate missions as America's forward engagement and expeditionary combined-arms force.

The Expeditionary Maneuver Warfare Division of Coastal System Station (CSS), Dahlgren Division of the Naval Surface Warfare Center, is leading the JMPS EXP development effort under OPNAV N75 sponsorship.

1 Scope

1.1 Identification

This paper provides a high level overview of the Joint Mission Planning System - Expeditionary (JMPS EXP) System and describes how it will be support Sea Power 21, particularly Sea Basing. This paper describes how the JMPS EXP System will automate and expedite Naval Expeditionary Maneuver Warfare planning functions and products required by the Marine Corps Planning Process (MCPP). It further describes representative ways that the JMPS EXP system can be used to decrease the amount of time required to plan a mission while increasing the fidelity of planning products.

While this document focuses on the staff planning functions of an Amphibious Ready Group (ARG) with an embarked Marine Expeditionary Unit (Special Operations Capable) [MEU(SOC)], the JMPS EXP System will be extensible and scaleable to both larger and smaller Naval Expeditionary Strike Group units.

The specific Naval Expeditionary mission areas to be initially supported by JMPS EXP include: Amphibious Operations, Maritime Operations, Supporting Operations, and Military Operations Other Than War.

1.2 System Overview

JMPS EXP is envisioned as a deployable full spectrum Expeditionary planning system, that will transform the ability of Naval Expeditionary forces to rapidly plan, manage and execute multiple, simultaneous expeditionary missions. JMPS EXP will build upon and extend the Joint Mission Planning System (JMPS) (an integrated aviation and strike warfare mission planning system, currently under development) to provide an automated, distributed, collaborative mission planning capability for all Naval Expeditionary maritime, ground, aviation, service support and CONUS based forces. Because it will be based on the JMPS scalable architecture, JMPS EXP will also enable Naval Expeditionary forces to directly collaborate with carrier battle group (CVBG) and Joint Task Force (JTF) planning cells for development and coordination of critical support missions (e.g., reconnaissance, surveillance, fire support, and interdiction).

JMPS EXP will operate in either a networked or standalone mode. JMPS EXP will be connected to DII COE/JTA application programs in the Landing Force Operational Center (LFOC), Flag Plot and other key planning locations via direct access local area network (LAN)/wide area network (WAN) connections, or remote world-wide access via satellite-capable link or Secret Internet Protocol Router Network (SIPRNET). When connected, the user will have access to and download capability from information systems such as Joint Services Imagery Processing System – Navy (JSIPS-N), GCSS (including GCCS-M), JDISS, Image Product Library (IPL), and other broadband data feeds.

JMPS EXP will be a PC-based system consisting of a 'Microsoft Office-like' suite of integrated expeditionary planning tools and decision aids and will be compliant with the Defense Information Infrastructure Common Operating Environment/Joint Technical Architecture (DII-COE/JTA). The JMPS EXP System will provide access to such information sources as the Joint Distributive Intelligence Source System (JDISS), the Joint Service Imagery Processing System (JSIPS), and the Global Command and Control System (GCCS).

JMPS EXP will support the spectrum of conceptual, functional, and detailed mission planning activities conducted by Naval Expeditionary forces, as shown in Figure 1-1. Planners will have a common set of automated planning tools that they can customize to address their specific mission areas, tasks, and functions.

1.2.1 Conceptual Planning

At the conceptual planning level JMPS EXP will support the conduct of anticipatory mission analysis, (i.e., prior to receipt of a preliminary Warning, Alert, or Planning order), to define and visualize developing situations and potential operational requirements. Should a preliminary order (Warning, Alert, Planning order) be received, the results of these anticipatory analytic efforts will be immediately available within JMPS EXP for continued concurrent and parallel planning using the MCPP.

1.2.2 Functional Planning

JMPS EXP will support a myriad of mission analysis tasks at the functional planning level, including the automated analysis of the preliminary order (Warning, Alert, Planning order) to determine specified and implied tasking in the development of the restated mission statement (which may include the assignment of the Mission Commander).

1.2.3 Detailed Planning

At the detailed planning level, JMPS EXP will support the analysis, development, and selection of Courses of Action (COAs) to accomplish the objectives of the restated mission statement. JMPS EXP will provide tools for staff planners to conduct threat analysis, terrain analysis, asset scheduling and tracking, route planning, logistical planning, fires coordination, communications planning, infrastructure development, and force protection planning. JMPS EXP will enable planners embarked aboard the flagship and planners at dispersed locations to access common data sources, share information, and collaboratively plan, visualize, and validate mission details as they coalesce. JMPS EXP will support a mission rehearsal capability and the generation of the confirmation briefs. Once the final plans are approved, JMPS EXP will then facilitate the publication and dissemination of plans to the assault and supporting units.

By adding a logistics capability to JMPS EXP, the JTF/MAGTF commander will have the capability to:

- Rapidly generate and assess COA(s) for logistic supportability, opportunity costs, and risk. Make logistic supportability and logistic requirements the reverse side of the evaluation of every COA. Provides continuous visibility on all cargo moving by sea.
- Provide the capability to select most appropriate ships for a sea base missions.
- Provide the capability to model and assess various concepts for organizing and operating the sea base. Allows comparison of strengths and weaknesses in various options including support to aviation, cargo refresh, sortie generation) including LCAC), specific roles, etc.
- Provide the capability to rapidly generate an aviation COA, to assess it in terms of inventory and sortie generation requirements, to identify risks, opportunity costs, and support requirements, and then produce appropriate plans.

As the final plans are promulgated, individual combat and supporting units will continue to use JMPS EXP to perform the remaining detailed planning and rehearsal necessary to accomplish their mission objectives. Computerized mission visualization and rehearsal capabilities will greatly improve the overall mission comprehension and increase the likelihood for mission success. JMPS EXP will enable better integration of mission planning with mission execution through the incorporation of planning functions with real-time battle space management. This will enable operational commanders to conduct dynamic replanning and deconfliction in support of Expeditionary Maneuver Warfare as an operation unfolds and to electronically disseminate planning updates to the assault forces.

2 Mission Planning

2.1 Operational Need

Recently, the Commander in Chief, U.S. Pacific Fleet (CINCPACFLT) endorsed the "Mission Needs Statement (MNS) for a Distributed Collaborative Planning (DCP) System for Expeditionary Forces". In this document, CINCPACFLT details a critical need for distributed collaborative planning (DCP) tools to facilitate expeditionary operational and tactical planning critical to the successful execution of Expeditionary Maneuver Warfare.
Expeditionary Maneuver Warfare has been described as "the most complex undertaking in modern warfare". Expeditionary Warfare mission planning remains a largely human intensive process that is not automated to a great degree of depth or breadth. The current process is also highly inefficient, time-intensive (in an environment where time may be the most critical resource) and cumbersome. A strong need exists for the current low-tech planning systems to be replaced with an automated planning capability that will modernize, streamline, optimize available time, and improve the product fidelity of the expeditionary mission planning process. The JMPS EXP system is such a capability.

2.2 Doctrinal Justification

Capstone documents such as *Joint Vision 2020*, *Forward ... From the Sea*, *Marine Corps Strategy 21, Expeditionary Maneuver Warfare, and Sea Power 21* establish the vision for how the United States Armed Forces will project power and defend America's interests in the 21st century. A critical common underlying thread across each of these visions is the immediate need for continued improvement in joint interoperability, real time information management, and distributed collaborative planning.

Marine Corps Strategy 21 defines a Marine Corps tailored to answer the Nation's call at home or abroad. It provides the vision, goals and aims that support the development of enhanced strategic agility, operational reach, and tactical flexibility that enable joint, allied and coalition operations. These capabilities will continue to provide the regional combatant commanders with scalable, interoperable, combined arms Marine Air-Ground Task Forces that shape the international environment, respond quickly across the complex spectrum of crises and conflicts, and assure access or prosecute forcible entry where and when required. Fundamental to the Marine Corps vision is:

To advance along this axis, the Marine Corps has implemented ***Expeditionary Maneuver Warfare***, a capstone concept that is the union of the Marine Corps' core competencies; maneuver warfare philosophy; expeditionary heritage; sea basing; and the integrating, operational, and functional concepts by which the Marine Corps will organize, deploy and employ forces today and in the future.

Sea Power 21 defines a Navy with three fundamental concepts: ***Sea Strike, Sea Shield, and Sea Basing***, enabled by ***FORCEnet.*** Respectively, they enhance America's ability to project offensive power, defensive assurance, and operational independence around the globe. A supporting triad of initiatives will develop those core operational concepts: ***Sea Warrior*, *Sea Trial*,** and the aforementioned ***Sea Enterprise*.**

Sea Power 21 is the Navy's vision for the future of the Naval Service, a future in which emerging anti-access and area-denial challenges require us to develop "transformational ways of fulfilling enduring missions of sea control, power projection, strategic deterrence, strategic sealift, and forward presence."[1] Sea Strike, Sea Shield, Sea Basing and FORCEnet are the fundamental concepts that underpin The Naval Transformation Roadmap (NTR).[2] Sea Strike describes the ability to project offensive power from the sea; Sea Shield delineates the ability to provide global defensive assurance. The operational construct and network of FORCEnet integrates warriors, sensors, weapons, and platforms to provide a Common Operational Picture (COP) to the Joint Force Commander (JFC) and facilitate integrated naval operations and forces that are fully interoperable with other joint forces.

3 Sea Basing Concept

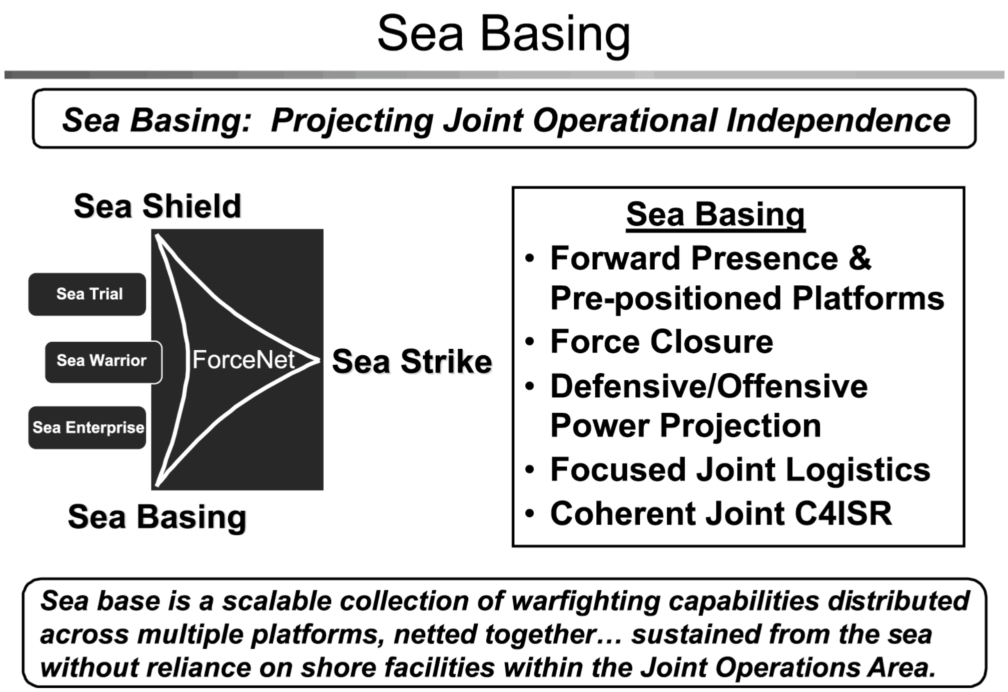

Figure 1.0 Sea Basing (from: VADM Charles W. Moore Jr. and LTGEN Edward Hanlon Jr., "Sea Power 21 Series Part IV – Sea Basing: Operational Independence for a New Century", Proceedings, January 2003)

Sea Basing is the core of Naval Transformation and will provide the operational and logistics foundation to enable the other pillars of the NTR. As originally described in "Expeditionary

[1] ADM Vern Clark (CNO), "Sea Power 21, Projecting Decisive Joint Capabilities", Proceedings October 2002
[2] Hon. Gordon England (Secretary of the Navy), ADM Vern Clark (CNO), Gen James Jones (CMC), "The Naval Transformation Roadmap", July 2002

Maneuver Warfare" (EMW)[3] and detailed in the draft Enhanced Network Sea Basing Concept paper,[4] sea basing provides enduring forward deterrence and enables a wide range of armed responses to anti-access crises. The fully-networked sea base will give the JFC a credible response capability, a springboard for Ship-to-Objective Maneuver (STOM), Operational Maneuver from the Sea (OMFTS) and Forcible Entry Operations (FEO). Further, the sea base will enable joint follow-on forces from a mobile platform unencumbered by host-nation requirements. Figure 1-1 illustrates this graphically.

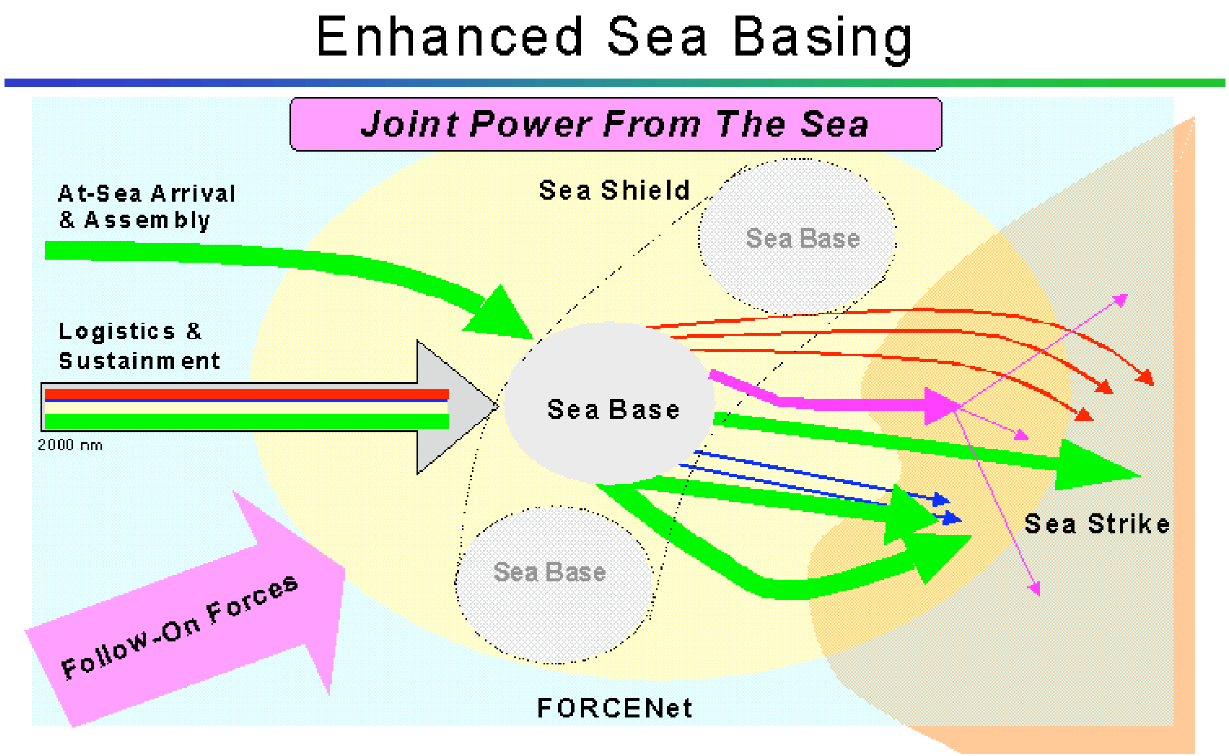

Figure 1.1: Enhanced Sea Basing

Currently and historically, Carrier Battle Groups (CVBG), Amphibious Ready Groups (ARG) / Marine Expeditionary Unit (Special Operations Capable) (MEU (SOC)), Surface Actions Groups (SAG), and submarines have demonstrated unique abilities to operate forward in critical regions for extended periods of time. Whenever a Regional Combatant Commander requires credible and flexible response across the full range of military operations, naval forces contribute to the Joint Force response. As the scale of conflict increases, larger Amphibious Forces (AF) and/or additional CVBGs may be sortied to provide the required forces. Maritime Prepositioning Squadrons (MPSRONs) close with large volumes of equipment, and offload in suitable ports or in sheltered waters where Marine Expeditionary Brigade (MEB) troops assemble with the

[3] GEN James Jones (CMC), 10 November 2001
[4] Navy Warfare Development Command/Marine Corps Concept Development Command Enhanced Network Sea Basing concept paper (Draft) dated 05 September 2002

equipment within weeks of a deployment order. Throughout, Advanced Bases (AB) may be utilized to optimize logistical support.

The Sea Basing concept builds from these current naval capabilities to achieve the more mobile and interoperable capability set needed to provide an operationally responsive and capable force to meet the strategic demands of the 21st century.

The U.S. Navy's global maritime dominance provides a secure maneuver space for U.S. forces. The threats that the U.S. faces in this century will demand forces ranging from small Special Operations Forces (SOF) engaged in combating terrorism to major combat forces capable of decisively defeating an adversary. Sea basing provides U.S. joint forces a sovereign, maneuverable and secure base capable of assembling, commanding, projecting, sustaining and reconstituting combat forces across the full range of military operations. Sea basing provides an asymmetric military advantage and a transformational capability to rapidly maneuver operational forces and support these forces from the relative security of the sea without imposing on a host nation's sovereignty. The rapid build-up and responsiveness of sea based forces will enable the United States to influence a potential crisis and may prevent escalation to large-scale conflict.

4 Logistics Information

With the adoption of Sea Power 21 by the U.S. Navy and U.S. Marine Corps, the Expeditionary Strike Group is more concerned how to implement them utilizing the Expeditionary Strike Group (ESG) ship configuration. And with the recent emphasis on a leaner, more mobile force, both the U.S. Navy and U.S. Marine Corps are deciding how to Sea Base the ESG assets such that mobility and sustainability of these assets will not be decreased.

Fortunately, recent developments in existing logistics system have included adaptive information based software capable of assisting to discipline, filter, and shape the flood of data and information which the IT revolution has unleashed in the ESG. These new wave of software systems give the promise to allow the computer to actually collaborate with the ESG staffs and commanders to provide continuous tailored decision support as a situation changed rather than merely store information and provide hard coded solutions when queried.

Now, at the operational JTF/MEB level, we must master the art of rapidly (and accurately) planning, executing, dynamically re-planning on the fly, and once again executing in order to deliver the right supplies and equipment to the right LZ, in the right quantity, at the right time, ready for use – and with full knowledge of the risks and opportunity costs inherent to our decisions. The initial plan is truly only the stepping off point in these future sea base operations. Once begun, the critical focus is the continuous identification and fulfillment of requirements to support the engaged force.

The focus on sea based expeditionary warfare, the growing attention to improving JTF capabilities at the operational level of war, the emergence of intelligent agent-based adaptive software, and the paucity of tools for operational logistics gave birth to SEAWAY. It was conceived and largely designed by Marine and Navy officers determined to be able to provide responsive sea based expeditionary logistics at the operational level of war. It was envisioned as a decision support tool for both planning and execution. It was designed to assist accomplishing functions in current battle, future operations, and future plans. It is dual use adaptive software whose agent based tools assist in planning and executing sea based expeditionary operations at the same time that the same tools assist combat developers in concept refinement and requirements determination.

The merging of logistics information into the mission planning process will allow increased time for the command staff to properly weigh the advantages and disadvantages of a particular Course Of Action (COA) against other COAs with logistics being a critical factor in their evaluation and comparison. This will allow mission commanders to provide "just in time" delivery of assets to objectives of opportunity with a shortened response time that more than adequately supports the maneuverability requirements of the Sea Power 21 concept.

5 Command Operation Center - Afloat (COC-A)

The Command Operations Center (COC) onboard existing command ships within the ESG consist of U.S. Navy and U.S. Marine personnel occupying and sometimes sharing spaces throughout the command ship. Each of these spaces are organized around a specific function, such as LFOC (Landing Force Operations Center) is the command space for the Commander of the Landing Force, the JIC (Joint Intelligence Center) is the space where intelligence information between all DoD Forces is coordinated and processed, and the SACC (Supporting Arms Coordination Center) is where the supporting arms systems are used by operators to support their planning and execution for a mission. These existing spaces all share the same issues:

- Separate little caves.
- Coordination between spaces require runners to pass messages.
- Populated by an assortment of stove-piped systems from a menagerie of suppliers that don't integrate with each other.
- No common tactical or operational system.

The Command Operation's Center – Afloat (COC-A) is a vision to turn the dedicated spaces onboard a command ship to spaces where the commander can perform any warfighting function that is required based on his resources and the mission he is performing. This allows the commander to rapidly reconfigure the spaces onboard his ship to support whatever efforts he is performing rather than shoe-horning his resources into spaces that cannot be easily reconfigured for his required efforts.

By utilizing the COC-A approach, the commander will not need as many resources to perform his mission because his resources are maximized ideally and could be utilized simultaneously by large group of personnel without decreasing their productivity. Also these resources can be co-located to facilitate the commander's ability to make decisions quickly and to integrally support the mission planning process.

Section 3:

Responder Support in Crisis Management

Critical Decision Making for the First Responder – Intelligence Support is the Key

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Introduction

Critical decision making in an emergency incident may be difficult because of many factors. When life or property is threatened the decision critical scale increases greatly. As a former member and chief officer of the Los Angeles Fire Department, I know the importance of decision making under the most extreme emergency conditions. The decision-maker should be trained to make these decisions in the classroom as well as under the most realistic conditions possible in exercises. Experience is still the best teacher, but we should be good at limiting conditions leading to critical decisions because of management skills in prevention, mitigation, good policies and procedures. Intelligent decision support systems can also be useful in pre-event preparedness. The "real thing" may occur rarely so we need to be ready to go into action from the daily routine environment into the worst case scenario incident. The adage that "practice makes perfect" is certainly true. Those emergency responders and others involved in continuous emergency decision making are able to improve their skills and become very good at managing emergencies. Most of us in the emergency management business can think of a few people who are really good at it. We need to think about why.

