December 2006

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ABSTRACT

Historically, clinical/biomedical engineering departments in hospitals have lagged in adoption of some of the leading-edge information system tools used in other industries. The clinical/biomedical engineering staff is responsible for ensuring that all medical devices are safe and ready to use, whether actively used in a hospital or buried deep in a stack of containers that the military keeps for emergency deployment. This present application is part of a DOD-funded Phase 2 SBIR grant to improve the overall Knowledge Management and Strategic and Tactical Decision Making for medical technology management issues, and it using strategic graphical dashboards (SGDs) to enhance usability. In general, in the past decade, each individual Air Force, Army, Marine, Navy Surgeon General only had oversight of their individual global medical supplies and resources, but in recent years they have been able to share a global enterprise by using a program called the Joint Medical Asset Repository (JMAR). One important role of this new and novel SGD is to enhance JMAR to allow much better clinical/biomedical enterprise management. The finished product was named JEDI (JMAR Executive Decision Initiative), and it was built on top of JMAR's core Oracle database. JEDI uses custom-written, JAVA-based web-apps to deliver dynamic, integrated, point-and-click graphic objects such as gauges, fuel tanks, and geographic information system (GIS) maps to improve and accelerate decision making. This Business Intelligence (BI) leverages the JMAR data; it allows real-time interactive data-mining tools and provides executive dashboards for rapid data analysis. Using JEDI, the military's global clinical/biomedical engineering resources can now be more efficiently and rapidly reallocated to military, veteran, family, or emergency civilian purposes. The safety, maintenance, and reliability of medical device inventories can now be maintained using lean approaches, with peak demands managed by interactive dashboards that reduce workload and errors.

KEYWORDS

Clinical Engineering, Biomedical Engineering, Health Technology Management, Lean Operations in Healthcare, Medical Supply Logistics, Military Logistics, JMAR, ERP, GIS, Patient Safety

INTRODUCTION

This paper discusses the design and development of an innovative Strategic Graphical Dashboard (SGD) application to improve the Clinical and Biomedical Engineering (CE/BME) support for the US military. In general, CE/BME functions have well-documented for the nearly four decades in numerous textbooks, journals, and conferences (including recent updates by David et al. 2003, Dyro 2004, and Wang, et al. 2006). Today, the major CE/BME responsibilities include healthcare asset management and healthcare technology assessment (David and Judd 2003 and Sloane 2004), scheduling and implementation of routine medical device safety and performance inspections and preventive maintenance (Wang, Sloane, and Patel 2001), risk and safety management (Gullikson 2004), and general department management and quality improvement (Autio and Morris 2004, and McClain 2004)

The CE/BME SGDs were developed to enhance the US Military's executive healthcare technology management decision making abilities of each of the Army, Air Force, and Navy Surgeon Generals. These Surgeon Generals share an integrated oversight and command role for the Joint Military Asset Repository (JMAR) system, which is used to manage all of the military's healthcare technologies (including drugs, medical devices, supplies, facilities, and personnel). JMAR itself is an

Oracle-based relational database system created to integrate very diverse medical supply information from all of the US military services' existing information 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 (HighTechMaui, 2002). In 2002, the military created an SBIR-funded project to add SGD functionality to make the JMAR system more user-friendly, and this project evolved from a Phase-1 feasibility study to a Phase-2 design and development task that became known as JEDI (JMAR Executive Decision Initiative).

The core JEDI system contains significant supply-chain and logistics SGD capabilities (Sloane, et al 2005). Also, however, the final JEDI implementation contains numerous novel CE/BME tools, which are the focus of this present paper. In the following sections we provide a brief system description, and show examples of JEDI's role in healthcare asset management and healthcare technology risk management.

SYSTEM DESCRIPTION

The military's basic logistics and supply chain management issues were not dissimilar to contemporary concerns in other industries. The Surgeon Generals of all four branches wanted to ensure access to any required drug, supply, or medical device regardless of which branch owns or inventories it. Therefore, an important early JMAR module integrated available blood supply information from all Army, Air Force, Marine, and Navy stockpiles. By updating the JMAR knowledge base daily, the Surgeon Generals were able to locate and deploy needed plasma and blood types, and to optimize replenishment activities. By many measures, the military appears to be ahead of many other US healthcare enterprises in using lean manufacturing techniques (Lewis 2001) to improve processes and reduce costs.

