Strategic Options for the Modernization of the Indian Health Service Health Information System

LEGACY ASSESSMENT

FINAL REPORT

14-May-2019

Revision History

Revision	Date	Author(s)	Description of Change(s)
1.0	03-May-2019	Legacy Assessment team	Initial Version
2.0	14-May-2019	Legacy Assessment team	Revised to incorporate suggestions and feedback from key stakeholders.
3.0	12/04/2019	HHS OCTO	Clearance Rewrites

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1.0 Executive Summary

On May 17, 2018, the Department of Veterans Affairs (VA) announced a decision to replace the legacy VistA electronic health record (EHR) with a commercial off-the-shelf (COTS) solution over the next ten years. The migration to a COTS solution and retirement of VistA has implications on the long-term viability of the Indian Health Service (IHS) Health IT system, the Resource and Patient Management System (RPMS), which relies upon core modules from VistA EHR. This fact, combined with the independent and well-recognized need for RPMS modernization based on feedback from the RPMS user base, IHS Programs and Offices, has led to the modernization research collaboration between the Department of Health and Human Services (HHS) Office of the Chief Technology Officer (OCTO) and the IHS, of which the Legacy Assessment is a component.

This executive summary presents the findings of the in-depth RPMS assessment, including an evaluation of the people, processes and technology that are part of the current RPMS ecosystem, designed to answer whether RPMS can be modernized. The Legacy Assessment team took a human-centered design (HCD) approach to assess whether RPMS can be modernized. This assessment leveraged code reviews, technical evaluation, interviews, observations, literature review, and feedback from stakeholders to assess the findings and recommendations.

This document is designed to answer two questions:

1. ***Can RPMS be modernized given its current state, functional scope, and known risks and constraints****?*
2. ***If RPMS can be modernized, what are the options to achieving such modernization while protecting the confidentiality, integrity, and availability of the longitudinal patient healthcare data stored in the system****?*

The terms ***modernization***, ***optimization***, and ***stabilization*** are defined below as used in the context of this legacy analysis.

Modernization is the continued process of updating, converting, or replacing a legacy technology system to improve business processes and maximize user agility.

Optimization is the process of modifying a legacy system to enable it to work more efficiently, use fewer resources, and provide the needed functionality. In this study, additional desired functionalities include but are not limited to interoperability, patient access to a personal health record, and improved usability and reporting.

The ***stabilization*** of a legacy system ensures that the current configuration will remain reliable and functioning for approximately the next 3-5 years.

The definition of IHS Modernization developed by the Legacy Assessment team is:

An organizational endeavor which brings a health IT system to a new state that is continuously evolving. It is people-and process-centric; it is adaptive, progressive, and aims to rethink and redefine the problem to evolve a system and its capabilities to deliver value to its users and stakeholders. It is resilient, and able to withstand forces from within and without. It is synergistic with the clinical vision for the healthcare system.

The findings of the Legacy Assessment are stated below. Please also refer to Section 5 - Opportunities, Section 6 - Required Steps, and in particular Section 6.3 - Summary Statement for more detail.

The IHS RPMS HIT system can be modernized — modernization will enable the system to provide critical information technology support for health care services to American Indian and Alaska Native people without relying on services provided by the VA. The process to modernize, however, is neither straightforward nor simple, regardless of how it is approached. Organizational maturity and a leaning into technology to meet the needs of the health care team as well as the population will be required to be successful.

An IHS RPMS HIT modernization effort is not a trivial process. Systemic challenges across all of the IHS ecosystem currently prevent providers, facilities and the organization from leveraging technology effectively. Success will require clinical as well as technical engagement, with leadership resting within

both groups. Most importantly, regardless of the final determination made by leadership, the modernization path forward cannot be assumed to be short.

The imperative to modernize grows each time it is delayed. Eventually, the ability to transfer knowledge from legacy experts to modern coders will go away, as the window of overlap shrinks. After years of maintenance deference, RPMS is approaching a crisis. The Required Steps for IHS Modernization section provides a potential pathway to IHS HIT modernization.

Findings
• The underlying RPMS code base will be unsupportable over the next decade
• The current user experience (UX) is disjointed across several applications; moreover, current user experience design (UXD), or lack thereof, leads to a high and constant risk of user error
• The system cannot be reliably and sustainably supported by the available infrastructure (hardware, network) with its present infrastructure constraints
• Currently available support, training, and adequately skilled resources are insufficient

Recommendations
• ***By establish cross-functional teams and implement a human-centered processes to address the underlying architecture; RPMS is a candidate for wrap and renew transformation;***
• Develop user-centric training, communities of practice, and centers of excellence, informed by organizational maturity models, can improve the delivery of training and support to improve operations with the existing system in the near term
• Develop and implement an infrastructure and network modernization approach to successfully meet the identified near term needs; initiate an approach to long term sustainment
• Identify M programmers that can be available to support the RPMS core

Strategy
• Develop a vision and plan of action for a new RPMS architecture where the application is cloud-based and logic is decoupled from RPMS packages
• Consolidate and stabilize RPMS with a response team of developers, potentially taking advantage of the current flow of outgoing VA VistA developers
• Simultaneously, create and support cross-functional and cross-disciplinary teams within the IHS to ensure application stability throughout the renewal process
• Include agile software engineering teams that utilize automated testing, conduct ongoing security reviews, and that can determine precisely when to use COTS based on a high knowledge of team capacity and product offerings
• Develop a methodology for renewal that includes human-centered design and iterative learning

Summary of Findings

Assessment Score: 0 Inadequate Not fulfilling all basic requirements. Needs significant work to become operative.
Assessment Score: 1 Operative Functional, but requires significant effort and workarounds that increase workload.
Assessment Score: 2 Up to Date Fulfills contemporary expectations for technology.
Assessment Score: 3 Modernized Exceeds current expectations for technology, future proof.

See the Assessment section for more information about the Legacy Assessment scoring system and for expanded assessment results.

User Experience			
Provider Experience Can doctors, nurses and other care providers provide adequate care using RPMS?	**Administration Experience** Can administrative staff perform their jobs with operational efficiency and accuracy using RPMS?	**Leadership Experience** Does leadership have the tools and insights they need to run IHS facilities?	**Patient Experience** Are patients enabled to proactively seek care, and understand their health?
Operative	**Inadequate**	**Operative**	**Inadequate**

Organization		
Support Is there sufficient systemic support for Tiers 1-3, ticketing, and enhancements?	**Training** Is there adequate system training across IHS?	**Availability of Skills/Expertise** Are there sufficient qualified, skilled IT professionals and are they retained?
Inadequate	**Inadequate**	**Inadequate**

Architecture					
RPMS Code Are the languages used to build RPMS effective and sustainable?	**Data Sharing & Portability** Can data flow seamlessly within RPMS?	**Interoperability** Can systems and applications external to RPMS exchange information in a seamless way?	**Health Information Exchange** Are all RPMS sites communicating between providers and patients and integrating data received from multiple facilities over multiple encounters?	**Application Integrations** Can RPMS applications integrate with themselves and other systems with relative ease?	**Extensibility** Does RPMS's system architecture account for future growth?
Inadequate	**Inadequate**	**Inadequate**	**Inadequate**	**Inadequate**	**Inadequate**

Telemedicine	Public and Population Health	Personal Health Record
Is there a patient-centered approach to care established that provides care when and where it is needed?	Does RPMS meet the needs of public health providers?	Do all RPMS sites provide a patient portal that integrates data and enables patient scheduling and interaction?
Inadequate	**Inadequate**	**Inadequate**

Infrastructure and Maintenance				
Hardware Is the hardware sufficient for the system needs and it is adequately maintained?	**Network** Are the network capabilities sufficient and consistent throughout the RPMS service area?	**Software Maintenance** Is the software properly maintained and are available updates/patches installed when available?	**Database Development and Support** Are database configurations up-to-date, current and stable?	**Current Overlap Between VistA and RPMS** Are the VA applications used in RPMS stable? Are they adequately maintained?
Operative	**Inadequate**	**Inadequate**	**Inadequate**	**Operative**

Security and Compliance	Regulatory Compliance
Is there a strict security policy established? Does the site support a single sign-on? Is there multi-factor authentication?	Can RPMS generate performance measures as well as Versa HRSA reporting? Is RPMS ONC2015 certified?
Inadequate	**Inadequate**

2.0 Introduction to IHS and the Resource and Patient Management System

2.1 The RPMS Modernization Question

2.1.1 Questions to be Answered

This document is designed to answer two questions:

1. **Can RPMS be modernized given its current state, functional scope, and known risks and constraints?**
2. **If RPMS can be modernized, what are the options to achieving such modernization while protecting the confidentiality, integrity, and availability of the longitudinal patient healthcare data stored in the system?**

2.1.2 Scope and Purpose

This legacy assessment (LA) is designed to identify, assess, and evaluate factors that impact health information technology (HIT) modernization at the Indian Health Service (IHS) through the prism of people, process, and technology. This evaluation includes an analysis of the technical and architectural features of RPMS that impact the agency's ability to efficiently support the delivery of patient care.

It is not uncommon for organizations moving away from legacy systems to be faced with unique challenges. Those familiar with the health IT community will recognize that many of the issues this report describes are shared by commercial implementations as well. RPMS has been, and continues to be, a critical resource for the health care delivery model that is supported by IHS as well as tribal and urban Indian health programs. IHS faces issues typically found in legacy health care systems, as well as those unique within the largest rural health network in the United States that provides care under fiscal, geographical, technological, and human constraints.

2.1.3 Goals of Modernization

The goals of RPMS modernization, if it is determined to be possible, would include:

1. Help AI/AN populations achieve health equity
2. Be supported by trained AI/AN members
3. Support improved clinical decision-making and health care quality improvements
4. Be capable of change and innovation
5. Have portable or cloud PHR seamlessly controlled by the patient
6. Be interoperable with other Health Systems and HIT solution
7. Preservation and continued access to decades of longitudinal patient health data
8. Maintain and leverage critical functionalities to meet the needs of the Indian health care system
9. Acquire and integrate preferred third-party solutions for particular functions and domains
10. Collect, aggregate, integrate and analyze data on a local, regional, and national level to support the agency's mission and reporting requirements

2.2 Background

2.2.1 IHS and its Mission

The IHS, an agency of the U.S. Department of Health and Human Services (HHS), is the principal federal health care provider and health advocate for American Indian and Alaska Native (AI/AN) people. The IHS provides health services to members of federal-recognized tribes pursuant to its statutory authorities (in particular the Snyder Act and the Indian Health Care Improvement Act) and the government-to-government relationship between the federal government and Indian tribes. This relationship is recognized in the United States Constitution, Article I, Section 8, and has been given form and substance by numerous treaties statutes, Supreme Court decisions, and Executive Orders. .

The mission of IHS is to raise the physical, mental, social, and spiritual health of American Indians and Alaska Natives to the highest level. The agency carries out this mission through a comprehensive direct and public health service delivery system spread across 37 states. The total service population is 2.3 million members of 573 federally-recognized tribes.

2.2.2 Description of the Current IHS Health Delivery System

The Indian healthcare system is comprised of hospitals and clinics directly managed by the IHS, hospitals and clinics operated by tribes that have exercised their self-determination prerogatives, and urban Indian health programs funded under the provisions of the Indian Health Care Improvement Act of 1976 (PL 94-437). Collectively, these three broad components of the Indian health care system are known as the I/T/U. Details about the I/T/U are published by IHS at www.ihs.gov/newsroom/factsheets/ihsprofile/.

IHS operations are directed from the agency's headquarters in Rockville, MD through twelve Area Offices. The Areas are further divided administratively into Service Units, typically comprised of a main hospital or clinic with a number of satellite facilities. There are 170 Service Units, most of which are managed by self-governance tribes. IHS direct services are delivered through 25 small, mostly rural hospitals, 55 health centers (ambulatory care facilities open at least 40 hours per week), and 21 health

stations. Additional services are provided through residential alcohol and substance abuse centers, school health clinics, and other community-based locations. The IHS organizational charts can be reviewed at https://www.ihs.gov/IHM/org/.

The remaining component of the I/T/U are 41 urban-based health organizations that principally, but not exclusively, serve AI/AN people.

2.2.3 History and Evolution of RPMS

The beginnings of the IHS health information system can be traced to the establishment of the IHS Office of Research and Development on the Papago (now Tohono O'odham) reservation in southern Arizona in the late 1960s. The launch of the Resource and Patient Management System (RPMS) is commonly placed as 1984 when the Patient Care Component (PCC) was first deployed. PCC remains at the core of RPMS to this day, linking data from across the system in an encounter-based record that can still be read more than 30 years later.

Over the years the evolution of RPMS has prioritized capabilities that reflect the organizational requirements of the agency. As a result, the suite today includes an eclectic mix of features that would be distinctly unusual as foundational components of a commercial system as seen in the table below.

Components of the RPMS Suite

• Integrated Care
  ○ Behavioral Health System
  ○ Women's Health
  ○ Well Child Care with age-appropriate anticipatory guidance
  ○ Prenatal Care module
  ○ Optometry/Eye Care module
  ○ Dental module and interface to commercial dental system

• Population Health
  ○ Diabetes Management System and Diabetes Audit
  ○ Immunization Tracking and Immunization Exchange
  ○ HIV Management System
  ○ iCare Population Management System
  ○ Improving Patient Care measures

• Agency and Government Reporting
  ○ Clinical Reporting System
  ○ Indian Health Performance Evaluation System (IHPES) and National Data Warehouse (NDW) exports from RPMS
  ○ Government Performance and Results Act (GPRA) reporting
  ○ Uniform Data Set (UDS) reporting for HRSA
  ○ Electronic Clinical Quality Measures

• Care in the Community
  ○ Community Health Representative module
  ○ Computerized Public Health Activity Data (CPHAD) module

The IHS received significant funding as part of the American Recovery and Reinvestment Act (ARRA) of 2009. The agency applied a portion of ARRA dollars to updating technology infrastructure, including the Wide Area Network. This was the last significant infrastructure upgrade IHS was able to undertake. ARRA resources were also dedicated to meeting the requirements of the HITECH[1] portion of the Recovery Act for certification of electronic health record technology. As a result of that effort, RPMS became the first (and still only) government-developed EHR system to achieve Office of the National

[1] Health Information Technology for Economic and Clinical Health Act of 2009 (PL 111-5)

Coordinator for Health Information Technology (ONC) certification.[2] This accomplishment was repeated when RPMS was certified to meet ONC criteria for 2014 Edition certification; this effort was funded by assessments of Meaningful Use incentive payments received by IHS (federal only) sites.

In the past fifteen years, enhancements to the RPMS suite have included the following:

- The RPMS Electronic Health Record
- iCare population management application
- Electronic prescribing through Surescripts (principally targeted to small sites)
- VistA Imaging - image archiving (DICOM/non-DICOM) and document scanning
- 2011 Edition ONC certification
- 2014 Edition ONC certification, which included:
    - SNOMED CT terminology
    - RPMS Network centralized services - Master Patient Index, C-CDA Document Repository, Direct secure messaging, Personal Health Record portal
- Bar Code Medication Administration (hospitals only)
- Transition from ICD-9 to ICD-10

The recurring IHS budget appropriation for health IT has been nearly flat for close to a decade.[3] As a result, the agency has prioritized urgent development in the past several years to meet certain regulatory requirements, specifically the new Medicare card and electronic prescribing of controlled substances. Other priorities, such as compliance with 2015 Edition ONC certification requirements, have not been addressed; as of January 2019 RPMS is no longer an ONC certified system.

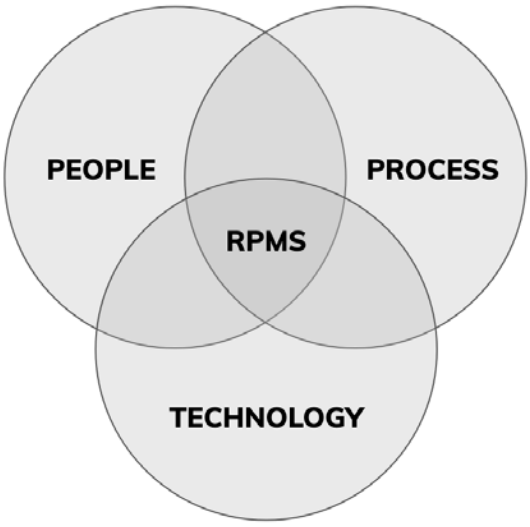
[2] https://www.healthit.gov/topic/certification-ehrs/about-onc-health-it-certification-program

[3] IHS Congressional Budget Justification documents show a health IT allocation of $172M in FY2010, and the allocation in FY 2019 is $182M; this is an increase of 5.6% over 9 years.

