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VistA—U.S. Department of Veterans Affairs national-scale HIS

Steven H. Brown [a,b,*], Michael J. Lincoln [a,c], Peter J. Groen [a], Robert M. Kolodner [a]

[a] *Department of Veterans Affairs, USA*
[b] *Vanderbilt University, USA*
[c] *University of Utah, USA*

Abstract

The Veterans Health Administration of the U.S. Department of Veterans Affairs has a long, successful, and interesting history of using information technology to meet its mission. Each medical center is computerized to a degree that surprises the uninitiated. For example, medical documentation and ordering are computerized at every facility. A sophisticated national infrastructure has been developed to replicate, support, and evolve single-center successes. With advances in inter-facility networking, data sharing, and specialized central support and technical tools, VistA is becoming a single, highly scalable national health information system (HIS) solution. In this paper, we present an historical overview of VistA's development, describe its current functionality, and discuss its emergence as a national-scale hospital information system.
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1. Introduction

1.1. The U.S. Department of Veterans Affairs

The Department of Veterans Affairs (VA) provides benefits to U.S. military veterans and their families. President Lincoln established the National Asylum for Disabled Volunteer Soldiers, the direct antecedent for VA, in 1866. The National Asylum became the Veterans Administration in 1930 under President Hoover, and then was elevated to cabinet-level status by President Bush in 1989 as the U.S. Department of Veterans Affairs. In 2001, the VA budget was approximately $44 billion. The Veterans Benefits Administration (VBA) administered $23 billion of that amount as direct payments for disability compensation, pension, and education assistance. The Veter-

* Corresponding author. Present address: CPEP Office, VA Tennessee Valley Healthcare System, 1310 24th Avenue South, Nashville, TN 37212, USA
E-mail address: steven.brown@med.va.gov (S.H. Brown).

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ans Health Administration (VHA) used its $21 billion budget to operate the nation's largest medical system. In 2001, VHA provided care to 4.2 million veterans out of an eligible population of 25.3 million. Over two-thirds of those served were disabled or had low incomes. VHA currently employs approximately 180,000 healthcare professionals at 163 hospitals, more than 800 community- and facility-based clinics, 135 nursing homes, 43 domiciliaries, 206 readjustment counseling centers, and various other facilities. In addition, VHA is the nation's largest provider of graduate medical education and a major contributor to medical and scientific research. VA medical centers are affiliated with more than 152 medical and dental schools, training more than 80,000 health-related students and residents each year. More than half of the U.S. practicing physicians have received training in VA hospitals. VA is the second largest funder of biomedical research in the U.S. VA also provides healthcare services to active military personnel during wartime and the general population in times of national disasters.

VHA has a long, successful, and interesting history of using information technology to meet its mission. Each medical center is computerized to a degree that surprises the uninitiated. Recently, the Wall Street Journal noted on its front page "In the drive to mine medical data, VHA is the unlikely leader" [1]. For example, medical documentation and ordering are computerized at every facility. During September 2002, providers entered 90.6% of all inpatient and outpatient pharmacy orders nationwide. A sophisticated national infrastructure has been developed to replicate, support, and evolve single-center successes. With advances in inter-facility networking, data sharing, and specialized central support and technical tools, the VA health information system (HIS) known as VistA is becoming a single, highly scalable national HIS solution.

In this paper, we will present an historical overview of VistA's development, describe its current functionality, and discuss its emergence as a national-scale hospital information system.

1.2. Historical overview

VistA, an acronym for Veterans Health Information Systems and Technology Architecture, has its roots in the late 1970s. At that time, the Office of Data Management and Telecommunications (ODM&T) was tasked with VA computerization nationally. ODM&T typically implemented large, centralized, batch transaction-based systems. Developing new systems required a lengthy traditional systems development life cycle process of justification, specification, programming, testing, and deployment. For example, work on a laboratory system began in 1968; in 1982, the system was implemented at eight sites nationwide (Fig. 1). During a 6-year time span, ODM&T implemented the

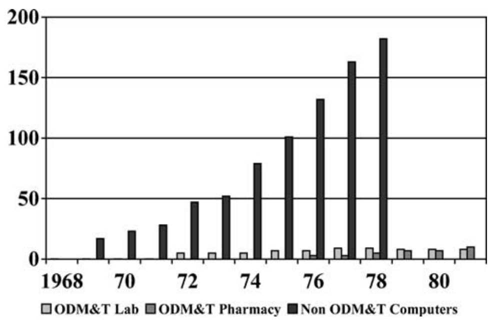

Fig. 1. Comparison of the number of sites implemented with centrally supplied laboratory and pharmacy computing support to the number of field-based computer systems overall. At this time there were approximately 172 VA medical centers in the field. The VA ODM&T was officially responsible for VA computing in the time period shown. ODM&T lab system development started in 1968 and the first site was implemented in 1972. Field systems were most commonly used for research purposes during the time shown.

APPLES pharmacy system at 10 sites. A 1980 paper detailing ODM&T's transactional patient treatment file (PTF) system promised an interactive national solution by 1990 [2]. Navigating the mandated 17 steps between system specification and deployment alone is said to have required at least 3 years [3].

During the same period, VA medical centers began to acquire their own computing systems, largely for research purposes. The first year medical center computers were noted in the VA Administrator's tabulation of computing assets was 1969. The first year when computers at medical centers outnumbered the medical centers themselves was 1978 (182 computers versus 172 sites). Field facilities were exposed to computing for research purposes at a far greater rate than ODM&T-provided services for the clinical enterprise (Fig. 1). Concurrently, facilities began to search for ways to improve efficiency and care through the use of locally controlled computer systems. Facility management and clinical staff were interested in low cost, locally controlled computerization to meet local needs. There was also interest in involving motivated clinical experts in rapid development cycles that bypassed lengthy administrative oversight processes. The Department of Medicine and Surgery (DM&S), the forerunner of VHA, supported computerization efforts outside the purview of ODM&T by creating the DM&S Computer-Assisted System Staff (CASS) Office in 1977.

CASS began operations by reaching out to medical centers with ongoing computerization efforts. Subsequently, they recruited and funded medical center-based MUMPS language programmers. In fiscal year 1978, CASS ordered 19 PDP 11s to support development efforts in the field, and of these, 15 were eventually installed for use in VA medical facilities. The first public description of CASS and medical center computerization innovations was at the second annual Symposium on Computer Applications in Medical Care (SCAMC) in November 1978. A panel discussion entitled "The Veterans Administration: Automated Healthcare Applications" was led by a member of the CASS Office. Architectural principles and building blocks articulated there became central to VA's Decentralized Hospital Computer Program (DHCP): interactive programs, mini-computers, MUMPS, table-driven reusable modules, and decentralized rapid prototype development. Programs to aid medical administration (patient registration, admission/discharge/transfer, and clinic scheduling), mental health, radiology, and dietetics were presented. In December 1978, medical center and CASS Office personnel held a VA computerization-coordinating meeting in Oklahoma City. A number of basic programming and data dictionary standards were agreed upon: strict adherence to American National Standard (ANS) MUMPS; the use of general tools whenever possible to leverage code sharing and reuse; and the use of an active data dictionary to map data and to design code to be portable across computer systems and organizations.