Emergency Command

The Incident Commander makes decisions in emergency situations based on training, experience, and on the information received at the time. Information is gathered in many ways, processed, displayed, or presented and then acted upon. The information needed must be timely, accurate, and easy to process. Time can be the enemy at an emergency when life, property, and the environment may be threatened. Information is needed to develop an action plan, set objectives, and priorities. The Incident Commander must decide, sometimes in seconds, what specific elements of information are needed for decision making. Information that is analyzed becomes intelligence and becomes input for the strategic planning and development of tactics needed for the incident.

This essential information must be obtained, communicated and displayed rapidly if it is to be useful. Decision support tools should be developed to assist the Incident Commander in answering the questions of what is the operational picture, what is critical, what are the objectives, priorities, options, and how will they be accomplished given the conditions and resources available at the time.

Response Scenario

The best way to describe what is needed by an Incident Commander to obtain information and manage an incident effectively is to illustrate by example. One of the many difficult incidents to manage is a structural collapse involving trapped victims and the hazards created that affect them and the responders.

The initial actions taken by the Incident Commander (IC) set the tone for the incident. The initial size up and structural triage provide information needed to:

- Develop the action plan.

  Size up provides the information needed to develop the Incident Action Plan (IAP). Structural triage helps identify and prioritize the rescue areas with the highest probability of success. Many factors regarding the collapsed structure incident must be considered to develop a rescue operational plan, objectives, priorities, command organization, and resource requirements.

- Provide for the safety of both rescuers and victims.

  The IC should initiate the risk management process to determine the safest commitment of resources. A personnel accountability system should be used to track and ensure rescuer safety. Hazards and dangerous working conditions may be reduced or eliminated through effective incident management.

- Increase operational effectiveness.

  Scene control must be initiated early to establish a safe and functional work-site.

  The initial scene assessment is critical and sets the direction for the response. Many factors must be dealt with when the IC arrives at an incident and attempts to size up the situation and begin operations. Incident personnel may need to perform the following activities prior to beginning structural collapse operations.

- Identify buildings individually (i.e., by address, physical location, unique design, etc.).
- General area triage to identify which buildings among many in a given area offer the highest potential for viable rescue opportunities.
- Assess and mark hazards prior to search-and-rescue operations in any specific building.
- Determine zones of operations, i.e., collapse zone, work zone, hot, warm and cold zones.
- Mark particular areas or buildings for search and rescue.

At least two possible situations exist when emergency responders arrive.

1. Civilians already may have identified viable search or rescue opportunities. This information greatly reduces the number of considerations that the IC must address. The IC must keep in mind the following factors:

- The location and identification of separate buildings may be marked clearly by volunteers.

- Many other general size-up activities may have been performed by the local volunteers. The IC may base the action plan and assignment of resources on this information.

- Information provided by local sources must be reviewed for validity. The IC should not accept information as fact (when approached by local civilians reporting entrapped victims), but rather should have a complete assessment of the overall situation verified by a team manager, Company Officer (CO), or by personal observation.

2. There may be little or no reconnaissance information available when the IC arrives.

The IC may be responsible for a geographic area (several buildings, part of a block, several block area) with no solid information as to where to concentrate efforts. In this case, size-up of the situation and the decision-making process becomes much more complex.

- If no search or rescue requirements are identified immediately, search priorities should be determined based upon victim entrapment in high probability occupancies such as schools, hospitals, multi-residential buildings, etc.

An IC may be faced with something as simple as a single site incident (i.e., one building or a single rescue within a building), or multi-site devastation. Depending upon the size and extent of the devastation, the IC may be faced with situations that require immediate decisions regarding the implementation of the operational plan. This initial plan is developed from the size-up, and the assessment of the incident is continuous throughout the incident.

Once the initial assessment is underway, the IC must begin to identify the overall mission objectives which should include:

- assess general situation at the designated rescue site(s);
- plan strategy and priorities;
- assign resources;
- manage ongoing operations; and
- follow up on the progress and make adjustments to the plan.

Size-up involves obtaining information about the incident so that a plan can be developed. The size-up should include:

- The problem's cause (how the structure collapsed).

- Hazards involved (i.e., additional collapse, fire, haz-mat, utilities, flooding, dust, toxic or flammable atmosphere, etc.).
- Incident conditions (i.e., structural stability, time, weather, access).
- Victims (how many exist as well as their location, viability, number, and degree of rescue difficulty.).
- Internal or external exposures.

The size-up of the collapsed structure and victim potential is much like that of a structure fire size-up. Consideration must be given to rescuer risk versus the benefit of rescuing a victim.

The IC needs to develop an Incident Action Plan (IAP) that includes appropriate objectives, priorities, strategies, and tactics, command structure, and resource requirements. The development of this plan should include consideration of the following factors:

- Time.
  The time of day provides information on the occupancy load and location of people in the structure.

- Location.
  Access is important to an effective operation.

- Occupancy.
  Knowledge of the occupancy yields information on hazards, occupant use, and types and number of businesses.

- Height and area.
  Consider all six sides and the area involved.

- Size of collapse area and structural hazards.
  This assessment will dictate resource requirements and safe methods of rescue.

- Fire problems and hazardous materials.
  Fire or hazardous materials problems may impede a collapsed structure rescue operation.

- Explosives
  The cause of the collapse may have occurred from an accidental explosion, i.e. natural gas, or from a criminal attack using explosives. Extreme caution must be used considering the possibility of secondary attack.

- Exposures.
  Interior and exterior exposures should be considered to prevent additional damage or injury.

- Secondary collapse.

The hazard of secondary collapse must be considered, whether from an earthquake aftershock or from failure of an already weakened support structure.

- Utilities.
  Control of gas, water, and electricity is a major safety factor to both rescuers and victims.

- Weather.
  Temperature variations affect rescuers and victims. Wind and rain certainly may create additional problems inside and outside the structure.

- Safety.
  Safety is the top priority in rescue planning and operations and must be considered throughout the incident.

- Victims.
  Victim location is a priority in the initial rescue plan and may be determined by a variety of methods.

- Traffic.
  Speed of response and access to the collapse site are critical. Alternate routes and traffic control should be planned.

- Rail.
  Surface and underground rail systems may be part of the collapse problem or may affect it because of vibration.

- Personnel.
  Rescue operations require a multi-disciplined response from fire, EMS, police, public works, building department, transportation department, volunteers, and many others.

- Incident command.
  The complexities involved in rescue require an effective Incident Command System (ICS) to manage and coordinate operations, planning and support.

- Communications/Information.
  Intra-agency and interagency communication capabilities, and intelligence information are essential to effective and safe operations.

- Medical.
  Rescue medical operations need to provide for victims as well as have a component to handle the needs of responders.

- Special equipment.

Collapsed structure rescue operations may require the use of specialized search equipment, and portable cutting, breaking, and breaching equipment.

- Construction equipment.
  Large, mechanized construction equipment may be needed to remove debris so that rescue operations can be expedited.

- Shoring materials.
  A large amount of shoring materials may be required for safe access to victims and for structural stabilization. Pre-incident planning of supply sources is important.

- Information updates.
  Continuous information updates are needed during every stage of the rescue operation.

- Staging Areas.
  Staging Areas should be established for incoming resources so that the response into the rescue site can be managed effectively.

- Responder rest, recovery, and relief.
  Long-term rescue operations necessitate periodic rest periods for rehabilitation of rescue workers, including provisions for relief so that operations may continue without pause. (Borden 1999)

Information needed on any of the items in the aforementioned list may come from a variety of sources. It may come from the Incident Commander's knowledge, another person, written documents, or by electronic means such as cameras, or computers. The Incident Commander needs to determine what information is needed at the time to make key decisions. Judging from the amount of information that may be needed it should be apparent that a decision support tool could be very useful when considering the time factor and the saving of lives.

Decision Making

Decision making in emergency situations is based on training, experience, and on information received at the time. Realistic training and exercising is very important and the more "hands on" that there is the better the results. The best decisions are made through a pattern of past similar experiences. Of course this takes time and opportunity, and is the most difficult to attain.

A research study indicates that experienced Incident Commanders are able to make better and more rapid decisions in emergency situations that less experienced Commanders. The majority of decisions in the study were characterized, not by option consideration, but by the Incident Commander recognizing the situation as an example of something they had encountered many times before. There was evidence for a matching process, rather than a calculational process. Because decisions were made in the form of complex pattern matching, much of the expertise came through in the situational awareness both initially in an incident and continuing throughout. The rapid generation of options came from their situational awareness. The recognition of a situation comes from an effective scene assessment or size-up and situational awareness. Other factors that improved decision making was knowledge gained through perceptual learning that linked past experiences or cues to situational awareness, and the ability of the Incident Commander to use his own imagery or visualization to create an image of how the operation would take place before deciding the strategy needed. One of the conclusions in the research stated that in time pressured situations, people will not be able to perform the operations needed to make comparative judgments. It would be much more valuable to make sure that decision support systems are providing an effective situational awareness. (Klein, Calderwood, and Cirocco 1988).

What is Needed

Maintaining an updated situation status and resource status, especially on major incidents, is difficult and electronic systems are useful for this purpose. What are the essential elements of information needed for decision making? How will it be communicated and displayed? Even more important is the input from system users in the development of decision support tools to assist the Incident Commander in selecting the right strategy and tactics for the response. The intent is to provide an on-line, real time, multi-discipline, multi-agency shared net based information system for multi-agency communications and access during an emergency. The system should provide users with a variety of decision support information coming from a variety of sources. The system does not make decisions, but could present critical intelligence and various strategy options. The system does not take the place of agency or department data bases, but will use data from these systems as appropriate.

- Keys to success are: quality of information, reliability of the source, relevance, timeliness, and accuracy. The system should keep people safe to do a better job.
- Make sure the system is user friendly.
- The system should be a "Push/Pull" design.
- To make the system more user friendly it should be in use day-to-day, and include a training mode.
- Decision support information may be useful for any incident, single or multiple, but especially for multi-agency and multi-jurisdictional responses.
- The threshold to trigger the system should be at the lowest level because data input is slow and emergency situations are dynamic.
- Push input and decision making to the lowest level.
- Set up system with filters and layers, determine degree of detail required by the user, and level of information required.

- The system would be most beneficial if: developed to respond to voice commands, use as many graphic representations as possible, provide red flag notifications of critical information, be incident specific in real time, identify providers of information, communicate with local, state, federal, and private agencies, track resources, provide demographics by the hour, display information at levels needed with common symbology and terminology.

- System displays may be text, verbal, fax, graphics, digital, video. (Verbal and graphics preferred). Transmitted by radio, fax/phone, net, messenger, etc.

- Within the Incident Command System organization a Decision Support Unit may be activated in the Planning/Intel Section to develop and work with this information for the Incident Commander.

- The system should be designed to assist in identifying strategies and tactics for specific incident or event types.

- The system should make inquiries or prompts for the Incident Commander or staff member, i.e., Do you need ---? Answer – Yes. Response – The --- is available at ---. There is great value to a question/answer system for specific incident types.

- The system may be real time and have a resident database.

- Graphic displays may use various maps with overlays, 3 dimensional and real time.

- A response matrix may be developed by users for specific incident types like structural collapse, and swift water rescue for example, and include specific site information pre-incident.

- Decision support information may be used under any of the Incident Command functions, e.g., Command, Planning/Intel., Operations, Logistics, Finance/Administration.

- The system may use historic data in a compressed time format to assist in decision making. (Borden 2000)

Information elements that could be used to assist in emergency incident decision making may include the following:

What is it?
Incident Type (All hazard)

Where is it?
Location
Boundaries and jurisdiction
Single or multiple incidents
Spread potential
Initial damage assessment boundaries
Single or multiple
Duration estimate
Jurisdiction in charge, jurisdictions affected

Conditions:
Weather
Geophysical
Sunrise/Sunset time
Visibility conditions
Damage assessment

Hazards:
Hazardous Materials, biological, explosives, fire, radiological, WMD, flood, crowd, weapons, terrorists, utilities
Threats or potential threats

At Risk:
Potential hazards
Prioritized by life, property, systems, infrastructure, environment (most serious to least)
Critical facilities (Hospitals, fire and police stations, communication centers, etc.)
Infrastructure (utilities, roads, dams, transportation, pipelines, etc.)

Mitigation:
Hazard identification
Define location(s)
Determine control methods
Mitigation methods
Safety requirements

Victims:
Location
Numbers injured (categorize) number dead
Condition/viability
Medical condition
Medical facilities/status

Displaced: location, evacuation needs, shelter locations, transportation requirements, accountability system, animals/pets, and logistical requirements

Operational Needs:
Optimum search and rescue tactics for the specific situation
Optimum medical treatment needed
Optimum control and stabilization procedures for specific situation
Resources required (Type and kind) for the incident
Locations and response times of resources requested (local, state, federal, private)
Resource information, agency, personnel, ETA, communications, etc.

Transportation/Access:
Safe access locations
Security/perimeter controls
Transportation routes (Road, water, rail, air)
Traffic flow patterns/restrictions
Resources needed
Evacuation routes
Emergency response vehicle response routes

Incident Facility Locations:
Command Post, Base, Staging area, Helibase, Helispot
Casualty Collection Point
Field hospital
Hospital locations
Mobilization centers
Department Operations Centers
Emergency Operations Centers
(Borden 2000)

The time criticality of decisions may vary throughout an incident depending on many factors. During larger incidents, the decisions for various functions may be delegated by the Incident Commander to subordinate officers in the organization. Information may then be accessed by these members of the Incident Management Team to assist them in the decisions needed to accomplish their objectives.

Conclusion

Our first responders are having to deal with new and more complex incidents than ever before and many times are required to make decisions based on very little information or be in a situation of unknown danger to themselves and the potential victims. Technology will certainly assist and support the Incident Commander in the future, but he or she will still have to make the critical decisions. Obtaining the “common operational picture” accurately and rapidly will help change decisions based on impulse to those based on reason in response. The goal in intelligence support in decision making for the first responder is “getting the right information to the right people all of the time”.

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TEGRID: *Demonstration of a Semantic Web Environment*

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Introduction

Over the past several years there has been an increasing recognition of the shortcomings of message-passing data-processing systems that compute data without understanding, and the vastly superior potential capabilities of information-centric systems that incorporate an internal information model with sufficient context to support a useful level of automatic reasoning.

The key difference between a data-processing and an information-centric environment is the ability to embed in the information-centric software some understanding of the information being processed. The term ***information-centric*** refers to the representation of information in the computer, not to the way it is actually stored in a digital machine. This notion of ***understanding*** can be achieved in software through the representational medium of an ontological framework of objects with characteristics and interrelationships (i.e., an internal information model). How these objects, characteristics and relationships are actually stored at the lowest level of bits in the computer is immaterial to the ability of the computer to undertake reasoning tasks. The conversion of these bits into data and the transformation of data into information, knowledge and context takes place at higher levels, and is ultimately made possible by the skillful construction of a network of richly described objects and their relationships that represent those physical and conceptual aspects of the real world that the computer is required to reason about.

In a distributed environment such information-centric systems interoperate by exchanging ontology-based information instead of data expressed in standardized formats. The use of ontologies is designed to provide a context that enhances the ability of the software to reason about information received from outside sources. In the past, approaches to inter-system communication have relied on agreements to use pre-defined formats for data representation. Each participant in the communication then implemented translation from the communication format to its own internal data or information model. While relatively simple to construct, this approach led to distributed systems that are brittle, static, and resistant to change.

It is the premise of the TEGRID (Taming the Electric Grid) proof-of-concept demonstration that, for large scale ontology-based systems to be practical, we must allow for dynamic ontology definitions instead of static, pre-defined standards. The need for ontology models that can change after deployment can be most clearly seen when we consider providing information on the World Wide Web as a set of web services augmented with ontologies. In that case, we need to allow client programs to discover the ontologies of services at run-time, enabling opportunistic access to remote information. As clients incorporate new ontologies into their own internal information models, the clients build context that enables them to reason on the information they receive from other systems. The flexible information model of such systems allows them to evolve over time as new information needs and new information sources are found.

The TEGRID Demonstration Context

Since mid-2001 the Emergency Operations Bureau of the Los Angeles Sheriff's Department has been assigned the additional task of coordinating the response to expected rolling electric power blackouts, as California's demand for electric power came perilously close to exceeding availability. While both the power outage areas and individual blackout periods are predefined in terms of a large number of power grid units that are distributed throughout the Los Angeles County, the emergency events that are likely to be triggered by blackout conditions (e.g., multi-vehicle accidents, carbon monoxide poisoning in enclosed parking garages, fires, criminal activities, and other disturbances) are less determinate.

The TEGRID proof-of-concept system has been designed to assist the Los Angeles Sheriff's Department by addressing this potentially chaotic situation in an autonomously evolving, just-in-time manner. TEGRID does not exist as a pre-configured system of tightly bound components that know about the existence of each other, have predefined connections, and predetermined capabilities. In fact at the beginning of the demonstration TEGRID, as a system, does not really exist at all. What does exist is a set of cooperating Semantic Web Services, based on standard Web Service specifications (e.g., SOAP, UDDI, WSDL, and XML) enhanced by the ability of sharing semantic-level descriptions of their own internal information models.

In essence TEGRID involves sharing information among a number of separate organizations, including local police stations, the Emergency Operations Bureau, a power supply management and monitoring organization, and a traffic control system. The proof-of-concept relies on a set of assumptions about the existing resources available from each of the organizations involved.

1. That each local sheriff's station has a database that includes (at least): current officer assignments; equipment manifests and status; and, priority infrastructure and intersections.
2. That the Emergency Operations Bureau has a list of Rapid Response Teams and their primary and alternative assignments.
3. That there exists some kind of Power Supply Organization that has a database of recent history of power consumption, plus the ability to provide a real-time feed of current power levels.
4. That there exists some kind of Traffic Control Organization that has some method of determining acceptable alternative routes for reaching a particular destination from a given starting location.

Another underlying assumption is that all of these organizations have Internet connections and either have an existing web site or are willing to establish one. TEGRID builds on these existing information and data sources to construct a web service infrastructure that allows information-sharing and automated decision-support.

Since the proof-of-concept system does not have access to live databases, it simulates them, using sample data to implement the demonstration scenario. There are also some potential applications that must exist in order to support the scenario, but are not part of TEGRID itself. For example, there is a requirement that new incidents (e.g., traffic accidents) would be reported to the local sheriff's stations before they are able to propagate through the system. Such a reporting application is assumed to exist, and has been simulated in order to produce the dynamic behavior called for in the demonstration scenario.

TEGRID features several kinds of web service providers. Each of these implements a set of operations that allows exchange of the information that makes the functioning of the system possible. These operations such as subscription, information transfer, warning and alert generation, discovery, and assignment, are the minimum necessary to provide the functionality described in the demonstration. More operations can be easily added as TEGRID's capabilities increase in the future.

In addition, TEGRID includes software agents with automatic reasoning capabilities. Some of these agents could conceptually be seen as services. For instance, the Station Monitor Agent is able to publish alerts that the local stations can subscribe to, and at the same time the Station Monitor Agent is able to subscribe to notifications of planned power outages. The relationship between agents and services is perhaps a fertile field for further investigation: When is it more useful to implement functionality as an agent, and when as a service? Are the two orthogonal? Is it reasonable to think that the same set of functions might be an agent from one point of view, but a service from another? Does an agent consume services, provide services, or both? Since it seems likely that the answers to these questions depend on the nature of the individual agent, the definition of a conceptual framework for making such determinations might be a productive future goal.

The Fundamental Web Service Elements

Within the Internet context of web services, TEGRID builds on a number of standard protocols and elements. These elements are combined into an executing software entity, capable of seeking and discovering existing web services, extending its own information model through the information model of any discovered web service, and automatically reasoning about the state of its internal information model. As shown in Fig.1, this entity or Cyber-Spider consists of three principal components: a web server; a semantic web service; and, an information-centric application.

The web server, utilizing standard Hypertext Transfer Protocol (HTTP), serves as the gateway through which the Cyber-Spider gains access to other existing web services. Web servers primarily provide access to Hypertext Markup Language (HTML) data sources and perform only simple operations that enable access to externally programmed functionality. However, these simple operations currently form the building blocks of the World Wide Web.

The second component of a Cyber-Spider is a semantic web service (i.e., a web service with an internal information model). A web service is accessed through a web server utilizing standard protocols (e.g., UDDI, SOAP, WSDL, SML) and is capable of providing programmed functionality. However, clients to a standard web service are usually restricted to those services that implement specific predefined interfaces. The implementation of web services in the Internet environment allows organizations to provide access to applications that accept and return complex objects. Web service standards also include a limited form of registration and discovery, which provide the ability to 'advertise' a set of services in such a way that prospective client programs can find services that meet their needs. The addition of an internal information model in a semantic web service allows the storage of semantic level descriptions (i.e., information) and the performance of limited operations on these semantic descriptions. In other words, the semantic web server component of a Cyber-Spider is capable of reasoning.