2.2.4 Guiding Principles and Methods for the Legacy Assessment

People, Process, and Technology

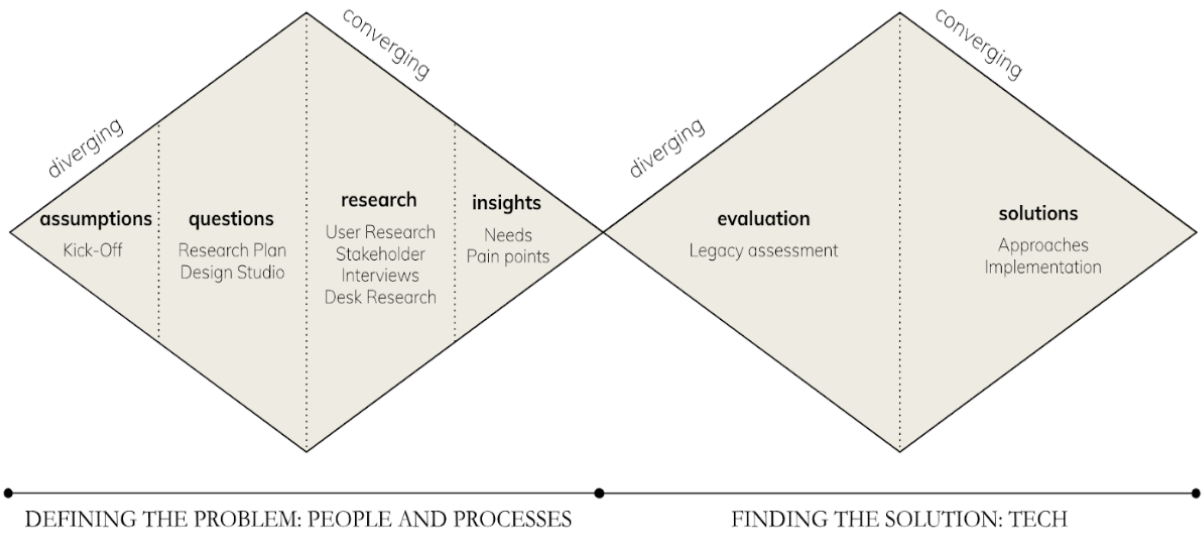
An assessment framework was developed to evaluate the feasibility of modernizing RPMS, and uncover potential barriers to modernization as well as possible mitigation strategies. This framework assesses legacy systems by following a People, Process, and Technology paradigm—in that order. Assessing the legacy product with an initial focus on People and Processes is a critical precursor to the Technological evaluation. A comprehensive study of current users' needs allows us to formulate the technological assessment through the people and process prism.



This holistic legacy assessment model requires an understanding of:

- **People:** the needs of People who use RPMS to do their jobs, People who service the system, and People whose health care depends upon the system's functionality.
- **Process:** the organization's Processes (i.e., the workflows the system supports), including the extent to which legacy system limitations have shaped those Processes, as well as the ways in which Processes have likewise influenced, constrained, or otherwise impacted the legacy system.
- **Technology:** the degree to which elements of existing Technology meet or do not meet the needs of People and Processes and in what specific ways existing Technology enables or inhibits better business Processes.

Phases of the Assessment



The technological evaluation was conducted across multiple dimensions identified in the following table.

Dimension	Description
User Experience	• Provider Experience • Administrator Experience • Leadership Experience • Patient Experience
Organization	• Support • Training • Availability of Skills/Expertise
Architecture	• RPMS Code (Language and Frameworks) • Data Sharing and Portability • Interoperability ○ Health Information Exchange • Application Integrations • Extensibility
Miscellaneous	• Telemedicine • Public and Population Health • Personal Health Record
Infrastructure	• Hardware • Network • Software Maintenance • Database Development/Support • Current Overlap Between VistA and RPMS
Security	• Security and Compliance
Regulatory	• Regulatory Compliance

2.2.5 Constraints and Mitigations

The following table describes some of the constraints and scope limitations of the Legacy Assessment:

Constraint/Barrier	Mitigation/Response
Government shutdown	Shortened the project schedule, reducing the amount of time the team could dedicate for the Legacy Assessment research.
Limited time to conduct an in-depth analysis of IT governance and operational policies, procedures and recommendations	Reliance on interviews with senior level Subject Matter Experts to identify these issues.
Readiness for change	Overall organizational readiness assessment is outside of project scope.
Specific functional gaps in various RPMS applications	Detailed assessment of functional gaps and requirements is out of scope. Certain gaps were identified as part of the research and are reported where appropriate.
Regulatory compliance	Outside the scope of this technical assessment. If desired in the future, this would require a specialized assessment with regulatory experts.
Security, confidentiality, patient privacy	Security is assessed in the Legacy Assessment, however if further details are required a dedicated security assessment could be conducted.
National Data Warehouse (NDW)	The need to routinely (and occasionally urgently) export data from RPMS to the National Data Warehouse was not a component of this evaluation.
Funding and staffing levels at IHS	Noted as a foregoing operational issue but not assessed in detail; this report assumes that funding to improve infrastructure, local and national support staffing, and development/implementation costs for new or updated systems will be available.

3.0 RPMS as a Legacy System

3.1. Organizational Technical Maturity

The Indian health care system, comprised of the IHS Headquarters, Area Office and Service Unit hierarchy in partnership with hundreds of tribes and urban facilities, is a complex federation of organizations. Technical maturity in software development and implementation is critical to support and maintain an enterprise health information technology solution. There are hundreds of independent production instances and/or configurations of RPMS currently deployed around the country, as well as numerous testing, training and shadow instances (real-time backup databases). There are additional (though limited) development instances. Each RPMS database is uniquely configured and supported, primarily by staff that are local to the facility or assigned to the Area Office. In some instances, the database itself is hosted remotely, e.g., at the Area Office.

3.2 Administration and Governance of RPMS

RPMS is part of the Health Information Technology Systems and Support (HITSS) investment that IHS reports under FITARA.[4] RPMS development is managed by the IHS Office of Information Technology (OIT), specifically the OIT Division of Information Technology (DIT). The RPMS Program Management Office (PMO) directs all RPMS development and enhancement in response to priorities generated from multiple sources, including those listed in the table below.

Sources of Influence that Generate Development and Enhancement

[4] Federal Information Technology Acquisition Reform Act of 2014

Regulatory	Office of the National Coordinator for Health IT (ONC), the Centers for Medicare & Medicaid Services (CMS), Drug Enforcement Administration (DEA), and others
IHS programs	DDTP (diabetes), ORAP (revenue cycle), Dental (Dentrix interfaces), others
Professional specialty and technical advisory groups	Pharmacy, laboratory, clinical, business office, others
Users	Through RPMS feedback submissions and help desk change requests

RPMS development is managed according to HHS Capital Planning and Investment Control (CPIC) procedures as adopted by IHS. All development is initiated through a Business Needs Statement (BNS) created on behalf of and approved by the application's Business Sponsor, with the concurrence of the IHS CIO. Proposals exceeding a specific cost threshold require an additional layer of rigorous project planning articulated in a Business Case document that must be approved at the level of the Information Technology Investment Review Board (ITIRB), made up of senior leaders outside of IHS Office of Information Technology (IHS OIT) and including tribal representation.

3.3 RPMS Current Implementation Overview

3.3.1 Settings where RPMS is used

RPMS is a decentralized solution for the management of both clinical and administrative information in I/T/U healthcare facilities. This means RPMS runs on regional installations, as opposed to operating off a single central cloud server. The most common location for hosting a regional RPMS instance is the principal facility of the Service Unit. Flexible hardware configurations, nearly 100 component applications, and network communication components combine to create a comprehensive integrated clinical, financial, and administrative health delivery system that can stand alone or operate in conjunction with other components.

As of 2018, there were 243 unique production instances of RPMS reporting data to the IHS National Data Warehouse. Many of these are multi-divisional instances accessed by organizationally distinct facilities, each with its own configurations. Authoritative estimates by IHS OIT staff of the number of operational installations of RPMS across the I/T/U go as high as 400. These instances are deployed across a wide spectrum of operational entities and support a broad range of functions. Examples include:

- IHS and tribal hospitals that utilize essentially the full range of RPMS - inpatient, emergency department, ambulatory, billing, reporting, etc.
- IHS, tribal and urban clinics that have in-house ancillary services (pharmacy, laboratory, radiology) and a variety of clinical services - medical, dental, behavioral health, optometry, physical therapy, etc.
- IHS, tribal and urban clinics that offer fewer in-house medical and ancillary services and use fewer RPMS functions accordingly
- Residential Treatment Centers for alcohol and substance abuse treatment
- Tribal hospitals and clinics or urban facilities that are using commercial EHR systems for most clinical operations, but continue to use RPMS for functions not included with their EHR
- Alaska Village Clinics - some may continue to use RPMS for limited functions such as those noted above
- PRC only clinics - locations that only provide referred and/or purchased care, no direct services

3.3.2 Users of RPMS

There are many users of RPMS. This wide user base requires a broad scope of applications that make up the RPMS suite. Examples of RPMS users include:

Front Office
- Registration
- Scheduling

Clinical Support
- Clinic clerks
- Medical and nursing assistants

Nursing
- Registered Nurses (RNs)
- Licensed Practical Nurses (LPNs)

Clinical Providers
- Physicians
- Nurse practitioners
- Physician assistants
- Pharmacy practitioners
- Optometrists
- Dentists
- Psychologists
- Nurse midwives

Ancillary clinical services
- Pharmacists
- Pharmacy technicians
- Laboratory technicians
- Radiology/imaging technicians
- Clinical social workers

Back Office
- Health Information Management (HIM) coders
- Billing & accounts receivable staff
- Purchased & referred care staff

Community-based health services
- Public Health Nurses (PHNs)
- Community health representatives

Supervisors/Managers
- Clinical (medical) directors
- Directors of Nursing (DNs)
- Administrative officers
- Chief Executive Officers (CEOs)

Support Staff
- Informatics and application support
- Site managers/IT support

Consumers of RPMS Data
- Area office program staff
- Headquarters program staff
- Epidemiologists
- Statisticians
- Tribal leaders
- Government agencies (HHS, OMB)

3.3.2.1 User Support

As is typical with large integrated health information technology systems, no single person is sufficiently knowledgeable about the full range of RPMS packages to expertly support the entire suite. This is particularly true at the small, rural locations that comprise the I/T/U. Site managers and other support staff (e.g., Clinical Application Coordinators, see below) and encounter significant learning curves as they assume support responsibilities.

Expertise in RPMS troubleshooting is distributed across the country geographically and administratively, since many of the experts are either located at Area Offices or are contractors.. Support for RPMS is offered via a three-tiered paradigm:

- **Tier 1 - Site**; provided by local IT staff and CACs
- **Tier 2 - Area Office**; Areas may have a designated Area CAC (or informaticist) as well as domain and IT experts to step in if local support needs are exceeded
- **Tier 3A - Headquarters**; contracted user support staff supplemented by Office of Information Technology (OIT) informaticists and subject matter experts (pharmacy, laboratory, business office, etc.)
- **Tier 3B - Headquarters**; for serious issues of a technical nature, tickets are elevated to developer staff (mostly contracted)

Clinical Application Coordinators (CAC), a term and role adopted from VA, are typically individuals who have demonstrated aptitude in particular RPMS domain areas and are assigned part- or eventually full-time responsibility to support and train local users. The roles and job classifications for CACs have been insufficiently standardized. Consequently, IHS is currently rebranding CACs as **Informaticists** and formalizing a training curriculum. A National Council of Informatics (NCI) has been created to "identify, define, prioritize, and advocate for the information resources management and technology needs of health care providers in I/T/U facilities."[5]

3.3.2.2 User Training

In most cases, employees or contracted health care staff receive on-the-job training supplemented by a range of recorded presentations and "office hours" sessions provided by Headquarters or Area staff. At the facility level, most training is informal and performed by local or Area-level application support staff or by co-workers, according to availability and skill level. Some of the available RPMS training resources can be viewed on the RPMS Training website: ihs.gov/rpms/training/.

[5] https://www.ihs.gov/ihm/circulars/2018/national-council-of-informatics-charter/

3.4 Technology -- RPMS Overview

3.4.1 Introduction

RPMS originated and evolved principally as a health record system optimized for longitudinal care in ambulatory settings. RPMS was a successor to an earlier IHS system called the Patient Care Information System (PCIS) that was written in COBOL and ran on mainframes. RPMS was developed as a successor to PCIS, to run on commodity hardware at local sites, using the same architecture and infrastructure as the VA's VistA (known at the time as DHCP), frequently taking entire modules from VistA to gain functionality in RPMS. For a more detailed discussion on the relationship between RPMS and VistA, see Appendix E. To understand the risks involved due to RPMS's reliance on VistA, see Current Overlap Between VistA & RPMS section.

3.4.2 RPMS Development Cycle

RPMS is an internally government-developed HIT system, and includes significant contributions from VA (see Appendix E), as well as contracted private vendors. Virtually all current RPMS development is done by contracted resources in close collaboration with IHS informaticists and subject matter experts. Agile/iterative development processes are utilized where practical. However, the tight integration of RPMS means that a single development project will touch multiple applications and hence multiple development teams, complicating development project management. Developers are responsible for internal testing, including unit and regression testing to the extent possible, and complete "alpha" builds are turned over to a separate contract team for production testing.

Typical production testing processes include alpha tests either in databases copied from production systems or at a very limited number (one or two) facilities who have an interest and local expertise in the application, have an established test environment and have volunteered to be the first. Following successful alpha testing, the enhancements are approved for beta.

Beta testing is always done in production, generally at a minimum of three facilities and sometimes more. Attempts are made to enlist a representative spectrum of sites to minimize the risk of unanticipated issues upon general release. Unless an exception is granted by the Standards and Conventions Committee (SACC), beta testing cannot conclude until it has gone at least 30 days without a significant code revision and all sites have signed off on approvals for release.

All software releases are accompanied by documentation which includes patch notes at a minimum and will also include supplements to technical and user manuals as needed. In fiscal year 2018, a typical year, there were five application versions released to the field, and eighty-nine patch releases. All version releases are accompanied by new User, Technical And Security Manuals, the latter of which are not publicly accessible. Upon release, responsibility for managing distribution and installation falls to the Area Offices, who work with site managers at the facilities to determine which versions/patches are appropriate for their sites and to coordinate installation.

In many locations the new patch or version is first installed into a local test environment that mirrors the specific configuration of that location. However, most facilities do not have test databases and the updates are installed directly into production. This emphasizes the critical importance of thorough testing at the alpha and beta levels.

3.4.3 RPMS Applications

The RPMS suite includes over almost 100 applications in three broad categories: clinical, administrative, and infrastructure. A listing of applications maintained by IHS is on the ihs.gov website. This assessment project will also produce an RPMS Monograph, which will contain an application by application breakdown of RPMS, similar to the VistA Monograph.[6]

ViViaN, a visualization software produced by the Open Source Electronic Health Record Alliance (OSEHRA - www.osehra.org), contains an interactive display of the RPMS applications and their complex relationships with one other. See https://code.osehra.org/vivianr/vista_pkg_dep.php.

[6] https://www.va.gov/va_monograph.htm

3.4.4 Current RPMS Architecture

3.4.4.1 Introduction

The core of RPMS is written in MUMPS using the VA VistA Architecture. MUMPS, or M, is a programming language and database designed for the healthcare industry.[7] RPMS currently runs on InterSystems Ensemble which includes the Caché database that operates the M portion of RPMS and Ensemble, an integration engine. Small parts of RPMS are written in Caché Objectscript, a superset of the ISO 11756-1999 standard M programming language.

RPMS also includes several graphical user interface (GUI) applications, all of which run in Microsoft Windows environments. These are written in Delphi, C#, and VB.Net. These applications communicate to RPMS using custom protocols layered over the Transmission Control Protocol (TCP).[8] Two applications are enabled to run in the web browser. RPMS is also interfaced with multiple external systems. Appendices to this document detail much of the technical architecture, RPMS GUI clients, and external interfaces. The appendices to consult are as follows:

- Appendix A - A table that shows the timeline and historical view of RPMS architectures
- Appendix C - Detailed discussion of RPMS architecture.
- Appendix C and Appendix D - Discuss and enumerate all RPMS GUIs.
- Appendix F - Lists all RPMS external interfaces.

3.4.4.2 The Three Architectures of RPMS

RPMS can be divided into three different architectures, which differ significantly from each other:

1. The Classic VA VistA Architecture
2. The Broker-Based GUI Applications Architecture
3. The SQL Projection/Object-Relational Mapping (ORM) Architecture

[7] https://en.wikipedia.org/wiki/MUMPS
[8] https://en.wikipedia.org/wiki/Transmission_Control_Protocol

Refer to Appendix C -- Core RPMS Technology and Applications for a detailed description of RPMS architecture.

3.4.4.2.1 Classic VA VistA Architecture

The Classic VA VistA Architecture was developed over the late 1970s into the mid-1990s and was adopted by IHS in the mid-1980s. It uses the 1995 ANSI standard version of MUMPS to provide an integrated database system for medical applications. Four other major commercial EHR vendors – Epic, Meditech, GE Healthcare, and Allscripts – share similar architectural dependencies on components that are built on a MUMPS database.

