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JEDI – An Executive Dashboard and Decision Support System for Lean Global Military Medical Resource and Logistics Management

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Abstract— **Each individual U.S. Air Force, Army, and Navy Surgeon General has integrated oversight of global medical supplies and resources using the Joint Medical Asset Repository (JMAR). A Business Intelligence system called the JMAR Executive Dashboard Initiative (JEDI) was developed over a three-year period to add real-time interactive data-mining tools and executive dashboards. Medical resources can now be efficiently reallocated to military, veteran, family, or civilian purposes and inventories can be maintained at lean levels with peaks managed by interactive dashboards that reduce workload and errors.**

I. Introduction

THIS paper describes new enhancements to an ongoing military medical informatics and business process reengineering research project. The Joint Medical Asset Repository (JMAR) is a relational database system created to integrate very diverse medical supply and medical maintenance management information from the US military services existing heterogeneous database systems. JMAR was originally envisioned to correct medical supply and drug distribution problems that occurred during Operation Desert Storm, and it received additional strong impetus and urgency from the September 11th terrorist attacks [1]. JMAR also is a critical component of the Joint Vision 2010 and 2020 concepts, plans to provide seamless clinical and medical supply information from the front lines to the home-based forces and their families (Stratton and Dick, 2002). The Joint Vision 2010 plan is an aggressive and all encompassing one, and it seems well be ahead of civilian efforts found in the literature to date. In order to use JMAR quickly and reliably, non-procedural data-mining and visualization tools were desired. To that end, the Department of Defense (DoD) created an SBIR-funded program to allow the development of the JMAR Executive Dashboard Initiative (JEDI). This paper describes the background and key features of the JEDI system, which was successfully delivered to DoD in late 2005.

II. BACKGROUND

The basic logistics and supply chain management issues are not dissimilar to published efforts in other industries like retail food sales [2]; simply stated, the Surgeon Generals of all three military branches must ensure efficient access to any required drug, supply, or medical device regardless of which branch of the military owns or inventories it. For example, an early Joint Military Asset Repository (JMAR) module was one that integrated the information on available blood supplies from the three services' existing – but disparate – information systems. By updating the JMAR knowledge base daily, the military's medical supply teams can locate needed plasma and blood types, deploy it where and when necessary, and coordinate replenishment activities to minimize overall waste [10]. This allows the military medical supply logistics program to operate in an efficient, lean style, as described by other healthcare researchers [6].

JMAR is based on a centralized Oracle engine, with a growing interface library to allow integrating information from the hundreds of heterogeneous systems in use by the medical services. This not only facilitates medical care to saves lives, but it also eliminates the hours and hours of staff time to make phone calls around the world that such searches required. Most drugs, supplies, and eventually most medical devices information will be integrated into the JMAR system, allowing it to serve as a global meta-database for the military's medical leaders. Realization of the full scope of JMAR will take many more years, as it must eventually integrate complex information models like those used for medical equipment maintenance, updates, recalls, and repairs. As each phase is implemented, the system architecture can be instructive for civilian applications. For example, JMAR's military project leaders would like to explore ways that the system might help the Red Cross improve its own blood management programs.

The general medical procurement process is integrated in JMAR, too. This allows visibility of purchases from Prime Vendors and/or alternate sources. This capability provides an excellent tool to improve efficiency and reduce costs by allowing centralized oversight and intervention when higher cost alternate suppliers are used instead of pre-negotiated, discounted Prime Vendors. No absolute remedy is expected to purchasing from alternate sources, however, as such purchases may have valid reasons. For example, product shortages or unexpected emergent requirements that cannot be fulfilled within the prime vendor's discount or delivery terms. Centralized information will allow Pareto charting and other statistical tools to identify and rectify the most significant problems as they occur.

III. TECHNICAL DISCUSSION OF THE EXECUTIVE DASHBOARD GRAPHIC ENHANCEMENTS

Technically, the JMAR system requires many layers of relational database meta-structures to allow mapping items from many disparate data sources, because every military service has adopted unique product and supplier coding, and each existing system stores different details about each item. Drugs, biologics, blood, and many supplies, for instance, often have expiration dates, lot/serial codes, and other

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important details that may be diffused throughout procurement and tracking databases. As each new category of medical resources is integrated – e.g., adding patient bed resources for each hospital around the world -- the data structures must be enhanced to facilitate those unique needs and environments. For the patient bed case, for example, some beds may be suitable only for burn patients, others for orthopedic patients, and still others for general adult patient care. Each system enhancement may expose new security problems, too, or they may involve patient privacy issues that are similar or identical to the HIPAA laws that private hospitals must meet.