ODM&T responded aggressively to the emerging DHCP. ODM&T dictated that development should stop, dismissed participating employees, forcibly removed computers from hospitals, and slashed the DM&S computer-related budget. Three production systems (one each in admission/discharge/transfer, radiology, and pharmacy) were actually shut down by ODM&T mandate [4]. The graph in Fig. 2 demonstrates that in 1979, ODM&T actually removed more hospital computer systems than they installed (based on pharmacy and lab services installations).

DHCP developers responded by continuing development in facilities outside the immediate grasp of central control. The network of

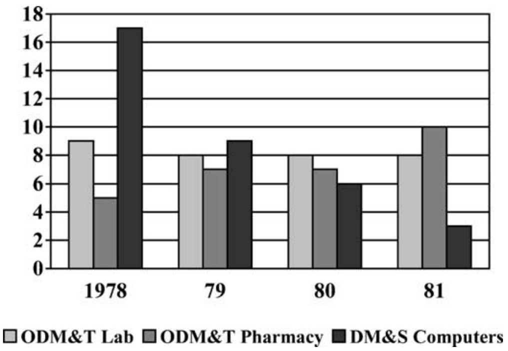

Fig. 2. Facility computerization due to ODM&T efforts between 1978 and 1981. During this period, ODM&T increased pharmacy computerization from 5 to 10 sites (of 172). Laboratory implementations decreased slightly. Interestingly, their efforts resulted in the loss of facility-based computers provided by DM&S in 1978 [4].

developers that emerged became known as the "Underground Railroad" following comments made during a site visit by VA's Chief Medical Director in 1981 to the Washington DC Medical Center. By that time the Underground Railroad developers had produced a working prototype of a hospital information system based upon common tools that included ADT, scheduling [5], pharmacy, lab [6–9], radiology, dietetics [10], pulmonary lab [11,12], and mental health applications [13–15]. These applications were built on a common database using a common data dictionary [16–18]. VA physicians were strong supporters of the decentralized development effort [4] and even congressional interest had been raised.

In a remarkable turn of events, in February 1982 Robert Nimmo, the VA Administrator, signed a policy that gave facility directors the authority to select and prioritize applications to be used at their facilities and endorsed the applications created by the underground developers in the field. Deployment of these applications was given further impetus by the following Conference Report Language for the VA appropriations bill in December 1982: "Any further delay in proceeding with the decentralized (MUMPS) system is not justified and will only result in VA's medical computer system falling further behind the private healthcare industry. The conferees are concerned that VA continue with all deliberate speed to develop plans to use the automated output of the decentralized systems in order to provide system-wide data to the Administrator." A first wave of 25 sites and 11 applications (addressing ADT, scheduling, and outpatient pharmacy) was installed by 1983, with a second wave of 40–100 sites and 17 additional applications in planning [19,20]. By 1985, the DHCP "full core" of applications (adding clinical lab, inpatient pharmacy, and some radiology functions) was installed at 169 sites nationwide. By 1989, the next eight applications (adding dietetics, fiscal/supply, medical center management, medical records tracking, mental health, nursing, radiology, and surgery) were nationally implemented. Congress required that commercial hospital information systems be installed in the other three VA medical centers (eventually accounting for 20% of the yearly central VHA IT budget). In the following section, we will provide an overview of current VistA functionality and architecture.

1.3. VistA present

DHCP system has evolved considerably since its initial deployment in 1983. For example, the implementation of a separate visual layer written in Delphi began the move to a "three-tiered" architecture. As a reflection of this evolution, its name was changed to VistA in 1996. VistA functionality has expanded greatly. At the beginning of 2002, VistA included 99 applications. Despite the changes, much of the production code and underlying system tools remain similar. VistA applications are built on a common data dictionary and database, and use the same core building blocks to provide functions such as security, device access, and communications. In this section, we will examine three of VistA's core components, briefly survey current applications, and present a more detailed look at two new applications: the computerized patient record system (CPRS) and bar code medication administration (BCMA).

1.4. Platforms

VistA is built upon a core of ANS MUMPS, now referred to as "M". MUMPS has been an ANSI standard since 1977 (ANSI/MDC X11.1-1977), and was also adopted as an ISO standard in 1992 (ISO 11756). Different MUMPS implementations have been used to support DHCP/VistA including products from Digital, Micronetics, Intersystems, Greystone and others.

Over the years, DHCP/VistA has been deployed on a number of different hardware platforms. Initially, Digital Equipment Corporation (DEC) PDPs were used. Subsequently, VAX, and Alpha systems with the VMS operating system have been deployed in the field. Smaller VA facilities have used Intel computers running either DOS or Windows operating systems. Several types of UNIX machines have also been used as DHCP/VistA hosts, though not in large numbers. There is even an Open Source Linux version available to run VistA. The most common hardware configuration in VA medical centers at present is Compaq Alpha clusters ranging from 1 to 12 or more processors.

1.5. Core VistA infrastructure

VistA applications are built on top of a common infrastructure. This approach serves several purposes. First, it integrates applications at the database level; common data are shared, not replicated. Second, it makes applications consistent from the perspective of both users and developers. Third, it minimizes maintenance expense. Core code is centrally updated and distributed for use by others. Finally, it provides a stable layer between applications and operating systems to help insulate applications from changes. Three key infrastructure components will be discussed in this section: kernel, FileMan, and MailMan.

The kernel provides shared services for VistA applications, system management tools, and a portability layer between the underlying operating system and application code. The shared services include sign-on and security management, menu management, error processing, a device handler, background task management, software installation, and library functions. System management tools permit optimization of site parameters to meet local requirements, system status reports, performance analysis, and alerting. Examples of site parameters include number of permissible failed access attempts before device lockout, password lifetimes, maximum spooled document size, batched job processor assignment, and task prioritization. The portability layer function provides application programmers with a stable environment despite changes in the underlying hardware, operating systems, or M interpreter.

MailMan is another of VistA's core element with roots in the late 1970s. MailMan's name does not fully describe its functionality. MailMan is a general purpose messaging system that transmits messages such as email and alerts, computer programs, data dictionaries, and data. Senders and recipients can be users or programs within a single facility or anywhere within VHA. MailMan provides programmers with an API so that messaging can be easily integrated into applications (e.g. email report output, or notify staff of particular events).

FileMan is VistA's database management system [21,22]. FileMan was initially developed in the late 1970s and has provided platform-independent database services ever since. FileMan's end-user interface allows easy access to medical center data via pre-stored or ad hoc queries. Programmer services include file creation and management, data archiving and transport tools, and import–export utilities. Client server access was added via the Database Server API and FileMan Delphi (Borland Pascal) components (used in VHA graphical user interface (GUI) applications). FileMan also supports an SQL interface.