3.4.4.2.2 The Broker-Based GUI Applications Architecture

By the late 1990s, personal computers running Microsoft Windows became the dominant workstations for government employees. To accommodate this, IHS developed Windows programs that communicate with the RPMS database via the Transmission Control Protocol/Internet Protocol (TCP/IP)[9] using an intermediate layer called the Remote Procedure Call Broker. Today, the majority of users who interact with RPMS do so via a Microsoft Windows program that communicates with the underlying RPMS system via TCP using a broker.

3.4.4.2.3 The SQL Projection/ORM/Service-Oriented Architecture

In the early 2010s, with the realization that there had not been any additional development or enhancement of the M language since the late 90s, and that the industry was shifting away from thick client applications to web-based applications, there were several parallel efforts to create web accessible applications. IHS elected to use new technologies offered by InterSystems, while still ensuring that all data was stored in the same format so that other applications in RPMS could continue to access the data. The result was the Practice Management Suite, which includes Registration, Scheduling,

[9] https://en.wikipedia.org/wiki/Transmission_Control_Protocol

Admission/Discharge/Transfer, and Clinical Quality Measures. The architecture was dubbed “Moonwalk” and provided for the following features:

- Service oriented architecture
- Commonly used programming languages and paradigms, so that new developers could be easily trained to develop on the system and have an easier time grasping the concepts
- An SQL interface and an Object Relational Mapping (ORM) system such as Hibernate
- A web-enabled interface

Although Moonwalk provides for web service Application Programming Interfaces (APIs) that can be consumed by other applications, the architecture has not been adapted for use outside of the Moonwalk Silverlight application. For further discussion on the limitations of Moonwalk, see Admission, Discharge, and Transfer (ADT).

3.4.4.3 RPMS Architectures over its Lifetime

Appendix A lists RPMS architectures over the lifetime of the suite.

No further architectures have been added to the core RPMS stack since those identified in the Appendix, but in 2014 the electronic Clinical Quality Measures (eCQM) calculation engine was moved out of the transactional cache.dat file that contains RPMS application code and data into a separate cache.dat file that can be located on the same server or on a different server either local or remote. In 2019, IHS deployed the eCQM Engine as a centralized service accessible to any instance of RPMS.

3.4.5 User Interfaces

RPMS user interfaces (UI) range greatly in sophistication and development and include, but are not limited to:

- Character-based user interfaces operated using only a keyboard (colloquially referred to as "roll and scroll") used in lab, pharmacy, business office and administrative packages
- Graphical user interfaces (GUI) written in Visual Basic (Legacy 6 and VB.net), Delphi, and C#. There are a variety of these. Two notable examples:
    - The RPMS Electronic Health Record (EHR) contains a large number of GUI components (written in Delphi, C#, and VB)
    - Practice Management Suite (written in Microsoft Silverlight) used for registration, scheduling, admit/discharge/transfer and electronic clinical quality measures

Appendix C contains a list of all the RPMS GUI applications. Appendix D discusses the RPMS Electronic Health Record and contains a listing of all its subcomponents.

Users operate the many RPMS applications in separate windows, as they are not integrated into a single application. For example, the iCare population health application is not integrated into the RPMS EHR. RPMS users who wish to view information about the same patient in iCare and in RPMS must log into each application separately. Many users, particularly in pharmacies and business offices, require two monitors to perform their duties -- one monitor that displays the primary application (typically a roll/scroll) and another that displays the EHR to enable review of clinical documentation. An expanded description of the provider experience can be seen in the Provider Experience analysis section.

User interface configurations and naming conventions (note titles, test names, etc.) vary widely as they are locally customizable, sometimes affecting application functions, clinical workflows (local EHR GUI design), and user interfaces.

3.4.6 RPMS Code

3.4.6.1 Code Language

As discussed previously, the core of RPMS is written in MUMPS (M) using the VA VistA architecture. The M language provides a built-in database. M is both a programming language and database that originated in the 1960s for use in the healthcare industry.

M by itself does not provide a schema as it is a non-SQL database. FileMan, built by the VA and later enhanced by IHS, provides the schema for all the data elements in the database. Data stored in the M database remains unstructured without the schema that FileMan imposes on it. Most of the data is exposed by FileMan as if the data is stored relationally. The M user interface is via VT-220 terminal emulation.

Over the years, RPMS has been deployed on a number of M platforms. From the mid-1980s to the late 1990s, Digital Standard MUMPS (DSM) and Micronetics Standard MUMPS (MSM) were the preferred platforms. Later, after InterSystems Corporation acquired DSM, MSM, and other M platforms, IHS moved to their flagship product, InterSystems Caché, an M implementation with object-oriented and web extensions. In the late 2000s, IHS also adopted InterSystems Ensemble, an integration engine built over Caché.

3.4.6.2 Integrating Code with RPMS

The RPMS codebase is primarily composed of various MUMPS code packages; the primary method by which RPMS applications integrate with each other is via a direct dependency model[10] where MUMPS routines directly call the routines of other packages. The second most prevalent method of application integrations is via Remote Procedure Calls (RPC) between applications.

RPMS maintains the same underlying code infrastructure as VA VistA while building new functionality and leveraging the foundations of VistA.[11] Due to MUMPS' lack of native namespace support or object

[10] https://code.osehra.org/vivianr/vista_pkg_dep.php
[11] https://www.osehra.org/content/rpms

inheritance, this level of integration is primarily achieved by segmenting the ownership of functions between IHS and VA based on a strict naming convention that consists of a unique prefix of between 2-4 alpha characters for globals, routines, templates, functions, etc.;[12] the prefixes are assigned by the database administrator (DBA) at VA; the same is true of the global number space. This practice enforces a namespace of sorts given the limitations of the language, but it is not a scalable or the modern method for achieving this level of integration at a code level.

There are three ways to integrate code with RPMS, depending on the integration direction:

- New applications or functions within the RPMS suite
- RPMS calling data from an external service
- External or application calling from or exchanging data with RPMS

Creating new application functionality within RPMS proper or one of the existing frameworks such as VueCentric (RPMS EHR) is typically a three-step process:

1. Create the necessary scheme and data elements in M;
2. Write the M code and remote procedure definitions to read, edit, and save records in the database;
3. Write the client code that will call the remote procedures.

Since 2012, using the Moonwalk architecture, developers can use object relational management (ORM). Needed schema elements must be created, but it is not necessary to write the remote procedures in M. Instead, the code for the data resides on the client. This configuration makes it easier to expand functionality in applications that utilize Moonwalk.

When RPMS requires data from an external service, RPMS dispatches data using a web service call (or any other real-time TCP connection) and then receives data back. A typical example is the terminology server configuration, which is queried by RPMS using a web service call.

[12] https://code.osehra.org/vivian/files/Namespace/Namespace.html

Finally, various HL7 standards can be transmitted over TCP to send and receive data; typically, the data is a patient-specific message. This integration is exemplified when patient data is sent to the dental system (currently a COTS program).

3.4.7 Databases

The database layer is a schemaless database with SQL projections. The data dictionary is stored in a core component of RPMS known as FileMan (see 3.4.6.1). FileMan provides semantic metadata (known as the data dictionary) to the stored data and also provides data integrity, preventing the saving of invalid data. FileMan provides a text-based user interface for adding/editing/removing the data defined in its data dictionary.

A full discussion on how data is stored and how the FileMan data dictionary works with the stored data can be found in the Data Layout section of Appendix C.

3.4.8 Data Maintenance, Sharing, and Portability

Historical patient data has been generated over the last forty-plus years for many facilities. Maintaining this data, while exposing it for use and sharing by new applications and potential migration to a new platform, is essential for creating a unified and longitudinal view of patient data from multiple IHS facilities or locations.

3.4.9 Database Extensibility

Extensibility is a guiding system architecture and design principle where future growth is accounted for within the system. As a principle, extensibility seeks to promote system design where the need to "rip and replace" existing system components is minimized and the level of effort to extend the system in terms of new functionality is achieved with minimal disruption and effort.

The overall architecture of RPMS as a suite of interrelated packages and applications (package components), is modular by design. RPMS has historically extended the system at the package level. Extending RPMS at the FileMan/Kernel/Menu/ListMan level or at the VueCentric level is also supported.

Similarly, adding new data elements and integrating them into various applications is supported. RPMS was designed with this kind of facile extensibility in mind.

Integrating RPMS with a program from a different environment is more difficult, as communication, data-caching, differing data formats, and error processing considerations needs to be taken into account.

The VueCentric Framework (the MS Windows program that hosts RPMS-EHR) provides excellent and well-documented extensibility mechanisms. It has been the principal way to extend RPMS clinically over the last 15 years. VueCentric provides services that a clinical component requires, including:

- Display services (how to display the component)
- Services to exchange data with RPMS
- Event Services (e.g., what happens when a patient is changed or specific patient data is updated)
- Update Services (how to update a new version of the component)

Many applications do not use the VueCentric extension framework. They can either use the BMX Broker, or the Fileman Mapper. Both of these approaches provide advantages over VueCentric in terms of code development, but both have been used to develop mainly monolithic applications.

The BMX Broker integrates data editing and display with the .Net framework, and enables faster development. iCare, RPMS' flagship population health program, is written in C# using the BMX Broker, Currently, iCare receives about two updates a year, demonstrating the sustainability of this model. See Appendix C to view graphics depicting RPMS Gui Applications.

3.4.10 Application and Device Integration

RPMS communicates with a variety of other systems. These systems may be local, such as laboratory devices and other clinical systems (e.g., Dentrix), while others are external to the facility, such as the National Data Warehouse. For the purposes of this discussion, an external system is defined as any system

that resides outside of the RPMS database, with the exception of GUI clients to RPMS. The external systems that RPMS communicates with can be classified as one of the following types:

- Systems that are part of RPMS but that are hosted outside the main database (e.g., VistA Imaging)
- Systems provided by external vendors for patient care (e.g., Dentrix)
- Systems that supplement RPMS functionality (e.g., Immunization Forecaster; Terminology Server)
- Systems that support medical services to patients (e.g., pharmacy dispensing machines, lab instruments and radiology instruments)
- Systems for billing patients (RPMS generates the billings messages; these systems tend to be hosted by third-party payers)
- Systems that collect patient information for statistical measures (e.g., Data Warehouse)
- Systems that support interoperability (e.g., Master Patient Index; C-CDA Repository; Direct Messaging)

RPMS has multiple data exchange systems. The most common methods include:

- **Flat Files:** These are written to the host machine's file system, and then uploaded via FTP/SFTP or HTTPS to the end point. This upload can happen automatically once the file is generated from RPMS using the Simple Message Mover application. The format of the flat file depends on the application.
- **Direct TCP/IP connection to the endpoint:** This is one of the most common ways to exchange data. Examples include Immunization Forecasting, Pharmacy Billing, and all the real-time HL7 2.X interfaces (e.g., Lab Auto Instruments, VistA Imaging) or HTTP Web Services.
    - HL7 2.X data exchange through one of these subsystems:
        - **GIS:** an interface engine written in MUMPS that originally came from the Department of Defense's fork of VistA, called CHCS.
        - **VistA HL7:** another interface engine written in M.

- **Ensemble:** an interface engine supplied by InterSystems

- Web Service clients provided by InterSystems Cache: This is done for the Terminology Server and the C32/C-CDA exporter.

A listing of all the external systems RPMS talks to is in Appendix F.

3.4.11 Interoperability

Health information exchange is the result of interoperability. Interoperability is the ability for different systems and applications to communicate, exchange data, and use information from other systems in a seamless way. There are three classes of interoperability as defined by HL7:

1. **Technical interoperability.** How computers exchange data.
2. **Semantic interoperability.** How EHRs interpret data for data presentation and decision support
3. **Process interoperability**. How computers support plans and workflows.[13]

RPMS supports interoperability as defined by Meaningful Use 2011 and 2014 certification.

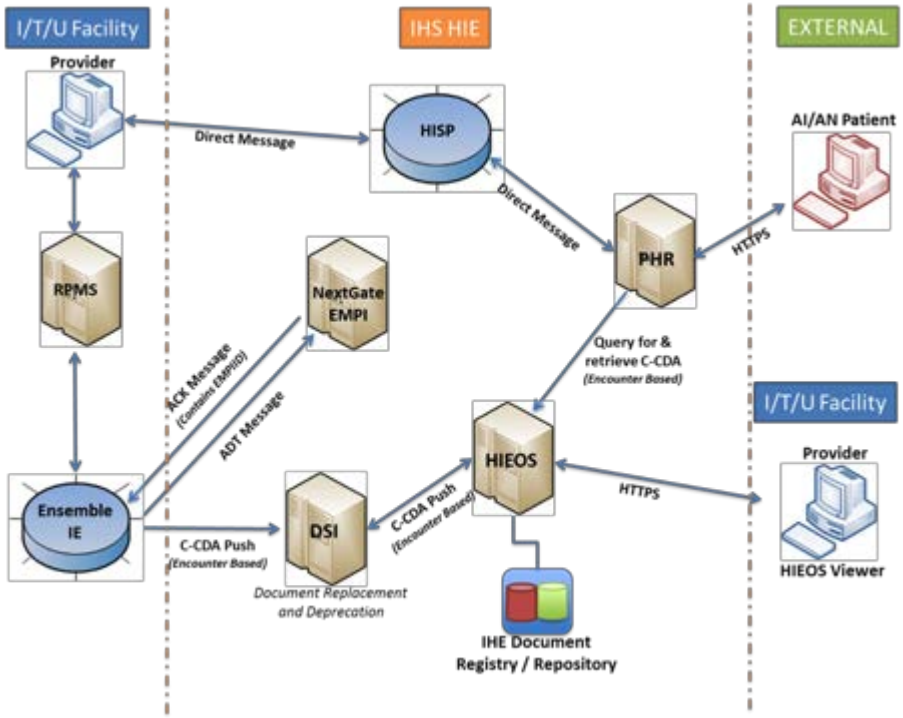
3.4.11.1 Health Information Exchange

The RPMS Health Information Exchange (HIE) was adapted from an open source solution that was developed for IHS;[14] it is only deployed at the IHS and has no open source community supporting it. The RPMS Network HIE is designed as a document storage and sharing service; it receives C-CDA[15] documents from IHS facilities and makes them available to requesting entities. The C-CDA documents stored in the Document Repository are available to patients who log in to the IHS Personal Health Record (PHR) portal (see the Personal Health Record section). As of this writing, however, no connections from the RPMS central network service to external (state or national) HIEs have been established, nor is the

[13] VA-DoD EHR Interoperability
[14] Health Information Exchange Open Source (HIEOS), developed by Vangent
[15] Consolidated Clinical Document Architecture (C-CDA), a Health Level 7 (HL7) clinical document implementation guide

RPMS Network portal used for internal queries. In the absence of a functioning national HIE, a few sites have successfully connected to regional/state HIEs through RPMS using an external contractor.

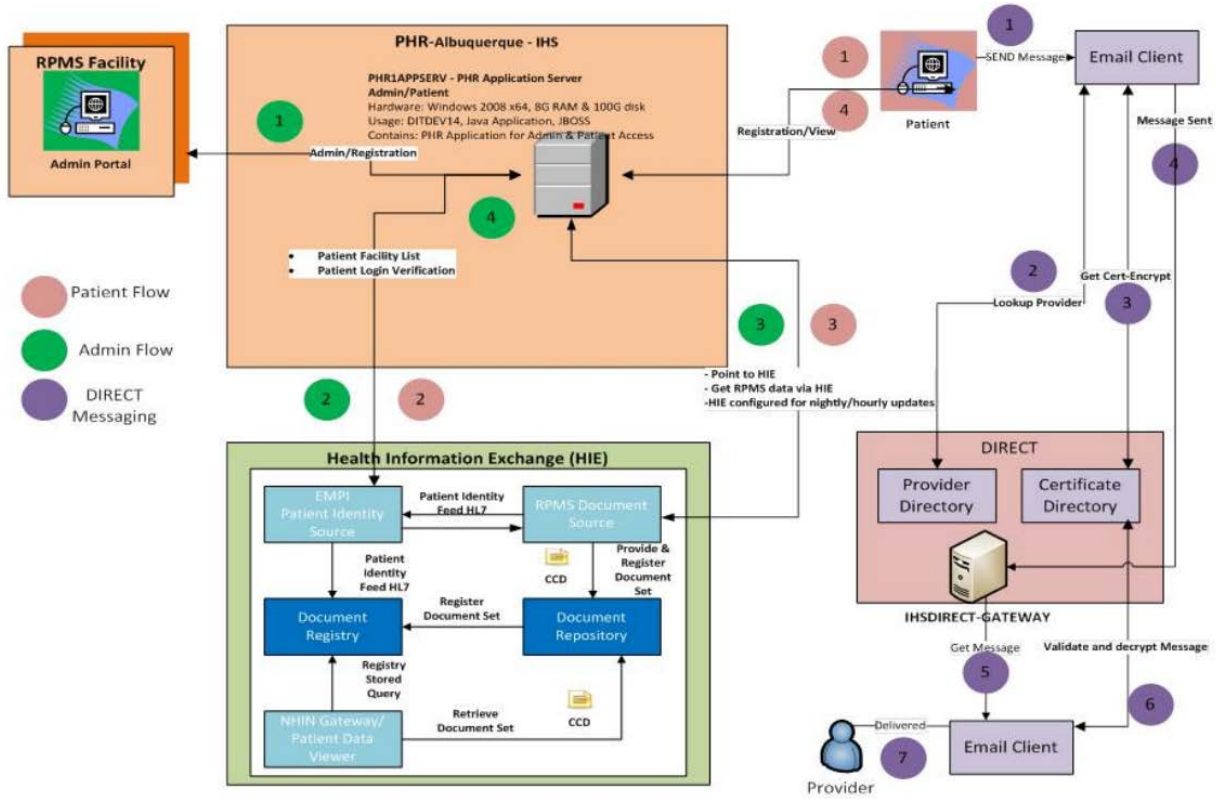
Current Architecture of RPMS Network (MPI, HIE, Direct and PHR)



3.4.12 Personal Health Record

The IHS Personal Health Record (PHR) portal was released in 2014 as part of the broad development effort resulting in 2014 Edition ONC certification. The PHR allows patients who were seen at a facility that contributes data to the RPMS Network Document Repository to log in from any computer, select the appropriate facility, and retrieve the personal data from a selected encounter at that location. It also allows them to download the information in various formats for their own use, or to email the information to others if they choose. These functions meet the "view, download and transmit" requirements for 2014 ONC certification.