As mentioned earlier, JMAR itself is based on a centralized Oracle engine, with a dynamic, customized interface library that integrates 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 to search for required resources. Because all drugs, supplies, and medical devices are integrated into the JMAR system, it serves as a critical dynamic global metadatabase to support the military medical services

The first generation of JMAR used complicated menus to navigate the system and to harvest information. JEDI's SGDs are designed to simplify use by allowing use of interactive graphical symbols for operation, and it reduce JMAR's routine and emergency workloads by making complex data easier to interpret quickly. These challenges are inevitable, because regardless of the cause (e.g., natural disasters, manmade disasters, or battles), the large quantities of product data, large numbers of potentially simultaneous actions, and the large number of information systems feeding the system create a very complex and rapidly-changing information-management challenge. The JEDI SGD project was created to help simplify interaction with, and interpretation from, the vast and dynamic JMAR information resource. JEDI was also designed to make the data much more accessible to the military users at all levels, including newly-recruited inventory managers, non-military financial planners, non-medical logisticians, as well as the senior medical officers like the Surgeon Generals. When JMAR's centralized information system is leveraged by JEDI's data-mining suite, users gain the ability to readily perform rapid and accurate regression analysis, seasonal forecasting, wartime and catastrophic modeling, and Pareto charting and other quality- and service-oriented statistical support. JEDI's SGDs, in turn, convert such information into more usable, easy-to-interpret images, symbols, and maps to enhance rapid and accurate real time decisions.

CLINICAL/BIOMEDICAL ENGINEERING (CE/BME) STRATEGIC GRAPHICAL DISPLAYS (SGD)

Brief CE/BME examples are given below to help illustrate the power that the JEDI SGDs have added. For example many parameters are shown in Figure 1. This management dashboard is designed to help make decisions about the age and value of biomedical equipment. The Total Value and Average Remaining Life of the at the selected medical center has been transformed from simple figures to graphic symbols. The "gauges" on the left side show that the Total Value and Average Life values with respect to at full-scale as well as the number of devices in the sample. On the right hand side, the stacked-bar graphs indicate the value of assets within each condition grouping. The graph line is a Pareto tool, allowing rapid assessment of the 80/20 point that many decisions can be made. It is important to realize that every part of the dashboard is dynamic. The user can select any military base, any type of equipment, any one or more condition codes, etc, and the gauges and charts will immediately be updated with the relevant information. This process is often referred to as "data mining," with the added graphical display enhancements directly and immediately tracking the selected data.

In addition, the user can "drill down" into any part of the graph shown on the right. For example, if the user clicked on the top part of the first stacked bars, they would see the individual pieces of equipment and all relevant data such as purchase

date, purchase price, vendor, etc. This type of interactive dashboard system works like many web browsers, in that one can move forward and backwards when drilling into information, or one can select a menu option to go directly to a different piece of information or function.