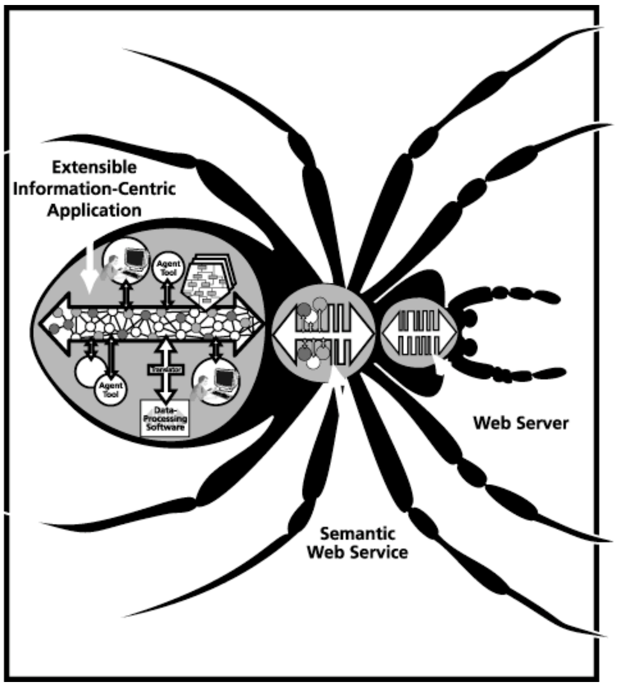

Fig.1: Anatomy of a Cyber-Spider

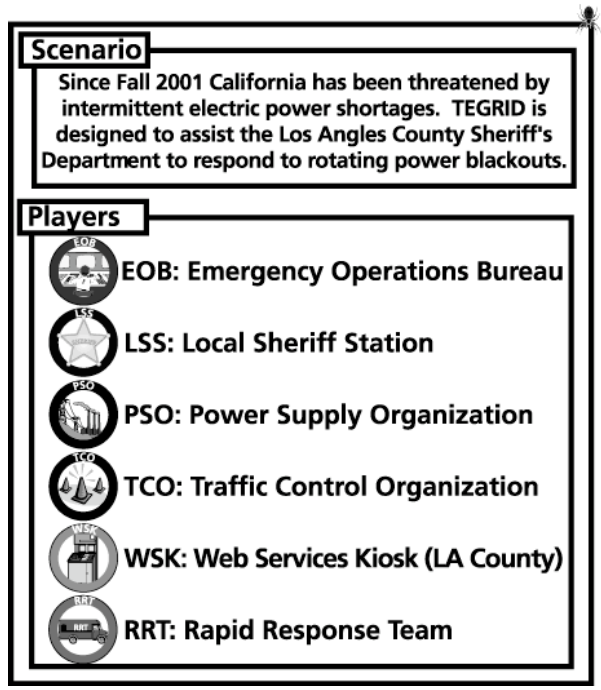

Fig.2: Cast of TEGRID players

The third component of a Cyber-Spider is one or more information-centric applications. These applications are designed to take advantage of the resources provided by a number of semantic web services, enabling them to reason about the usefulness of each service and support more sophisticated discovery strategies. Moreover, the application component is able to construct relationships among the information models of different services, with the ability to integrate services without requiring agreement on a common information model.

With these three components Cyber-Spiders are at least minimally equipped to operate in an Internet environment as autonomous software entities, capable of discovering needed services; accepting services from external offerers; providing services to external requesters; gaining context through an internal information model; automatically reasoning about available information; extending their information model during execution; extending their service capabilities during execution; and, learning from their collaborations.

The TEGRID Players

The cast of players in the current TEGRID proof-of-concept demonstration includes six players or existing web services (Fig.2): the Emergency Operations Bureau (EOB) of the Los Angeles Sheriff's Department; several Local Sheriff Stations (LSS); a Power Supply Organization (PSO); a Traffic Control Organization (TCO); several Rapid Response Teams (RRT); and, a Los Angeles County Web Services Kiosk (WSK).

Fundamental to each player are three notions. First, each player operates as an *autonomous* entity within an environment of other players. Most, but not all of the other players are also autonomous. This requires the autonomous players to be able to discover the capabilities of other players. Second, each autonomous player has a sense of *intent* to accomplish one or more objectives. Such objectives may range from the desire to achieve a goal (e.g., maintain situation awareness, coordinate the response to a time critical situation, or undertake a predetermined course of action following the occurrence of a particular event) to the willingness to provide one or more services to other players. Third, each player (whether autonomous or not) is willing to at least *cooperate* with the other players. In some cases the level of cooperation will extend to a collaborative partnership in which the partnering players contribute to the accomplishment of a common objective. In other cases the cooperation may be limited to one player providing a service to another player, without any understanding or interest in the reason for the service request.

To operate successfully in such an autonomous Internet-based environment a Cyber-Spider player should be endowed with the following capabilities:

1. Subscribe to information from external sources (e.g., alerts, ontology extensions).
2. Accept subscriptions from external clients.
3. Dynamically change its subscription profile.
4. Extend its internal information representation.
5. Extend its own service capabilities.
6. Generate new agents for its own use.
7. Describe its own service capabilities to external clients.
8. Seek, evaluate and utilize services offered by external clients.
9. Provide services to external clients.
10. Describe its own (intent) nature to external clients.

The Cyber-Spiders in TEGRID are currently capable of demonstrating eight of these ten desirable capabilities. The ability of a Cyber-Spider to dynamically change its subscription profile, while technically a fairly simple matter, has not been implemented because it is not used in the demonstration scenario. The ability of a Cyber-Spider to describe its own nature to external clients, on the other hand, is technically a much more difficult proposition. It will require a Cyber-Spider to have an understanding of its personality as a collective product of its internal information model and the relationship of that model with the external world. At best this must be considered a challenging research area that is beyond the current capabilities of information-centric software systems.

The TEGRID Agents

Most of the reasoning capabilities available in TEGRID are performed by software agents that are components of the players (e.g., Cyber-Spiders). In other words, agents are predefined clients within player systems (i.e., information-centric applications) and perform internal functions that are necessary for the particular player to deliver its services and/or accomplish its intent. The following agents (i.e., collaborative tools) are available in the current TEGRID implementation:

Name of Agent	Owner	Description of Agent Capabilities
Risk Agent	EOB	Identifies high risk entities in the jurisdictional region of an activated LSS.

Deployment Agent	EOB	Determines whether RRT support is required for a particular activated LSS.
Power Level Agent	PSO	Determines if electric power demand has exceeded supply.
Situation Agent	EOB	Prepares and updates the 'EOB Situation Status Report'.
Station Monitor Agent	EOB	Identifies all LSSs that will experience power blackouts during the current and next blackout cycle.
Status Agent	LSS	Prepares and updates the 'LSS Situation Status Report'.
Local Station Agent	LSS	Determines whether sufficient local resources are available to deal with current conditions.
Scheduling Agent	EOB	Assigns RRTs and equipment to situations requiring RRT involvement.
Incident Agent	EOB	Monitors the response to a particular situation supported by one or more RRTs.
Routing Agent	TCO	Determines alternative routes to a particular situation location.

Demonstration Objectives

Stated succinctly, the objective of the TEGRID scenario is to demonstrate the discovery, extensibility, collaboration, automatic reasoning, and tool creation capabilities of a distributed, just-in-time, self-configuring, collaborative multi-agent system in which a number of loosely coupled Web Services associate opportunistically and cooperatively to collectively provide decision assistance in a crisis management situation. Specifically, these capabilities are defined as follows:

Discovery: Ability of an executing software entity to orient itself in a virtual cyberspace environment and discover other software services.

Extensibility: Ability of an executing software entity to extend its information model by gaining access to portions of the information model of another executing software entity.

Collaboration: Ability of several Web Services to collaboratively assist each other and human users during time critical decision making processes.

Reasoning: Ability of a software agent to automatically reason about events in near real time under time critical conditions.

Tool Creation: Ability of a Web Service to create an agent to perform specific situation monitoring and reporting functions.

Players' Intent

The TEGRID players or Cyber-Spiders are initialized with intent or willingness to cooperate based on their role and operational responsibilities, as follows:

EOB (Emergency Operations Bureau): To be immediately informed of imminent power blackout conditions, to coordinate all assistance to LSSs, to maintain situation awareness, and to take over local command responsibilities when conditions require actions that cross the jurisdictional boundaries of two or more LSSs.

LSS (Local Sheriff Station): To activate a predefined response plan as soon as it receives notification (from the EOB) that a power blackout condition is imminent within its jurisdiction, to respond to new emergency missions in its jurisdictional area, to provide RRTs to the EOB, and to request assistance from the EOB.

PSO (Power Supply Organization): To share information relating to the current status of power demand and availability with subscribers, to provide subscribers with information relating to a predefined rolling power blackout schedule on request, and to alert subscribers whenever the schedule is intended to be implemented.

TCO (Traffic Control Organization): To share information relating to historical traffic flows under typical conditions with subscribers, to provide subscribers with information relating to traffic control capabilities (e.g., types and location of traffic signals, sensors, and web-cameras), and to provide subscribers with alternate traffic routes on request.

RRT (Rapid Response Team): To share information relating to its current mission and location with subscribers, to execute missions requested by the EOB, and to provide assistance to any assigned LSS, and to request assistance from the EOB.

The TEGRID Demonstration Scenario

Armed with their individual intent and intrinsic Cyber-Spider capabilities (i.e., ability to: discover useful web services; subscribe to information and accept subscriptions from external clients; extend their internal information models; describe and provide services to external clients; seek, evaluate and utilize services offered by external clients; and, extend their own service capabilities by generating new agents) the players commence their partly intentional and mostly opportunistic interactions.

Orientation

The players orient themselves in the virtual cyberspace environment by accessing one or more directories of available services and registering an information subscription profile with those services that they believe to be related to their intent (Fig.3).

EOB (Emergency Operations Bureau): Accesses the WSK (Los Angeles County Web Services Kiosk) based on its predefined authorization level, and:

Subscribes to any service changes in the WSK.
Finds the PSO address which it was seeking.
Discovers the TCO.
Discovers all of the LSSs.

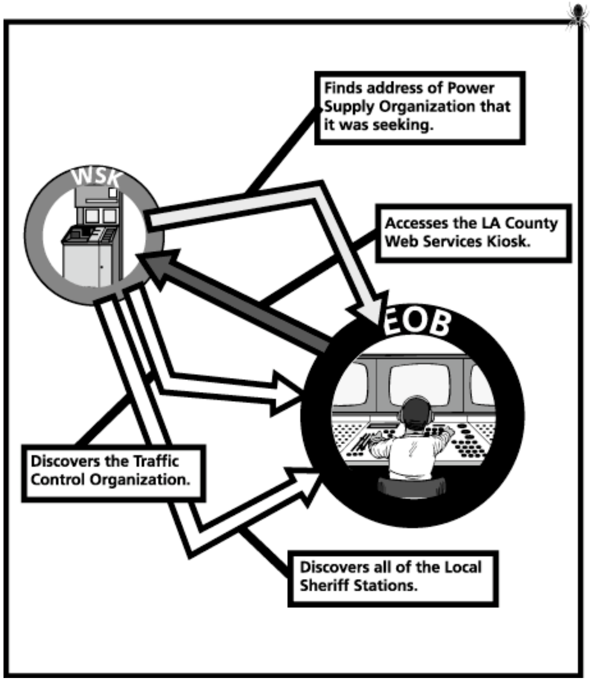

Fig.3: Orientation and discovery

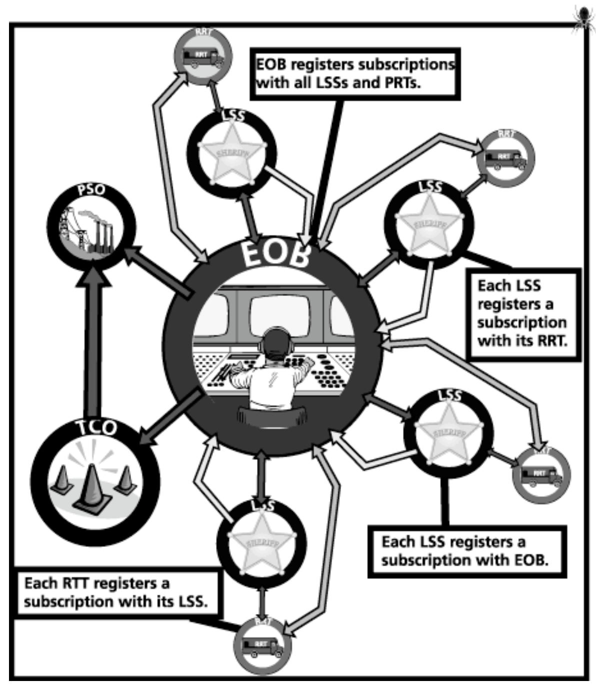

Fig.4: Information subscription

Subscription

The players access the services that they require to achieve their intent, register appropriate subscription profiles, and query for information that they believe to have a need for (Fig.4).

EOB (Emergency Operations Bureau): Registers a subscription profile with each LSS (Local Sheriff Station) that includes all current police unit locations, mission completion events, new mission events, and any information changes relating to the availability of its RRTs (Rapid Response Teams).

Queries each LSS (Local Sheriff Station) for all information relating to its RRTs (Rapid Response Teams) and extends its information model.

Registers a subscription profile with each RRT (Rapid Response Team) that includes its current location and mission.

Registers a subscription profile with the PSO (Power Supply Organization) that includes the current status of electric power demand and availability, and any change in its intention to implement the predefined rolling power blackout schedule.

Registers a subscription profile with the TCO (Traffic Control Organization) that includes any change in the status of traffic signals, sensors, and web-cameras.

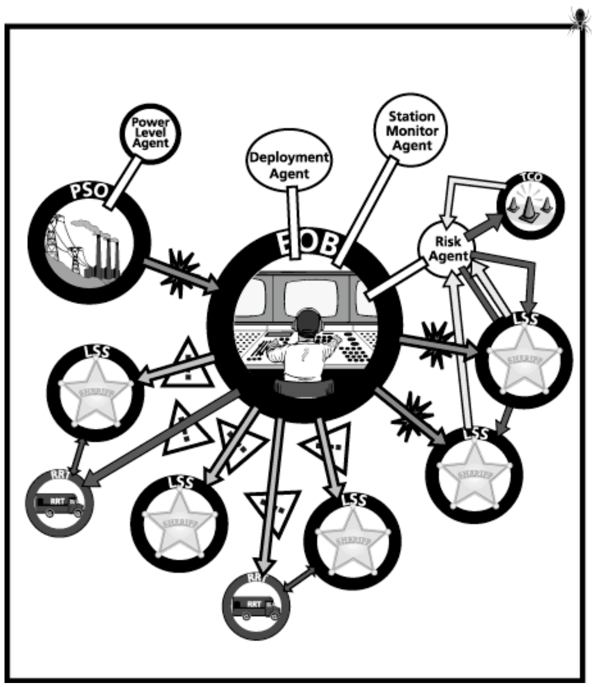

Fig.5: Power supply ‘Warning’

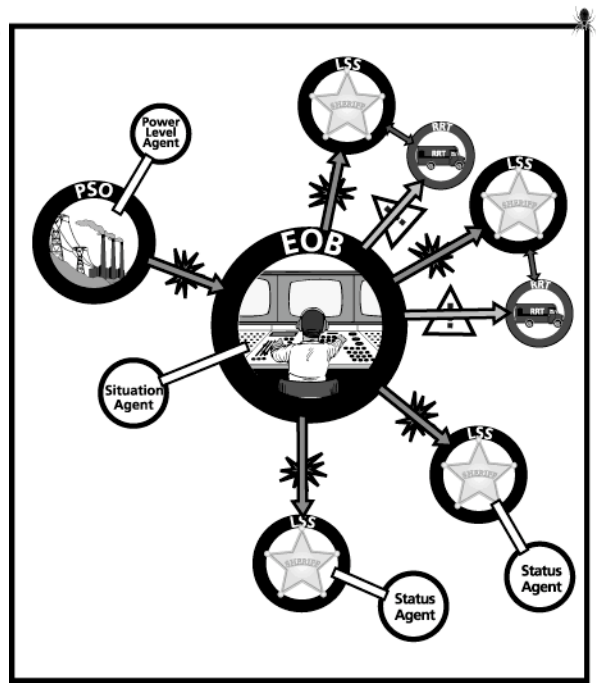

Fig.6: Power outage ‘Alert’

LSS (Local Sheriff Station): Each LSS responds to the EOB (Emergency Operations Bureau) registration by registering a corresponding subscription profile with the EOB that includes the current mission and location of its RRTs (Rapid Response Teams), any EOB requests and orders to this LSS, and changes in the current 'situation status report’ maintained by the EOB.

Each LSS (Local Sheriff Station) registers a subscription profile with its RRTs (Rapid Response Teams) that includes the current mission and location of the RRT, mission completion events, and new mission events (this duplication of its EOB (Emergency Operations Bureau) subscription profile allows the LSS to verify the accuracy of this portion of the ‘situation status report’ maintained by the EOB).

TCO (Traffic Control Organization): Registers a subscription profile with the PSO (Power Supply Organization) to include the location of all current power blackout areas.

RRT (Rapid Response Team): Registers a subscription profiles with the EOB (Emergency Operations Bureau) that includes any requests or orders to this particular RRT (Rapid Response Team), and any changes in conditions that impact the current mission and location of this RRT.

Registers a subscription profile with its home base LSS (Local Sheriff Station) that includes any request for information, and any ‘situation status report’ maintained by this LSS.

Power Outage Notification

The PSO (Power Supply Organization) alerts its subscribers that a rolling power blackout condition is imminent (i.e., will commence per predefined schedule within 15 minutes) (Fig.5).

PSO (Power Supply Organization): Utilizes its Power Level Agent to continuously monitor the relationship between power demand and supply. The PSO determines that demand is close to exceeding supply and sends an Alert to all appropriate subscribers.

EOB (Emergency Operations Bureau): Receives an Alert from the PSO (Power Supply Organization) that the predefined rolling power blackout schedule will be implemented within 15 minutes.

Utilizes its Station Monitor Agent to identify all LSSs (Local Sheriff Stations) that will experience power blackouts in their jurisdiction.

Warns all LSSs (Local Sheriff Stations) of imminent power blackout condition.

Alerts all LSSs (Local Sheriff Stations) in whose jurisdictions blackouts will occur and requests them to commence immediate implementation of their respective ‘blackout response plans’.

Warns the RRTs (Rapid Response Teams) assigned to assist the LSSs (Local Sheriff Stations) in whose jurisdictions the first set of blackouts are scheduled to occur, to prepare for potential deployment.

Utilizes its Risk Agent to identify all high risk entities in the jurisdictions of the activated LSSs (Local Sheriff Stations). Utilizes its Deployment Agent to determine whether RRT (Rapid Response Team) involvement is anticipated under normal conditions.

LSS (Local Sheriff Station): Each LSS assumes ‘alert’ status. The LSSs in whose jurisdictions the first set of blackouts is scheduled to occur, prepare for deployment.

RRT (Rapid Response Team): The RRTs notified by the EOB (Emergency Operations Bureau) assume ‘alert’ status in preparation for potential deployment.

Power Outage Implementation

The PSO (Power Supply Organization) alerts its subscribers that the predefined rolling power blackout schedule has been implemented (Fig.6).

PSO (Power Supply Organization): Utilizes its Power Level Agent to determine that demand has exceeded the availability of electric power.

EOB (Emergency Operations Bureau): Receives an Alert from the PSO (Power Supply Organization) indicating that the predefined rolling power blackout schedule has been implemented.

Utilizes its Situation Agent to prepare the first version of the 'EOB Situation Status Report'.

Alerts all LSSs (Local Sheriff Stations) in whose jurisdictions the next scheduled set of blackouts will occur, to prepare for potential deployment.

Warns the RRTs (Rapid Response Teams) assigned to assist the LSSs (Local Sheriff Stations) in whose jurisdictions the next set of blackouts are scheduled to occur, to prepare for potential deployment.

LSS (Local Sheriff Station): All activated LSSs utilize their Status Agent to prepare the first version of their 'LSS Situation Status Report'.

The LSSs (Local Sheriff Stations) in whose jurisdictions the next set of blackouts is scheduled to occur, prepare for deployment.

Traffic Accident in Power Outage Area

A multi-car traffic accident occurs in a blackout area located within the jurisdiction of a particular LSS (Local Sheriff Station) (Fig.7).

EOB (Emergency Operations Bureau) Receives an Alert from a LSS (Local Sheriff Station) that a multi-car traffic accident has occurred on State Highway 5 south of Harbor Freeway.

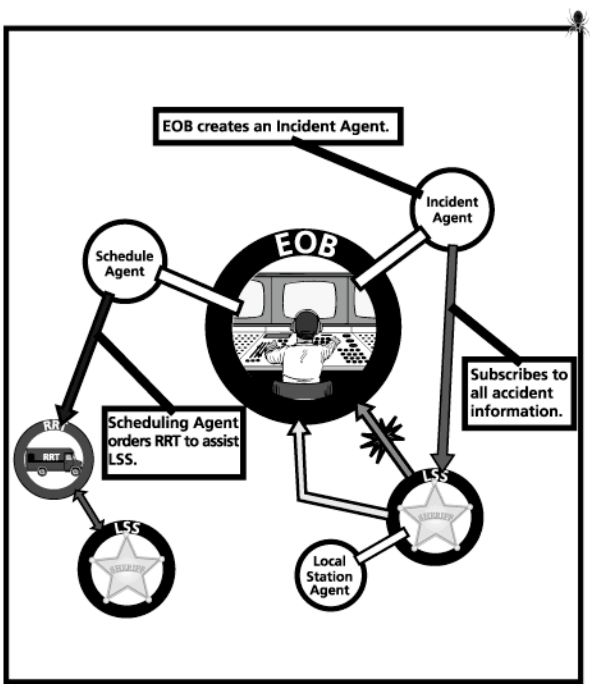

Fig.7: Traffic accident 'Alert'

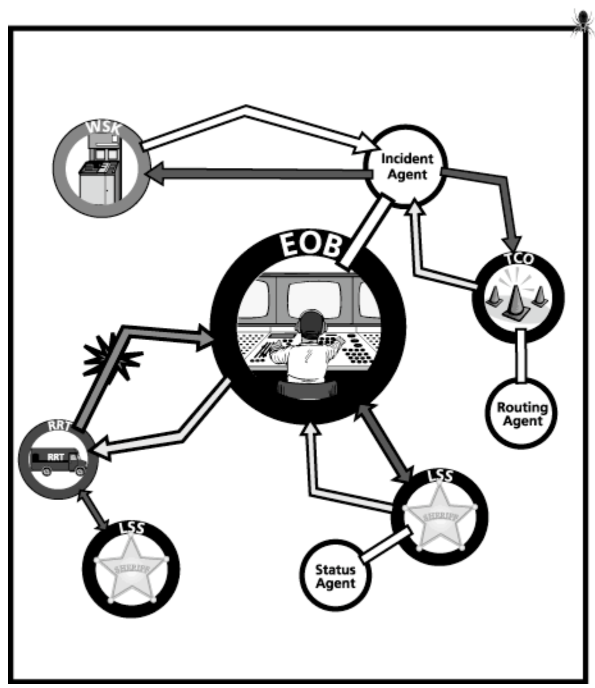

Fig.8: Routing assistance request

LSS (Local Sheriff Station): Utilizes its Local Station Agent to determine that it has insufficient resources to deal with the multi-car traffic accident.