The PHR portal is also designed to allow the patient to send a secure message to the provider (typically through a designated "message agent" at the facility who triages the message and routes it as appropriate) using the Direct protocol, and to reply to any secure message they have received. During site visits, patients have reported not getting notified of messages being received.



Architectural Diagram of Personal Health Record (PHR) component of RPMS Network

3.4.13 Telemedicine

Telemedicine has long been a part of the IHS services. There are activities at all levels, with nationally-led telemedicine solutions that include the **Telebehavioral Health Center of Excellence (TBHCE)** and the **IHS-Joslin Vision Network Teleophthalmology Program**, a regional solution in the Great Plains utilizing a contracted telemedicine provider called Avera Health, new innovations in collaborative service for tele-genetics and tele-development pediatrics on the Navajo Nation, and numerous site level initiatives across various service areas and specialties. These initiatives all aim to reach an already underserved population, with a focus on providing specialty care in communities where such care has previously not existed or existed in very limited ways. In addition, there are numerous site-level telemedicine initiatives that are being successfully deployed for specific populations; such as, providing health services to students from the Phoenix area while away at boarding school, providing mental health services to the AI/AN youth in partnership with children's hospitals, or providing primary consults from the southwest region to patients in need in the midwest. For an expanded analysis of telemedicine and RPMS, see Appendix H.

3.4.14 Infrastructure

3.4.14.1 Hardware

The RPMS Server mostly runs on commodity hardware on Microsoft Windows 2008 Server. There are a few (less than 10) RPMS instances that run on IBM AIX Servers. Since most clients are Windows-only, the client computers are all Microsoft Windows computers, running either Windows 7 or Windows 10. There is a data call in progress at the time of this writing that is attempting to get comprehensive data on the servers and client hardware configurations.

3.4.14.2 Network

All RPMS client applications exchange data in real time with the database and application server. RPMS architecture depends on stateful connections between clients and servers, requiring an uninterrupted network connection. In the vast majority of RPMS installations, this issue is mitigated through the on-site

installation of the RPMS server and database. Connectivity issues can still arise, however, between the site where RPMS is installed and satellite facilities that use the same database. Some connections from host sites to satellites are direct, but others are indirect (e.g., satellite clinic connects to host facility via the IHS wide area network).

A preferred installation model for many sites, from a support standpoint, is to host the RPMS servers remotely, i.e. at an Area Office. This reduces the complexity of local support and upkeep, and is implemented for a limited number of sites at several Areas. However, due to the requirement that a stateful connection be present, and thus an uninterrupted connection, it is often not possible at many IHS sites in network availability, reliability, and connection bandwidth. (See sample data analysis w/visualization of bandwidth vs. WAN circuit utilization in Appendix G)

Bandwidth is a known issue in many IHS Areas. Restrictive geographical constraints result in connectivity and bandwidth issues. Less than 10% of homes in Indian country have broadband access and only 70% have basic telephone access. The expansion of cellular service availability has outpaced that of cable and fiber in recent years, but neither is yet sufficient to meet the level of access required for delivery of modern healthcare, education, and other services.

Approximately 75% of IHS sites are located in areas defined as “rural” by the Federal Communications Commission (FCC). These rural sites pay a higher percentage of their operating budget than urban locations on monthly internet circuit costs. When bandwidth upgrades are required, rural IHS sites are frequently asked to fund the capital costs of these upgrades. These projects can range from tens of thousands to over a million dollars in cost, and can take years to complete. In some cases, telecommunication providers are not able to offer any upgrade options for IHS locations.

At rural I/T/U locations, internet circuit outages and restoration times are above industry averages, due to outdated equipment and small regional telecommunication providers covering large geographical areas with long travel times and limited staff. Network connectivity to provide clinical services is affected by this.

There continues to be a large amount of network equipment which has reached end-of-support status from the vendor. Industrial averages for IT equipment refresh are normally within 5 years from the date of purchase.

A recent analysis of the network equipment on the IHS network revealed that approximately 49% of the IHS network equipment is more than five years old, with 19% 10 or more years old.[16]

During 2016, IHS upgraded network bandwidth at over 50 locations. IHS is moving away from slow speed internet circuits such as T1 lines (1.5Mbits) to Ethernet circuits which offer bandwidth in the 10 to 100 Mbits range. To help fund the monthly recurring circuit costs associated with these upgrades, IHS is increasingly leveraging the financial support provided by the Healthcare Connect Fund (HCF). The HCF is an FCC program to provide rural healthcare providers with financial support for bandwidth charges. However, large numbers of IHS facilities do not currently have sufficient bandwidth to offer telehealth and related services.

Approximately 50% of the IHS sites still depend on circuit connections based on one or two T1 lines (3 Mbits). Their circuits are constantly saturated with staff experiencing slow response times when using traditional IT applications. The addition of telehealth and mobile health services is not an option at these locations at this time.

3.4.14.3 Software Maintenance

RPMS is modified/upgraded using what are known as **Kernel Installation Distribution System (KIDS) builds**. KIDS builds can deliver anything from data updates (e.g., new terminology sets) to full package version upgrades. The number of software "patches" in a given year greatly exceeds the number of application "versions" that are delivered. The term "patches" is somewhat misleading; sometimes these are bug fixes, but in most cases patches will include substantive functional enhancements, sometimes quite substantial. This is particularly true for IHS patches to VistA-derived applications, because IHS

[16] http://www.tribalselfgov.org/wp-content/uploads/2017/05/CCrowder_Solutions-to-Modernize-IHS-Health-IT-4.26.17.pdf

cannot change the version number. As an example, VistA Lab has been at version 5.2 since 1994; the current iteration of Lab in RPMS includes 41 IHS-developed patches in addition to many released by VA.

Frequently, if the KIDS build transports code that is used by a Windows GUI, it is necessary to install a new version of the Windows GUI, depending on the extent of changes. This is distributed separately and needs to be installed on each client machine that accesses RPMS.

3.4.15 Software Security and Compliance

The evolution of RPMS as a series of diverse applications deployed over multiple organizations has resulted in a system with significant security challenges in its support of role-based access control (RBAC), identity verification, and comprehensive auditing.

There are a wide variety of security keys that can be assigned according to role (e.g., physician, nurse). Each package supplies its own keys, and assignment requires knowledge of the package. Local site managers assign security keys at their discretion.

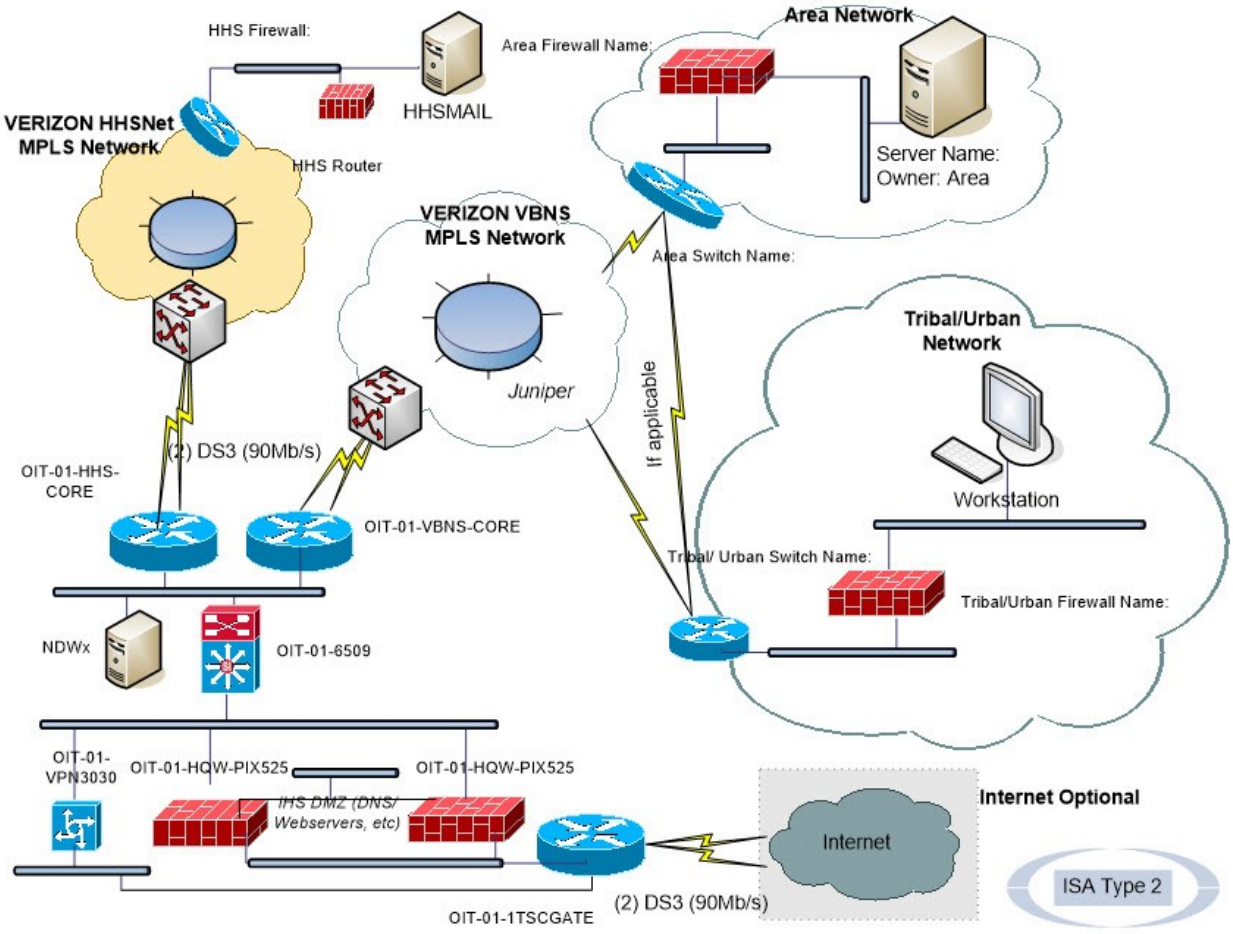
The RPMS User Security Audit package (namespace BUSA) is compliant with ONC certification requirements though it only performs the auditing functions required for certification. Many user interactions with RPMS are not included in the data collected by BUSA.

3.4.15.1 User Identity Management, User Login IDs

The RPMS application does not require multi-factor authentication (MFA) for login. RPMS login only requires legacy Access/Verify codes (which are equivalent to modern username/password). Multi-factor authentication is typically required when logging into the desktop. Multi-factor authentication was implemented in 2019 for ordering controlled drugs.

As a policy, users log off their desktop when not using their terminal. Users log out after each session. Sessions are terminated after a predetermined amount of time as set by the national program office. Single Sign On (SSO) has not been implemented across the RPMS suite.

3.4.15.2 Software Security Measures at Rest and in Transit



IHS Network Security

IHS uses an encrypted VPN tunnel for remote connections and data transfer. IHS uses network-based, passive intrusion detection systems to inspect all inbound and outbound network activity and identify suspicious patterns that may indicate a network or system attack from someone attempting to break into or compromise a system. The system contains firewalls to control the ports, protocols, and IPs leaving the boundary of the network. IHS uses a VPN concentrator to authenticate the user against IHS Active Directory and RADIUS.

Logical security

Users with access to IHS systems do not have access to the data except through their system security software inherent to the operating system. Access is provided by a written approval process. Access is controlled by authentication and role-based methods to validate the users' access.

Audit Trail

Activities recorded by the audit log include event type, date and time of event, user identification, workstation identification, success or failure of access attempts, and security actions taken by system administrators or security officers. Audit reports are retained for six years.[17]

[17]www.ihs.gov/ihm/includes/themes/responsive2017/display_objects/documents/pc/p8c15_ex_c.doc

3.4.16 Regulatory Compliance

RPMS, when operated by federally operated sites, must comply with federal policies and procedures. For instance, the use of wireless solutions must be consistent with federal policy. The ability to ensure that a system can meet federal guidelines is critical. One historical exception has been for Section 508[18] accessibility standards, for which IHS was granted a waiver in the past. Such exceptions would not likely carry forward to new or redeveloped systems.

As noted earlier, IHS was successful in achieving ONC certification for the RPMS suite in 2011 and 2014. However, 2014 certification is no longer sufficient for compliance with the Centers for Medicare and Medicaid Services (CMS) quality payment programs. Only part of RPMS is certified to 2015 Edition criteria at this time.

Performance and quality measures were a core component of RPMS long before they became regulatory requirements. Among others, RPMS supports the calculation of Government Performance and Results Act (GPRA) and GPRA Modernization Act (GPRAMA) measures as well as a substantial number of CMS electronic Clinical Quality Measures (eCQM).

A number of tribal/urban sites operate as Federally Qualified Health Centers (FQHC) and are partially funded by grants offered by the Health Resources and Services Administration (HRSA). FQHCs have specific reporting requirements that differ from other facilities, and these requirements (Uniform Data Set reports) are supported by RPMS.

[18] Section 508 of the Rehabilitation Act of 1973 as amended in 1998

4.0 Assessment of RPMS

This section summarizes the team assessment following an analysis of RPMS. For each area, findings are summarized based on what's working and areas of concern. Recommendations were added where that kind of content could be summarized.

A score is assigned to each area based on the original question: *Can RPMS be modernized?* This scoring assessed the current stage of modernization for each area. This assessment helps evaluate the potential level of effort needed to bring these areas to a modernized state.

RPMS Assessment Score Table

Can RPMS Be Modernized?

Assessment Score: 0 Inadequate Not fulfilling all basic requirements. Needs significant work to become operative.
Assessment Score: 1 Operative Functional, but requires significant effort and workarounds that increase workload.
Assessment Score: 2 Up to Date Fulfills contemporary expectations for technology.
Assessment Score: 3 Modernized Exceeds current expectations for technology, future proof.

Constraints and barriers identified during the legacy assessment include the following:

Constraint/Barrier	Mitigation/Response
Limited review of RPMS code	Possible to miss critical constraints
Infrastructure survey still in progress	Once completed, this information will be reviewed for inclusion in this assessment
Informant sampling process	Possible to have missed key informants; mitigation through multiple informants
Formal requirements for HIT modernization assessments do not exist	Informants identified and elaborated on their needs

4.1 RPMS User Experience and User Evaluation

On Qualitative Research Methods and Findings

The opinions and concerns presented here were collected during site visit interviews and listening sessions, from data calls, and via personal interviews. These statements are offered as a window into the perspectives of RPMS users. The findings described come from the perspectives of those users and may not factually represent the capabilities within the HIT system. Moreover, those familiar with the health IT landscape nationally will recognize that many of the observations are common regardless of the systems being used. The Legacy Assessment team does not place judgment on the validity or accuracy of these statements, but offers them as a reflection of current user experience.

End users were interviewed about their workflows, needs, and challenges when using RPMS.
Findings have been organized into four categorizations:

1. **Provider Experience:** primary RPMS clinical users include physicians, nurses, specialists, public health nurses (PHN), and others in the clinical management of patient care.
2. **Administration Experience:** practice management users are primary users of RPMS, for work such as billing, purchased/referred care (PRC), authorizations, medical scheduling, release of information, and health information management (HIM).
3. **Leadership Experience:** officers, directors, and tribal representatives use RPMS for reporting and other leadership activities.
4. **Patient Experience:** in some facilities patients have access to their records through a Patient Portal.