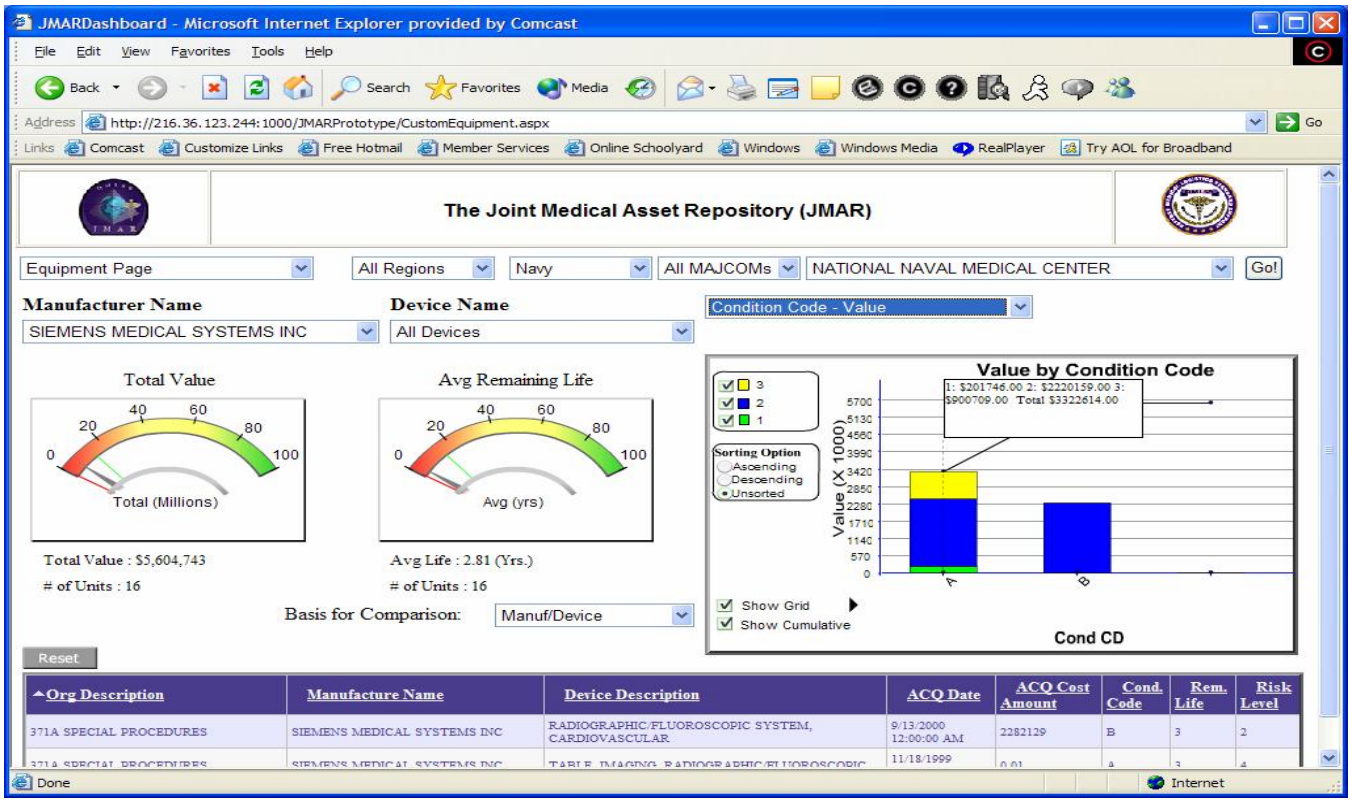
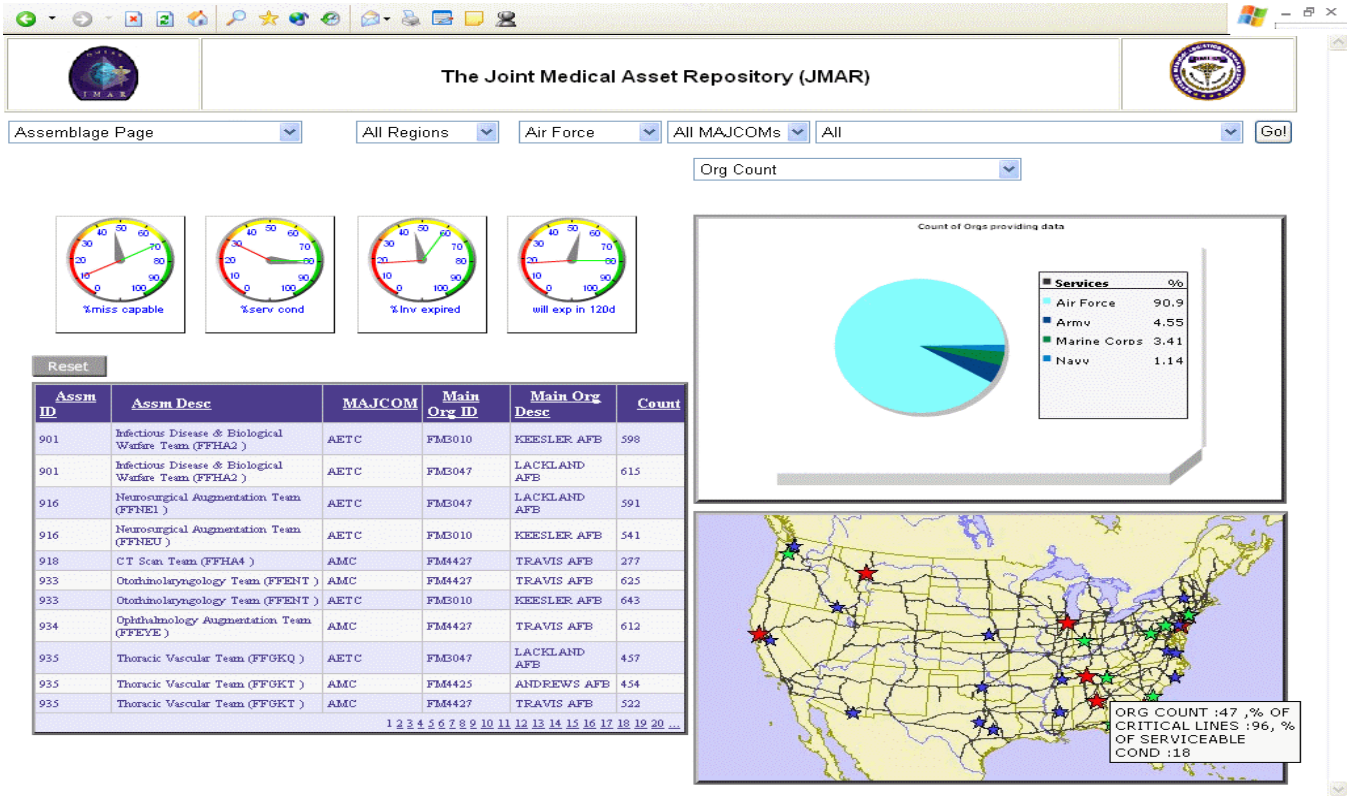