EOB (Emergency Operations Bureau):Receives a request for assistance from the LSS (Local Sheriff Station) to deal with the multi-car traffic accident.

Utilizes its Scheduling Agent to assign a RRT (Rapid Response Team) and equipment to the multi-car traffic accident.

Creates an Incident Agent to monitor the response to the multi-car traffic accident.

The new Incident Agent subscribes to the LSS (Local Sheriff Station) in whose jurisdiction the multi-car traffic accident has occurred (to obtain all information about this accident from now on).

<u>Routing Assistance Required</u>

The dispatched RRT (Rapid Response Team) cannot reach the multi-car traffic accident due to traffic congestion and requests assistance in determining an alternative route (Fig.8) to the accident.

RRT (Rapid Response Team): Sends alert to the EOB (Emergency Operations Bureau) and requests assistance in determining an alternative route to the traffic accident.

EOB (Emergency Operations Bureau): Utilizes its Incident Agent to determine an alternative route. The Incident Agent accesses the WSK (Los Angeles County Web Services Kiosk) and discovers the TCO (Traffic Control Organization). It then registers a subscription profile with the TCO that includes routing information, and requests assistance in determining an alternative route to the traffic accident.

TCO (Traffic Control Organization): Receives the request for assistance from the EOB's (Emergency Operations Bureau) Incident Agent and utilizes its Routing Agent to determine an alternative route to the traffic accident.

Sends the alternate route to the EOB's Incident Agent..

EOB (Emergency Operations Bureau): Responds to the RRT (Rapid Response Team) by sending it the alternate route to the traffic accident.

Significance of the TEGRID Demonstration

The TEGRID proof-of-concept project was undertaken by the Collaborative Agent Design Research Center (CADRC) at Cal Poly (San Luis Obispo) as a small internally funded research endeavor with three objectives. The first objective was to explore the main capabilities that would be required of web service type entities (i.e., Cyber-Spiders) serving as largely autonomous decision-support components in a self-configuring, just-in-time, intelligent decision-assistance toolkit of collaborating software agents. Second, to determine if the currently available information-centric software technology could support at least basic (i.e., meaningful and useful) implementations of these required capabilities. And, third, to build a working experimental system that could serve as a test bed for longer term research studies focused on the behavioral characteristics of self-configuring intelligent systems in general, and the ability of such systems to deal with specific kinds of dynamic and complex problem situations.

The principal capabilities that are required by a Cyber-Spider to support the desired self-configuring, just-in-time, intelligent decision-support behavior have been identified and demonstrated in the TEGRID test bed environment, at least at a base level of functionality. These capabilities include the ability to: discover desired existing external services; accept and utilize services from external offerers; provide services to external requesters; gain understanding through the context provided by an internal information model; automatically reason about available information within the context of the internal information model; extend the internal information model during execution; spontaneously generate new agents during execution as the need for new capabilities arises; and, learn from the collaborations that occur within the cyberspace environment.

Section 4:

Intelligent Decision-Support Systems

The Knowledge Level Approach
To Intelligent Information System Design

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Abstract

Traditional approaches to building intelligent information systems employ an ontology to define a representational structure for the data and information of interest within the target domain of the system. At runtime, the ontology provides a constrained template for the creation of the individual objects and relationships that together define the state of the system at a given point in time. The ontology also provides a vocabulary for expressing domain knowledge typically in the form of rules (declarative knowledge) or methods (procedural knowledge). The system utilizes the encoded knowledge, often in conjunction user input, to progress the state of the system towards the specific goals indicated by the users. While this approach has been very successful, it has some drawbacks. Regardless of the implementation paradigm the knowledge is essentially buried in the code and therefore inaccessible to most domain experts. The knowledge also tends to be very domain specific and is not extensible at runtime. This paper describes a variation on the traditional approach that employs an explicit knowledge level within the ontology to mitigate the identified drawbacks.

Keywords

Data, Information, Knowledge, Knowledge Management Ontology, Object Model, UML

Introduction

This paper employs a simple example to describe the knowledge level approach employed in several of the software projects currently being developed at CDM Technologies, Inc. CDM Technologies specializes in the development of collaborative decision support systems for large government and private organizations particularly in the field of maritime logistics. The example builds a simple medical diagnostic model and accompanying agent rules capable of diagnosing infection types and of recommending actions to assist in the diagnosis. The model and rules are first developed using what this paper calls the traditional approach. Next, an interim technique, termed the taxonomic approach, is developed to address some of the shortcomings identified in the traditional approach. Then the knowledge level approach is developed to address some of the shortcomings identified in the taxonomic approach. Finally, summarizing conclusions are provided, which identify the strengths and weaknesses of the knowledge level approach and provided guidance as to when it should be considered for use.

The progression from the traditional approach to the taxonomic approach to the knowledge level approach parallels those taken by the ARES development team at CDM Technologies in the successive development of three projects sponsored by the United States Office of Naval Research (ONR). These systems are: the Collaborative Agent Based Control and Help System

(COACH), the Ordnance Tracking and Information System (OTIS), and the Shipboard Integration of Logistics Systems Mission Readiness Assessment Tool (SILS MRAT). This effort extensively leverages the work of Martin Fowler described in his book Analysis Patterns, Reusable Object Models (Fowler 1997a) and the work of David Hay described in his book Data Model Patterns, Conventions of Thought (Hay 1996).

This paper assumes but does not require a rudimentary knowledge of the basic concepts of object-oriented modeling. A good introduction to this subject can be found in the book Inside the Object Model by David Papurt (Papurt 1995). All the figures in this paper use a small subset of the graphical object-oriented notations defined by the Unified Modeling Language (UML). A brief overview of the UML notations employed in this paper is provided in Figure 1. A concise summary of UML can be found in UML Distilled by Martin Fowler (Fowler 1997b). The UML based figures in this document provide only the minimum level of detail necessary to understand the concepts under discussion, and therefore they leave off many of the details typical in UML diagrams such as role names and multiplicity constraints. This paper capitalizes and italicizes ontological class names, quotes and italicizes object instance names, and italicizes association, attribute and method names. Class, attribute, and method names are word separated by underscores while association names are word separated by dashes.

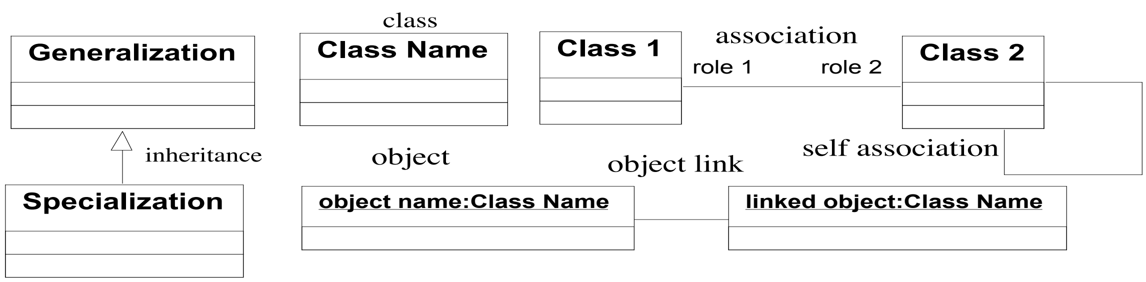

Figure 1: UML Notions Employed in this Paper

Traditional Approach

The traditional approach utilizes a statically compiled ontology that virtually mirrors the real-world entities associated with the targeted system domain. Ontology development is followed by developing agent rule sets, which are grounded in the vocabulary and structure the ontology provides, to produce the desired intelligent behavior. Following this approach an ontology for the simple medical diagnostic domain must first be developed.

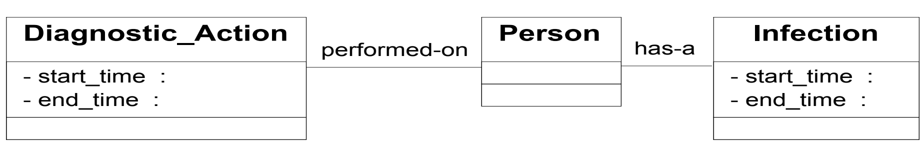

Figure 2: Mirror Image Ontological Framework

At the highest level of abstraction, the example ontology consists of three entities: *Person*, *Infection*, and *Diagnostic_Action*. Both *Diagnostic_Action* and *Infection* are temporal and therefore contain attributes to indicate the applicable time span. These entities are related in that a *Person* may optionally have an (*has-a* association) *Infection* and a *Diagnostic_Action* is *performed-on* a *Person*. This level does not provide enough detail for a diagnostic agent to perform any useful tasks but does provide the structural framework, depicted in Figure 2, with which to further develop the ontology. In order to make this a bit more interesting the diagnostic agent needs to be provided with some different types of *Infection* to diagnose. In this regard, The *Infection* class can be further specialized into *Bacterial_Infection* and *Viral_Infection* as shown in Figure 3. *Person* can also be specialized into two types: *Young_Person*, and *Old_Person*. These additions are shown in Figure 4.

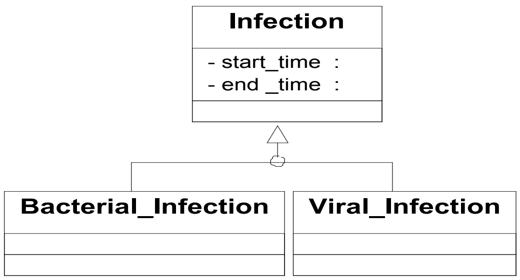

Figure 3: Types of Infection

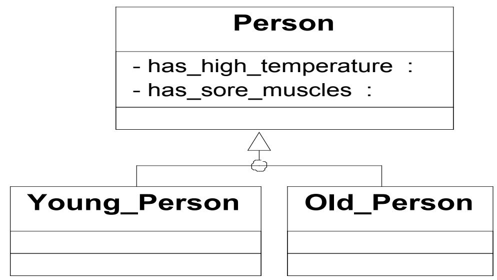

Figure 4: Types of Person

For the sake of simplicity, assume that bacterial infections are indicated by a high fever and viral infections by sore muscles. In this regard at least two types of *Diagnostic_Action* are required: *Body_Temperature_Measurement* and *Sore_Muscle_Check*. To make things more interesting, *Body_Temperature_Measurement* can be further specialized into *Oral_ Temperature_Measurement* and *Aural_Temperature_Measurement* as shown in Figure 5. It will be assumed that the *Diagnostic_Action Oral_Body_Temp_Measurement* applies only to an *Old_Person* while *Aural_Body_Temp _Measurement* applies only to a *Young_Person*. A place is needed to record the results of these diagnostic actions. For this purpose an attribute *has_high_temperature* and an attribute *has_sore_muscles* (both true or false) can be added to the *Person* class as shown in Figure 4.

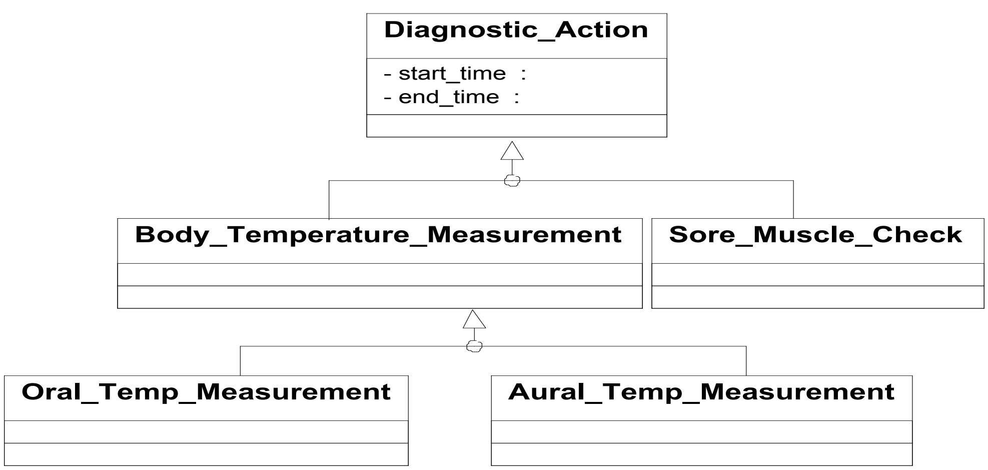

Figure 5: Types of Diagnostic Action

This completes the traditional approach developed ontology for the simple medical diagnostic example. Note that while the ontology was developed with the intended usage in mind it does not capture the associated agent rules in any manner. These may be specified in a declarative manner using condition action pairs as listed in Table 1. The rule conditions specify patterns of linked objects and are therefore specified in terms of the class names that the ontology defines. Since the diagnostic agent is targeted to diagnose types of infection, it should not be triggered until a person is known to have an undiagnosed infection. In terms of the ontology, an undiagnosed infection is indicated by the association of an object that is a kind of person (instance of class *Person*, or of a subclass of class *Person*, ad infinitum) to an instance of class *Infection* (not *Viral_Infection* or *Bacterial_Infection*). The rule scheme employs a priority to control the order in which triggered actions will be invoked.

Table 1: Diagnostic Agent Rules for the Traditional Approach

	Condition	Action	Priority
1	A kind of *Person* has_sore_muscles	Indicate *Person has-a Viral_Infection*	1
2	A kind of *Person* *has_high_temperature*	Indicate *Person has-a Bacterial_Infection*	1
3	A kind of *Old_Person has-a* undiagnosed *Infection*	Recommend *Oral_Temp_Measurement* performed on *Person*	2
4	A kind of *Young_Person has-a* undiagnosed *Infection*	Recommend *Aural_Temp_Measurement* performed on Person	2
5	A kind of *Person* has-a undiagnosed *Infection*	Recommend *Sore_Muscle_Check* performed on *Person*	3

The core strengths of the traditional approach are that the resulting ontologies are typically easier to understand, particularly for the uninitiated, than other approaches and typically results in more efficient implementations of agent behavior as modern languages natively support operations associated with the mirror image type of classifications hierarchies upon which a large percentage of agent logic is typically based.

A primary drawback of the traditional approach is that the agent logic dependent classification hierarchies are not easily modifiable at runtime because the class model must be extended which in turn requires recompilation. In addition, the traditional approach tends to produce models that are not reusable in the context of other domains. Since the agent and application logic of a typical information system are built directly on top of the ontology, these too will find little reuse in the context of different domains. Finally, the traditional approach does not readily support the common real-world concepts of dynamic and multiple classifications that are introduced in conjunction with the taxonomic approach in the following section.

Taxonomic Approach

The taxonomic approach utilizes a statically compiled ontology that is more abstract and generic than that employed by the traditional approach, but can be tailored to a particular domain using runtime instances that capture the specialized or unique concepts within it. In this approach, the logical classification of an object is provided by associative mechanisms rather than the native classification mechanisms provided by the implementation language, which is employed only for the purpose of inheritance mechanisms it provides to gather up the attributes, associations, and behaviors of a particular class of object.

With the taxonomic approach, the classes of the statically compiled model are partitioned into two distinct categories: *Operational_Object* and *Taxonomic_Object* as shown in Figure 6 for the simple medical diagnostic example. The *Operational_Object* classes: *Action*, *Asset*, and *Observation* can be respectively substituted for the classes: *Diagnostic_Action*, *Person*, and *Infection*, the difference being that the logical classification of instantiated objects, upon which much reasoning by intelligent software agents can be applied, is provided by specific associations to subtypes of the *Taxonomic_Object* class. Note that concepts of action, asset, and observation from the taxonomic approach are much more general than the traditional approach concepts of diagnostic action, person, and infection and are therefore applicable to a much broader domain than that of the medical diagnostic example.

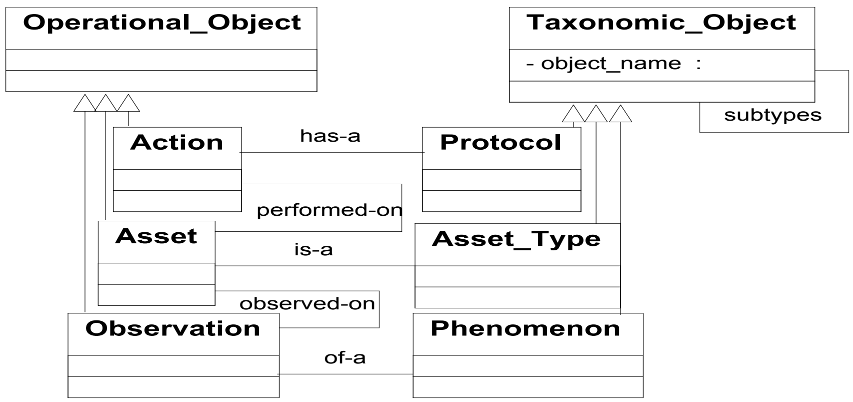

Figure 6: Taxonomic Class Model

A key part of the taxonomic approach ontology is the subtypes association of the *Taxonomic_Object* class. This allows object instances created from the *Taxonomic_Object* class to be linked together to form taxonomies that can be iterated over at runtime to provide a much more flexible classification scheme than that provided by the traditional approach. The taxonomies that substitute for the classification provided by class hierarchy of the traditional approach are shown in Figure 7 for the simple medical diagnostic example. One can easily see the *Infection* (Figure 3), *Person* (Figure 4), and *Diagnostic_Action* (Figure 5) classification hierarchies mirrored in the structures of linked object instances of the respective *Protocol*, *Asset_Type*, and *Phenomenon* classes from the taxonomic approach.

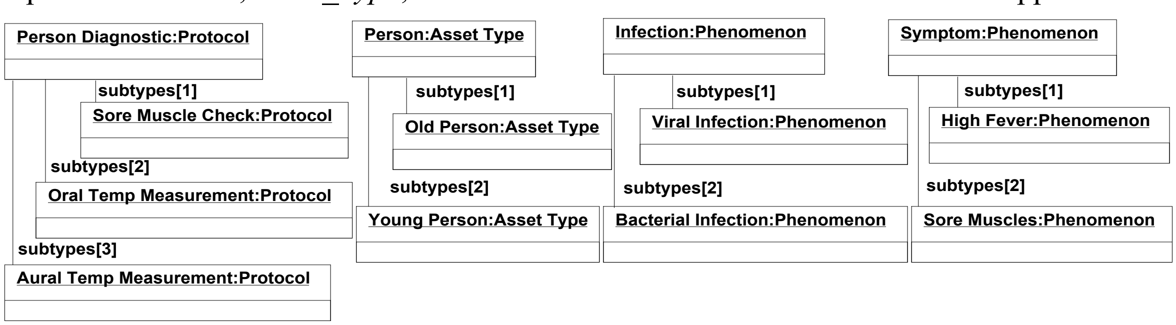

Figure 7: Taxonomic Approach Taxonomies

A *Phenomenon* hierarchy for symptoms can be defined so that observations of symptomatic phenomenon on '*Person'* Assets can be used to eliminate the need for the *has_sore_muscles* and *has_high_fever* attributes required for objects of class *Person* from the traditional approach ontology (Figure 4). This pattern of posting observations on phenomenon to replace attributes of the *Asset* class eliminates the need for complex inheritance hierarchies that traditionally tie attributes to classes making a domain neutral statically compiled ontology a feasible system design and development option.

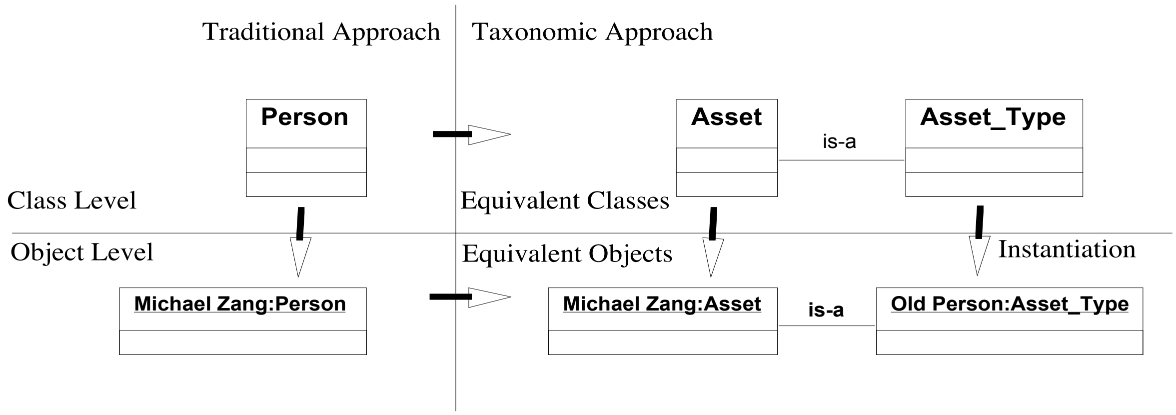

Figure 8: Equivalent Representations of Person

In order to provide the same logical meaning as objects from the traditional approach, objects instantiated from *Operational_Object* classes must be associated with an object instantiated from the corresponding *Taxonomic_Object* class. In this manner, an object instantiated from the *Person* class of the traditional approach is logically equivalent to an object instantiated from the *Asset* class of the taxonomic approach and associated to an object instance of the *Asset_Type* class with an *object_name* attribute value of '*Person'* as shown in Figure 8.