4.1.1 Provider Experience

What's Working	Areas of Concern	Recommendations
• EHR is sufficient to get the job done, but not without effort. • Labels and navigation are intuitive. • Population health reports are a key feature of RPMS, not available in other Health IT systems.	• Data entry is a time-consuming process that distracts from providing care • Reviewing clinical information is cumbersome, and there is potential for overlooking key information • It is hard for providers to identify the tasks and information they need • Specialty packages for obstetrics and emergency medicine are missing • Flowsheets are not supported • Communication between providers lacks context	• Redesign data entry for fast entry and multitasking (reviewing labs, meds, problem lists) • Semantic search for notes, labs, and more • Prioritize notifications • Redesign provider dashboards to provide key personalized information for providers • Incorporate flowsheets functionality • Attach contextual information to provider communications • Incorporate voice dictation
Assessment Score: 1 Operative Functional, but needs significant effort and workarounds		

Providers rely on Health IT to view and document clinical interactions with patients, make clinical decisions, interact with other providers and the patient, and more. Many providers

wished that it was a tool to help them make clinical decisions and add to the visit rather than distract from it.

Providers' frustrations with RPMS are many, but it is important to note that many of RPMS's shortcomings are the same as commercial off-the-shelf (COTS) solutions available in the market. The EHR is one of the top three main contributors to physician burnout in 2019, with bureaucratic tasks (also related to EHR) being the first.[19] However, in the IHS data call, providers using RPMS were considerably more frustrated with RPMS than providers using other COTS.

Reviewing and Prioritizing Clinical Information

- **CRITICAL: It is hard for providers to know what they need to focus on in the moment**. Lack of a dashboard makes it difficult to prioritize and focus on patients, outstanding orders, relevant notifications, latest messages, reminders, and other tasks.
- **CRITICAL: Reviewing past history is hard, as a semantic search of notes is not available.** Clinicians can only search for notes by the name of the clinician who wrote them. The ability to search for text, labs, and medications within notes is not available.
- **Lack of markup makes notes hard to scan.** There's no ability to emphasize text, headings, or add rich media (such as photos). This makes subsequent review of notes difficult.
- **It is difficult to differentiate notes from visits and interactions.** Each interaction within a visit is entered into the system as a separate note, and there is no way to differentiate them from one another.
- **Problem List, Medication Reconciliation, Labs, and Orders are difficult to review.** Lists are disorganized, sometimes full of inactive and outdated entries. Labs often do not

[19] https://www.advisory.com/daily-briefing/2019/01/18/burnout-report

integrate as expected into the patient record. Orders sometimes do not get dismissed, making it difficult to know what's outstanding.

- **Safety alerts are provided, but lack prioritization.** Alerts for drug interactions, allergies, drug-lab checking, and others are available, but can result in an overload of notifications which causes critical alerts to be missed.

Data Entry

- **CRITICAL: RPMS does not support flowsheets, so they have to be created on paper.** This creates extra steps, and paper flowsheets can easily be misfiled.
- **CRITICAL: Clinical data is spread across multiple tabs, making it slow to cross-reference when writing a note.** Providers need to save and close the active note to be able to cross-reference old notes, labs, and patient information located in the other tabs. This creates a slow process and makes it possible to miss information.
- **CRITICAL: Satisfying compliance regulations in notes may compete with providing care.** EHR compliance requirements can create additional work for clinicians. Two clinicians were frustrated that they needed to enter a diagnosis into every note, when sometimes there was no diagnosis to provide. Clinicians from one facility noted they have to finish notes (a slow process) to prescribe drugs, which was a source of frustration to patients.
- **CRITICAL: RPMS does not have integrated voice dictation.** Providers believe that the ability to use voice dictation would help document notes faster and more completely.[20]

[20] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4642384/ and https://www.modernhealthcare.com/article/20151212/MAGAZINE/312129980/nurses-turn-to-speech-recognition-software-to-speed-documentation

- **Many templates have too many steps, slowing down note-taking.** Templates are often slow to load and take a long time to complete. Sometimes the use of note templates is slower than free text.

- **Facilities rely heavily on paper for initial paperwork with patient history, but RPMS does not support scanning.** The process to transfer patient information into RPMS through manual retrospective data entry adds additional work, and can result in transfer errors.

Customization and Standardization of Care

- **CRITICAL: EHR does not recognize its users' frequent patterns.** Physicians mentioned there are a handful of conditions, labs, and orders they work with frequently, but RPMS does not prioritize that information.

  "A smart system would learn my frequent diagnoses. There are 10 or 15 that I use every day."

- **Many templates make it difficult to know which one to use.** Templates are customized for each facility and sometimes per user. Some staff question whether the information is being recorded using the right template, and find inconsistency between template quality.

  "Everyone uses the templates they want. Some people take good notes, others do not."

Communication and Collaboration

- **Multiple communication functions in EHR results in fragmented communication.** A communications tab can send messages between users. However, there are problems with lack of message triggers, and the inability to thread message conversations. Orders can

also be used to send communications, but providers must regularly check to see if they have pending orders. These communication tools do not allow attachment of notes (such as for a referral).

- **Communication workarounds are used.** The "Additional Signers" field on notes is sometimes used between providers as a communication workaround. Providers may also communicate through unofficial channels such as text messaging and Skype.
- **Patients miss notifications from providers in the Personal Health Record (PHR).** Therefore, providers rely on the phone to contact patients as the PHR is an unreliable method.

4.1.2 Administration Experience

What's Working	Areas of Concern	Recommendations
• Data collection leads to uniquely holistic reporting capability • Moonwalk's visual scheduling has improved scheduling and registration's ability to book appointments. • For basic tasks, the speed of roll-and-scroll keyboard operated user interfaces is beloved, once it is learned.	• Redundant information entry and excessive back and forth create enormous operational inefficiencies and increased risk of user error. • Staff report that establishing eligibility for patients who are transient or homeless is difficult, and means of documenting absence of an actual address is lacking.	• Administrative tasks should take place in a single, consistent user interface, which displays only relevant features based on user role. • Future graphical user interfaces should consider incorporating keyboard shortcuts for speed.
Assessment Score: 0 Inadequate Not fulfilling all basic requirements. Needs significant work to become operative.		

IHS administrative staff uses RPMS applications to enter patient and insurance information, schedule patient visits, check in patients, code patient visits, bill for patient visits, refer patients to external providers, release information to the patient and outside providers, and report information to leadership.

4.1.2.2 Admission, Discharge, and Transfer (ADT)

- **CRITICAL: Inefficient workflows increase patient wait times.** The Moonwalk registration process requires registration staff to ask the patient ten pages of questions. This often causes a patient check-in to exceed the ten-minute check-in window. This is a problem because if the patient is then marked as a no-show, they must wait to see a doctor as a walk-in instead. Scheduling staff report that the phones can become overloaded and result in dropped calls.

  "I took too long to enter patient information into Moonwalk, so the nurses actually no-showed that same patient they were supposed to see because they didn't think they were checked in."

  "I would like patients to be able to go in and schedule their own appointment and not have to go on the phone and wait on the line."

- **CRITICAL: System does not accommodate transient populations.** The system has no means of entering patient information for individuals who might not live within the boundaries of the reservation, who might be homeless or transient, or who might be living with family and cannot prove their address.

  "I wish for those people who live here with daughters or in-laws that we could at least get a notarized letter that they live here but with someone else."

- **Data fields do not cover several use cases.** For transgender patients, there is no option to enter sex versus gender, there is no option to state "other," and there is no field for sex at birth.

An area office mentioned that the system also cannot handle unidentified trauma patients—it requires a name—making it very hard to order labs, radiology, and more.

4.1.2.1 Reporting

- **CRITICAL: Long work backlogs inhibit facility from accurate reporting, collecting claims, and providing timely care.** Because referrals, release of information (ROI), prescriptions, and billing are dependent on final coding, the backlog in final coding can result in delays in both referrals and payment for patient care. In many locations, HIM specialists have unaddressed report notifications dating back three to four months, which also increases the likelihood of inaccurate reporting.

- **Generating reports is time-consuming, requires staff to use workarounds, and results in variable outcomes.** When generating a report, certain fields lag (for instance, when selecting a date). A significant limitation is the inability to save a report template for reuse. Some steps are completed in RPMS, with further work required in Excel. One admin reported the inability to disaggregate data by hour, resulted in the need to generate a unique report for each hour.

  This workflow leads to reports that are sometimes inconsistent, leading administrators to question the accuracy of the data.

  "Unless you have instructions, it is hard to pull the same report twice."

Application Usability and Training

- **Multiple interfaces are required to perform one function.** Staff must memorize which programs to use for each task. Sometimes information does not transfer or only partially transfers from one interface to another. When entering claims, billing admins must use three separate systems and cross-reference their output.

"Would have been nice to be able to code right in here [in ADT] instead of having RPMS be open. Might be easier."

- **A high level of domain knowledge is required to perform basic duties.**

  "You can be in the system a long time if you do not know the shortcuts for accessing insurance information."

- **Once learned, "Roll and Scroll" is beloved by many administrative staff.** Because of its speed and simplicity, many admin staff enjoy using the keyboard operated Roll and Scroll interface over mouse operated graphical user interfaces such as the EHR and Moonwalk. However, not everyone prefers the Roll and Scroll interface, one admin noted, "It is like going back in time."

- **At most sites, paperwork is still integral to record keeping and workflow.** At one clinic, registration staff used printed work orders to alert nurses of a patient arrival. However, if a work order is printed multiple times, multiple nurses may begin working on the same file, creating confusion, duplicated work, and inefficiencies. In addition, release of Information (ROI) admins suggest a need for e-signatures.

  "We want a signature pad for ROI, but we still do wet signatures."

- **Alerts are seen as ineffective.** Due to slow alert systems, some staff have determined that it is faster to transport information on foot.

  "Right now, we manually walk paper over to another building."

4.1.3 Leadership Experience

What's Working	Areas of Concern	Recommendations
• Facility leadership has access to years of patient data, even before EHR, and the numerical trending of data (including vitals, labs, and growth charts) is extremely helpful. • Population health reports are a key feature of RPMS, not available in other Health IT systems.	• Changing and improving RPMS is met with concern because even small upgrades are known to break the system. • Time consuming workflows and duplicate work mean that leadership is unable to efficiently use and train their staff. • Leadership must fulfill complex reporting requirements from disparate systems. • Population health reporting is not linked to national registries.	• Provide improved and integrated reporting tools for facility leadership. • Provide guidance, tools and support for facility leadership to take advantage of government programs and telemedicine learning initiatives. • Retain access to years of patient and population health data.
Assessment Score: 1 Operative Functional, but needs significant effort and workarounds. Making workload more difficult.		

The I/T/U leadership is responsible for maintaining a high standard of care at their facilities with limited resources. Operational inefficiencies are particularly damaging to I/T/U facilities because of chronic understaffing. Facility leadership is concerned with inefficiencies, staff retention, compliance, reporting requirements, and finding funding and solutions to keep the facilities running and able to continue serving their population.

Operational Planning

- **CRITICAL: Extending and improving RPMS is seen as difficult.** Leadership expressed that they would like to simplify workflows and improve care - such as printing patient wristbands directly from RPMS, collecting patient signatures electronically, and data sharing with biomedical equipment and Laboratory Information System (LIS). However, due to failed past attempts to upgrade the system, I/T/U facility leaders have learned to be cautious of changing or extending the system. RPMS has compatibility issues making an attempt to upgrade or extend the system complex.

  "IT was stuck on Windows 7, so they could not procure new systems that wouldn't be compatible with Windows 7."

  "We're decades behind the VA software. Our spend is so low compared to others. If we got the middle things (not even the best), we would be where we need to be today."

- **Doctors performing data entry is an inefficient use of facility resources.** Use of physician time to perform data entry is an expensive use of resources. Adding scribes to assist with documentation has not been seen as an affordable option for I/T/U facilities. Some facilities have implemented voice speech-to-text software, but some users report configuration issues that led to "unacceptable abbreviations in the notes". Leadership seeks a scenario where doctors can record patient encounters efficiently.

  "[Our] Doctors spend close to 50/50 between documentation and the time with the patient."

- **A lack of standardization between IHS sites makes it difficult to compare documentation and establish best practices.** The inability to see and share information with other Indian Health sites was cited as a missed opportunity by leadership.

- **Provider scorecards are useful tools for leadership.** Leadership likes that everyone can see a provider's scorecards. They allow leadership to evaluate performance and make decisions.

Linkage to National Registries

- **RPMS does not link directly to other registries.** Users often have to use an external system to view population health information for national registries and manually enter information into RPMS and the external registry, this is not the case for all of the sites. For instance, facility staff in the Bemidji region are tasked with manual entry of immunizations into the Michigan Immunization registry (MCIR), but RPMS does not receive immunization information back from MCIR.

Reporting and Compliance

- **Complex and extensive reporting requirements are difficult to fulfill because report generation is slow and not integrated.** Leadership generates reports from VGEN, PGEN, and iCare, but without real-time data or the ability to integrate these systems, reporting is difficult. The report system generates reports extremely slowly. It could take 30 to 40 minutes to populate a report between UFMS and RPMS. Therefore, Leadership often runs reports overnight, particularly with the iCare interface. Regular external report generation reduces the time available to use RPMS to generate report for internal leadership.

  "I would like to be able to pull information from the system that could help with productivity, efficiency data, tracking data manually over a 12-hour shift."

4.1.4 Patient Experience

What's Working	Areas of Concern	Recommendations

• Patient portal is part of RPMS functionality.	• It lacks the ability to schedule appointments, obtain referrals, and refill prescriptions. • Patients miss provider notifications in the portal, and end up relying on their own memory to call ROI for results and to learn about next steps. • PHR may be difficult to interpret without a provider or confuse patients. • There is a lack of guidance focusing on preventative care and wellness.	• Provide a portal for patients to access their Patient Health Records (PHR), schedule appointments, communicate with their doctor, get referrals for outside care, and refill prescriptions. • Provide culturally relevant health care materials for different communities for preventative care and wellness • Provide patient level information about results in the PHR to make it more readable.
Assessment Score: 0 Inadequate Not fulfilling all basic requirements. Needs significant work to become operative.		

Patients are affected by how facilities' staff interact with the personal health record. We have interviewed several non-clinical and administrative IHS employees who use the facilities as patients to understand their experiences. To compensate for any biases from this sample, we have added feedback from the clinical staff's experience interacting with patients.

Access to Patient Health Records (PHR)

- **Some facilities provide a patient portal, but it is not used.** Facility staff says that patients aren't aware of the patient portal nor take advantage of its communications area. Additional patient education could be provided by the portal.

  "We'd like to see a functional patient portal that allows two way communication. The current one is not used and the sign up is horrible!"

- **Legal guardians want to have access to and control over their dependents' records.** Legal guardians who are responsible for the health of their dependents spend time to follow up on health histories and communicate with physicians.

Communication with Providers

- **Understanding the PHR content is important to patients.** Patients sometimes are worried when they read notes and results on the patient portal without an expert to assist in interpretation.

Workflows and Care Pathways

CRITICAL: Scheduling, following up, and obtaining refills over the phone and during visits is time-consuming or unavailable. Patients would like more convenient ways to access care than waiting on the telephone or waiting at a facility.

4.2 Organization

The information gathered to evaluate IT support and training was obtained primarily from interviews with IHS staffers at the national Office of Information Technology level. IT teams at the area office and facility levels were interviewed as well. The following areas were considered:

- Support: Tiers 1-3, ticketing, enhancements.
- Training: Training repository, manuals, onboarding as an RPMS user, knowledge transfer.
- Availability of Skills/Expertise: Finding and hiring developers to maintain RPMS.

4.2.1 Support

What's Working	Areas of Concern	Recommendations
• Some sites are able to thrive when they hire RPMS developers directly	• All tiers of support are understaffed due to the non-transferable nature of the job. • All tiers of support are under-resourced. • Enhancements and training are limited due to lack of resources • No global ticketing platform • The high variability of hardware, versions, and configurations of RPMS installed in the facilities make it hard to diagnose issues.	• Develop standard staffing recommendations for facilities • Implement global ticketing platform • Move to a RPMS gold DB
Assessment Score: 0 Inadequate Not fulfilling all basic requirements. Needs significant work to become operative.		

IT support encompasses troubleshooting daily tasks to running system-wide patches. These support teams report that their workflow is currently reactive. Support personnel are constantly scrambling to fix issues—both basic and urgent—instead of enabling the clinical team to provide care to the community. They are challenged with an environment constrained for resources. They usually barely have enough to satisfy basic IT needs, let alone provide the specialized support that RPMS requires to run smoothly.

As explained previously, IT support for the IHS happens in three levels, or tiers: the facility level, or tier 1, which includes IT personnel and Clinical Informaticists (CIs), often referred to by their previous title of Clinical Application Coordinators (CACs); the area office level, or tier 2; and the national office level, or tier 3. This support is offered for all IT issues, including RPMS.