For example, the military, and the Veterans Hospital Administration, has had to create their own coding systems for drugs because no industry standard existed. The FDA's March 2003 requirement for industry-wide drug coding will eventually make its way into the JMAR universe.

An Oracle database server environment has been established to store the JMAR information. Each of the tables in this star database design has to have the flexibility to store the disparate data in tables that share relatively common fields, though the fields may not be precisely matched to every application. For example, every location exists in a Facility table that provides many more fields than most facilities require. For example, most inventorying facilities may not have patient beds. Another example is that most inventoried items may not bear a serial number or have an expiration date, but the Inventory table includes those fields so that they are available when needed. Though this format "wastes" some storage and may not strictly be a formal third normal form design, it offers substantial simplicity for users and access speed advantages. A further operational complexity tradeoff exists in this design, too: the use of various fields creates hidden data-related meanings. For example, an item that bears an individual serial number must be inventoried in single unit quantity.

Further complexities of medical supply information have been incorporated into the design, including the following:

1. Assemblies (pre-packed sets of items) are themselves inventoried items, with recursive numbering that uses other the existing inventory numbers of each subcomponent and the appropriate quantities to specify the assembly composition.
2. Substitution of non-prime-vendor alternatives is supported, along with quantity multipliers to accommodate situations in which the substitute item is issues in different packaging (e.g., batteries that are single items instead being in a six-pack.)
3. Reservation of specific quantities of items for specific purposes (e.g., emergency rooms supplies) is supported, along with purpose-specific reorder levels

Synchronizing the information from each source requires careful analysis and programming with each service's medical logistics and IS teams. The synchronization must, by necessity, be robust enough to tolerate unavoidable lapses caused by urgent situations like natural disasters or military operations. If blood or other supplies are transferred from one service to another and the records are not updated simultaneously or contemporaneously, the system might show episodic shortages or double-counting until all updates are posted. As bar code, IR, and other automatic, real-time data acquisition is implemented by the military bases, however, these problems will be reduced. These are the exact same trends recommended by the Institute of Medicine reports [3, 4, 5] to help reduce drug errors, and they are also the trends that helped retailers like Wal-Mart create efficient, leading-edge supply chains.

Future planned JMAR and JEDI enhancements include medical equipment, repair parts, and specialized repair tool tables and reporting and management programs. These information decision support will facilitate implementing more effective, uniform computerized medical maintenance management system (CMMS) programs throughout all of the services [8] and may significantly reduce MTTR (mean time to repair) and increase MTBF (mean time between failure) by locating necessary parts and tools quickly and/or ensuring timely preventive maintenance respectively. Because of the size and complexity of the global medical technology infrastructure that the US military services must support, the savings in money – and response time – can be very substantial and can also save lives.

IV. JEDI EXECUTIVE DASHBOARD ENHANCEMENTS

The latest enhancements to the JEDI project come in the form of graphic Data Mining and Business Intelligence software. Examples of these Strategic Digital Dashboards are shown in Figures 1, 2, and 3 (not real data, codes, or locations). They have been developed through military-funded IDOD) Phase 1 and 2 SBIR projects [12]. As can be see in the Figures, these Strategic Display Dashboards (SDDs) present carefully selected tactical and strategic management information using graphic metaphors like fuel gauges, multi-color bar displays, general meters, and colored lights.

Figure 1 illustrates a very sophisticated dashboard capability that concisely displays a hypothetical example of a blood supply activity at a San Diego Naval hospital. The map on the upper right hand side shows differing Blood

Figure 1 Sample JEDI SDD for blood supply management.

Types (O+, A+, etc) as stacked bars that disclose the storage form of each Unit of blood (Red Blood Cells (RBC), Frozen Plasma, Frozen RBC, etc). The bars are sorted from the highest to the lowest quantity of each available Blood Type. The box near the top of the chart shows the raw data in total Units of blood of each storage form for the first column (O+), broken down in color-coded stacks by storage form. The data displayed in the box can be dynamically controlled by moving the cursor to any desired column.

Continuing in Figure 1, the map on the bottom right hand side uses a Geographic Information System (GIS) in which the national map is used to also show the flight numbers of the next military transports to Washington or Norfolk. The flight numbers could also be replaced with transit times or costs, if desired. On the top left side of the Figure are four gauges: The outer two circular gauges show the number of Units received (left) or shipped (right) today. The two center bar gauges show the total Units available (left) and the current total Units that can be used locally (i.e., total available – total already committed or reserved). In the bottom right hand of the Figure, the inventory is listed by expiration date, to ensure LIFO inventory management. Blood that has expired cannot be used for patient care, and must be safely and legally disposed.