The most current VistA Monograph [23] and Pfeil [24] present a more detailed description of VA core infrastructure for the interested reader. In addition, manuals can be found online at http://www.va.gov/vista/VistAdocs/infrastructure.

1.6. Overview of VistA applications

Presently, VistA is composed of 99 packages (see Appendix A for listing). Of these, there are 16 infrastructure applications, 28 administrative and financial applications, and 55 clinical applications. VistA applications perform functions in common with other HISs such as laboratory, pharmacy, radiology, ADT, and scheduling. VistA functions less commonly found in other HISs include police and security, library, and missing patient registry applications. These applications are built upon a common database using common tools and techniques. Describing each application is beyond the scope of this paper. The reader is referred to the VA Web site (http://www.va.gov/vista) for application descriptions, user and programmer manuals, and the software source code.

Attention will be given to two relatively recent applications: CPRS and BCMA. These two applications have transformed VHA through their direct involvement in the day-to-day processes of tens of thousands of doctors, nurses, and ancillary staff.

1.7. Computerized patient record system

CPRS [25,26] represents a dramatic upgrade in the steady evolution of VistA. First, it advances a patient-centered approach to clinical computing rather than a department-centered approach. Patient-centered computing began in the early 1990s with the release of health summary package. Second, it was VA's first concerted effort at client server programming with a GUI. Third, its deployment at the VA medical centers enables a work process shift from paper-based charting to computer-based charting. CPRS includes provider order entry and provider-entered electronic progress notes. Both are often believed to be difficult to deploy. CPRS was initially released in 1996. Its installation was mandated nationally in 1999 and virtually all clinicians in VA now use it.

CPRS is an umbrella program that integrates numerous existing programs for the clinical user. Its tabbed chart metaphor organizes problem lists, pharmacy data, orders, lab results, progress notes, vital signs, radiology results, transcribed documents, and reports from various studies such as echocardiograms in a clinically relevant manner (Fig. 3). Providers using CPRS can enter, edit, and electronically sign documents and orders. Between the fall of 1999 and the spring of 2002, 3.5 million notes and 7.2 million orders were entered into CPRS at the VA Tennessee Valley Healthcare System alone, an organization that provided 468,000 outpatient visits and 130,000 bed days of care in fiscal year 2001. Provider order entry [27–30] is the norm for most types of orders, except when complicated scheduling is required. Nationwide,

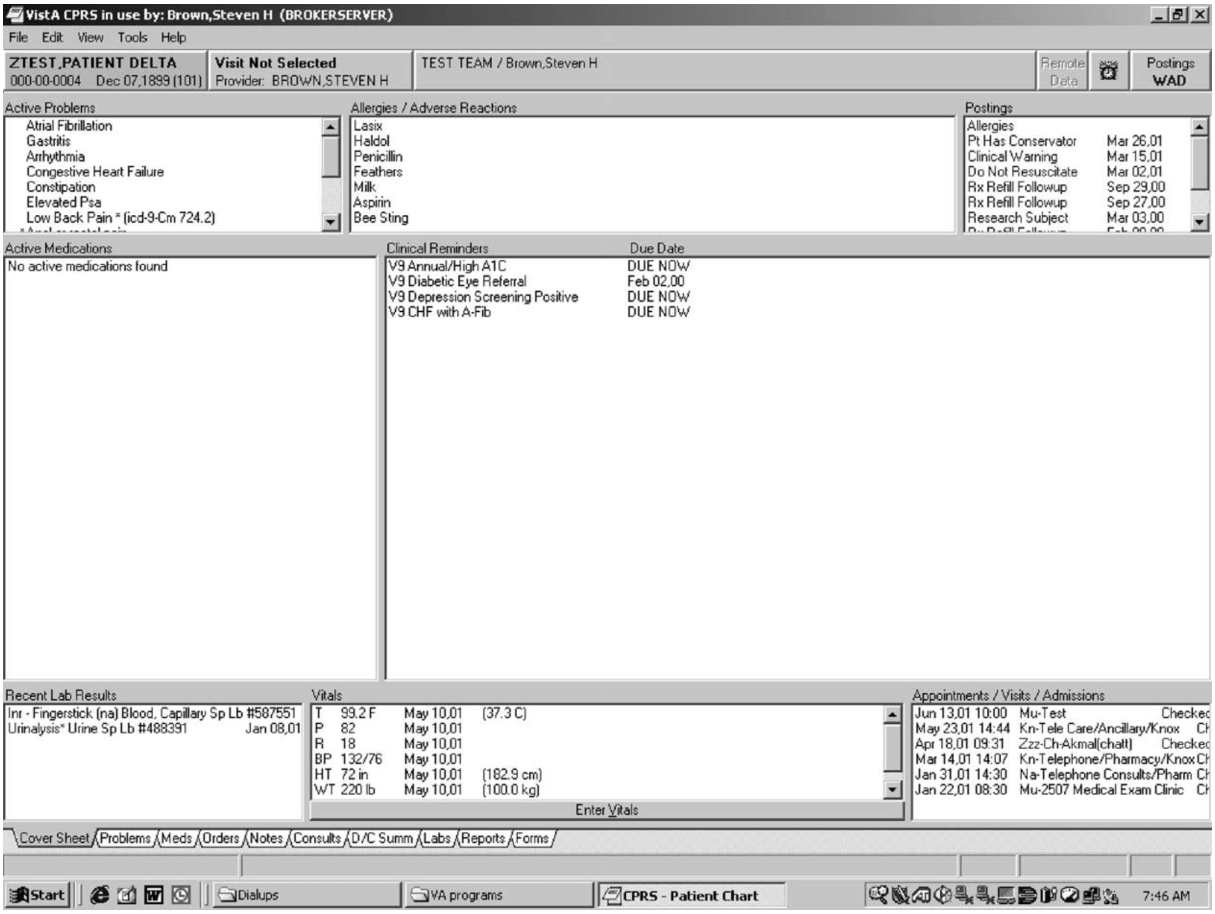

Fig. 3. Coversheet from CPRS.

providers directly entered 90.6% of 3.3 million medication orders during September 2002. Behind the scenes, applications provide order checking, allergy checking, a notifications engine, a clinical lexicon, and clinical reminders. CPRS has had two user interfaces. The "list manager" version was designed to be compatible with existing terminal hardware and to provide a hardware and network transition until sites could provide GUI workstations and network infrastructure for all users. As this transition has been completed, it was recently decided that the list manager version would no longer be supported.

CPRS preparation at VAMC in Nashville, Tennessee unfolded over 30 months and cost about $2 million [31]. Most of these expenses were devoted to the purchase and deployment of workstations [32] and server upgrades. System growth since implementing CPRS has been rapid (Fig. 4). Similar preparations were undertaken at each VAMC across the country.

1.8. Bar code medication administration

BCMA is a bedside application that validates the administration of medications [33].