4.2.1.1 Findings Across All Tiers

- **Critical: Staffing is a huge issue across all tiers.** MUMPS developers are hard to find. IT staff across all tiers need to be trained in RPMS to be able to support it, but time and availability to get that training is limited.
- **Budget is insufficient across all tiers.** The money allocated by the IHS to IT and RPMS support is not sufficient to cover all the basic needs of the facilities.
- **RPMS is extensively customized at the facility level, making it challenging to support.** Unless the IT staffer is highly familiar with how RPMS was implemented at a facility, it can take a long time to diagnose an issue and solve it.

  "It can be challenging because we have different stakeholders at all levels. Everybody wants something different, they all want the newest and greatest, there's no centralization to obtain software or hardware. Everyone is doing what they think is best for their area. It is a huge challenge. We'll create patches, versions, write policies, procedures on how to load and manage applications. But once it leaves IHS Office of Information Technology we can't control that." IHS Staffer

- **The high variability of hardware, versions, and configurations of RPMS installed in the facilities make it hard to diagnose issues.** This makes it hard for IT support to collaborate and diagnose RPMS bugs and issues. Hardware purchase decisions are made at the facility level based on their budgets and other needs, often without consulting the IHS on compatibility.

  "EHR is so different between sites that it is hard to provide support and training remotely. Differing hardware and OS add to complexity troubleshooting."

- **Various ticketing systems across tiers leads to inefficient and leaky processes in reporting, resolving, and escalating issues.** Facility staff reported using Outlook (email), phone calls, and catching a CAC in person to report tasks. Without proper tracking, issues are slow to resolve and sometimes lost. Tier 3 tickets are sent over email then entered into the HEAT ticketing system, but it is not possible for the people who initiated that ticket to track it.
  "I get a ticket through email. It is sent to me, like if I get a dental support ticket, it pops up in my email. We have to be pretty vigilant about reading emails on a constant basis throughout the day because that is our sole source for retrieving our tickets." Tier 3 staffer

- **Poor roll out of the IHS Office of Information Technology (OIT) ticketing system has led to low adoption at the I/T/U site level.** Many sites are using email to report and track tickets with Tier 3 despite the fact that OIT recently launched a ticketing system. Using this method, many tickets are lost and are reported multiple times without resolution. Beyond the issue of inefficiency, this also impacts the ability to use data analysis to understand where the bulk of issues lie.

  "OIT has a ticketing system, but their implementation was poor. They did not gather requirements from tribal and urban sites, so no one uses it."

  "[There was] no quality improvement. Continuous issues are not being dealt with, even after being repeatedly reported."

4.2.1.2 Support -- Tier 1

- **RPMS.** A long backlog of support tickets makes it difficult to prioritize proactive measures for maintaining the facility IT system. In addition, because there is not much time allocated to training staff, Tier 1 support often trains "on the job" when things go wrong as opposed to comprehensively training staff to do things right in the first place.

  "We're more of a reaction-based training program. We do not really have a strong IT training workforce that I think should come from the agency."

- **Because the VA will move to Cerner, many sites are concerned about the affordability and availability of training for Tier 1 support.** Currently, sites rely on training and development provided through the VA. It is difficult to find applicants with relevant experience, so most Tier 1 support staff are hired from within I/T/U facilities, and they rely heavily on VA support to acquire the domain knowledge needed to perform their jobs.

  "Support has been adequate, but [the] VA has been a crutch for us."

- **With limited manpower and a complex HIT system, Tier 1 staff cannot support the full application in much depth.** Often, the issues reported are quite granular and may be related to specific packages. The Tier 1 support team cannot troubleshoot in these instances because they are not Subject Matter Experts (SMEs) on a given package.

  "Some people have 18-20 hats. You should be able to specialize in 1-2 domains."

- **Smaller sites have left RPMS because they were unable to maintain Tier 1 support.** Smaller sites like Denver Indian Health and Family Services (DIHFS) used to be on RPMS, but they moved away in order to outsource their support needs. They could not maintain RPMS on their own due to its complexity.
- **Purchasing without review by IT causes a further lack of interoperability.** Tier 1 support reported that leadership sometimes purchases COTS systems and hands them over to IT to figure out how to make them compatible with RPMS, forcing IT to find complicated resolutions.

- **Tier 1 support is often called upon to aid in basic tasks.** RPMS is challenging for users, and IT teams are heavily relied upon to aid users with job-specific tasks outside the scope of basic support. For example, supervisors need to create profiles for employees, but they lack experience or knowledge with the software and wait for IT to set up profiles instead.
- **CIs are bogged down in the effort to lock down provider notes.** Template creation is a laborious task. It is not an efficient process and lacks standardization between individuals and sites. Currently, it takes two to three weeks to set up a template.

4.2.1.3 Support -- Tier 2

- **Level of Tier 2 services between area offices varies widely based on how knowledgeable the staff is with RPMS.** Some area offices are able to provide a high level of service to facilities, helping them solve RPMS bugs, configuration, and customization issues. Others feel unable to help facilities with RPMS, and often are only able to escalate tickets to the national level.
- **Some facilities feel they cannot count on technical support from their Area Office.** These facilities often resort to contacting Tier 3 directly to solve RPMS (and other) issues.
- **There are ongoing efforts from some area offices to standardize templates across their facilities.** Once templates are standardized across facilities based on best practices, providers will then be able to use RPMS from one facility to another without having to relearn it. It also ensures high standards of care across facilities.

4.2.1.4 Support -- Tier 3

Other issues regarding Tier 3 support have been mentioned under the Infrastructure sections.

- **Staffing challenges at the Tier 3 level results in more contractor based support.** RPMS tickets are being addressed entirely by contract developers, while there is only enough IHS staff to manage those contractors and their tickets. This approach can be expensive, and when contracts expire, there is risk that a company will be replaced by a different one, which would then need to spend time learning how to support RPMS.

- **The RPMS development workload is overloaded with regulatory compliance and certification updates, which limits the ability of development staff to address I/T/U requests.** Enhancement requests coming from facilities may take months to get addressed. If a knowledgeable area office cannot help, a facility may be left with issues caused by configuration for a long time.
- **CRITICAL: The budget to support RPMS is very constrained.** This reduces the number of resources available for RPMS support and training.

4.2.2 Training

What's Working	Areas of Concern	Recommendations
• Training content is created based on user feedback	• No official on-site training. • Limited awareness of training resources. • Training resources are dispersed and hard to browse and search for. • Training resources do not cover practices from facility to facility • Inadequate transfer practices	• Reduce customization of RPMS to make training more global. • Move training material to a centralized, searchable platform. • Create a peer-to-peer forum for knowledge exchange
Assessment Score: 0 Inadequate Not fulfilling all basic requirements. Needs significant work to become operative.		

Like most Health IT, RPMS is a highly complex platform, and can never be intuitive enough for staff to learn how to use it without any training. This training may have to be tailored per facility, as most health organizations have different needs and workflows that affect the way they incorporate Health IT into care. While some training, and even some facility-specific training, is to be expected with any Health IT, RPMS has unique challenges in this area.

- **CRITICAL:** There are no official training programs available for employees starting on the job. Many organizations using Health IT only let an employee start after they undergo training on the systems and workflows for a few days. IHS facilities are unable to ensure this. Most employees hit the ground running, trying to learn as much as they can while on the job.

  Employees get trained by other employees—if they are available—or have to learn RPMS on their own. Most IHS employees were trained by other employees while on the job. Sometimes clinicians or other employees took on the role of mentoring new staff on RPMS. Many facilities had no trainer, and claimed they had to learn through trial and error. In these cases, the training was only as good as the expertise of the person teaching new staff.

"You just have to learn from your own mistakes. Everybody's just basically teaching themselves. You explore different areas and find out for yourself what's in there."

"New staff make comments about the system."

"It takes a while to do EHR, but if you're trained right, get more practice time, if [they] could familiarize themselves... I think we need more training time. IT goes over that so fast, and the next day we're expected to see patients."

"The disadvantage to hands-on training is they are only going to teach you what they know. There are a lot of other ways you can use that tool."

- **CRITICAL:** Training resources are dispersed and hard to find.[21] IHS provides manuals in PDF format on their website, as well as the Training Repository with video recordings of RPMS training sessions sorted by category in a tree-style navigation. The content for these two resources is not intuitive. The PDFs can be hundreds of pages long, and users have to rely on knowing the package they need help with, and the table of contents of each PDF to find what they are looking for.

The Training Repository does not include a search engine; videos do not have descriptions, date stamps, or keywords to help users find what they need. Some videos may run a few minutes or over an hour long.There are no platforms for RPMS users to help each other—this type of interaction is only available through the employee's own social circle. Note: At the time of release of this report, the team had not been granted full access to the Training Repository to do a more thorough review.

"I feel like it works if you know how to use it. It is not an intuitive program. The training is not helpful—it is either so basic I do not need it or it is not helpful. It is not intuitive."

[21] Training resources: https://www.ihs.gov/rpms/training/

- **CRITICAL:** Staff are not aware of training resources. When asked about how they learn RPMS, most employees mentioned a colleague, or doing it on their own. No one mentioned using any of the available training materials, aside from IT personnel. Facilities and area offices that were most satisfied with RPMS-related IT service usually had one staffer who was more knowledgeable about RPMS
- **CRITICAL:** . There are limited knowledge transfer practices in place across tiers. The last RPMS Standards and Conventions (SAC) Developer Guidelines document was published in 2009. Several rules have been put in place since that time, but have not been formalized or updated in SAC document.

  "If [IT support person] leaves, I will retire too. He knows we need him. It'd be great to have someone he can train on this." CI at a facility

  "I know that [IHS staffer] worked on [a Standards and Conventions Developer Guidelines document update] in 2012 and it wasn't approved. Then seems like we've been hopping from chairman to chairman. I tried to start up a whole other one last year but we lost staff and it is kind of difficult."

- **CRITICAL:** High rates of customization of RPMS and different versions and packages at each site make training challenging. RPMS is known for being highly customizable. While many facilities appreciate the ability to tailor the solution to their needs in an environment where user needs vary widely for each facility, this creates a challenge in training. Workflows, position of navigation elements, labels, and colors may be different in each location, making it difficult to train staff using a common language, document, or training course module.

  "Each template...different facility. Often times we have to set up screen sharing. Each one can be different."

  "EHR is so different between sites that it is hard to provide support and training remotely. Differing hardware and OS add to complexity troubleshooting."

“Providers (like specialists) who are working at different sites have to re-learn at each site, wastes a lot of time.”

- **CRITICAL:** Workflows in each facility vary, deeming the national-level training resources insufficient. Each facility spends time educating their staff on how to use RPMS the way it is used at the facility, and how to use RPMS to collaborate with other staff members.

  "I waited a long time to receive training. It is a big issue. Availability of information, how-tos, knowledge bases, it is too confusing with all of these options. They do not have anything in there for security or HIM."

- Some area offices provide training, but access is limited. Training time with area offices is very highly valued, but there are not enough spots for everyone to get trained in person.

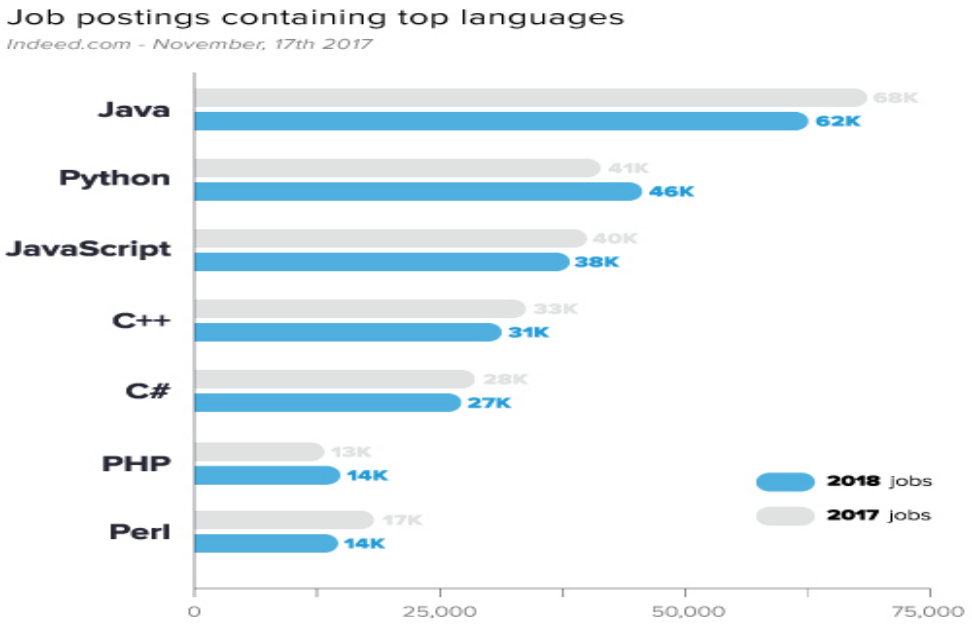
4.2.3 Availability of Skills/Expertise

What's Working	Areas of Concern	Recommendations
• Contractors are still available to work on MUMPS	• Skill gap for qualified MUMPS developers will continue to grow. MUMPS is not taught in engineering schools. • The underlying technologies of RPMS do not attract new-to-IT-careers entrants, MUMPS is archaic and not transferable outside of HIT. • Economies of scale in the public engineering skills market cannot be leveraged. • IHS does not have the resources to train MUMPS developers in-house.	• Adopt modern, more marketable programming languages.
Assessment Score: 0 Inadequate Not fulfilling all basic requirements. Needs significant work to become operative.		

The Office of Information Technology (OIT) Human Capital Management Plan (09/20/2017) by the IHS Information Systems Advisory Committee (ISAC) recognizes challenges in retention and recruitment of skilled IT professionals for IHS, and by extension, RPMS. The presentation highlights a "shortage of qualified IT health care professionals" both nationally and within the federal government.

- **Skills gap for qualified IT professionals will continue to grow.** The rate at which the current set of RPMS developers ages out of the job market will increasingly outpace new hires that are willing to learn a technology that is perceived to be "legacy" and "archaic." A global search on LinkedIn for MUMPS developers yielded only 8.5 thousand results, as opposed to 8.5 million results for Java, 5.4 million for JavaScript, and 3.5 million for either PHP or Python.
- **The underlying technologies of RPMS do not attract new-to-IT-careers entrants.** The underlying technologies of RPMS may be a further hindrance to attracting top IT talent. Working on systems like RPMS does not confer readily transferable software development or IT skills given the proprietary nature of the programming language and frameworks used. The MUMPS programming language does not appear on any lists of recommended programming languages to

learn,[22] or on any lists of the most in-demand skills for software engineers; these lists are both important resources that are used in the field when deciding what languages and frameworks to invest the time to learn.[23]



- **Economies of scale in the public engineering skills market cannot be leveraged.** RPMS uses bespoke technologies, protocols, and frameworks; programming languages that are considered archaic by most software engineers and that few choose to learn; and closed, proprietary systems, built and owned by private corporations that require specialized training to build and maintain. As a result, the pool of available resources on the public market with the skills to continue to build and maintain RPMS will continue to shrink, and the cost of recruiting and training new hires will continue to rise. Modern and popular open source languages and frameworks that developers have the ability to learn from other employers, that confer more transferable skills, and that are

[22] Programming languages in highest demand
[23] https://www.codingdojo.com/blog/7-most-in-demand-programming-languages-of-2018

used in areas outside of healthcare will allow IHS to leverage bigger pools of trained IT talent and create a more attractive employment offering for new recruits.

"RPMS has outgrown the agency's ability to support and enhance it due to flat IT funding and the withdrawal of tribal IT shares by large tribes opting for commercial solutions to meet their own requirements."[24]

4.3 Technical -- Current Architecture

RPMS architecture was analyzed for modernization potential via the following approaches:

- **Review of code**
- **Examination of writings by developers of RPMS**
- **Interviews with RPMS developers from the national to the facility levels**

The following areas were considered:

- **Code (Language and Framework):** M/MUMPS, Silverlight, Application Logic, Kernel and FileMan, VistA, Testability
- **Data Sharing and Portability:** The relative ease of data migration to different platforms
- **Interoperability:** Communication protocols, data exchange, APIs
    - **Health Information Exchange:** The communication between providers, patients, and facilities
- **Application Integrations:** Communication between modules, FileMan and Silverlight, Integration of third-party applications
- **Extensibility:** Options for customization

[24] Solutions to Modernize IHS Health Information Technology, by Carolyn Crowder, 2017 Annual Tribal Self-Governance Consultation Conference: http://www.tribalselfgov.org/wp-content/uploads/2017/05/CCrowder_Solutions-to-Modernize-IHS-Health-IT-4.26.17.pdf

4.3.1 RPMS Code (Language and Framework)

What's Working	Areas of Concern	Recommendations
• MUMPS database can access hierarchical data through the use of global variables. • Collaboration with the VA	• MUMPS functions violate contemporary data security norms. • Availability of MUMPS developers is declining, MUMPS is not taught in engineering schools. • IHS does not have the resources to train MUMPS developers in-house. • Loss of support from the VA within the next decade	• Standardize current databases in the RPMS systems using a process similar to VHA to create a Gold RPMS database • Consider wrap and renew approaches as described herein
Assessment Score: 0 Inadequate Not fulfilling all basic requirements. Needs significant work to become operative.		