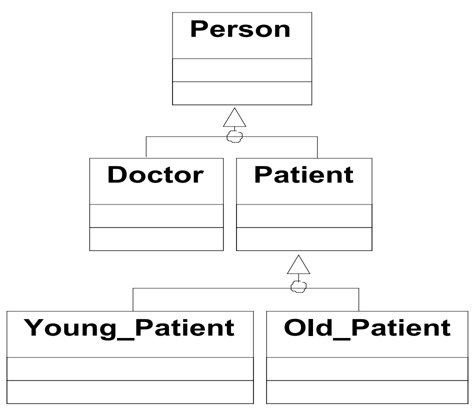

Figure 9: Extended Person Class Hierarchy

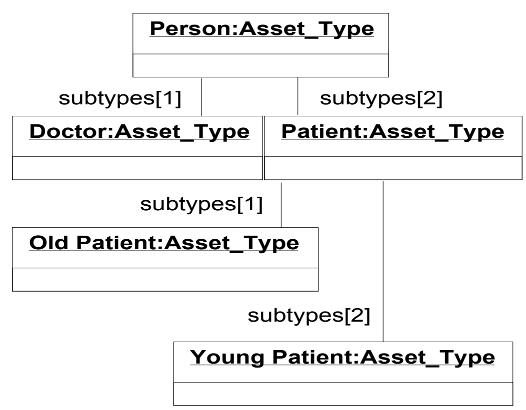

Figure 10: Extended Person Taxonomy

In addition to providing support for extensibility at runtime, the taxonomic approach also supports the concepts of dynamic and multiple classification both of which are common in practice but difficult to implement using the traditional approach. Dynamic classification refers to the ability of an object to change its classification at runtime. Multiple classification refers to the ability of an object to belong to more than one class. The ongoing medical diagnostic example has been extended in Figure 9 for the *Person* class hierarchy of the traditional approach and in Figure 10 for the *'Person'* taxonomy of the taxonomic approach in order to provide examples of these concepts.

The example extension indicates diagnostic actions are *performed-on* a *Patient* and *performed-by* a *Doctor*. This is shown in Figure 11 for the traditional approach and in Figure 12 for the taxonomic approach. These extensions show that the flexibility provided by the taxonomic approach in regards to classification and runtime modification comes at the cost of additional complexity. This is evidenced by the complex constraint on the *Action* class that is required to, for example, prevent patients from diagnosing themselves.

Suppose a doctor gets sick and needs to be admitted to a hospital as a patient. With the taxonomic approach, this situation is represented by breaking the link between the representative *Asset* object and the *Asset_Type* object with *object_name 'Doctor'* and connecting it instead to the *Asset_Type* object with *object_name 'Patient'*. With the traditional approach this situation is much more difficult to deal with because the representative object and its classification are inseparable. The representative object of class *Doctor* must be destroyed and a new object of class *Patient* created. This process results in a loss of identity, which, in turn, results in a complete loss of the professional history (i.e. diagnostic actions performed on patients) of the doctor as the traditional approach physically constrains *Patient* objects from linking to *Diagnostic_Action* objects with the *performed-by* association. Although the taxonomic approach preserves the individual identity of the *Asset* object as the logical classification dynamically switches from *'Doctor'* to '*Patient'*, there is still an issue with the logical constraint put in place to mimic the physical constraints inherent in the traditional approach. While the logical constraint could be relaxed to deal with this, a better approach is to employ multiple classification.

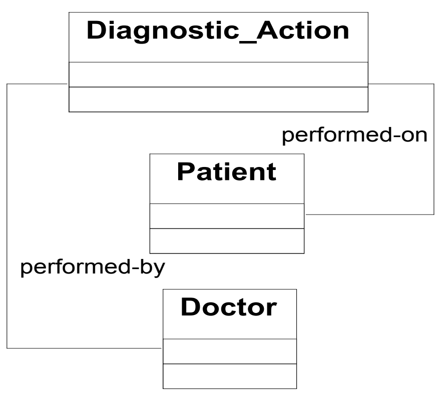

Figure 11: Extensions for Traditional Approach

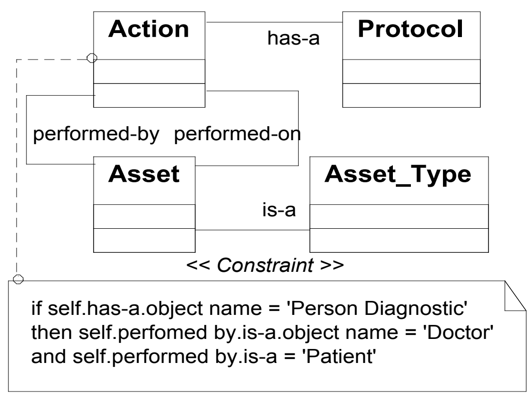

Figure 12: Extensions for Taxonomic Approach

Multiple classification allows the person in question to be both a doctor and a patient, thus preserving both identity and history. This is easily accomplished using the taxonomic approach by changing the multiplicity of the *is-a* association between the *Asset* and *Asset_Type* classes from exactly one to one or more. This allows multiple *Asset_Type* instances to be associated with an *Asset* instance; thereby, allowing the *Asset* instance of the example to be logically classified as both a *'Doctor'* and a '*Patient'*.

The concept of multiple classification is difficult to implement using the traditional approach, which combines the concepts of inheritance and classification. In order to create objects that are classified as both a *Patient* and a *Doctor* in the traditional approach, language provided multiple inheritance mechanisms must be used to create a new class *Doctor_Patient* that inherits from both the *Doctor* class and the *Patient* class (Figure 13). While this in itself is messy, additional complications are incurred because the diagnostic agent rules (specified in Table 1) require that a patient be additionally classified as young or old; thereby, requiring additional usage of multiple inheritance to create classes *Young_Doctor_Patient* and *Old_Doctor_Patient*. This approach dilutes the clarity of the classification hierarchy and quickly becomes untenable in realistically scoped models.

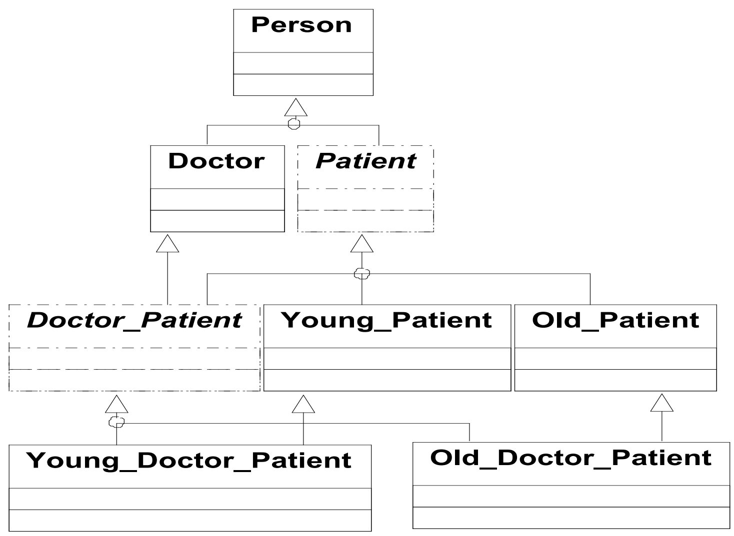

Figure 13: Multiple Classification Problems with the Traditional Approach

The taxonomic approach results in rules with more complex conditions than those resulting from the traditional approach. The specified condition for rule number 1: "*Observation* of *'Sore Muscles'* on *Asset* that is a kind of '*Person*" is shorthand. A more rigorous specification is "an *Observation* object linked to a *Phenomenon* object, through the *of-a* association between the *Observation* and *Phenomenon* classes, of type '*Sore Muscles'*, that is also linked to an *Asset* object, through the observed-on association between the Observation and *Asset* classes, that is a kind of '*Person'*". Further, note that "of type '*Sore Muscles'*" is shorthand for "a *Phenomenon* object that has an *object_name* attribute with value equal to the character string '*Sore Muscles'*. Also, note that "is a kind of '*Person'*" is shorthand for an *Asset* object linked to an *Asset_Type* object, through the *is-a* association between the *Asset* and *Asset_Type* classes, that has an *object_name* attribute with value equal to the character string '*Person'* or that has parent *Asset_Type* objects in the taxonomic tree formed by the subtypes association defined for the *Asset_Type* class. Additional complexity is required for rule condition specification in the presence of multiple classification as set notation is then required.

The complexity in rule specification can be alleviated some by providing convenience methods within the *Operational_Object* classes that mimic the native language provided behavior that was abandoned in the taxonomic approach to separate identity and inheritance from classification. Considering the more rigorous example specification of the previous paragraph, a method named *of_type* that takes a character string as an argument and returns true or false can be added to the *Observation* class that walks *of-a* links to associated *Phenomenon* objects and compares the values of their *object_name* attributes to the string passed in as an argument. A similar method named *kind_of* can be added to the *Asset* class to walk links to associated *Asset_Type* objects then recursively searches up the taxonomic tree looking for objects with *object_name* attribute values equal to the string passed in as an argument. This sort of model dependent and domain independent behavior is ideal for implementation by statically compiled class methods.

Table 2: Diagnostic Agent Rules for the Taxonomic Approach

	Condition	**Action**	**Priority**
1	*Observation of_type* '*Sore Muscles' observed-on Asset* that is a kind of '*Person'*	*Observation of_type 'Viral Infection' observed-on Person*	1
2	*Observation* of '*High Fever' observed-on Asset* that is a *kind_of* '*Person'*	*Observation of_type 'Bacterial Infection' observed-on Person*	1
3	*Observation* of '*Infection'* on *Asset* that is a *kind_of* '*Person'*	Recommend *Action of_type 'Sore Muscle Check'* be *performed-on Person*	2
4	*Observation of_type* '*Infection'* on *Asset* that is a *kind_of* '*Young_Person'*	Recommend *Action of_type* '*Aural Temp Measurement'* be *performed-on Person*	2
5	*Observation of_type* '*Infection'* on *Asset* that is-a *kind_of* '*Old_Person'*	Recommend *Action of_type 'Oral Temp Measurement'* be *performed-on Person*	3

The taxonomic approach appears to have addressed many of the shortcomings identified with intelligent information systems developed using the traditional approach. The abstract statically compiled ontology of the taxonomic approach is generally applicable to any collaborative, intelligent agent based (human and software) information system. The taxonomic level of the model serves as a constraining meta model that can be extended and specialized for a specific target domain by instantiating objects from the meta-level classes and configuring them to be representative of the concepts within a domain by linking them together into runtime navigable taxonomies. This flexibility comes at the cost of additional complexity, as it requires the logical classification provided by the ontology be represented using an associative pattern rather than the mechanisms provided directly by the implementation environment. In addition to providing for runtime extensibility of the core ontology, the associative classification pattern allows for a richer and a more dynamic information environment by seamlessly supporting the fundamental concepts of dynamic and multiple classification.

The domain neutral, statically compiled ontology naturally leads to powerful domain neutral application components such as observation recorders, action schedulers, and taxonomy builders. Rather than hard coding such things as selection menu choices and graphical display layouts, system applications query the ontological model at runtime to configure themselves appropriately for both the target domain and the current user. This sort of dynamic querying is very applicable to the highly optimized, statically compiled, procedural (albeit event driven and object-oriented) environments commonly employed in the development of highly interactive applications and interfaces. Unfortunately, it is not as well suited for the declarative rule based environments commonly employed in development of intelligent agents intended to assist users in making sense of and utilizing the information and knowledge stored within the underlying software system. This is evident in the rule condition specifications for the taxonomic approach. Notice that the rule conditions in Table 2 specify patterns that include not only the statically compiled class names employed in the specification of rule conditions in the traditional approach (Table 1) but the textual values of linked object instance names as well.

The taxonomic approach successfully addresses all the issues identified with the traditional approach except the need for domain independent agent logic. When applying the taxonomic approach, one starts with an abstract, domain independent, ontology and powerful, domain neutral, application tools. Then the specialized taxonomies applicable to the domain are created from object instances of the *Taxonomic_Object* classes defined by the ontology, perhaps with the assistance of domain neutral application tools designed for the construction and maintenance of these sorts of domain specific ontologies. Finally, agent logic, based on both the statically compiled ontology and the specialized linked object taxonomic structures for the domain, is develop to provide intelligent collaborative support for system users. While it is possible to extend this agent logic at runtime as most declarative rule based inference engines support the dynamic loading and interpretations of rules at runtime, the corresponding rule development environments have not typically been accessible to even the most advanced users of typical information systems, which greatly compromises the user extensibility of the taxonomic approach.

Note however, that recent advances in applied artificial intelligence are beginning to result in reasoning facilities with that are more accessible to technically savvy subject matter experts or applicable to supervised or unsupervised algorithmic learning approaches. An example of such is the Taxonomic Case-Based Reasoning System (TCRS) (Aha 2002)(Gupta 2001) that has been successfully utilized in the development of CDM systems employing the taxonomic approach. TCRS is particularly well suited to the taxonomic approach, and by extension the as yet to be introduced knowledge level approach, because it employs taxonomically linked objects to tailor the characteristic question and answer dialogs associated with case retrieval to the level of expertise of the user.

Knowledge Level Approach

The knowledge level approach addresses the single identified shortcoming of the taxonomic approach by further extending the fundamental tenets of the approach by inter linking the taxonomic object instances, through logically typed associations, to record additional knowledge about them and the associated usage of them by the objects in the operational level. Unlike the rule-encoded knowledge employed the traditional and taxonomic approaches, the knowledge recorded through logically typed associations is in a form that is both dynamically extensible and conceptually accessible by system users. The ontology developed for the simple medical diagnostic example using the knowledge level approach is depicted in Figure 14. It can be readily seen that basic elements and structure of the ontology are the same as in the taxonomic approach except for two significant differences: the generalization of all linkages between levels and the additional associations defined within levels.

In order to both formalize and standardize the use of associations to knowledge level classes to provide logical classification to instances of operational level classes a single *type-of* association between the *Operational_Object* class and the *Knowledge_Object* class has been provided. This association substitutes for the individual associations defined between the *Action* and *Protocol*, *Asset* and *Asset_Type* and *Observation* and *Phenomenon* classes in the taxonomic approach (Figure 6). The generalization of these associations allows generic implementations of the type_of and kind_of convenience methods to be applicable to all subtypes of the *Operation_Object* class. This generalization requires the addition of fixed constraints on the *Action*, *Asset*, and *Observation* classes.

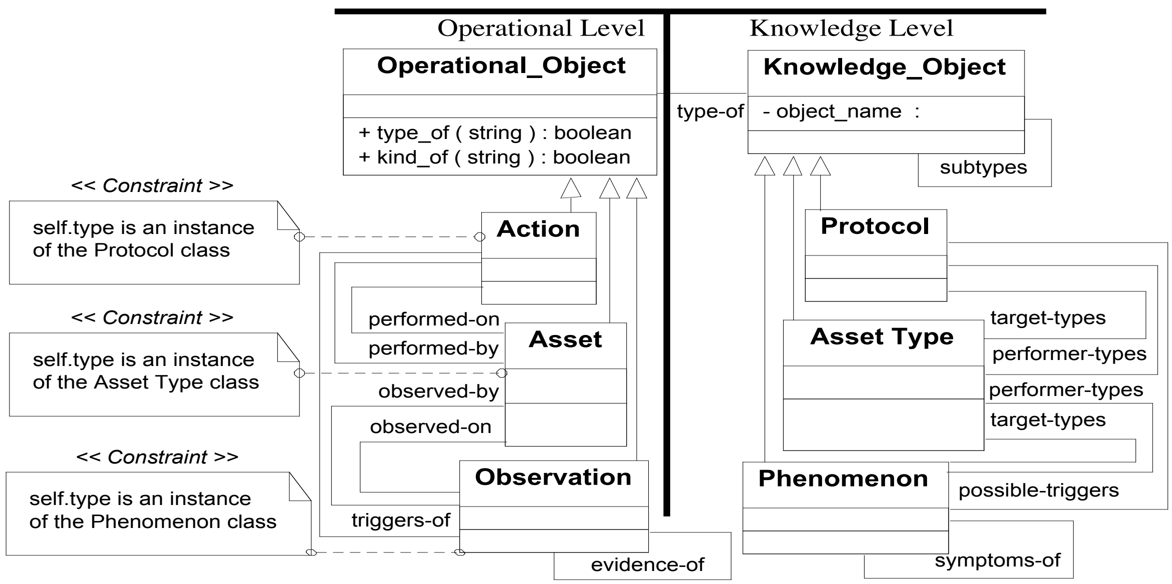

Figure 14: Knowledge Level Approach Ontology

In order to eliminate the agent logic dependence on specific object instances in the taxonomies formed through the subtypes association defined for *Knowledge_Object* classes exhibited by the rules developed using the taxonomic approach (Table 2) the self-association symptoms-of has been added to the Phenomenon class and the association possible-triggers has been added between the Phenomenon and Protocol classes. Set membership in the object links formed by these associations is used as a substitute for the hard coded *object_name* attribute values required by the taxonomic approach rules. This allows for the creation of domain independent rules based only on the generic statically compiled ontology and set operations.

The symptoms-of association allows a single domain independent rule (rule 1 in Table 3) to replace the two domain specific diagnostic observation rules developed using the traditional and taxonomic approaches (rules 1 and 2 in Table 1 and Table 2). The possible-triggers association allows a single domain independent rule (rule 2 in Table 3) to replace the three domain specific diagnostic action recommendation rules developed using the traditional and taxonomic approaches (rules 3, 4, and 5 in Table 1 and Table 2). By cross-linking the taxonomic concept hierarchies using logical associations the essence of the rules developed under the traditional and taxonomic approaches has been moved into the form of instance data that can be readily extended at runtime just as the taxonomic approach allowed for runtime extensions of the core concepts within the ontology.

Table 3: Diagnostic Agent Rules for the Knowledge Level Approach

	Condition	Action	Priority
1	*Observation* of *type_of Phenomenon observed-on Asset* with *type_of Asset_Type* in *Phenomenon target-types* with parent *symptoms-of* link	Create *Observation* instance observed-on Asset of type_of Phenomenon equal to the Phenomenon associated as a parent with the symptoms-of link	1
2	*Observation* on *type-of Phenomenon observed-on Asset* with *type_of Asset_Type* in *Phenomenon target-types* and a *Protocol* in *possible-triggers*	Recommend Action of-type *Protocol* be performed-on *Asset*	2

The rules that remain under the knowledge level approach act as domain generic machinery for reasoning on the domain specific knowledge instance models. The domain specific knowledge instance models (interlinked *Knowledge_Object* instances) are loaded at runtime or created by advanced users to tailor the statically compiled, domain independent ontology to support the specialized concepts with in the target system domain. By adding new linkages, which exist as data elements rather than code, an unlimited number of rules like those developed under the traditional and taxonomic approaches can be added to the system at runtime. These new linkages can just as easily be connected to new user added concepts as to existing ones; thereby, eliminating the problem identified for the taxonomic approach.

Summary

The knowledge level approach to developing intelligent information systems utilizes an abstract, domain independent, statically compiled ontology divided into two distinct levels. The operational level provides classes to serve as templates for creating object instances that record the day-to-day events within the domain. The knowledge level provides classes to serve as templates for creating object instances to record domain specific concepts and knowledge of their application. Rather than using the language provided classification mechanisms operational level objects associate with knowledge level object to represent information related to their logical classification. This approach provides support for the powerful modeling concepts of dynamic and multiple classification and allows for the development of generic statically compiled ontologies that can be reused across multiple disparate domains.

The statically compiled knowledge level provides a control structure and generic rule activation mechanisms that system developers, subject matter experts, or advanced users may utilize to tailoring the generic ontology to address the specialized or unique concepts within a particular system domain. The fixed statically compiled ontology also allows for the development of powerful, domain neutral, application tools such as: action schedulers, observation recorders, and taxonomy editors that leverage the knowledge recorded by knowledge level instances in order to tailor the application and its interface to the specialized requirements of the domain. Ultimately the knowledge level approach is a structural layering pattern used in the specification of ontologies for intelligent information systems. A well-designed ontology may be layered in other compatible dimensions as well and examples of this are provided in (Pohl 2000) and (Zang 2002).

The knowledge level approach is not necessarily applicable to development of all information system. Although it reduces complexity by reducing both the number of classes and the number of rules, it increases complexity in other ways that make ontologies developed using the knowledge level approach much more difficult to understand for novice programmers and for experienced programmers new to a knowledge level approached based project. The knowledge level approach is particularly applicable for use by development teams involved in the development of multiple (concurrent or over time) information systems that have focus on either intelligent agents or knowledge management.

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Standard K-Languages as a Powerful and Flexible Tool for Constructing Ontological Intelligent Agents

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Abstract

The necessity of developing more powerful and convenient formal means (in comparison with the widely used ones) for building ontologies is grounded. The basic principles of a new mathematical approach to this problem are outlined; this approach is given by the theory of K-calculuses and K-languages, or the KCL-theory (developed by the first author). For each K-calculus, the main subclass of its well-constructed formulas is called the standard K-language (SK-language) determined by this K-calculus.

The examples of building semantic representations (SRs) of natural language texts (NL-texts) and of constructing definitions of concepts pertaining to medicine and biology are considered. The advantages of the SK-languages in comparison with Discourse Representation Theory, Theory of Conceptual Graphs, and Episodic Logic are stated..

The considered examples show that SK-languages enable us, in particular, to describe the conceptual structure of texts with: (a) references to the meanings of phrases and larger parts of texts, (b) compound designations of sets, (c) definitions of terms, (d) complicated designations of objects, (e) generalized quantifiers ("arbitrary", "certain", “all”, etc.), (f) complicated goals of intelligent systems and destinations of things.