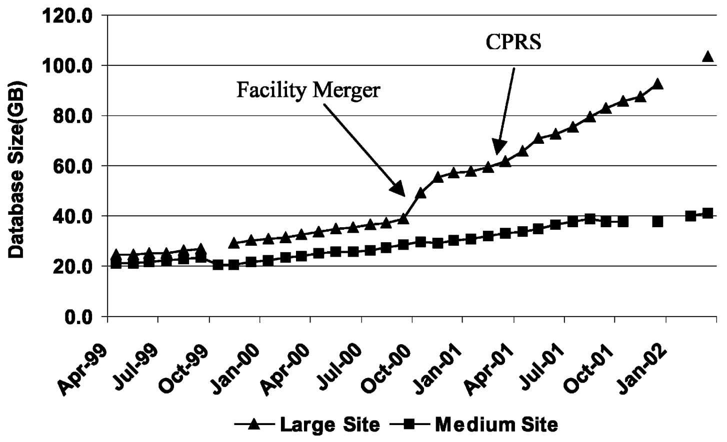

Fig. 4. Thirty-six month measurement of VistA database size at two VA facilities.

It was installed nationwide in the 1999–2000 timeframe. BCMA enables nursing to use a bedside computerized medication administration record (MAR) implemented via wireless laptop computers and hand-held scanners. Patient identification wristbands and nursing staff identification cards are bar-coded with unique identifying numbers. Medications are packaged in plastic containers with bar-coded content identifiers and placed on the medication carts by the pharmacy service. To administer a medication, the nurse scans the patient's wristband, the packaged medication, and the employee id card. The data are sent to an electronic MAR. Advantages include positive verification of patient identification and prescribed medication at the point of care, an immediate alerting capability to prevent the wrong medication from being administered, precise medication administration documentation noting on time, early and late dosing, and automated missing dose requisition. The system was initially developed at the Colmery O'Neil VA Medical Center in Kansas. Medication errors at the Colmery O'Neill VAMC dropped 70% following BCMA introduction in 1994 (Fig. 5).

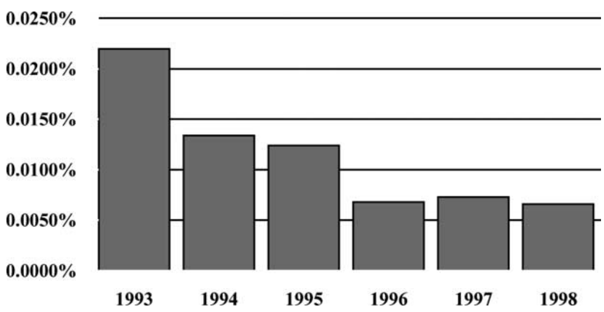

Fig. 5. Medication error rate at the Colmery O'Neil VA Medical Center, the BCMA prototype site. Overall medication errors decreased 70%. They did not drop to 0 because medication errors also arise from medication processes other than administration.

1.9. Adoptions outside VA: evidence of success

VistA is a widely implemented and heavily used hospital information system within VA. DHCP and VistA have also been adopted by a number of organizations worldwide. The other large U.S. federal healthcare providers use DHCP-derived systems. For example, the Department of Defense (DoD) has installed the composite health care system (CHCS), a modification of the "full core" DHCP system provided by a commercial vendor, at each of its 105 Military Treatment Facilities. The Indian Health Service uses the Resource and

Patient Management System (RPMS), which uses many of the DHCP applications, at its facilities and clinics. Appendix B, taken from the Hard Hats Web site (http://www.hardhats.org), lists 31 organizations worldwide that use DHCP or VistA code.

1.10. Open source M and VistA

VistA code is freely available via the Internet (http://www.va.gov/vista/). Presently, the source code for Greystone Technologies M on x86 GNU/Linux is available to the world under an open source license (http://sourceforge.net/projects/sanchez-gtm).

2. Scalability

VistA should be viewed as an emerging national-scale HIS rather than a large number of isolated implementations. Single VistA implementations are scalable in their own right. However, VistA is more than the sum of its individual implementations. An extensive national VistA support structure has been developed for VA that coordinates functions. In addition, data sharing between sites has become increasingly sophisticated in recent years. VA clinicians can now access patients' data from any VA in the country in near real-time without knowing in advance where that information may be located. Beginning in 2002, VA clinicians also have near real-time access to electronic health information, with the veteran's permission, from DoD CHCS systems while the veteran was on active military duty. In this section, we will examine the VA's needs for a national-scale information system, describe the national support structures that bind the VistA community together, and detail several approaches to information sharing that have been developed.

2.1. Why is scalability important to VA?

There are several institutional characteristics of VHA that mandate a sharable, scalable information system. Shared maintenance burden is the most obvious. Munnecke [34] described the benefits of multiple VA sites sharing the maintenance costs for a single locally configurable information system in 1981. Twenty years of experience has validated his observations. More difficult to quantify, but potentially more significant, is the value of enhanced opportunities for data sharing and rollups between sites.

"When you have seen one VA, you have seen one VA" is a common saw within the organization. While somewhat overstated, it does accurately point out that there is significant variability in the size and complexity of VA medical centers. Small facilities provide routine primary care and a subset of specialty services. Larger centers provide expanded services, frequently relying on the clinical expertise of their academic affiliates. Most moderate size facilities provide outpatient services at a number of geographically separated locations. The larger facilities may offer inpatient services at more than one campus as well as highly specialized medical services such as spinal cord injury care and organ transplantation.

VistA implementation sizes reflect the size of the facilities they serve. The largest VistA implementation results from the integration of the databases during the merger of two facilities. In fact, one VistA implementation integrates an entire region (known as Veterans Integrated Service Networks or VISNs). VistA implementations within VA vary in size by more than an order of magnitude. One of the largest sites is the regional implementation for upstate New York (located in Buffalo) that had 152.8 GB of textual data in March 2002. This implementation resulted from the integration of implementations in Albany, Bath, Batavia, Buffalo, Canandaigua, and Syracuse, New York. One of the smallest current VistA implementations is an outpatient facility in Anchorage, Alaska at 10.7 GB of text.

Other institutional factors create a need for interconnected systems that can share data and scale easily. First, veterans do not receive care at only one location. Within the catchment of a single facility, a veteran may go to different campuses or different community-based clinics. Within regions, referral for subspecialty care is common. For example, interventional cardiology and cardio-thoracic surgery are performed at two of six sites in VISN 9. Between regions, referrals are made for highly specialized care and uncommon services such as transplants. Veterans move, visit, and vacation away from the medical centers primarily responsible for their care. Of over 8.5 million "active" patients in the master patient index (MPI), 1.1 million (13%) have information at two sites, 272,000 (3%) have information at three sites, and 1.5% have information at four or more sites. Of the 8128 possible pairs of sites that could theoretically share information about a patient, 8124 pairs actually do. A number of solutions discussed below support patient data transfer between sites.