Figure 1 SGD showing medical device asset values by condition codes (A-Excellent; B-Average; C-Fair/Poor)

Figure 2 shows another powerful application that affects "assemblages," which are pre-configured combinations of devices and supplies (e.g., portable x-ray equipment, film, and developers, or surgical tables, lamps, drapes, scalpels, sutures, etc.) Assemblages very important for rapid and effective military deployments because they help assure all necessary technologies are on-hand when needed.. However, managing the large quantity of the individual items in the assemblages is a complex task. Each individual package of drugs or supplies may have unique expiration dates. Similarly, the individual medical devices and subassemblies are likely to have unique safety and performance inspection and preventive maintenance needs, and may even be subject to recalls, updates, or other critical action. The CE/BME teams must track each of the hundreds or thousands of individual items in each assemblage in order to assure that proper schedules are followed. To make matters worse, unlike in a single hospital or regional hospital system, the assemblages themselves are moved around the world in response to emerging military tasks, so tracking down life-critical devices like anesthesia units, x-ray systems, and infusion pumps can be a tremendous challenge.

In the map shown on the right side of Figure 2 are different colored stars (green, red, and blue), indicating the number of serviceable or unserviceable assemblages and their locations. In addition, the system indicates the proportion of the assemblages that are located at Army, Air Force, Navy, or Marine bases, which helps ensure that no opportunities are overlooked. If desired, plane flights, train transit and departure times, driving times, or postal service alternatives can all be overlaid on the map to aid decision making.



Assm ID	Assm Desc	MAJCOM	Main Org ID	Main Org Desc	Count
901	Infectious Disease & Biological Warfare Team (FFHA2)	AETC	FM3010	KEESLER AFB	598
901	Infectious Disease & Biological Warfare Team (FFHA2)	AETC	FM3047	LACKLAND AFB	615
916	Neurosurgical Augmentation Team (FFNE1)	AETC	FM3047	LACKLAND AFB	591
916	Neurosurgical Augmentation Team (FFNEU)	AETC	FM3010	KEESLER AFB	541
918	CT Scan Team (FFHA4)	AMC	FM4427	TRAVIS AFB	277
933	Otorhinolaryngology Team (FFENT)	AMC	FM4427	TRAVIS AFB	625
933	Otorhinolaryngology Team (FFENT)	AETC	FM3010	KEESLER AFB	643
934	Ophthalmology Augmentation Team (FFEYE)	AMC	FM4427	TRAVIS AFB	612
935	Thoracic Vascular Team (FFGKQ)	AETC	FM3047	LACKLAND AFB	457
935	Thoracic Vascular Team (FFGKT)	AMC	FM4425	ANDREWS AFB	454
935	Thoracic Vascular Team (FFGKT)	AMC	FM4427	TRAVIS AFB	522

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 ...

Figure 2 Assemblage management dashboard using map capabilities for all four military services.

CONCLUSIONS

Although many internal details of the JMAR system design are not available for public discussion or disclosure, the overall JMAR metadatabase design and dashboard implementation are useful examples of innovative ways to tackle the challenges and constraints of integrating a large amount of disparate information from a number of heterogonous databases. The JEDI SGD allows easy interactive use by novice and expert users, and it reformats very complicated worldwide data into more readily-interpreted, graphically-enhanced symbols. Together, these characteristics enhance the users' ability to mine this data for statistically valid and important knowledge. The SGDs show critical information it in a format will allow rapid decisions, reduced costs, and better confidence. This SGD development fir the JMAR project is another step in the evolution of complex medical information systems that improve military and civilian medical supply logistics at a time when healthcare's economic losses and clinical errors continue to be headline news. Clinical Engineering departments in individual hospitals may well benefit from implementing such changes in their own systems, as the ongoing diffusion of technology, the rapidly aging population, and never-ending economic pressures demand innovative ways to provide excellent, affordable healthcare.

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