An experience of using SK-languages in the design of an ontological intelligent agent being a component of a computer consulting system destined for the sommeliers is outlined.

Keywords

natural language processing; semantic representation; standard K-languages; knowledge-based system; consultation system; formal ontology.

Introduction

An ontology can be defined as a specification of a conceptualization (Guarino 1998). The term "conceptualization" is used for indicating a way an intelligent system structures its perceptions about the world. A specification of a conceptualization gives a meaning to the vocabulary used by an intelligent system for processing knowledge and interacting with other intelligent systems.

In the last decade, one has been able to observe a permanent growth of interest in building and studying ontologies. The reason is that the researchers and systems developers have become more interested in reusing or sharing knowledge across systems. Different computer systems use different concepts and terms for describing application domains. These differences make it difficult to take knowledge out of one system and use it in another. Imagine that we are able to construct ontologies that can be used as the basis for multiple systems. In this case different systems can share a common terminology, and this will facilitate sharing and reuse of knowledge.

In a similar way, if we are able to create the tools that support merging ontologies and translating between them, then sharing knowledge is possible even between systems based on different ontologies.

The main source for automatically building ontologies is a great amount of available texts in natural language (NL). Taking this into account, we need the powerful formal means for building semantic representations (SRs) of (a) NL-definitions of concepts and of sentences and of (b) sentences and discourses in NL expressing knowledge about an application domain.

Multi-agent systems are being constructed in many fields of human activity. An important subclass of computer intelligent agents (CIAs) constitute ontological intelligent agents (OIAs). The discussed main functions of such agents are as follows: (a) the transformation of natural language definitions of concepts into SRs of such definitions; (b) the transformation of natural language questions of the users about the concepts into SRs of such questions; (c) generation of the answers to the questions of the users.

The analysis of formal approaches to representing knowledge provided by the Theory of Conceptual Graphs (Sowa 1999), Episodic Logic (Schubert and Hwang 2000), Description Logics shows that these approaches give formal means with very restricted expressive possibilities as concerns building SRs of definitions of concepts and SRs of sentences and discourses representing fragments of knowledge about the world.

That is why we need to have much more powerful and convenient formal means (in comparison with the widely used ones) for describing structured meanings of natural language (NL) texts and, as a consequence, for building ontologies. A new mathematical approach to this problem is given by the theory of K-calculuses and K-languages, or the KCL-theory (Fomichov, 1992 - 2002). For each K-calculus, the main subclass of its well-constructed formulas is called the standard K-language (SK-language) determined by this K-calculus.

The examples of building SRs of the NL-texts and of constructing definitions of concepts pertaining to medicine and biology are considered in this paper. The advantages of the SK-languages in comparison with Discourse Representation Theory, Theory of Conceptual Graphs, and Episodic Logic are stated.

An experience of using SK-languages in the design of an ontological intelligent agent being a component of a computer consulting system destined for the sommeliers is outlined.

Constructing Definitions of Concepts by Means of SK-languages

Let's consider a number of new important possibilities of building formal definitions of concepts provided by standard K-languages. If T is an expression in NL and a string *E* from an SK-language can be interpreted as a semantic representation (SR) of T, then *E* is called a K-representation (KR) of the expression T.

Example 1. Let Def1 = "A flock is a large number of birds or mammals (e.g. sheep or goats), usually gathered together for a definite purpose , such as feeding, migration, or defence". Def1 may have the first-level K-representation *Expr1* of the form

*Definition1 (flock, dynamic-group * (Compos1, (bird mammal * (Examples, (sheep □ goal))), S1, (Estimation1(Quantity(S1), high) □ Goal-of-forming (S1, certn purpose * (Examples, (feeding migration defence)))))*

Example 2. The definition Def1 is taken from a certain book published in a certain year by a certain publishing house. The SK-languages allow for building SRs of definitions in an object-oriented form reflecting its external connections. For instance, object-oriented SR of the definition Def1 can be the expression

*certn inform-object * (Kind, definition)(Content1, Expr1)(Source1, certn dictionary * (Title, 'Longman Dictionary of Scientifc Usage') (Publishing-house, (Longman-Group-Limited/Harlow □ Russky-Yazyk-Publishers/Moscow)) (City, Moscow)(Year, 1989))*

Example 3. Let T1 be the definition "The Eustachian tube is a canal leading from the middle ear to the pharynx".

. One can associate with T1, in particular, the following K-string interpreted as a semantic representation of T1:

*Definition1 (Eustachian-tube, canal1, x1, □z (person) Lead1 (x1,certn middle-ear**

*(Part, z), certn: pharynx * (Part, z))).* (1)

Example 4. If T2 = “Sphygmomanometer is instrument destined to measure blood pressure”, then T2 may have a KR

*(sphygmo-manometer ≡ instrument * (Destination, measuring1 * (Param, blood-pressure)(Subject, any person))).* (2)

The semantic item *Destination* in (2) is to be interpreted as the name of a binary relation. If a pair (A, B) belongs to this relation, then A must be a physical object, and B must be a formal semantic analogue of an infinitive group expressing the destination of this physical object.

Example 5. Let T3 be the definition “Thrombin is an enzyme which helps to convert fibrinogen to fibrin during coagulation”. Then the K-string:

(thrombin ≡ enzyme * (Destination, helping * (Action, converting1 (Object1, certn fibrinogen)(Result1, certn fibrin)(Process, any coagulation))))

can be interpreted as a possible KR of T3.

Representing Knowledge about Application Domains by Means of SK-languages

Example 1. Consider the text D1 = “An adenine base on one DNA strand links only with a thymine base of the opposing DNA strand. Similarly, a cytosine base links only with a guanine base of the opposite DNA strand”.

For constructing a KR of D1, the following remark may be helpful. A molecule of deoxyribonucleic acid (a DNA molecule) is composed of thousands of nucleotides (combinations of three basic elements: deoxyribose, phosphate, and a base). There are four kinds of bases: adenine, guanine, cytosine, and thymine. The nucleotides of a DNA molecule form a chain, and this chain is arranged in two long strands twisted around each other.

Taking into account this remark, one can associate with the first sentence of D1 a KR *Expr1* of the form

*□x1 (dna-molecule) (Link (arbitr base1 * (Is, adenine) (Part, arbitr strand1 **
*(Part, x1) : y1) : z1, definite base1 * (Is, thymine) (Part, certn strand1 * (Part, x1)* (3)
(Opposite, y1) : y2) : z2) □ □ □z3 (base1) (Is (z3, □ thymine) □
□ □z3 (base1) (Is (z3, □ thymine) □ Part (z3, y2) □ Link (z1, z3) : P1

In the string *Expr1* of the form (3) the variables *y1* and *y2* are used to mark the descriptions of two strands of arbitrary DNA molecule *x1*; the variable *z1, z2, z3* mark bases.

The variable *P1* (with it the sort “sense of statement” is associated) is used to mark the semantic representation of the first sentence of D1. This allows for building a compact SR of the second sentence of D1, because the occurrence of the word “similarly” in the second sentence of D1 indicates the reference to the meaning of the first sentence.

In particular, the second sentence of D1 in the context of the first sentence may have a K-representation *Expr2* of the form.

(Similarly (P1, P2) (P2 ≡ x1 (dna-molecule) (Link (arbitr base 1 (Isa, cytosine)*
*(Part, arbitr strand 1 * (Part, x1) : y3) : z4, definite base 1 * (Is, guanine) (Part,*
*certn strand1 * (Part, x1) (Opposite, y3) : y4) :z5)   z6 (base 1) (Is (z6, guanine)* *(4)*
* Part (z6, y4) Link (z4, z6)))))*

Then we can associate with the text D1 the K-string *Expr3* of the form *(Expr1 Expr2)*, where *Expr1* and *Expr2* are strings of the form (3) and (4) respectively. Such a string can be interpreted as a possible KR of D1.

The K-string *Expr3* illustrates an important opportunity afforded by standard K-languages: to mark by variables the fragments of K-strings being semantic representations of narrative texts, infinitive groups, or questions. This opportunity allows us to effectively describe structured meanings of discourses with references to the meanings of fragments being statements, infinitive groups, or questions.

The presence of such references in discourses is indicated often by the following words and word combinations : “this recommendation”, “for instance”, “e.g.”, “that is”, “i.e.”, “the idea discussed above”, “in other words”, etc.

The constructed KR *Expr3* of D1 illustrates several additional original features of K-strings (besides of features discussed above). Firstly, the symbol ≡ connects a variable and a semantic representation of a sentence. Secondly, the symbol of negation can be connected with designations of notions. In such a way the substings * thymine, guanine* are built.

Some more useful properties of standard K-languages

Example 2. Let’s construct a second possible SR of the text D1. Note that the K-string of the form (30) representing the structured meaning of the first sentence S1 of D1 is not so compact as S1. The main cause of this is the occurrence of the word “only” in S1 : the meaning of “only” is S1 is expressed by means of the substring

* z3 (base 1) (Is (z3, thymine) Part (z3, y2) Link (z1, z3)).*

However, standard K-languages allow us to build more compact semantic representations of texts with the word ”only”. For this we can use in a SR of D1 the substring. *Only (R1, z2) ,*
where *R1* is a variable marking the meaning of the sentence “An adenine base on one DNA strand links with a thymine base of the opposing DNA strand”.

That’s why the text D1 may have the following more compact K-representation :

*□x1 (dna-molecule) ((Link (arbitr base1 * (Is, adenine) (Part, arbitr strand1 *
(Part, x1) : y1) : z1, definite base1 * (Is, thymine) (Part, certn strand1 * (Part, x1)
(Opposite, y1) : y2): z2) : R1 □ Only (R1, z2)) : R2 □ Similarly (R2, R3) □
(R3 ≡ (Link (arbitr base 1 * (Is, cytosine) (Part, arbitr strand 1 ** (5)
*(Part, x1) : y3) :z4, definite base1 * (Is, guanine) (Part, certn: strand1 * (Part, x1)
(Opposite, y3) :y4) :z5) :R4 □ Only (R4, z5)))).*

Thus we see that standard K-languages permit to build compact SRs of texts with the word "only".

The considered examples show that SK-languages enable us, in particular, to describe the conceptual structure of texts with : (a) references to the meanings of phrases and larger parts of texts , (b) compound designations of sets, (c) definitions of terms , (d) complicated designations of objects , (e) generalized quantifiers ("arbitrary", "certain", etc.). Besides, SK-languages provide the possibilities to describe the semantic structure of definitions, to build formal analogues of complicated concepts, to mark by variables the designations of objects and sets of objects, to reflect thematic roles.

The advantages of the KCL-theory in comparison with Discourse Representation Theory (van Eijck and Kamp, 1996; Kamp and Reyle, 1996), and Episodic Logic (Schubert and Hwang, 2000) are, in particular, the possibilities: (1) to distinguish in a formal way objects (physical things, events, etc.) and concepts qualifying these objects; (2) to build compound representations of concepts; (3) to distinguish in a formal manner objects and sets of objects, concepts and sets of concepts; (4) to build complicated representations of sets, sets of sets, etc.; (5) to describe set-theoretical relationships; (6) to describe effectively structured meanings (SMs) of discourses with references to the meanings of phrases and larger parts of discourses; (7) to describe SMs of sentences with the words "concept", "notion"; (8) to describe SMs of sentences where the logical connective "and" or "or" joins not the expressions-assertions but designations of things or sets or concepts; (9) to build complicated designations of objects and sets; (10) to consider non-traditional functions with arguments or/and values being sets of objects, of concepts, of texts' semantic representations, etc.; (11) to construct formal analogues of the meanings of infinitives with dependent words.

The items (3) – (8), (10), (11) indicate the principal advantages of the KCL-theory in comparison with the Theory of Conceptual Graphs, or TCG (Sowa, 1999). Besides, the expressive possibilities of the KCL-theory are much higher than the possibilities of TCG as concerns the items (1), (2), (9).

An Application of SK-languages to the Design of a Sommelier Consulting System

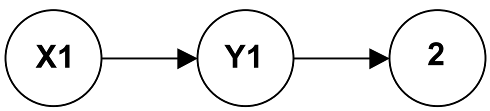
Let's consider several central ideas underlying the use of standard K-languages for the design of a computer consulting system destined for the sommeliers and including a NL-interface (or a linguistic processor). A request of the user or a knowledge fragment expressed in NL is transformed by a semantic-syntactic analyzer into a K-representation (KR), i.e. into a semantic representation being an expression of a SK-language. Then it is transformed into a K-graph – a graph representation being isomorphic to the constructed K-representation. This second form is used in order to increase the effectiveness of processing SRs of the requests or statements.

Example 1. Suppose that we need to represent the meaning of the expression "2 wines Chablis" taken from the sommelier knowledge field. Then this expression can be transformed into the K-representation

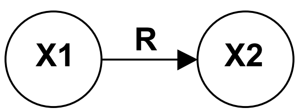
Certn set * (Class, X1)(Sort, X2)(Number, 2) ,

where: X1 is a general classification of the beverage – wine; Y1 is the title of wine – Chablis; 2 is the quantity of wine Chablis.

At the next step, we can construct a simple semantic net:



While building such kind of data representation, we deal with the construction of a relation of the following type:



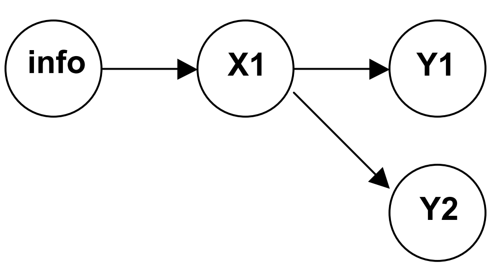
where: X1 and X2 – some objects; R is a kind of the relation between X1 and X2.

Proceeding from a metadata description, the system can analyze the requests, retrieve the information about main concepts.

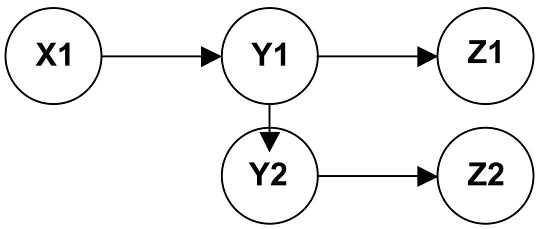
Example 2. Let's consider a situation, when a user would like to get information about the sort of wine.

Request*: I need information about Chablis Blanc and Saint Emilion Grand Cru.*

We have here a situation with one main set – the set of wines and at least two data subsets – the set of wines Chablis Blanc and the set of wines Saint Emilion Grand Cru. A semantic representation in the form of a K-graph can be defined in the following way:



The vertex info – the additional information about wines – indicates what to look for; X1 is a general classification of the beverage – wine; Y1 is the sort of wine – Chablis; Y2 is the sort of wine Saint Emilion.
According to this data structure analysis, the system can create the following answer, based on the recognized concepts and data sets:.



On this figure, X1 is a general classification of the beverage; Y1 and Y2 are the sorts of wines Chablis and Saint Emilion; Z1 and Z2 – additional information about these wines respectively.

The mechanism of the data recognition on the conceptual level is based on the strong definition of concepts and their relations. For instance, the system knows that we have one main set – wines. We describe many sorts of wine, including Chablis, Saint Emilion and etc. But each sort of wine can be defined as a separated concept that belongs to the set "wine". Moreover, each sort of wine has its own number of descriptions, that's why we must add some additional relations between sort of wine and its details (Z1, Z2, and etc.) When everything is defined on the conceptual and relation levels, we can start operating the data in the form of requests and questions.

A formal K-representation can be defined in the following way:

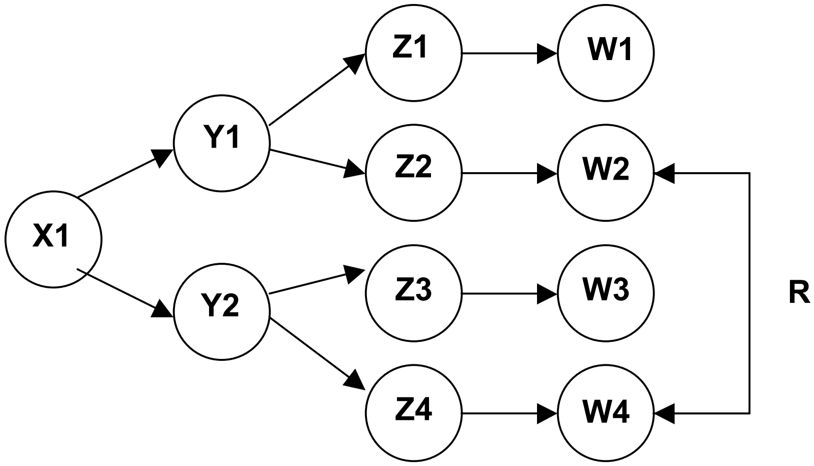
*certn object * (Class, X1) (Sort, Y1) (Info, Z1)*

Actually, the requests can be more complicated.

Example 3. A user would like to get a help information about wine, and at the same time he/she not specifies the certain sorts.

Request: *I need help with wine's map composing.*

In this particular situation the system must make a selection among all wine's sorts and titles that it has in its knowledge base. Using K-graphs, we can represent the available knowledge in the following way:



On this figure, X1 is a general classification of the beverage; Y1 is the first wine manufacturer – France; Y2 is the second wine manufacturer – Italy; Z1 is the sort of French wines Chablis; Z2 is the sort of French wines Saint Emilion; Z3 is the sort of Italian wines Amarone; Z4 is the sort of Italian wines Recioto; W1- W4 – information how to use and keep these titles of wines.
The knowledge from knowledge base is needed for helping the system to make a selection, what wines to recommend first of all and what sorts to keep for later time. In this case, we may have relations between W4 and W2 or others. It means that when you drink Recioto don't forget to recommend your guests Saint Emilion.

Conclusions

The analysis of the expressive possibilities of standard K-languages and the accumulated experience of using SK-languages and K-graphs in the design of NL processing systems enable us to believe that the popularization of the theory of standard K-languages may essentially contribute to the speeding-up of the progress in the theory and practice of constructing ontologies and designing ontological intelligent agents in arbitrary application domains.

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Prognostics-Enabled Adaptive Logistics: Learning Agents for Decision Support

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Abstract

Information overload and data complexity challenges in distributed information networks are demanding more powerful, scalable solutions to pattern recognition and knowledge discovery. This paper will describe a new approach to near-instantaneous agent-enabled learning for the purposes of real-time performance tracking, failure prediction and decision support. We describe the application of new associative memory technology that is capable of recognizing patterns in performance data in order to anticipate component or system failure in vehicles such as trucks and aircraft. The learning agents are capable of observing and learning complex correlations across multiple parameters, and collaborating with other agents for knowledge discovery. These agents lend themselves to distributed multi-agent configurations for real-time networked visibility and decision support across complex functions including supply chain management, maintenance and fleet control.

Introduction

Prognostics-enabled maintenance and logistics strategies, and corresponding design guidelines, represent a significant opportunity for commercial and military enterprises to achieve significant cost savings and enhanced readiness. Such a solution requires overcoming the disconnects between technology and operations – building smart processes between prognostics-enabled products and their maintenance and logistics practices. The central driver of prognostics capabilities in the "enterprise," commercial or military, is the benefit derived from real-time, closed-loop logistics system in which prognostics serve as an integral element in the feedback control scheme.

In this context, closed-loop describes to the capability of the system (for example a military maintenance and logistics system) to self-regulate based on a real-time comparison of the actual system response and the desired response (comparing actual performance signatures to normal base-line signatures). Just as in a classic feedback control scheme, the deviation from intended performance values, obtained from an on-going comparison of intended and observed values drives the maintenance and logistics processes.

The enabling breakthrough comes from emerging intelligent agent technology. Embedding the entire logistics chain and, in the future, the entire enterprise, in real-time information visibility both upstream and downstream is, in principle, made possible through Multi-Agent-Systems (MAS's). The advent of Internet technology with its TCP/IP protocol enabled open-architecture has given us the ability to make information posting and access available anytime, anywhere, in single copy, and searchable. Thus, the ability to provide prognostics information along the chain, thereby closing the feedback loop is becoming a reality.

Until now, the bottleneck has been the human operator's limitation in exploiting information in real time and recognizing complex relationships across large-scale information systems. A combination of rule-based, collaborative and learning intelligent agents can be deployed as an underpinning to current logistics systems and as an enabler of a dynamic logistics feedback loop—agents connecting, in real-time, all control elements from the in-use, onboard diagnostics/prognostics system to the upstream control and command, maintenance and logistics processes.

We refer to feedback connectivity from on-board diagnostics/ prognostics to the decision-maker, and an appropriate dynamic response, as "adaptive logistics." The associative memory technology, developed and implemented by UNC partner Saffron Technology, is the first commercially viable pattern recognition technology suitable for large-scale, distributed information networks—enabled by new compression techniques with unprecedented scaling capability and speed.

The goals of this paper are to: 1) advance the state-of-practice of pattern recognition in massively complex and distributed information environments; 2) provide decision-support capabilities for the intelligent use of sensed information; and 3) improve the effectiveness of logistics operations with embedded prognostics.

Current Prognostics Applications

Prognostics is the process of predicting the future state of the system. A prognostics system is comprised of sensors, a data acquisition system, and micro-processor-based software to perform sensor fusion, analysis, and reporting/interpreting of results with little or no human intervention, in real time or near real time.

Offline prognostics for vehicle health monitoring, as well as remote diagnostics, are used extensively in complex products like aircraft engines and long haul vehicles for both surface and rail transport, and on defense products such as weapons platforms and munitions. More recently this technology is infusing commercial products such as washing machines, personal automobiles and even buildings.