VA employees tend to move between facilities too. Having very similar systems reduces new job training times and allows an accumulation of expertise over time and between sites. VHA has a hierarchical management system that needs similar reports and rolled up data from subordinate healthcare systems. Facilities face common national drivers of change including newly enacted and changed laws, congressional oversight, Veterans Service Organizations, and other political influences. An example of how many of these drivers of change can influence VistA's need to intercommunicate and scale arises during facility integrations. Between April 1995 and October 2001, 78 VistA systems were merged to form 45 new multi-site VistA implementations. Overnight, the merged system must gracefully handle a major increase in data, users, and processing. To aid in this process, VHA has created a national database integration team to assist merging sites. There are 128 VistA implementations in 2002 (vs. 169 in 1985) as the result of database integrations.

2.2. *Enabling organizational resources*

A number of national resources exist in VA that enable VistA to function as a single entity. The VHA Office of Information (OI) provides central organization for VistA and supports all other VHA national information technology initiatives. OI's 700 employees and 250 contractors work in five functional areas. The Enterprise Strategy Office assesses new technologies and future directions for VHA information systems and services. The Software Design and Development (SDD) Office develops and maintains software for national distribution. SDD lists 116 active projects as of March 2002. The Systems Implementation Office provides national training and support for new systems. The Customer Support Office oversees national support and procurement for all applications and platforms. Finally, the Enterprise Systems Management Office provides oversight of activities that cross organizational boundaries. An associate chief information officer heads each functional office and reports to the VHA chief information officer. Many OI employees are based at the original DHCP development field offices, now called OI Field Offices.

VHA's process to identify and prioritize VistA requirements is one of the support structures that permit VistA to function as a single national-scale system. In 1989, the

Chief Medical Director formed the Information Resources Advisory Council (IRAC) composed of experts from the field for guidance and oversight of DHCP. This committee advised the Chief Medical Director (later the Under Secretary for Health) on information systems and DHCP/VistA development issues. The IRAC charge was to update the Strategic Information System Plan annually, establish specific application requirements groups (ARGs), monitor the ARG process, and recommend the budget for systems implementation. Since VHA was reorganized into 21 regions, the Information Technology Advisory Committee (ITAC) has assumed responsibilities similar to the original IRAC.

ARGs were formulated to further derive benefits from DHCP's long history of field participation. Beginning in the early days of the "Underground Railway," local developers and clinicians have collaborated to envision, develop, and support VistA applications. ARGs worked in management, clinical, and integration domains, and were comprised of systems developers and clinical users from the field. Each ARG then had multidisciplinary expert panels that focused on specific application areas. Today, the successors to the Clinical Expert Panels are focused on application areas such as CPRS, patient care encounters, and clinical reminders. Clinician-experts at local VA sites help developers at the OI Field Offices specify new CPRS functions. One exemplar of this effort culminates each year in "Camp CPRS." Held annually in the spring, this meeting brings together CPRS clinical coordinators, clinical experts and "champions" from local sites, and the national development team.

Requirement and enhancement feedback from end-users to national developers are also provided through a process known as Electronic Error and Enhancement Reporting (E3R), wherein electronic requests for enhancement are submitted to developers. Discussion of E3R requests has traditionally occurred on the VA FORUM mail system. FORUM mail uses the VistA MailMan software and provides an excellent interface for threaded messages that can take the form on ongoing discussions. Similar to the days of the Underground Railroad, progressive VA sites develop software that helps their facility. Software developed in the field is often shared between sites, and is occasionally adopted at the national level. Recent examples of national adoption include BCMA (mentioned above) and CAPRI, a GUI interface into VistA data for VBA compensation and pension examiners.

One of the earliest design visions of VistA was to enable communications among people and computers. MailMan (discussed above) has been widely adopted and heavily used by VA staff. FORUM extends MailMan to permit asynchronous group discussion at a national level. FORUM has promoted the development of numerous special interest communities, most of which are clinical or administrative in nature. FORUM is also used to discuss VistA-related technical and implementation issues. VistA users and developers participate actively. The net result is a highly functional, VistA feedback and support mechanism.

The support structures for the development, distribution, and implementation of VistA software are another way that VistA functions as a national system. VistA code is subject to several technical reviews prior to release that ensure its compatibility with existing systems and programs. Areas that are reviewed include code effects on the data dictionary, code effects on other applications, messaging use, and system resource consumption. VistA packages contain routines, data dictionaries, and application programming interfaces that are updated according to a formal process known as “patching.” The national patch module is a VistA application that helps developers manage the numbering, inventory, and release of patches. Patches are developed in response to E3R submission and an error-reporting request system known as national online information sharing (NOIS). A process called KIDS (kernel installation distribution system) is used to roll up patches into text messages that can be sent to sites along with installation instructions. The patch builds are sent as text messages via email, and the recipient (e.g. a site administrator) can run a PackMan function to unpack the KIDS build and install the selected routines. PackMan monitors the install progress, and then summarizes the installed routines. Optionally, PackMan can send a message back to the patch developer regarding installation status, providing a means for nationally monitoring the progress of patch installations.

Training of VistA users and implementers occurs at the local and national level. Possibly, the greatest training challenge faced to date was the rollout of CPRS. When CPRS was first adopted, most VistA users were familiar with a “roll-and-scroll” character-based interface that worked well on “dumb terminals,” but few were familiar with a GUI. Basic classes in computer literacy and even typing were necessary at early CPRS sites. Most sites followed a national CPRS implementation strategy that focused on implementation committees that were empowered to act in the best interests of successful implementation in their VISN or local VA medical center. VA researchers had previously determined the factors responsible for the success of an earlier version of a provider order entry system [35]. The research found that factors positively associated with successful versus unsuccessful adoption were: (1) early formation of an empowered implementation committee, well in advance of actual implementation, (2) high-intensity user support during early implementation days, and (3) strong support from clinical and administrative leaders. Interestingly, the formation of an empowered user committee early on (rather than as a patch for a partly failed implementation commanded solely from the top down) was the most important factor. This research was incorporated into the national CPRS implementation strategy. An additional factor that seemed to facilitate CPRS implementation was the local ability to craft order sets that aligned with the preferences of the different specialties and treatment settings. As Homer R. Warner, Emeritus Professor of Medical Informatics, has said “Medical Informatics is 10% medicine, 10% computer science, and 80% sociology.” Experiences with CPRS implementation certainly proved this. The support structures guided by national strategy and established at VA medical centers for CPRS proved useful in the subsequent rollouts of CPRS enhancements, clinical reminders, and other clinical applications.

Several national level VistA support programs are active in VHA. One of the most important of these is “Camp CPRS”, which was described above. Another important training is the Information Technology Conference (ITC) that is held annually at Austin, TX. ITC has an intensive schedule of presentations, tutorials, and demonstrations for VA medical center staff, VISN staff, developers, and vendors. Each medical center typically sends at least one clinical application coordinator and a clinical champion in addition to a chief or associate chief information officer. Attendance recently has numbered over 2000.