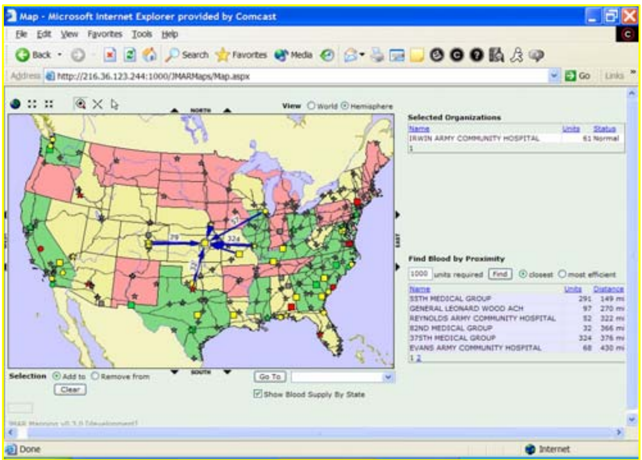

Figure 2. JEDI SDD for blood management.

Figure 2 shows an example of a blood procurement management system. For any selected blood product, the map shows the transit times from the nearest military supply sources with air transport. Because the application is GIS-based, the display can be used to "drill down" to any data level desired. For example, if a source location is clicked, their detailed blood inventory can be explored. If unusual weather or casualty demands are anticipated, other green (available) or red (emergency only) sites can be manually added to the map. Many GIS "layers" can be added onto the map, too, such as highway and waterway routings, private express carrier costs, or public hospital sources and costs (presuming that data is available).

Figure 3 shows a sample top-level executive dashboard. Key tactical and strategic region, country, or global situations can be monitored with the carefully chosen graphs, gauges, and data. In this example, new information, such as procurement from "prime vendors" vs. other sources allows monitoring contract compliance. This can be used as an indicator of quality and cost control, because the prime vendors have been pre-selected as the optimum source for virtually all medical supplies. On the left side, below the prime vendor information are gauges showing the Not In Stock (NIS) situation, a common cause (or excuse) for bypassing the prime vendor contracts. Below the NIS displays are a series of vertical bar displays showing the inspection and preventative maintenance situation for medical devices used in diagnosis or therapy, to ensure readiness and safety. On the bottom left side is a trend and forecasting display, that allows visualization of these trends to facilitate decision-making. Lastly, the overall critical

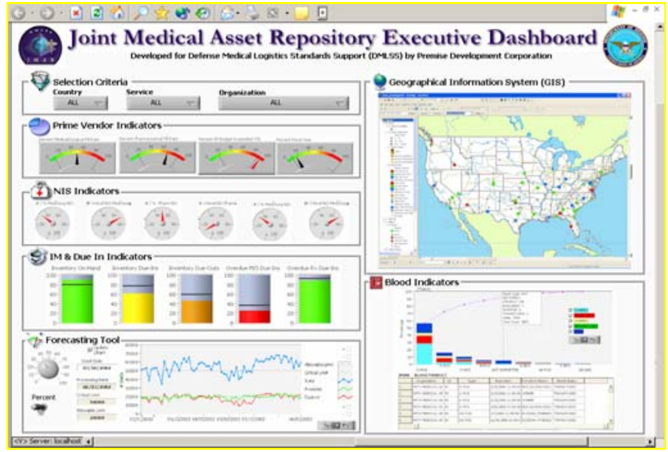

Figure 3. A JEDI SDD for Executive Decision Support.

information about the blood supply is shown on the bottom right hand side of this Executive Dashboard. All of the gauges and graphs can be "drilled" into by clicking different parts of the display, so menus are not needed to get facts quickly.

Lastly, in these SDD systems, an alarm setting can be selected for many of the gauges or graphs. By using these alarms, the SDD can help prevent the operator from having "blinders" on, which may cause them to miss a serious trend because they are focusing on another area or activity. The selected alarm can include visual, audible, or intelligent agent capabilities, too. In this context, the intelligent agent could annunciate alarms using words spoken via a loud speaker or cell phone instead of sounds ("WARNING. YOU WILL RUN OUT OF A-POSITIVE BLOOD IN TWO HOURS!). Furthermore, the intelligent agent software could activate remote pagers or even send email or phone messages to ever-escalating levels, depending on severity.