It is difficult to obtain a percentage of code by language, as M is very dense compared with C-syntax languages, but a good estimate is as follows (estimating code maintained by IHS and not by the VA, a vendor or an open source community). These estimates are based on experience and not a count of lines of code. As such, they should be taken as indicative of the type of skills required to maintain RPMS, not as an exact code amount.

- MUMPS: 75%
- Delphi: 5% (VCL framework)
- C#: 15% (various frameworks: WinForms, WPF, Silverlight)
- All others (VB6, VB.Net, Cache Objectscript): About 5%

As detailed in the Three Architectures of RPMS section, RPMS is mainly written in the MUMPS programming language. MUMPS is both a programming language and database that was created in the 1960s for use in the healthcare industry. One of the key features and selling points of MUMPS is the database and its ability to access hierarchical data through the use of global variables; MUMPS Globals are directly tied to the database and manipulations are stored on disk and persisted. However, the language is described as "highly cryptic, with terse acronyms that obscure the meaning of the code."[25]

The drawbacks of the MUMPS language are many, including:

- All MUMPS data on disk ("called globals") can be accessed from the code. While this is very similar to Object Relational Mapping (ORM) technologies used today with Java and .NET platforms, a few of the authors may consider this feature as breaking encapsulation, information hiding, and data visibility.
- "MUMPS scoping rules are more permissive than other modern languages. Declared local variables are scoped using the stack. A routine can normally see all declared locals of the routines below it on the call stack, and routines cannot prevent routines they call from modifying their declared locals. By contrast, undeclared variables (variables created by using them, rather than declaration) are in scope for all routines running in the same process, and remain in scope until the program exits."[26] This violates principles of proper variable scoping.
- Portability constraints enforced by the RPMS Programming Conventions and originally imposed by the original hardware constraints of the 1980's have persisted to this day, at the critical expense of maintainability. These include:
    - 8 character variable names, routine names, global names, and labels
    - everything is Uppercase (making code hard to read)

[25] Ulrich, William M. Information Systems Transformation (The MK/OMG Press) (pp. 302-303). Elsevier Science. Kindle Edition.
[26] https://en.wikipedia.org/wiki/MUMPS#Criticism

- Legacy code written before the 1990 M Standard has more persistent issues with globally scoped variables and the lack of functions. Such code is harder to read and maintain.
- No current ANSI standards accreditation or governing standardization body: "The M Technology Association was accredited by ANSI as a Standards Development Organization that produces voluntary standards related to the use of the programming language [MUMPS]. When the M Technology Association ceased to exist (as per 1 January 2002), this accreditation elapsed, as well as all existing ANSI standards."[27]

The foundation of software systems is the language that they are written with and the frameworks that they use. Analyzing the core languages of a legacy system when deciding whether continued investment in expanding the system using the same language(s)/framework(s) is feasible, and a sound business decision. "Modern languages depend heavily upon reusable component frameworks and open source communities to boost programmer productivity through the reuse of components and shareable software. Modern programming practice depends heavily upon languages following established, sound principles of computer science. MUMPS fails to satisfy these principles in virtually every category."[28]

The cost of maintenance and ease of future modernization is correlated with the market trends of available developers with sufficient knowledge of the languages and frameworks used. In this respect, the MUMPS programming language is perhaps the biggest hindrance to any modernization efforts of RPMS, and by extension any systems that are reliant on MUMPS as the core programming language: systems such as InterSystems Caché and VistA.

- **The community of MUMPS developers outside of a few organizations is insufficient for sustained growth or continued maintenance.** MUMPS is not a popular language; it does not rank within the top 100 programming languages as tracked by the TIOBE

[27] http://71.174.62.16/MDC/

[28] Ulrich, William M. Information Systems Transformation (The MK/OMG Press) (pp. 302-303). Elsevier Science. Kindle Edition.

Index[29]. The market of developers with the proficiency in, or willingness to learn, MUMPS is limited. Organizations that rely on MUMPS must invest greatly in training new developers in the language and cannot tap into more cost-effective resource pools. As a result, the rate at which MUMPS developers move on or retire will outpace the rate at which MUMPS developers can be identified, willingly trained or hired. Newer software engineers gravitate to more popular languages that offer more transferable skills and better career paths. A global search on LinkedIn for MUMPS developers yielded only 8.5 Thousand results, as opposed to 8.5 Million results for Java, 5.4 Million for JavaScript, and 3.5 Million for either PHP or Python.

- **There is a single dominant corporation as the primary vendor.** InterSystems is the primary vendor of MUMPS technology today within healthcare.[30] The availability of code libraries outside of what InterSystems or the VA (through VistA) provide is limited. This over reliance on a single entity for libraries increases risks, both in the business and information security areas.
- **The benefits of MUMPS do not outweigh the drawbacks.** For the patterns of data access and the speeds at which RPMS needs to operate, the benefits of MUMPS database access operations do not outweigh all of the aforementioned drawbacks of the language. Equivalent efficiencies can be achieved with modern programming languages and more widely supported COTS RDBMS/NoSQL technologies and architectures, with increases in ease of maintainability and lower technical risks.
- **Legacy systems are difficult to modernize if the underlying programming language remains archaic.** Unless there is a resurgence of MUMPS interest in the software engineering community that increases the available pool of programming resources, RPMS modernization efforts that maintain and continue to expand with MUMPS will become increasingly difficult to support. Over time, the effect will be similar to what has

[29] "TIOBE Index." https://www.tiobe.com/tiobe-index/.

[30] Coffey, Brendan. Little-known InterSystems grows to dominate an IT market in age of Obamacare. Washington Post.

happened with the COBOL programming language and the many critical government systems that have relied on it. **Cache ObjectScript can be used to mitigate this concern, but IHS has minimally used this language (which is modern and distinct from MUMPS)**.

Given the diminishing rates of MUMPS adoption across the market, and the rising popularity of other languages, it would become increasingly difficult to modernize RPMS in-place without a transition plan for the core language and the technologies currently underpinning it. A modernization effort would need to include a migration to newer languages with a growing market of programmers, and to newer frameworks with a growing level of industry support. This is particularly important for organizations with more limited resources that cannot hire and custom-train a constant stream of developers that do not exist in the open market.

See Wrap and Renew Legacy RPMS in section 5.0 for more detail. Also refer to Appendix I for a subset of organizations that have undertaken successful modernization of MUMPS-based systems.

4.3.2 Data Sharing and Portability

What's Working	Areas of Concern	Recommendations
• Data sharing is available through workarounds created at a site level	• No common set of standards for data exchange • OS compatibility issues is a barrier to FHIR standard implementation • Data exchange is at risk of vulnerabilities due to potential insecure connections.	• Identify, implement and support terminology experts
Assessment Score: 0 Inadequate Not fulfilling all basic requirements. Needs significant work to become operative.		

The lack of data sharing and portability in RPMS is tightly bound to the operational environment. Operational environments are different from site to site due to custom configurations deployed by local IT staff, and data sharing is heavily reliant on these configurations. Some sites have achieved success in expanding data sharing and portability by introducing workarounds. Although these workarounds allow report generations in varied file format options to transfer between devices within the site, the process of transmitting patient information to outside facilities still remains manual, tedious, and time consuming.

4.3.3 Interoperability

What's Working	Areas of Concern	Recommendations
• Data exchange and communication protocols are in place.	• Custom and not standards compliant communication protocols hinder support, time to build, costs, and security. • Underlying data architecture complicates data exchange adoption. • No APIs for data exchange. • Custom RPC not well understood by development resources. • No terminology support	• Leverage VHA interoperability work • Develop APIs for data exchange as appropriate • Leverage previous based solutions to initiate near-term interoperability using regional and/or local HIEs • Initiate membership with known national HIE solutions (e.g., Sequoia) • Terminology support as a foundational HIT function
Assessment Score: 0 Inadequate Not fulfilling all basic requirements. Needs significant work to become operative.		

RPMS has various interoperability challenges. The primary challenges reflect the communication protocols used by the various subsystems of RPMS and the data schemas or serialization formats used.

- **Most communication protocols are custom and not standards compliant.** The IETF standard protocols used by RPMS are Telnet, SSH, HTTP(S), FTP, TCP/IP. However, the majority of protocols are esoteric custom implementations (and not IETF standards): BGU, BMX, CIA, ECP, XWB. These custom protocols are often not well documented or well understood by IHS developers and technical staff, with implications on time to build, costs, and security.
- **Industry standard data exchange formats are able to be used, but underlying data architecture complicates widespread adoption.**[31] RPMS has the ability to use HL7, an industry standard for exchanging electronic health records, but the underlying data storage and the custom protocols used complicate this ability.
- **Lack of externally accessible APIs.** RPMS does not have sets of comprehensive APIs that can be used as a primary means of data exchange. The primary interface to the majority of the system via custom protocols complicates the ability of RPMS to exchange data in newer, safer, best-practice methods. One illustrative API requests C32 documents using a SOAP API in the C32/CCD Clinical Summary (BJMD) application.[32] SOAP does have some benefits over REST, but achieving interoperability and widespread adoption with SOAP APIs has been a greater challenge when compared to

[31] https://www.hl7.org/fhir/overview-arch.html

[32] C32/CCD Clinical Summary, Section 9.4, Web Service API https://www.ihs.gov/RPMS/PackageDocs/BJMD/bjmd010t.pdf

RESTful APIs. “SOAP is very ‘breakable’ – changes in parameter types – even simple changes of the type that changes 16 bit int to a 32 bit int – can break all clients (consumers).

Brittle is probably a better word to describe SOAP interoperability.”[33]

- **Limited use of FHIR for data sharing** Fast Healthcare Interoperability Resources (FHIR) is a recent industry standard that is intended to leverage newer web technologies and is based on RESTful web services/APIs which facilitate standards-based interoperability with newer systems. FHIR is believed to open up a path of robust interoperability between third-party applications and EHRs, and, thus, improve data sharing and portability. FHIR-enabled interoperability is only beginning to be explored for RPMS, although it is used in parts of VistA.

  “One of the significant disadvantages of [the logic being embedded in the database] is the lack of portability. So much of your operational environment is bound to the language." —IHS Staffer

Impact on RPMS Users

- **Lack of interoperability forces data to be handled manually across systems, which increases the chance of error.** During site visits, clinicians reported that they must enter data into two systems because the systems didn't speak with each other. In one case where two EHR systems were being used in the same facility, a specialist relayed his frustration at having to get his staff to pull a patient's notes from one system as a print-out, then type them into that patient's record on RPMS. Some facilities had to obtain off-the-shelf solutions to cover for modules that RPMS either does not cover or covers poorly, such as OB and dental. Clinicians fear losing paper notes or documenting incorrectly.

[33] http://www.anujvarma.com/restful-versus-soap-is-soap-obsolete/

"Dovetailing X System with RPMS is a nightmare, I can't import anything from outside."

4.3.3.1 Data Interoperability Standards

A process is established to support ongoing upgrades to new terminology code releases such as ICD 10 and SNOMED CT, however, the following deficiencies are noted:

- LOINC codes are not routinely updated
- There is limited access to terminologists on staff within IHS to guide the understanding and need for standard terminology

4.3.3.2 Health Information Exchange

What's Working	Areas of Concern	Recommendations
• The Direct Health Information Service Provider (HISP) developed by IHS in 2014 is functioning reliably. • Sites that set up Direct processes locally are able to send and receive secure messages among providers and between providers and patients who use the IHS Personal Health Record portal. • The RPMS Network Data Repository is receiving and storing C-CDA documents automatically uploaded from contributing IHS RPMS sites. • Stored C-CDA are selectable by patients using the PHR to view and download their information.	• The Master Patient Index (MPI) application currently underlying the RPMS Network is an unsupported proprietary product not suited for an enterprise. If it fails there will be no MPI. • The RPMS Network Document Repository is only a document repository, not a database. There is no integration or normalization of patient data received from multiple facilities or over multiple encounters. As a result, inquiries to the RPMS Network by patients or providers retrieve incomplete information. • IHS has not onboarded the RPMS Network with any HIEs. Nor is it used internally to IHS as designed. There is no ability to exchange data with other I/T/U, VA or private facilities the patient has visited. • There is no directory of Direct email addresses. • The HIE functions of the RPMS Network have not been updated to meet 2015 Edition certification requirements.	• HIE capabilities can be implemented independently of the underlying EHR(s); commercial options exist that are ONC certified and would offload development, maintenance and certification to vendors. • IHS has researched using COTS solutions as an alternative approach to HIE. These options could be implemented in the near term independently of the eventual EHR solution and could be continued or migrated after that solution is selected.

Assessment Score: 0 Inadequate
Not fulfilling all basic requirements. Needs significant work to become operative.

4.3.4 Application Integrations

What's Working	Areas of Concern	Recommendations
• MUMPS routines directly call the routines of other packages. • Applications are integrated via Remote Procedure Calls (RPC)	• The lack of proper namespace support or object inheritance of the RPMS stack results in a complicated dependency model. • Lack of integration at the authentication layers. • Not all applications used by I/T/U personnel are integrated with RPMS, and some only have unidirectional integrations.	• Improve code by using API calls and using data structures. • Plan and expand on creating a service oriented architecture, this would allow developers to accelerate development without worrying about the underlying data structure.

Assessment Score: 0 Inadequate
Not fulfilling all basic requirements. Needs significant work to become operative.

The Application Integration assessment examines the relative ease and methods by which applications integrate with themselves and with other systems. The RPMS codebase is primarily composed of various MUMPS code packages; the primary method by which RPMS applications integrate with each other is via a direct dependency model[34] where MUMPS routines directly call the routines of other packages. The second most prevalent method of application integrations is via Remote Procedure Calls (RPC) between applications.

RPMS maintained the same underlying code infrastructure as VistA while building new functionality and leveraging the foundations of VistA.[35] Due to MUMPS's lack of native namespace support or object inheritance, this level of integration is primarily achieved by segmenting the ownership of functions between IHS and VA based on a strict naming convention

[34] https://code.osehra.org/vivianr/vista_pkg_dep.php
[35] https://www.osehra.org/content/rpms

that consists of a unique prefix of between 2-4 alpha characters for globals, routines, templates, functions, etc.;[36] the prefixes are assigned by the database administrator (DBA) at VA; the same is true of the global namespace. This practice enforces a namespace of sorts given the limitations of the language, but it is not a scalable or the modern method for achieving this level of integration at a code level.

- **The lack of proper namespace support or object inheritance of the RPMS stack results in a complicated dependency model.** The dependencies of all of the RPMS packages can be visualized by the OSEHRA Visualizing VistA and Namespace (ViViaN-R) tool[37] which shows a complicated web of inter-package dependencies. Packages in RPMS directly call routines provided by other RPMS packages. This direct integration with other packages' routines' results in low-level dependencies between packages that make it increasingly more challenging to change or replace any RPMS package.
- **Lack of integration at the authentication layers.** Not all RPMS applications leverage a Single Sign-on solution , resulting in a risky security posture and increased users' burden while navigating between applications. Because of this lack of integration, navigation between applications often results in multiple logins.
- **Seamless integration between RPMS user interfaces does not exist.** RPMS' UIs range from command-driven and menu-driven character interfaces to various graphical interfaces written in different technologies (from Silverlight, to VisualBasic, Delphi, and C#). Users often need to manually open multiple applications, with vastly different UIs, in order to do their jobs. There exists no seamless integration between applications. VueCentric sought to solve this by utilizing various templates that can all be combined into one application, but the multitude of applications and lack of cohesive integration still prevails.

[36] https://code.osehra.org/vivian/files/Namespace/Namespace.html
[37] https://code.osehra.org/vivianr/vista_pkg_dep.php

- **Not all applications or biomedical equipment are integrated with RPMS.** There is limited interfacing with biomedical devices such as infusion pumps, for example. For direct sites providing labor and delivery services, there is no interface to third-party obstetrics applications. Dental providers use Dentrix, a commercial electronic dental record application, but the interfaces are limited to demographic information coming from RPMS and procedure codes sent to RPMS. In some cases, specifically with the Moonwalk application, there exists some bidirectional integrations with RPMS, but some integrations are only unidirectional. For example, insurance data entered into Moonwalk is not written back to RPMS- only the insurance data written to RPMS flows to Moonwalk.

Impact on RPMS Users

- **Leadership must manually create and enforce strict schedules around billing for the software to be effective.** At one site, leadership explained that the business office creates billing files and exports them from RPMS and enters them into UFMS. On Thursdays, they export to a third-party billing software and post payments. These payments show up on the following Tuesday in the budget.