Several other critical centralized functions exist that enable a national VistA system. The capacity management group provides national system resource monitoring of each VistA implementation. These data are critical for hardware planning and purchase justification. The data presented in Fig. 4 resulted from their efforts. Centralized hardware support provides sites with specifications for appropriately sized and tested VistA servers. On several occasions since the inception of DHCP, hardware has been specified, sized, purchased, and installed at each VistA site with national support. Centralized software support provided by the OI Customer Support Office gives sites with problems access to the nation's leading VistA experts and problem solvers. Without such day-to-day support, VistA systems nationwide would lose functionality and suffer downtime. VHA's national network backbone is another essential piece. Network services enable the data sharing approaches discussed in the next section. Finally, the national database integration team merges VistA systems in response to organizational mandates. We apologize in advance to members of the teams whose services we have failed to mention.

2.3. Enabling enterprise software resources

Two software resources that contribute to VistA's ability to function as a single system are the enterprise MPI and the enterprise single sign-on (ESSO) project.

The original VistA installations used a "Patient File" to store all demographic information about served veterans. Package developers used the U.S. Social Security Number (SSN) as a unique patient identifier. While the SSN is not guaranteed to be unique, the combination of name and SSN has proven to be "unique enough" for a single site. However, this is not the case for a national-scale system.

The master patient index/patient demographics (MPI/PD) package was developed to establish an authoritative national MPI and to track treating facilities for each patient. The MPI/PD Integration Control Number (ICN) (unique national patient identifier), main treating facility identifier (coordinating master of record or CMOR), and list of all treating facilities are shared between all facilities that care for a patient. It is the responsibility of staff at the main treating facility to monitor and approve all demographic information updates for the patient.

The MPI/PD, located in Austin, TX, manages this sharing process. A process known as patient record integration determines when patient demographic information for shared patients changes. When this occurs (e.g. a name change following marriage, an address change), a change message is sent to the patient's CMOR (main treatment facility) to validate the change. The validated information is propagated throughout the national network and to local VistA MPIs (patient files).

The first time a patient is seen at a VA facility, the national MPI is queried to determine if the patient has previously registered at another VA facility. If the patient is new to VA, the Austin MPI assigns a new ICN and registers the patient. If the patient has already been seen at another VA facility, the patient's ICN and demographic data are passed back to the requesting site. An update message is sent to CMOR (main treatment facility) requesting the addition of the new treating facility to the patient's authoritative list. The resulting updated treating facility list is propagated to all the other treating facilities for that veteran. The non-CMOR treating facilities all "subscribe" to patient data changes that are broadcast by the CMOR and other treating facilities. These registration and query processes against the national MPI all occur in real-time. In the event that the national MPI is not available, a temporary ICN is assigned that is later resolved against the Austin database.

ESSO is an ongoing project within VHA. Presently, users are required to maintain usernames and passwords for each system they are permitted to access. A single VistA username–password combination is manageable for most users. However, because VHA has moved to Windows NT clients for GUI programs, NT level logon has become mandatory. The CPRS GUI client can be used to access VistA clusters anywhere on the VA network. However, site-specific user accounts are required. For users who routinely access data from multiple medical centers, such as subspecialty referral care coordinators, managing multiple accounts and passwords is difficult. ESSO's goal is to allow users to access any systems they are authorized to use with a single authentication step. A limited version of ESSO has been deployed for VBA claims specialists across the country, and a fully functional version is being developed.

2.4. Data sharing issues that relate to scalability

The possible goals of "data sharing" are diverse. VA has organizational need to share, compare, and roll up data regionally and nationally. At the simplest level, this means the sharing of textual information for human consumption only. At a more complex level, this means the sharing of computer-processable coded data for decision support and aggregation based on machine-determined similarity. VistA routinely accomplishes the former. The latter has been demonstrated in prototype.

One of the design goals of the initial DHCP developers was flexible local configuration. This was achieved by giving local users control over the content, but not the structure, of data dictionaries. Thus, each site has local drug definition files, local lab definition files, and local document title files [36]. This flexibility allows sites to meet local users' needs and is one reason why DHCP/VistA has been so successful. On the other hand, local variability in data dictionaries presents problems for clinical data aggregation between sites, which was not a requirement 20 years ago.

Data sharing is critically important for patient care and management functions within VHA. VistA has three production applications and at least one prototype application designed to meet this need. Communications employ protocols standardized at different levels of abstraction including TCP/IP, MailMan, Health Level Seven (HL7), and remote procedure calls (RPCs). Patient data exchange (PDX) was an early effort that enabled communications between sites. Authorized users of PDX can request a patient's data from specified sites. The request-receiving site can elect to answer the request automatically, or to review it manually prior to responding. Demographic and eligibility data can be uploaded into the requesting site's VistA system. Other PDX information, such as prescriptions, cannot be integrated into the requesting site's VistA system and is typically printed out for review. An unsolicited "push" of data between sites is also possible. Data "push" is useful when patients notify their current medical center of their plans to move their care to another site. PDX response time varies from minutes to weeks. Long delays can occur when the manual request review process is delayed.

Network health exchange (NHE) is a second production application for data sharing within VistA. NHE is made available to all clinical users (unlike PDX) and does not require approval from the request-receiving site. As a result, data are typically returned within minutes to the requesting clinician. Like PDX, NHE users must know the sites they want data from in advance. NHE results are standardized free-text reports that cannot be uploaded into the receiving site's VistA system. The requesting clinician can print or view onscreen the returned standardized report. NHE is popular because access to its services is broadly granted and results are promptly returned.

CPRS remote data views (RDV) is the third and most recent VistA application for sharing clinical data between sites. RDV is integrated into the CPRS GUI client application and is made available to all CPRS users. RDV consults the local "treating facility list" file each time a patient's electronic chart is opened in order to locate other facilities where the veteran has been treated. The "treating facility list" file is updated nightly from the enterprise MPI. The application informs the user when remote data are available and allows them to request a wide variety of clinical reports. RDV can partially merge data based on report type, but lacks the semantic foundations for true interoperation. RDV functionality has recently been adapted to serve the first increment of Federal Health Information Exchange (FHIE), formerly known as the Government Computer-based Patient Record (GCPR), as described below. RDV is a highly useful and rapidly responsive system that directs the requesting clinician to their patient's data wherever it may reside on another VA system or a Federal partner's system, e.g. DoD.

One approach to resolve the semantic problems caused by site-specific data dictionaries is to use a national standard dictionary as an interlingua. The VA national drug file (NDF) is such an interlingua. NDF contains approximately 13,000 unique clinical drugs (e.g. "ampicillin 250 mg tablet") mapped to approximately 87,000 purchasable drug products (including manufacturer and packaging information). Medical centers map their local formulary entries to NDF (e.g. "Nashville_Ampicillin 250 mg tablet" is equivalent to "ampicillin 250 mg tablet"). Outpatient prescriptions are filled by translating the local name for a drug to a national name for the same item, and then transmitting the national name to one of seven automated mail-out pharmacies around the nation. This solution solves the problem of semantic identity. A prototype project named remote computable access to pharmacy (ReCAP) demonstrated how patient drug information from one site could be transferred to another VistA system on demand, and used for decision support during order entry. ReCAP used NDF as an interlingua to achieve semantic interoperability. ReCAP was built on a combination of HL7 messaging and CorbaMed clinical observation access services (COAS).