Most of the current applications focus on diagnostics, rather than prognostics. These technologies diagnose problems after failure or service degradation has occurred. In the commercial aircraft arena, for example, The Boeing Company has develop The Mechanics Compass, a system that facilitates the airplane maintenance process by automatically gathering, organizing and presenting the most pertinent information required by a mechanic to identify the source of a specific system failure, as identified by observable symptoms and findings. The Mechanics Compass uses a technology called Bayesian Belief Networks that models probabilistic dependencies between the cause and effect variables in the event of failure.

As an intermediate step towards full-scale prognostics, many companies have implemented remote diagnostics in which sensor information is downloaded to base stations for analysis. While information is downloaded for analysis, and may avert some failures, these systems have not achieved the real-time, on-board prognostics capability described in this paper. The application of real-time, on-board prognostics promises to have the greatest impact in complex industries such as aerospace, automotive and defense.

Most of the following industries have implemented some form of remote diagnostics with sensor information downloaded to base stations for analysis, but have not yet achieved real-time, on-board prognostics capability.

Ford Motor Company

Ford Motor Company represents the state-of-the-art of thinking about prognostics in the automotive industry. Currently, accurate diagnostics, fault isolation and acquisition of repair parts are only possible after the vehicle is brought to the service bay. Ford is moving towards a system that utilizes a combination of on-board diagnostics, modest on-board computational capabilities (memory and processing), moderate bandwidth two-way communications between an analysis-decision center and the vehicle, and a comprehensive computing center (server). On-board diagnostic unit controls high-speed data acquisition including diagnostic trouble codes and flags representing various system states. Triggering events signal automatic data storage and transmission to the decision center, and the trigger criteria are dynamically configurable.

General Electric Aircraft Engines

General Electric Aircraft Engines has in place a diagnostics and prognostics-capable service and maintenance support system that uses in-flight communications and data acquisition capabilities for diagnosing and predicting operational interruptions. For example, sensors track blade clearance between the blade tips and the matched surface in high-precision turbines. An increase in temperature accompanied by a drop in thrust is strongly correlated with an increase in blade-tip clearance. Trend analysis predicts when maintenance needs to be performed (CBM).

General Electric Marine Engines

Similarly, shipboard, GE Marine Engines recently tested an on-line remote diagnostics system on a GE LM2500 aeroderivative gas turbine that allows for analysis of key operating data for gas turbines located anywhere in the world. The remote diagnostics system allows GE to electronically visit customer sites when necessary 24-hours-a-day, 7-days-a-week. The system can track more than 1,000 parameters on each gas turbine, including variable data from sensors and controls, as well as status reports such as alarms and equipment on-off conditions.

US Army

Pacific Northwest National Laboratory is working to assess the feasibility of developing an on-board PHM (prognostics health monitoring system) for the gas turbine used on the M1 Abrams tank. In this proposed system, the prognostics/diagnostics system control box gets inputs from

38 sensors mounted on the engine, including pressure sensors, temperature sensors, and vibration sensors located at strategic points on the engine. The system then uses regression models to assess trends that are then compared to established metric failure limits.

Moving from Diagnostics to Prognostics

The benefits of moving from "fix it" mode to averting failure through prognostics is especially clear in the airline industry where lengthy gate delays not only motivate customers to switch airlines, but have the potential to disrupt the nation's airline network. The evolution from diagnostics to prognostics is illustrated for aircraft maintenance in Figure 1. Today's typical situation, reporting problems at the gate, often involves late departures or equipment substitutions if the problem cannot be diagnosed and fixed.

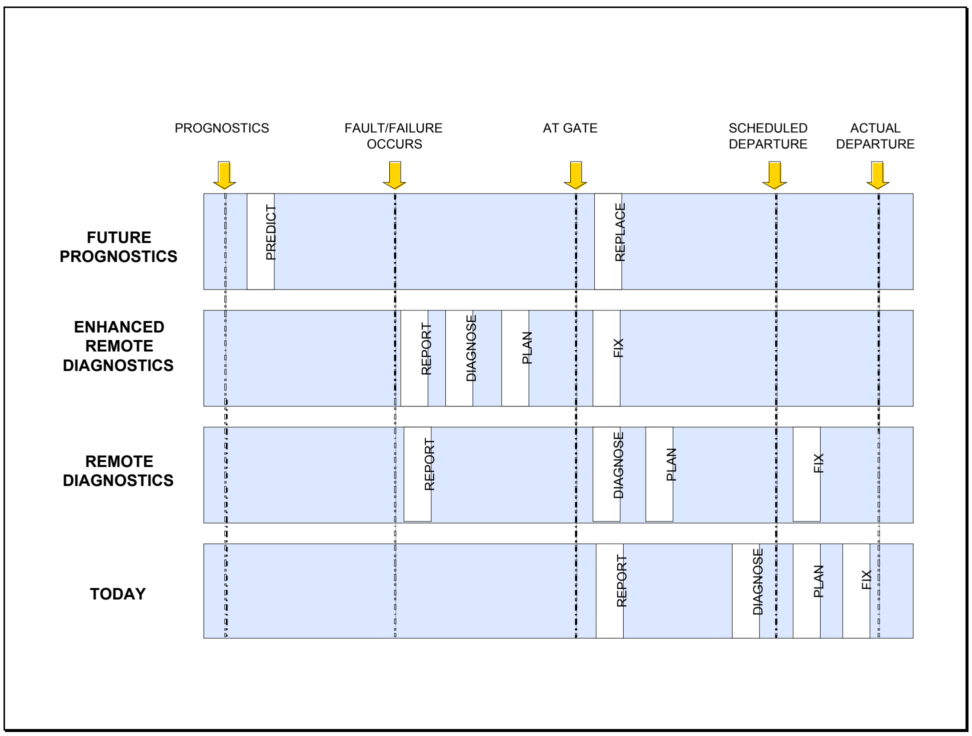

Figure 1: Prognostics-Enabled Maintenance Process Improvements

With some remote diagnostics, sensors are able to report deteriorating conditions or failure while the aircraft is in the air, but diagnostics are not able to pinpoint the source of the problem and fix it until the plane is on the ground since diagnostics processing is located off-board. This situation can also result in late departures, or equipment changes. Enhanced remote diagnostics have on-board capability that is able to diagnose and plan for the fix while the plane is in the air. In the future, prognostics will be able to avert failure, and system deterioration, replacing parts before they fail on a condition-based maintenance schedule. Moreover, if performance deterioration is observed en route, command and control can modify the vehicle profile, limit engagement, or recall the vehicle before catastrophic failure occurs.

Technologies for Pattern Recognition

A major barrier in prognostics advance is the availability of technologies that can interpret large and complex datasets in real time. Many of today's prognostics use technology that is based on statistical inference in which observed events in the past are used to assess statistical probabilities (Bayesian approaches) or to fit statistical models (regression or neural nets, for example). These approaches cannot handle large data sets efficiently, may involve model building, and often require off-line analysis. An innovative new technology, referred to as associative memory technology, bridges these barriers thereby enabling real-time control of physical processes through its ability to discern patterns in large-scale, distributed, dynamic data.

Most statistical approaches extract information by reducing data (c.f. mean, mode, distribution, etc). Because the human mind is not able to resolve large, complex datasets, these approaches collapse information into something that the human mind can understand. This process of data reduction removes potentially crucial information that may not be statistically significant for a population, but can be the critical factor in a particular context. Intelligent agent technologies, especially new associative memory technologies, extend the reach of the human brain with its ability to make correlations between—and see patterns in—very large, complex data sets in real time.

The computational advantage of new intelligent pattern recognition technologies, like associative memory, lies in their ability to "see" unusual patterns that cannot be detected by traditional analytical methods, or by humans. The typical human brain cannot simultaneously comprehend more than 8 to 10 parameters or data elements. Associative memory technologies extend the capability of the human brain by perceiving patterns across hundreds or thousands of attributes. For example, patterns involving as many as 20 or more factors such as vibrations, engine temperature, oil viscosity, oil pressure and so forth, can signal the impending shut-down of an engine or catastrophic part failure, allowing the pilot and/or ground crews to avoid unanticipated failure.

The challenge for researchers today is to develop tools that can fully exploit the information content and MEANING in extremely large, complex and distributed datasets. Most, if not all, current data mining and other pattern recognition techniques are ineffective—and expensive—because they are unable to process the voluminous amounts of information typical of large-scale, sensored environments.

Associative Memory Technology

Pattern recognition and associative memory concepts have evolved together over the last several thousand years. Associative memory technology has its roots in ancient Greece where Aristotle established the idea of associationism, which he defined as the method by which people observe and imagine their experiences. People learn by understanding the relationships between things, over time. The idea that associations underlie all human thought was the foundation for the new field of psychology in the late 19th century, and again during the emergence of numerical computing in the mid 20th century. In his famous 1945 article "As We May Think" , Vannevar Bush originated the idea of an "associative memory device which he called the "memex" machine, and which utilized an associative look-up as opposed to an indexed look-up.

The development of neural computing and neural networks in the 1980s offered new approaches to implementing associative memories [Haykin 1999; Ripley 1996]. The underlying premise of neural computing is that computer hardware and software can be used to simulate the activity of biological neurons in the human brain. Early researchers focused on two types of neural engines: hetero-associative models such as back-propagation and auto-associative models including Hopfield nets [Hopfield 1982]. These neural engines were applied to a variety of pattern recognition problems with varying degrees of success [Carpenter 1988].

At the current state-of-the-art, neural nets have had limited success with many problems such as handwriting analysis, risk analysis and financial forecasting. For comparison with the human brain, each Purkinje Neuron in the human brain has approximately 100,000 inputs for a single output. By analogy, neural computers are defined as linear summators with associated thresholds. However, the behavior of biological neurons is linear in contrast to neural computing techniques that attempt to capture the nonlinear behavior of biological neurons. At their current state of development, neural computing approaches have limited suitability for massively complex, large-scale problems due to an inherent problem with scaling. As these approaches were pushed to their limits, however, researchers have turned to more complex cognitive structures (Multi Agent Systems) to achieve increasingly better performance.

In this research we utilize an innovative representation of associative memory developed by Saffron Technology. Associative memories can be implemented as a type of content-addressable memory (similar to hash tables), or co-occurrence matrices over a large sets of attributes. Details of the technology and its applications are provided in two white papers *Saffron Technology: Technical White Paper* (October 2002) and *Application Brief: SaffronNet* (September 2002)

High Performance Compression for Real-Time Prognostics

Saffron exploits a proprietary lossless (i.e. does not lose information) compression routine that is capable of creating extremely compact models. This implementation has demonstrated extremely high performance compared with other available technologies and, for that reason, is being used by DARPA, FBI, and other agencies on problems of homeland security and national intelligence. Further, the Saffron implementation is able to operate on compressed datasets, unlike other pattern recognition technologies, thereby enabling dramatic reduction in storage and CPU hardware, thus enabling the application of associative memory technology in a distributed, "on-board", environment.

The human vocabulary is said to comprise approximately frequently used 5,000 words. Using compression, Saffron associative memory can simultaneously evaluate more than 1,000,000 unique attributes in real time. At 30,000 attributes, the uncompressed associative memory requires close to 3,000 MBs of free space, whereas the compressed associative memory model requires approximately 150 MBs (version 3.0), achieving a 20:1 compression ratio. In recent experiments (version 3.1), developers have achieved a 1850:1 compression ratio, representing more than 37,000 attributes in a compressed memory of less than 20MBs. The scaling properties of versions 3.0 and 3.1 are shown in Figure 2 below.

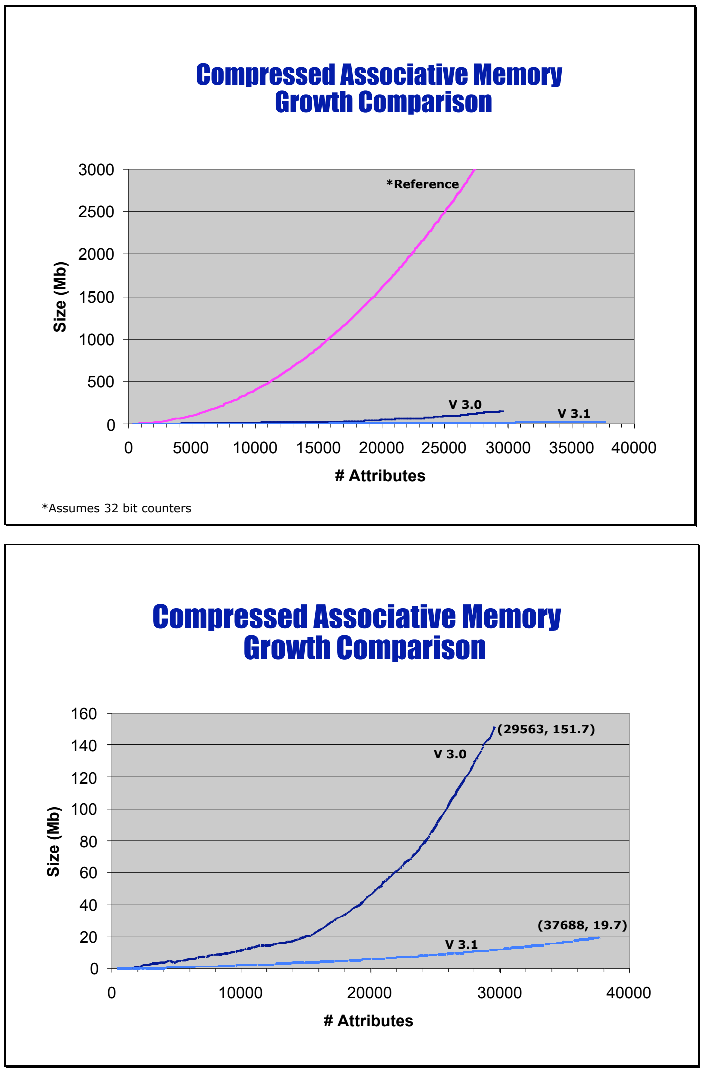

Figure 2: Compression Performance

Prognostics-Integrated Logistics: Closing the Loop

The challenge is to design a MAS architecture compatible with the target business processes. Maintaining vehicle health maintenance is the first step. The concept is, of course, extensible all the way upstream, thus connecting the entire enterprise. Consider the following example.

Over the Atlantic Ocean, a B-18 is en route from the United States to Turkey via Germany when irregular sensor readings in the jet engine are interpreted by on-board pattern-seeking agents as an impending turbine failure. This potentially catastrophic condition is reported to both the pilot and emergency maintenance crews on the ground who prepare to swap the deteriorating engine at the nearest airport.

Without the assistance of pattern recognition software there is a considerable possibility of turbine failure with potentially catastrophic consequences for the jet, and its crew. In this case, the aircraft makes an emergency landing in the UK where maintenance crews replace the engine, saving both time and money—and lives. Further, the plane departs with minimal delay since, with early warning, the airline has been able to fly a replacement part to the UK.

The above scenario is rapidly being played out in both the aircraft industry and long-haul truck industry. From the Joint Strike Fighter program at Lockheed Martin to the Airplane Health Management (AHM) program at Boeing, the concept of predicting failure or degradation of performance to avoid delay in airline dispatches. Operators of remote strip mining operations and locomotive engine operators were early pioneers in this area.

The initial benefits of prognostics integrated into the logistics chain are a reduction in the number and length of aircraft dispatch delays. Not only can maintenance crews be waiting with part of repair manual in hand as the aircraft taxis to the gate, but time spent analyzing the problem can be avoided as shown earlier in Figure 1. In addition, the companies expect to decrease their cost of operations by allowing operations to move to condition-based maintenance of components.

Conceptually, this means that instead of replacing components upon failure, upon physical inspection and finding of an impending fault, or upon the passing of a certain number of hours of operation (mean-time-to-failure), components can be replaced when prior to failure based on their own state or condition, rather than a conservative "average" that is based on the failure history of many parts.

While maintaining the health status of the aircraft or vehicle is the primary concern in the above example, even greater value can be attained by embedding the prognostics in a MAS in which the prognostics agents collaborate and share knowledge across the fleet, or enterprise, all the way up the value chain to R&D as illustrated in Figure 3 below:

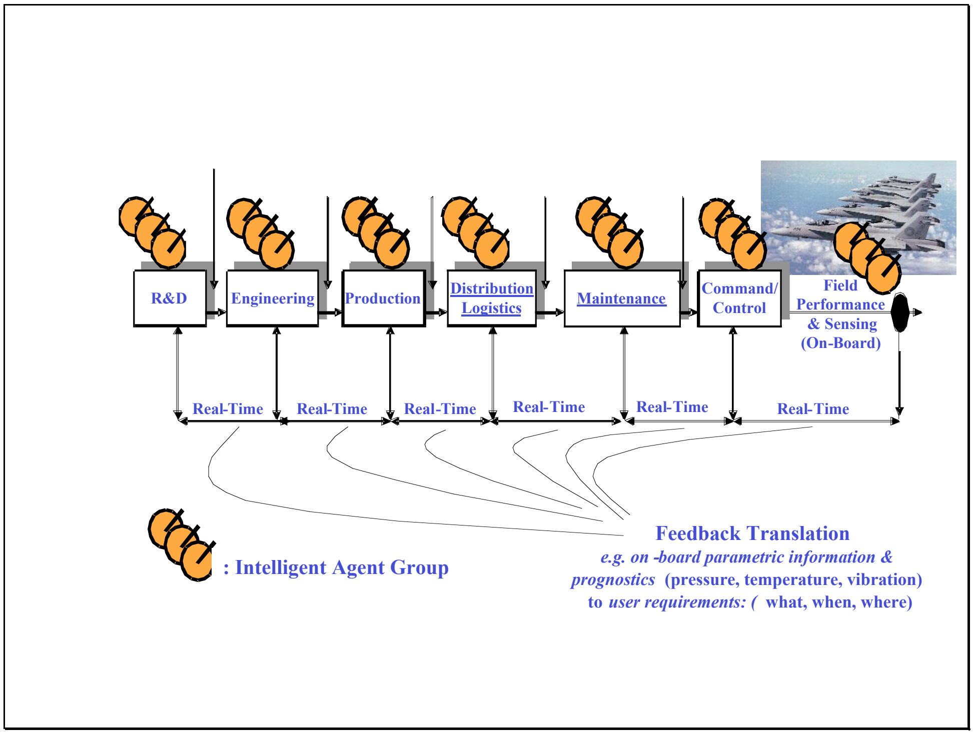

Figure 3: Enterprise Prognostics Feedback and Feed-Forward Control

In the figure above, a community of mobile, collaborative and learning agents provides feedback and feed forward control as follows:

Field Performance
Reliability is enhanced in field performance as described above through feedback of real-time sensor information from the vehicle using mobile agents, and learning agents that are able to correlate attributes that signal impending failure or degradation.

Command and Control
When vehicles are critical elements of a competitive strategy, whether on the battlefield such as combat vehicles in a ground assault or long-haul vehicles that must get to a customer's facility for just-in-time delivery, the ability to assess the health of these vehicles can be factored into tactical decisions—do I send Alpha Company to the forward front or do I divert a long-haul vehicle already en route to another location to a higher priority customer?

Maintenance
Prognostics enable companies to adopt condition-based maintenance practices in which individual vehicles or machines are serviced based on their own performance rather than average historical data. For example, engine deterioration rates can vary tremendously. Each engine costs between $5M and $10M and must be overhauled every three to five years. In order to avoid catastrophic failure, companies are very conservative, replacing engines well in advance of failure according to FAA guidelines about number of flights completed. In reality, only one-

third of engines are replaced using this criterion. Another third are replaced because exhaust gas temperatures get too high indicating parts are wearing out faster than expected. The last one-third are replaced because of various unique events such as cracks or bird events. When each engine's need for repair is based on individual performance, then maintenance scheduling can be managed dynamically, avoiding long waits at the maintenance center or excess on-hand spares. Dynamic maintenance scheduling can be accomplished by collaboration between agents according to a self-scheduling set of rules.

Distribution Logistics
Enhanced predictability of failure will improve not only the forecasting of the need for spares, but also require rethinking of current inventory and distribution practices. Currently, inventory is placed in maintenance locations based on projected forecasts of need. Ideally, inventory should be held at the sites of maximum likelihood of need. Prognostics will help to identify these locations. In addition, the ability to response to the need for spare parts may require that supply networks be reconfigured in real time so that an engine en route to a maintenance hub for storage may be diverted to an airport where an aircraft needs an immediate engine replacement. A community of rule-based and collaborative agents can identify the optimal part to select based on efficiency and effectiveness criteria.

Production
Real time information about the need for spare and repair parts can also be used to build production schedules. In some cases, the unanticipated need for a part of engine can signal immediate production of a replacement part. This part will not be used on the vehicle or aircraft but will replace the actual repair part.

Engineering
The correlation of performance information across a fleet of vehicles or aircraft can help to avoid costly engineering changes by providing advance warning of problems of failures. For example, a particular part may not wear well under certain ambient conditions—e.g., engines may experience degraded performance in desert conditions. Engineering changes for vehicles in the same conditions can avert similar problems before they occur. Further, fleet-wide performance can help companies make better decisions concerning life cycle management—for example identifying the optimal time for replacing a wing on an aging aircraft.

Research and Design
The accumulation of fleet-wide information about degradation and failure can ultimately be used in the research and design process in the search for more reliable products. Currently, little performance data is shared within an enterprise across fleets of vehicles or machines. Once this information is shared, failures that may be statistically insignificant in small samples will become known—initiating a search for better designs or newer and better materials.

Conclusion

The convergence of new sensor technology, the Internet, and emerging agent technology is making it possible for companies to make better "health" decisions about their assets and products. Sensor technology has made large strides, as has communications technologies. Currently, agent technology is reaching a level of maturity in which prognostics can move into more widespread use in commercial applications. The Center for Logistics and Digital Strategy at the University of North Carolina is working with The Boeing Company and other clients to develop communities of agents—mobile, collaborative, and learning agents—that can help to transform logistics practices in both the military and commercial sectors.