A. Methodology

The earliest prototypes of this system were developed using an instrumentation simulation software package known as LabVIEW. That software offered an advantage of allowing clinical waveforms such a heart waveform to be displayed side-by-side with business intelligence information (e.g., availability of a cardiologist or a defibrillator.) Further, the LabVIEW software allowed Pareto or other graphs to be displayed from clinical or operational data [7]. When the decision was made to implement dashboard-style displays such as fuel gauges for this military application, a software package known as Business Objects was integrated into the design. Lastly, when maps were needed to enhance the flexibility and utility of the system, the Geographic Information System (GIS) designed and sold by ESRI (www.esri.com) was selected because it was already widely deployed in the military. That GIS also allows very sophisticated interactive filtering and computation (e.g., travel time between two cities), further enhancing users' situational understanding.

Although the prototypes served the purpose for illustrating a wide range of potential user interface designs, this military application did not actually require clinical waveform displays. Therefore, in the final design, LabVIEW was replaced by general purpose programming languages. This change had several advantages, including elimination of the need to transform much non-instrumentation data into

LabVIEW-compatible formats. In addition, the development team decided to create the JEDI own web-services-based meter, gauge, and charting objects using JAVA. This decision was made to offer a smaller, more customized fit to the application, and it also eliminated another external software interface. The ESRI-based GIS was retained for this system, however.

Underlying the entire application is the main Oracle database that was mentioned earlier. The JMAR database and all of the data input and general reporting tools are maintained at a secure military base. Moment-to-moment data management is performed by the purchasing and operations staff of each military service. Updates are done online and by batch continuously, and that all is independent of the JEDI suite of Executive Dashboard tools. All access is done via web browsers through secure Internet links. The "dice and slice" and "drill down" capabilities that the Dashboard user has is implemented by application programs which use Oracle interfaces as necessary to implement real time OLAP.

V. Discussion

SDD's may have applications in real-time battle or emergency activities to help manage "alarm overload." Even in the public health sector, the industry has found that the large number of medical and information technologies deployed in healthcare settings have created a huge cognitive overload for clinicians. The Joint Commission for the Accreditation of Healthcare Organizations (JCAHO, www.jcaho.org) regulatory body has created a new set of alarm management goals for 2003 to begin the process of applying systemic thinking to resolving these problems. Since the SDD software intercepts and translates each incoming alarm, it can be given priority rules to follow. This can ensure that low-risk information-only alarms – e.g., running out of gauze – do not clutter or block crucial alarms like imminent blood shortages.

SDD's for healthcare applications may become indispensable in the future because the convergence of information and medical technologies (Sloane 2001). When all of the clinical and operational data is continuously available, it will become feasible to integrate and graphically transform that information, including alarms, from many, if not most clinically- and managerially-relevant systems. For example, a properly-designed SDD will make it easier for a nurse or doctor to focus on critical, life-threatening alarms instead of delaying care by attending to less pressing alarms. Improvements in this area may make home health care safer and more effective, too, as lay users have great difficulty interpreting the significance, and selecting actions, when faced with multiple simultaneous alarms.

The SBIR-funded SDD project is intended to make the vast JMAR information resource more accessible to the military users at all levels, including inventory managers, financial planners, logisticians, and senior medical officers like the Surgeon Generals. JMAR's centralized information system will allow regression analysis, seasonal forecasting, wartime and catastrophic modeling, Pareto charting and other statistical tools to be mined. The SDD, in turn, will turn that information into usable symbols for rapid and accurate decisions instead of relying on complex, voluminous reports.

VI. CONCLUSIONS

The emerging consensus is to be that the JMAR meta-database has become an invaluable and efficient tool for managing the heterogeneous information systems and databases. It allows strategic and tactical decision making without the cost, complexity, risk, and delay of forcing each military service to convert to a standard platform. It has allowed the military services to synthesize a "single view" from their disparate systems now, not a decade from now. The JEDI interfaces allow rapid, non-procedural data-mining and –visualization capabilities to executive managers up to, and including, each individual Surgeon General for the Army, Air Force, and Navy.

From an operations research perspective, this effort resembles "lean manufacturing practices" that are being developed for healthcare [6]. This is a new area of Health Systems Engineering research, because systems that serve a manufacturer like Dell may, or may not, be adequate or appropriate when considering the life-and-death consequences of potential supply shortfalls following catastrophic events. It is one thing to run out of keyboards or disk drives for a week, but it is quite another story if plasma or critical antibiotics are unavailable. The military's logistics supply expertise is quite extensive, however, and lessons learned should be instructive to the civilian healthcare community.

Although many aspects of the JMAR system design must remain secret, the overall JMAR and JEDI designs and implementation represents a valuable opportunity to explore the challenges and constraints of integrating a large number of heterogonous databases to facilitate executive decision making and to effect administrative efficiencies. Its successful development and evolution offers encouragement for civilian medical supply logistics at a time when healthcare's economic losses and clinical errors continue to be headline news.

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