VHA is interested in sharing data with other government agencies as well as between its own facilities. The administration is participating in several initiatives designed to facilitate inter-governmental exchange of health data. The GCPR initiative was a collaborative project between the DoD, Indian Health Service, and Department of Veterans Affairs that started in 1998. The first increment of GCPR has been renamed FHIE. FHIE was implemented in all VA facilities during the summer of 2002. The first increment transfers text-based data from DoD to VA in the form of HL7 messages. The VA CPRS client can access these data using the remote data views function. Subsequent FHIE increments will add additional DoD data (currently limited to pre-separation data for privacy reasons) and enable multi-directional data transfers.

2.5. *Scalability as a series of tradeoffs*

VistA is a highly scalable and interconnected hospital information system installed at 128 VA sites. A number of national support infrastructures are beginning to permit VistA to be viewed as a single entity. For example, remote data views can rapidly locate and bring data to the desktop from anywhere in the country. From this perspective, adding a new medical center to the national whole is similar to adding a new processor to a local cluster.

Scalability has come as the result of a series of design and implementation tradeoffs. One of the earliest philosophies of DHCP was to permit a high degree of local configuration flexibility, while exerting only the minimal necessary central control. This was accomplished by careful design of general-purpose tools, and rapid development cycles with end-user feedback. The choice to permit local control of data dictionary content contributed to VistA's acceptance. However, as our information systems evolve into a national network, this decision is proving to be an impediment to comparable and computer manipulable data.

Another tradeoff that was addressed by the DHCP developers was to encourage local development and subsequent sharing in favor of a centralized development process. An astonishing number of applications were rapidly designed, developed, and implemented nationwide (28 in 5 years) as a result of this choice. The choice of using a common database, programming conventions, and technical review has provided sufficient guidance to ensure that applications function in harmony. Using dissimilar database services would have resulted in disintegrated incompatible "stove pipe" systems such as those found in many other institutions today.

Central versus local control of hardware configurations is another tradeoff that relates to scalability. In this case, VA has centrally purchased VistA computers on several occasions, but permitted local sites to add hardware (from an approved list) as needed. This pattern has made it possible for sites lacking large-scale funding or computer systems expertise to adopt and continue to use VistA. Printers, workstations, and other ancillary devices have been left under the site's control.

Growth has been accomplished via increasing the size of existing implementations, by cookie cutter replication of implementations, and via the addition of specialized services. Individual implementations have grown steadily over the years. Since the deployment of CPRS, the rate of data accumulation has increased dramatically as more of the medical record data are captured electronically. For example, the amount of stored data at Nashville has nearly doubled in 15 months (Fig. 3). Growth via creation of entirely new systems was initially the major route. In recent years, this trend has reversed as the result of facility integrations. We now have 128 VistA sites rather than 169. Growth via the addition of specialized services is exemplified by the national MPI. This added functionality ties sites more tightly into a single unit. ESSO is another such resource.

The number of unique sites maintaining data was a choice made early in DHCP's development that has undergone subsequent revision. Initially, virtually all VA medical centers had a DHCP implementation (1985–1996). Facility integrations and VISN data centers have subsequently reduced the number of VistA implementations. The "right" balance of local maintenance and equipment costs with network performance and communications costs is likely to change continually into the foreseeable future based on technologic advances and organizational priorities. In any case, reliable network services are essential for VistA to function as a national HIS.

Finally, another important tradeoff contributing to scalability pits big-bang deployment versus continual evolution. Clearly, following initial deployment in 1983, VA has elected a process of continual evolution. VistA has grown from the initial 28 applications to 99 applications in the current distribution.

3. VistA in the future

VistA has evolved during the past 5 years to accommodate a greater proportion of outpatient care delivered in VHA. VistA applications such as the primary care management module (PCMM) and clinical reminders have become increasingly important. Development of the CPRS GUI has greatly increased clinician acceptance of VistA electronic records. At most VistA sites, virtually all clinical documents are entered and accessed using CPRS including all forms of clinical notes, physician orders, consultations, procedure reports, and radiology and pathology examinations. Most sites maintain only a single notebook of wet-signed patient documents (e.g. procedure consents and living wills) for all inpatients on a particular floor or ward. All remaining forms of documentation are electronic. At most sites, no legacy paper charts are pulled for outpatient clinic visits. This revolution in medical documentation is quite simply without precedent in a large and diverse healthcare system such as VHA.

VistA faces important challenges in the future, and will be implemented using a strategy we call Health*e*Vet. While CPRS has successfully abstracted the user presentation layer from the tightly integrated VistA applications, a variety of other issues remain. One of the most important is the necessity to separate the data repositories from the underlying VistA applications. Another is the necessity to standardize on formal reference terminologies that yield computable and comparable data across the VHA organization. A third issue is whether to retain the M database environment, or whether to migrate to a relational or object-oriented technology. As in the past, VA will seek to adopt data and communications standards that are open and publicly available.

The first migration challenge is to abstract the data repository layer from the underlying VistA applications, just as the CPRS initiative successfully abstracted the user presentation layer. Currently VistA applications store their data in M "globals" located on pre-allocated disk sections called volume sets. These globals, which are local to each VistA installation, grow as additional patient data are added. Performance degrades with current systems when DSM volume sets (disk storage) exceed 16 GB. Three factors increase this limitation's urgency. First, data accumulation has accelerated since the implementation of CPRS. Second, VHA has a record retainment requirement of 75 years after the last patient visit (even after the patient has died). Third, physicians demand availability of all VistA records online, immediately, even if the patient has been inactive. The availability of excellent computerized medical records has driven demand. This is one reason why VHA is planning a national health data repository (HDR). HDR will reduce the storage of clinical data at the individual VistA implementations. CPRS will retrieve most or all clinical data from HDR rather than from local VistA systems. The result will be a reduction in workload on M servers and centralized responsibility for records retention.

Complicating the HDR initiative is the fact that VistA permits local sites to determine data dictionary entries for clinical data. For instance, lab test names and drug names can be locally idiosyncratic (e.g. "Dr. Mike's Miracle Enema Mix"). Nonstandard names have impeded VHA's ability to integrate sites, transfer data between sites when patients move, perform clinical research across sites, and query clinical data for regional or national administrative purposes. The decision support system (DSS) is a good example. DSS is a national database composed of selected local site clinical and financial data that allows aggregation of patient services by provider types and clinic types, and allows queries for mission critical laboratory values such as hepatitis C results. A great deal of time is spent at each VistA site mapping "DSS extracts" of local files such as lab, pharmacy, and clinic names to the standard DSS forms. Despite the time invested, the DSS system still suffers from mapping errors and non-comparability of results. Another complication for the HDR approach to resolve is that network reliability and bandwidth to each and every healthcare delivery site are variable.