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Adaptive Pattern-based System for Automated Machine Design

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Abstract

A software concept and its realisation based on heuristic knowledge and pattern identification techniques for automated design of a multi-spindle drilling gear machine used in furniture production process is presented. The aim is to find an optimised design of the target-machine, this means to find a machine design with minimised number of drills and with the antagonistic goal to provide a fast production of the boards by minimising production-cycles per board. The design experience of a human expert was transferred to a design tool using his heuristic knowledge in combination with special developed pattern detection and recognition algorithms. Known and interpretable patterns are identified and used as information for a pre-design of the machine. The feasibility to manufacture each board is reached by analysing each single board to recognise known patterns for which drills are already equipped on the gears and the detection of new, un-interpretable patterns for which free spindle places can be equipped with suitable drills.

Keywords

Automated design, knowledge processing, pattern detection, pattern recognition, database techniques, decision support systems, adaptive pattern-database.

1 Introduction

The target machine for the research work is a large flexible machine consisting of up to eight drill supports and each drill support has one or two drilling gears each having up to 40 individual drill locations called spindles. Each machine has to be specifically designed with regard to the minimum number of drill supports, gears and spindles. The antagonistic goal is to minimise the production time by reducing the number of drilling cycles of a board during production. During one cycle the supports and gears are positioned and a selection or all of the holes of the board are drilled by moving up the spindles for selected drills. In other words, there are two antagonistic minimisation goals: the optimisation of the machine design and the optimisation of the board production. Each machine is designed to cover the customer's board specifications that are given by structural component engineering drawings.

The aim of the project is to automate the design of such multi-drilling gear machines. Dependent on the customer's requirements a few hundred different boards have to be processed on a machine. The time to design such a machine depends on the amount of boards and their complexity as well as the maximal number of drilling-cycles requested by the customer. A typical amount of time for the manual design is about three month for a machine to be designed for approximately 300 boards and maximal three cycles per board. An automated multi-spindle gear design based on intelligent database techniques using heuristics of the expert's design procedure [1-4] with pattern detection and pattern identification [5] is introduced to solve this multi-criteria optimisation problem [6] to reach a strong saving of time during the design process.

2 Target Machine and Board Data

The machine can be described by the set of supports, a set of gears on each support, and set of spindles on each gear (Fig. 1). Each spindle can be equipped with one drill whereby the type of drill-tool is a sink-drill, a through-drill or a drill that can be used for both kinds of holes. The used position field notation [8] denotes a filled spindle by a drill specific tool number and a free spindle by zero. The tool number gives information about the drills diameter and the drilling mode related to the kind of holes to be drilled like sink-holes or through-holes.

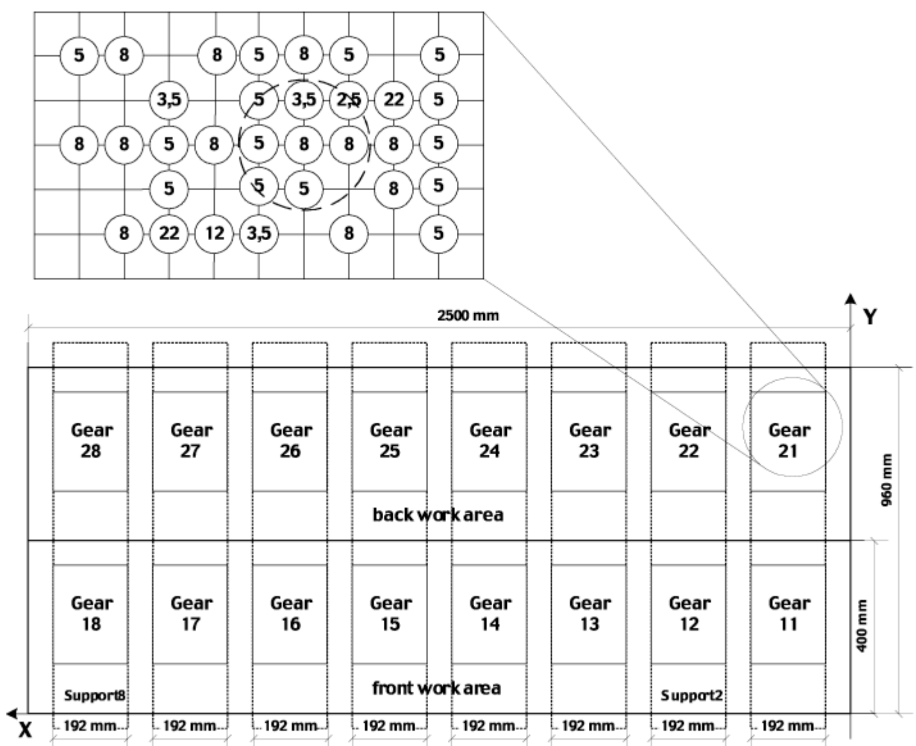

Fig. 1. Schematic of a multi-drilling gear machine and one specific gear.

During the design of the machine different constraint have to be considered rising from the construction of the machine, the control electronic or from production restrictions e.g. to underrun the maximal allowed time for a cycle. Important constraints are:

- the maximal number of spindles on one
  - gear,
  - gear in x-direction,
  - gear in y-direction,
- the maximal distance of the
  - feed-in piston,
  - stopper,
- the maximal
  - length of the machine (maximal length of work area),
  - width of machine (maximal width of work area),
  - distance between gears and y = 0,
  - distance between zero spindle (reference spindle on a gear) and y = 0 for back gears,
  - allowed distance to be driven in x-direction for one support between two cycles,
- the minimal distance between
  - the gears and y = 0,
  - two supports in x-direction,
  - two gears in y-direction,
  - distance between zero spindle and y = 0 for front gears,
  - distance between y = 0 and lowest spindle row of front gears,
  - width of a support etc.

The board data are made up from the set of work pieces to be manufactured on the machine. Each work piece (Fig. 2) has a number of holes. The x- and y-position, the diameter, the depth of the hole and the drilling-mode determine each hole. The drilling-mode identifies each hole as a sink-hole or a through-hole.

3 Automated Design

Following the human expert the problem of automated configuration of the drilling gears can be divided in two major tasks [9-10]. The first step is to find a generalised pre-placement of drills. The second step is an iterative process, which processes each board by defining the placement of the board in the area of work of the machine, by finding optimised positions for each support and gear and by achieving the possibility to produce each board by defining cycles and suitable drills. A sequence for the consideration of boards is determined using the board complexity [7-8] before the iterative configuration process starts. During this configuration process restrictions related to the parameters of the machine have to be observed and each structural component has to be checked to ensure that the production is feasible. Boards containing holes for fittings are detected and planned in a previous step considering special requirements.

3.1 Pattern Detection and Identification

The hole patterns can be separated into the groups of either a known and interpretable patterns or a group of unknown patterns. The pattern identification process works in analogy to the human expert who classifies the boards into structural parts such as cupboard units, side and middle walls, bottom boards and doors. The group of known and interpretable patterns used for the automated drilling system consists of a set of holes in rows, for metal fittings and for construction holes. The holes in rows are later called x-rows because they are a set of holes in x-direction and the construction holes are called y-rows. An x-row pattern can be defined as at least three holes in combination that fulfil the conditions: a) placed on the same work piece, b) equal diameter, c) equal mode, d) equal y-coordinate, and e) distance between holes = grid or 2 times grid. The holes of an identified pattern are stored in a fuzzy way to the generated tables [11]. Further processing can identify that there is the same x-row on different boards. The metal-fitting pattern has a hole with diameter ≥ 12mm and the location is close to the edge of the board and most time they have further holes, e.g. for mounting near the main hole. Algorithms identify these patterns and save them to a fitting-pattern database with the diameter of the main hole, the diameter of the accessory holes for screws, the distances between the accessory holes and the main hole, and the location of the pattern on the board, e.g. the bottom or top surface. With this the pattern is independent from the real x- and y-coordinates on the board. This enables a later check to determine if the same drill-combination planned for one board can be used on a different board.

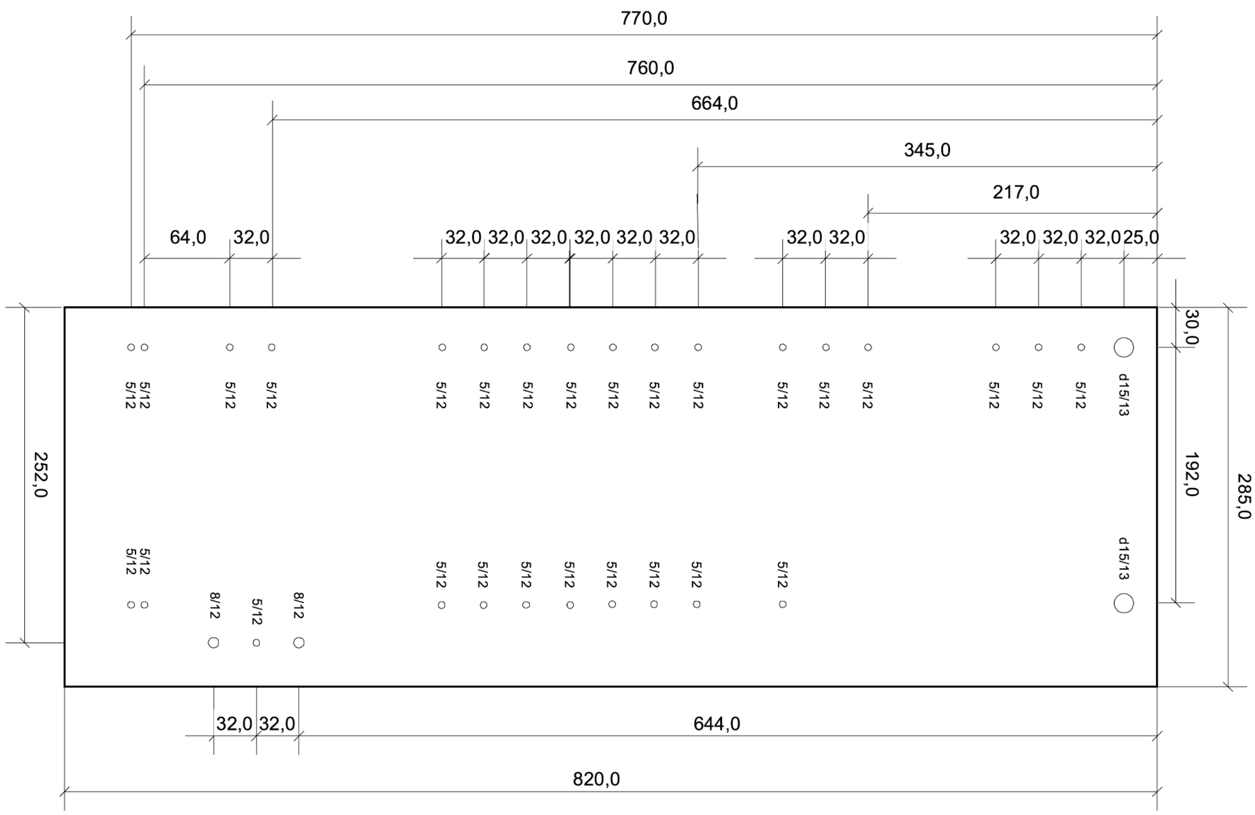

Fig. 2. Schematic of a board.

Unknown patterns are an arrangement of at least three holes that are in a modulo grid distance in the x- and y-direction from each other. They cannot be interpreted as a previous pattern but they can be used to find similar patterns on different boards. They are saved in a pattern-database independent from the real coordinates of each hole. Only the number of the first hole – with this it is possible to get all information about the hole like coordinates and other parameters – and the distances between the holes and the parameters of the holes like the diameter and the mode are saved. Furthermore the gear and the spindle place number are saved in relation to the gear and the spindle place number of the corresponding drill.

3.2 Initial Number of Supports, Gears and Spindles

Before the design process can be started an initial configuration defining the number of supports and the number of spindles on each gear is entered by the operator. The operator has to decide if special gears, that are mainly used to drill the metal-fitting holes, are required. The program supports the operator by giving a visual prompt that shows the number of fitting holes compared to all holes of all boards and the number of required supports to drill the fitting pattern in least number of cycles. The human expert has to decide if he wants the program to include and plan special supports for metal-fittings because this decision is dependent upon a value judgement made by the customer. The customer has to consider the impact of additional process cycles as against the additional costs for special supports. Furthermore the operator is given information if x-row drills are useful. If the amount of x-rows is large and the operator decided to use special rows for x-row drills, the operator has to initially define the number of spindle places to be planned for x-row drilling on each gear. These values and customer decisions are used to allocate spindle places in the database that are planned in a grid distance in columns and rows for all non-fitting gears. Each spindle place is related to the gears and has the coordinate on the gears as well as a data field for the tool number. The tool number characterises a drill by its diameter and drill mode. The initial tool number is 0 and indicates a free spindle place.

3.3 Design Process

The automated design process depends on heuristic knowledge from the human expert and on the knowledge derived from the different pattern databases. One heuristic is, e.g. that the mapping of holes to the drills or free spindles starts from a right support and runs from this start-support for the board to next support on the left side of the start-support and then support by support to the most left support required for the board. If it is not possible to use the planned supports because there is not enough drills or free spindles than the next left support of the initial start-support is chosen as a start-support and the whole process starts again until it is possible to produce the board. This heuristic was transferred to the program in the way that in the first step an optimised start-support is identified by checking all possible start-supports regarding their suitability. This step is done by selecting a set of holes from the right part of the board dependent on the width of the actual support. If the best start-support is found the holes for this support are processed and then the next set of holes is chosen dependent on the width of the next left support and the left edge of the support before. These holes are processed and so on until the end of the board is reached. If all holes cannot be processed in the first cycle, a second cycle is required. Dependent on the complexity of the board and on the suitable drills and free spindles on the gears further cycles are required until all holes of the board can be drilled. Between each cycle the supports can only be driven in a maximal driving distance between two cycles. This is covered in such a way that for a second or further cycle maximal and minimal x-positions of each support are calculated dependent on the position of the supports in the previous cycle.

The board-by-board processing (Fig. 3) is characterised by the two major algorithms "pattern-DB algorithm" and "search algorithm". The first algorithm is based on a pattern database where all hole patterns ever found on the boards before are saved. A pattern identification algorithm returns the gears that contain suitable drill pattern for the hole pattern or a part of the hole pattern which is actual processed. All gears containing the required drill combinations are checked regarding the constraints of the machine and the maximal driving distances. Only gears that fulfil the constraints are considered for the search for additional drills or free spindles to produces all holes of the actual hole pattern. The gear that can produce the most holes in one cycle is used. If no gear is found by the pattern-DB algorithm the actual hole pattern is processed by the search algorithm. This algorithm is searching for the best gear by variation of x- and y- coordinates of the supports and gears under the mentioned restrictions and is searching for the best gears for the actual hole pattern. The best gear is that which can produce the most holes in one cycle.

The pattern-DB algorithm and the search algorithm are used together to find an optimised start-support. The support is chosen as start-support that can produce the maximal number of holes. This has the advantage that free spindle places on more left supports are considered, e.g. on a right support there is 6 suitable drills and 2 suitable free spindle places but a support more right has only 3 suitable drills but 8 free suitable spindle places. In this case the more right support is chosen as the start support because with that one 11 holes can be produced in one cycle compared to the more left support which can produce only 8 holes in one cycle. This proceeding is similar to the heuristic knowledge of the expert and enables the uniform distribution of drills on the gears. The pseudo-code formulation is given by:

```
DO until all boards are processed
    DO until all holes of the actual board can be drilled
        select holes for work area of actual support
        IF first cycle AND first support of board THEN
            use search algorithm and pattern-DB algorithm to find optimised start-support
            process holes for the start-support
        END IF
        FOR all supports
            select holes for work area of actual support
            use pattern-DB to identify similar pattern on the gears
            IF similar pattern on gears THEN
                search for possible gears/supports
                IF possible gears/supports exist THEN
                    process holes for the best support/gears
                ELSE
                    use search algorithm to find best supports/gears
                END IF
            END IF
        NEXT support
        new cycle
    LOOP 'all holes
LOOP 'all boards
```

Fig. 3. Pseudo-code algorithm for the board-by-board processing.

If fitting-pattern where detected and the operator choose the program option to generate special fitting-supports a fitting pre-placing algorithm is used to design gears for fitting-drills.

4 Results, Summary and Conclusions

The program was tested with different datasets and produced suitable machine designs which allow to manufacture all boards tested. Compared to the human expert the program is very fast.

To get a more optimised layout automatically rules regarding the construction of each gear, e.g. minimal distances of the drive gears etc. has to be covered by the program. Initial results show that there is a good chance to overcome this disadvantage using artificial immune systems [12-13] to generate an optimised design for the fitting gears.

After introducing the target machine important design goals for multi-spindle drilling gear configuration where shown and a technical concept for automated multi-drilling gear design dependent on a heuristic knowledge and pattern detection and -identification was described. The generalised pre-placement of the automated concept is based on the detection of characteristic interpretable pattern and a pre-configuration of the machine depended on generalised interpretable pattern. Moreover the iterative board-by-board process is characterised by a pattern-database algorithm and a search algorithm. The pattern-database algorithm uses the information of already equipped drill pattern to find optimised gears while the search algorithm is used if the first algorithm is not successful. Both algorithms are used in competition to define an optimised start-support for each board. The pattern-database is growing during the program execution and with that suitable drills on a gear are located very fast. Fitting-boards are processed by a special fitting pre-placing algorithm using a special fitting database. The automated design is very fast compared to the design of the human expert. The machine designs are similar to that ones produced by the human expert.

A further advantage is the documentation of the expert's design procedure and its verification in this application software tool. The provision of a database providing knowledge as to which drill is used for each single hole provides a simple interface to the CNC-programs that will control the manufacturing machine.

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InterSymp-90 ($17.00)	Proceedings of the focus symposium on 'Knowledge-Based Systems in Building Design' (ed. J.Pohl); InterSymp-90 5th International Conference on Systems Research, Informatics and Cybernetics, Baden-Baden, Germany, Aug.7-8, 1990.
InterSymp-91 ($17.00)	Proceedings of the focus symposium on 'Computer-User Partnerships in Design' (ed. J.Pohl); InterSymp-91 3rd International Symposium on Systems Research, Informatics and Cybernetics, Baden-Baden, Germany, Aug.13-14, 1991.
InterSymp-92 ($17.00)	Proceedings of the focus symposium on 'Advances in Computer-Based Design Environments' (ed. J.Pohl); InterSymp-92 6th International Conference on Systems Research, Informatics and Cybernetics, Baden-Baden, Germany, Aug.18-19, 1992.
InterSymp-93 ($17.00)	Proceedings of the focus symposium on 'Advances in Computer-Assisted Building Design Systems' (ed. J.Pohl); InterSymp-93 4th International Symposium on Systems Research, Informatics and Cybernetics, Baden-Baden, Germany, Aug.2-5, 1993.
InterSymp-94 ($17.00)	Proceedings of the focus symposium on 'Advances in Computer-Based Building Design Systems' (ed. J.Pohl); InterSymp-94 7th International Conference on Systems Research, Informatics and Cybernetics, Baden-Baden, Germany, Aug.15-21, 1994.
InterSymp-95 ($20.00)	Proceedings of the focus symposium on 'Advances in Cooperative Computer-Assisted Environmental Design Systems' (ed. J.Pohl); InterSymp-95 8th International Conference on Systems Research, Informatics and Cybernetics, Baden-Baden, Germany, Aug. 16-20, 1995.

InterSymp-96 ($20.00)	Proceedings of the focus symposium on 'Advances in Cooperative Environmental Design Systems' (ed. J.Pohl); InterSymp-96 International Conference on Systems Research, Informatics and Cybernetics, Baden-Baden, Germany, Aug.14-18, 1996.
InterSymp-97 ($20.00)	Proceedings of the focus symposium on 'Collaborative Design and Decision-Support Systems' (ed. J.Pohl); InterSymp-97 International Conference on Systems Research, Informatics and Cybernetics, Baden-Baden, Germany, Aug.18-23, 1997.
InterSymp-98 ($20.00)	Proceedings of the focus symposium on 'Collaborative Decision- Support Systems for Design, Planning, and Execution' (ed. J.Pohl); InterSymp-98 International Conference on Systems Research, Informatics, and Cybernetics, Baden-Baden, Germany, Aug.17-21, 1998.
InterSymp-99 ($30.00)	Proceedings of the focus symposia on 'Computer-Based and Web-Based Collaborative Systems' (eds. J.Pohl and T. Fowler); InterSymp-99 International Conference on Systems Research, Informatics, and Cybernetics, Baden-Baden, Germany, Aug.2-6, 1999.
InterSymp-00 ($30.00)	Proceedings of the focus symposia on 'Advances in Computer-Based and Web-Based Collaborative Systems' (eds. J.Pohl and T. Fowler); InterSymp-2000, 12th International Conference on Systems Research, Informatics, and Cybernetics, Baden-Baden, Germany, Jul. 31, Aug. 4, 2000.
InterSymp-01 ($30.00)	Proceedings of the focus symposia on 'Advances in Computer-Based and Web-Based Collaborative Systems' (eds. J.Pohl and T. Fowler); InterSymp-2001, 13th International Conference on Systems Research, Informatics, and Cybernetics, Baden-Baden, Germany, Jul. 30-Aug. 4, 2001.
InterSymp-02 ($30.00)	Proceedings of the focus symposium on ' Collaborative Decision-Support Systems' (ed. J.Pohl); InterSymp-2002, 14th International Conference on Systems Research, Informatics, and Cybernetics, Baden-Baden, Germany, Jul. 29-Aug. 3, 2002.
InterSymp-03 ($30.00)	Proceedings of the focus symposium on ' Collaborative Decision-Support Systems' (ed. J.Pohl); InterSymp-2003, 15th International Conference on Systems Research, Informatics, and Cybernetics, Baden-Baden, Germany, Jul. 28-Aug. 1, 2003.

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