Another important initiative, termed Health*e*People, is a generalization of VA's Health*e*Vet strategy. The Health*e*People (Federal) strategy will result in federal adoption of common data, communications, architecture, security, technical, software standards in federal healthcare information systems, and a growing core of shared software to be used within each federal healthcare provider agency. The end result will be full interoperability among the separate federal healthcare information systems. For example, a native American may receive childhood care in the Indian Health Service, be treated as an adult serviceman in Military Treatment Facilities, and receive care from mid-life on from the Department of Veterans Affairs. This veteran may later enroll in a National Institutes of Health study for cancer treatment. Health*e*People (Federal) contemplates establishing interoperable databases for registration, enrollment, and eligibility to correctly identify federal healthcare system patients. The broader Health*e*People initiative is designed to share the benefits of this standardization and these information systems with other non-federal entities as appropriate.

4. Conclusion

The Department of Veterans Affairs has a long and successful history of using information technology to meet the Department's mission. DHCP was highly innovative and successful from its initial implementation. DHCP evolved as new needs and technologies emerged. Accordingly, its name was changed to VistA in 1996. Since then, computerization has played an increasingly important role in veterans' healthcare delivery. VA providers now use CPRS and BCMA for the day-to-day and minute-by-minute care of their patients. In the future, VistA will continue to evolve as demands and opportunities dictate. The next challenges center on semantic interoperability, and extending our information provision models to meet veterans' consumer health information needs. These challenges will doubtlessly be met with the same vigor and creativity that have characterized past successes.

Acknowledgements

VistA is the result of the dedicated efforts of thousands of VA employees across the country. Because of their vision, hard work, and sheer tenacity, VistA is a reality and veterans have been better served.

Appendix A: VistA Applications 2002

Infrastructure Applications:

1) Duplicate Record Merge: Patient Merge

2) Health Level Seven (HL7)
3) Kernel
4) Kernel Toolkit
5) List Manager
6) MailMan
7) Master Patient Index (MPI)
8) Master Patient Index/Patient Demographics (MPI/PD)
9) Minimal Patient Dataset (MPD)
10) National On-Line Information Sharing (NOIS)
11) National Patch Module
12) Network Health Exchange (NHE)
13) Patient Data Exchange (PDA)
14) Remote Procedure Call (RPC) Broker
15) Survey Generator
16) VA FileMan

Administrative and Financial Applications:

1) Accounts Receivable (AR)
2) Automated Information Collection System (AICS)
3) Automated Medical Information Exchange (AMIE)
4) Automated Safety Incident Surveillance Tracking System (ASISTS)
5) Clinical Monitoring System
6) Current Procedural Terminology (CPT)
7) Decision Support System (DSS) Extracts
8) Diagnostic Related Group (DRG) Grouper
9) Engineering
10) Equal Employment Opportunity (EEO)
11) Equipment/Turn-In Request
12) Event Capture
13) Fee Basis
14) Generic Code Sheet
15) Hospital Inquiry (HINQ)
16) Incident Reporting
17) Income Verification Match (IVM)
18) Integrated Funds Distribution, Control Point Activity, Accounting And Procurement (IFCAP)
19) Integrated Patient Funds
20) Integrated Billing (IB)
21) Library
22) Missing Patient Registry
23) Occurrence Screen
24) Patient Representative
25) Personnel And Accounting Integrated Data (PAID)
26) Police And Security
27) Record Tracking
28) Voluntary Timekeeping

Clinical Applications:

1) Admission, Discharge, Transfer (ADT)/Registration
2) Computerized Patient Record System (CPRS)
   a) Adverse Reaction Tracking
   b) Authorization/Subscription Utility (ASU)
   c) Clinical Reminders
   d) Consults/Request Tracking
   e) Health Summary
   f) Hepatitis C Extract*
   g) Problem List
   h) Text Integration Utilities (TIU)
3) Dentistry
4) Dietetics
5) Home-Based Primary Care (HBPC)
6) Immunology Case Registry (ICR) Overview
7) Intake and Output
8) Laboratory
   a) Anatomic Pathology
   b) Blood Bank
   c) Electronic Data Interchange (LEDI)
9) Lexicon Utility
10) Medicine
11) Mental Health
12) Nursing

13) Oncology
14) Patient Care Encounter (PCE)
15) Pharmacy
    a) Automatic Replenishment/Ward Stock (AR/WS)
    b) Bar Code Medication Administration (BCMA)
    c) Consolidated Mail Outpatient Pharmacy (CMOP)
    d) Controlled Substances
    e) Drug Accountability/Inventory Interface
    f) Inpatient Medications
    g) Inpatient Medications—Intravenous (IV)
    h) Inpatient Medications—Unit Dose (UD)
    i) National Drug File
    j) Outpatient Pharmacy
    k) Pharmacy Benefits Management (PBM)
    l) Pharmacy Data Management (PDM)
    m) Pharmacy Prescription Practices (PPP)
16) Primary Care Management Module (PCMM)
17) Prosthetics
18) Quality: Audiology, Speech Analysis, And Reporting (QUASAR)
19) Radiology/Nuclear Medicine
20) Remote Order Entry System (ROES)
21) Resident Assessment Instrument/Minimum Data Set (RAI/MDS)*
22) Scheduling.
23) Social Work
24) Spinal Cord Dysfunction
25) Surgery
26) Risk Assessment
27) Veteran Identification Card (VIC)
28) VistA Imaging System
29) Visual Impairment Service Team (VIST)
30) Vitals/Measurements
31) Women's Health

Appendix B: VistA Adopters outside of VA

City of Berkeley Health and Human Services.
Department of Defense, Consolidated Health Care System (CHCS).
Department of Veterans Affairs.
Epidemiological Laboratory at Brooks Air Force Base, TX.
German Heart Institute, Berlin.
Government hospitals in Bogota, Colombia.
Group Health Northwest.
Health Partners, Minneapolis.
Helsinki University Hospital.
Indian Health Service.
M Technology Association.
Memphis International, Inc.
Minnesota Department of Health.
Nakasero Blood Bank in Kampala, Uganda.
National Cancer Institute, Cairo.
Obafemi Awolowo University Teaching Hospitals, Nigeria.
Pioneer Data Systems.
Robert Morris College.
Science Applications International Corporation.
Sea Island Systems, Inc.
SKM Cancer Hospital and Research Centre, Pakistan.
Soza.
TB Control Division, Department of Public Health—City and County of San Francisco.
Texas Cancer Data Center.
University Hospital of Kuopio, Finland.
University of Wurzburg, Germany.
Veterinary Teaching Hospital, University of Tennessee.
Western State Hospital, Washington State.
World Health Organization's Collaborating Center on AIDS and Sexually Trans-

mitted Diseases, University of Nairobi School of Medicine.
WV CONSULT, West Virginia University.
XORS, Inc. (Czech Republic).

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