4.3.5 Extensibility

What's Working	Areas of Concern	Recommendations
• Package-centric architecture enables macro-level extensibility. • VueCentric Framework provides excellent and documented extensibility mechanisms that have been the main way to extend RPMS clinically over the last 15 years.	• Tightly intertwined MUMPS code within packages themselves create challenges for extensibility. • Limited application options to meet specific clinical workflows such as OB	• Map existing data model to provide object and relational access • Expose existing legacy code as services via standard APIs • Consider domain specific HIT solutions
Assessment Score: 0 Inadequate Not fulfilling all basic requirements. Needs significant work to become operative.		

The overall architecture of RPMS, as a suite of interrelated packages and applications (package components), is modular by design at the architectural level. Depending upon the level of granularity of the system perspective, RPMS is both highly extensible and suboptimally extensible.

The entanglement of business, access, and control logic creates significant issues around extensibility. For example, extending the Laboratory package has a reputation with developers as being exceptionally complex. Extending core packages themselves, as opposed to adding packages as described earlier in this section, will likely incur a rip and replace methodology. In this sense, RPMS struggles with extensibility.

On the GUI side, the VueCentric Framework (the MS Windows program that hosts RPMS-EHR) provides excellent and documented extensibility mechanisms that have been the main way to extend RPMS clinically over the last 15 years.

RPMS is an extensible platform and its development history is reflective of that capability. The FileMan Mapper was developed by InterSystems to enable object or SQL access to MUMPS-based FileMan data. FileMan Mapper is a generalized interface that, properly leveraged, can be used to extend RPMS features into a modern platform.; however, it does not address the larger issue of business logic intertwined with control and access logic.

Functionality Gaps

The RPMS suite supports both ambulatory and inpatient facilities, but historically its development has prioritized ambulatory care. Even though a number of the core applications in RPMS were derived from VistA, some VistA packages that were developed for and are widely used in hospitals at the VA have not been adapted for use in RPMS.

Only a small number of IHS hospitals need the full range of inpatient capabilities. Some examples of missing or inadequate functionality in the RPMS suite include:

- Emergency Department
- Intensive Care Unit
- Inpatient Flowsheets
- Surgery/Operating Room
- Labor and Delivery
- Blood Bank
- Microbiology
- Surgical Pathology
- Receiving e-prescriptions from external providers
- Narcotic e-prescribing (currently in testing)

  The future state should support integration of such third-party solutions using standards-based APIs.

4.4 Telemedicine

What's Working	Areas of Concern	Recommendations
• Specialty care telemedicine centers successfully organizing the clinical pathway • Interest by a broad range of service areas, providers, and patients in conducting telemedicine visits • Telemedicine visits are supporting team-based approach to care and providing more consistent healthcare engagement by high-risk patients	• Lack of a national coordinating telemedicine program has created a fragmented ecosystem of telemedicine pathways, technologies, and business models that leaves unfulfilled potential to reach patients in need • No clear, replicable processes for managing credentialing privileges, and authentication/authorization has led to wasted efforts for providers accessing systems to provide care • Unharmonized documentation across sites without adequate training and IT support are barriers for providers • Contracts with third party technology vendors are highly specific and not replicable broadly • Limited remote monitoring and/or patient-centered technology interfaces • Adequate bandwidth to support high-definition (HD) video and high-resolution cameras; suboptimal bandwidth may impact quality of care delivered	• National telemedicine coordinating agency to produce recommendations/policies for supporting telemedicine technology and HIT; and provide support for HIT used for telemedicine; • Published recommendations for telemedicine technologies, technology policies (including identity management and information security), standard operating procedures for technology authentication and access management, documentation standards within the various technologies, business models that include technology providers, and resources needed for supporting the telemedicine package. • Appropriate bi-directional interfaces between the EMR and technologies used for telemedicine visits for documentation, remote monitoring, and PGHD.
Assessment Score: 0 Inadequate Not fulfilling all basic requirements. Needs significant work to become operative.		

The current telemedicine system is a fragmented ecosystem of pathways, technologies, and business models. In some regions and sites, there are current contracts with third-party vendors to support the

video conferencing, hardware, and networking needs, with appropriate encryption applied. These contracts are highly specific to the regions and/or sites. No reliable or consistent technology architecture has been developed to support and sustain work in clinical service delivery via telemedicine. In some cases, this has resulted in either the limitation or discontinuation of service innovation. Through the modernization project, each of the existing telemedicine efforts at both the national-level and site-level present opportunities for understanding the clinical, operational, and technical infrastructure needs to build a business plan and clinical strategy pathway for broader deployment of telemedicine and related innovation across IHS.

A coordinated centralized body for providing best practices and guidance of requirements to successfully run telemedicine programs is essential to making the biggest impact to patient care and outcomes through this pathway. This guidance should include topics regarding technologies, technology policies (including identity management and information security), standard operating procedures for technology authentication and access management, documentation standards within the various technologies, business models that include technology providers, and resources needed for supporting the telemedicine package.

In addition, the modernization project should take into account the need to ensure RPMS has appropriate bidirectional interfaces for secure exchange with other technologies used for telemedicine visits and consultations, including those technologies and digital health applications utilized for remote monitoring and patient/consumer generated health data, such as patient reported outcomes, health applications and consumer health devices for heart rate and blood pressuring monitoring and more. Outside the IHS, healthcare delivery models are rapidly changing, with new collaborations emerging in care delivery approaches and methodologies. Local Indian health facilities and regional Indian health systems must be capable of participating in these dynamic changes and practices in order for Native American communities served by the IHS to maximally benefit from the opportunities that will become a regular part of health care delivery.

4.5 Public and Population Health

What's Working	Areas of Concern	Recommendations
• Ability to create static and dynamic panels and reports • Early awareness of certain diseases and conditions • Dashboard • Unidirectional immunization exchange	• Lack of integration of population and public health data within the clinical workflow • Different GUI with different look and feel • Lack of asynchronous data capture and data entry	• Enhance functionality to reflect new concerns (e.g., opioid concerns) • Integrate application into user workflow • Establish bidirectional data sharing when appropriate • Support asynchronous data entry and use
Assessment Score: 0 Inadequate Not fulfilling all basic requirements. Needs significant work to become operative.		

The RPMS suite has been extended to meet the needs of public health providers, such as public health nurses, and public health reporting. This functionality augments traditional direct clinical care practice, and ensures that the specific public and population health needs of AI/AN communities can be met. Much of this care occurs outside of the four walls of the facility, resulting in a requirement for virtual asynchronous data collection that can be synced after data collection occurs. No applications within RPMS have been designed to efficiently meet this need.

The iCARE population health suite is not integrated into the clinical workflow, resulting in potential loss of the benefit of population health data for monitoring and reporting. In addition, state based reporting to meet public health needs such as immunization and cancer registries, require state based interfaces that can meet the needs of 37 states. This is also true for Medicaid childhood assessment requirements that can vary from state to state. This multi-state need creates additional pressure on development plans, as application design should include the ability to meet these state based reporting needs.

4.6 Personal Health Record

What's Working	Areas of Concern	Recommendations
• Patients can log in to PHR portal and review information from a selected encounter. • Patients can receive Direct secure messages from providers and reply to them. • Patients can download data from encounters in various formats. • Patients can view upcoming appointments. • Patients can request refills of non-expired prescriptions.	• The PHR has not been updated to 2015 Edition certification requirements. • The PHR portal is not optimized for mobile devices. • There is no integration of data across facilities or encounters. Patients must first select the facility and then the specific encounter, so viewable data is incomplete. • Patients cannot send a Direct message to a specific address, only to the message agent at the selected facility or in reply to a message they have received. • There is no notification to the patient (e.g., by text) of a new message received. • Patients cannot enter new Direct addresses in order to transmit their health data to other providers, but instead must download and print or send via regular email. • Patients cannot request/schedule new appointments or renewals of prescriptions.	• Most PHR functions are independent of the underlying EHR; commercial options exist that are ONC certified and would offload development, maintenance and certification to vendors.. • Most COTS EHR solutions offer add-on PHR portals; IHS could opt to include delivery of a PHR with its replacement solution.
Assessment Score: 0 Inadequate Not fulfilling all basic requirements. Needs significant work to become operative.		

4.7 Infrastructure and Maintenance

This section contains an assessment of the current infrastructure and how that infrastructure is maintained. The information gathered was based on interviews with IHS staff at the national Office of Information Technology level, and with IT teams at the area office and facility levels. The following areas were considered:

- **Hardware:** RPMS hardware requirements assessment
- **Network:** Assessment on network health and performance
- **Software Maintenance:** Versions, patches, roll out, feedback

- **Database Development:** M, Cache, InterSystems Ensemble®, individual database standardization

4.7.1 Hardware

What's Working	Areas of Concern	Recommendations
• RPMS can run on commodity, off-the-shelf hardware. • Hardware performance is not a hindrance for server needs.	• Hardware performance may be a hindrance for networking and client needs. • Heterogeneous and aging hardware demand disparate support skill sets and increase maintenance costs.	• Develop and implement a plan to fund, upgrade and maintain hardware • Enterprise wide purchasing of standardized hardware
Assessment Score: 1 Operative Functional, but needs significant effort and workarounds		

Hardware can be an asset or pitfall to any software system. The best software systems grow independently of hardware constraints and also rapidly take advantage of the latest technologies.

- **RPMS can run on commodity, off-the-shelf, hardware.** This benefits the purchasing and maintenance of hardware in terms of costs and availability of personnel that can maintain it.
- **Hardware performance is not a hindrance for server needs, but may be for networking and client needs.** Server performance is measurable through analyses of various runtime metrics maintained by the server. Consistently, such analyses reveal the current configuration of server hardware as adequate for optimal performance of the RPMS server, and not a contributing factor to the reported performance issues. In fact, RPMS services run efficiently on commodity hardware, and the volume of transactions processed seems to be below the threshold of the hardware's capabilities as reported by Level 3 support. However, the client hardware at the local

facilities may be under-provisioned as workstations can be slow to load applications like VueCentric for some users.

- **Heterogeneous and aging hardware complicates maintenance.** Different models of networking, server, and client hardware are deployed within and across IHS I/T/U sites. The differences in hardware do not enable the methods of mass-provisioning that would benefit support by Level 3.

  "For sites with VistA imaging, cost performance could be improved by consolidating scanner purchases. It is currently 'a mess.' By using the task order system, purchasing efficient could be improved. Sites currently do not do this and it is likely because many of them do not know the option is available."

4.7.2 Network

What's Working	Areas of Concern	Recommendations
• Network infrastructure exists and is partially managed centrally • Network architecture has been designed at a central level • Network monitoring is adequate with opportunities to expand beyond current scope	• Not all of the network is managed centrally • Use of custom, non-standard, ports and protocols degrade network security. • Some applications use insecure Telnet (Port 23). RPMS uses the unsafe Telnet protocol for some application. • Insecure Remote Procedure Calls (RPC) are used by core applications. • Heterogeneous and out-of-date hardware within and across facilities demand disparate support skill sets and increase maintenance costs of the RPMS networking environment.	• Detailed review of how IT infrastructure is supported and managed at Indian Health Service with recommendations

	• The remote nature of the facilities makes network needs more complex. • Regional and local vendors have influence on architecture, equipment and other decisions resulting in fragmented architecture	

Assessment Score: 0 Inadequate
Not fulfilling all basic requirements. Needs significant work to become operative.

A robust telecommunications infrastructure is critical to a modern health care delivery system, not just for providers but for patients and their families as well. The vast majority of IHS and tribal health care facilities are in rural locations with connectivity that is much slower and less reliable than that available in urban settings. Capabilities such as telehealth, patient access to records, staff and patient education, clinical decision support, and transmission of medical data and images, are severely hampered by bandwidth insufficiency. Upgrading bandwidth can be extremely costly and often must be paid from the facility's health care operations budget. In some cases, local telecommunications providers are simply unable to provide the upgrades needed for the health care facilities. A large percentage of network IT equipment at IHS facilities has exceeded reliable operating lifespan and vendor support, but insufficient funds exist to upgrade this.[38]

- **In most cases, the bandwidth issues at the extremely remote locations that are typical across Indian country are beyond the direct control of the IHS.** These connections are owned by local telco service providers who have limited incentive to invest in high-performance upgrades and will only do so at considerable cost to the customer. Any health IT system envisioned for IHS needs to take into consideration that data connections will often be slow and/or unreliable. As such, restrictive geographical constraints, connectivity and bandwidth should inform and influence future design and solution choices, particularly with respect to disconnected mode operation on mobile devices and data caching strategies.
- **Use of custom, non-standard, ports and protocols degrade network security.** RPMS uses custom, not standard, ports and protocols for communication. Network engineering is unclear on which ports RPMS actually uses or will need to use in the future to maintain functionality. Version upgrades sometimes change the communication ports. Because of these reasons, creating firewall rules that are properly scoped to ports is not feasible, and traffic over the network is difficult to analyze for threats. Network security can only be achieved via IP to IP firewall rules, which is not ideal and results in rules that may be overly permissive.

[38] http://www.tribalselfgov.org/wp-content/uploads/2017/05/CCrowder_Solutions-to-Modernize-IHS-Health-IT-4.26.17.pdf

- **Some applications use insecure Telnet (Port 23).** RPMS uses the telnet protocol for some applications. The Telnet protocol is fundamentally unsafe, as it sends data insecurely using clear text over the network. This could allow an attacker to intercept traffic, read credentials, siphon Protected Health Information/Personal Identifiable Information (PHI/PII), and potentially inject commands that exploit Remote Code Execution vulnerabilities via man-in-the-middle attacks.
- **Insecure Remote Procedure Calls (RPC) are used by core applications.** The use of the RPC protocol is a key dependency for the exchange of information among components of the RPMS system. These protocols transmit data in clear text and are not secure. The only way of securing them is to isolate RPC protocol communication to isolated network segments, which is a burden on network administrators. There are more secure and more modern means of data exchange between systems that are built with security by default.
- **Heterogeneous and out-of-date hardware within and across facilities complicates the environment.** There are challenges provisioning hardware, specifically on the networks. For example, network engineering would like to configure consistent Quality of Service (QOS) policies on all network routers to protect and improve the efficiency of network traffic, but the mix of device and the use of older routers does not support more modern QOS implementations. There is an inability to deploy similar configurations across the facilities because the equipment does not support homogeneous configurations.

"Across multiple machines, I and several of my colleagues suffer frequent freezes and crashes that lose my notes. The most common errors and crash reports seem to refer to problems with threading and temporary networking issues that it seems it can't recover from." Provider

4.7.3 Software Maintenance

What's Working	Areas of Concern	Recommendations
• Some sites have management and documentation to recover from breaks with application	• I/T/U Sites provide limited feedback on patches to National IHS or the help desk. • Sites may be patches behind,	• Standardize the RPMS dB and applications to increase efficiency with new version and patch deployment

	sometimes because they have custom modifications to support their needs that are broken by patches • Software upgrades for fixes may lead to connectivity issues later on. • Sites that delay install of patch fixes may generate support tickets. • Server software and Client Software must be upgraded separately, leading to incompatibility issues if the upgrade is not done for both at the same time	• Evaluate options for additional approaches to software updates • Consider cloud hosting

Assessment Score: 0 Inadequate
Not fulfilling all basic requirements. Needs significant work to become operative.

Software maintenance is managed through a series of patches which are released to the area offices and subsequently distributed across the 400+ physical sites that run their own instances of RPMS. These patches come in the form of fixes or enhancements which may include new features suggested by clinicians. Maintaining RPMS applications creates issues with sites being patches or versions behind, especially when there have been custom configurations. Ideally, sites would have identical dB and applications.

- **I/T/U Sites do not give consistent feedback to area or national IHS.** Site managers manage their own system and schedule for patch deployment. Problems identified may be corrected at the site and not reported to the area or national program. National IHS has limited visibility into local problems.
- **Sites may be patches behind the current supported version.** With some sites continuing to run old commodity hardware and outdated version, the support team must customize their support to address these issues. Help desk tickets illustrate how sites accommodate breaks associated with patch acceptance and with being behind on patches.

"My advice is to reinstall v 2.1 and patch 1 and then check that BPHR global is there, then install patch 2. That is the only way to be absolutely certain that all the BPHR classes and the SSL definitions are up-to-date and there as well."[39]

"Because they change the port number during a software upgrade, we on the network infrastructure side were not aware of this and subsequently the firewall rules need to be upgraded" IHS internal presentation

"If the system is down, we can't document in system or put in order. We have to wait to put in later, but sometimes we forget." Provider

"It is chaotic. We're not able to check in patients." Provider

- **Some sites have custom modifications to support their needs.** Custom modifications at individual sites occur on occasion. These changes are made in an effort to support individual site needs. Customization presents challenges in receiving new updates as well as potential security issues.

[39] Ticket citation, Tier 3C VSTS Heat Ticket Listing 1-6-2018 to Present

- **Ambiguity in software change terminology causes confusion within support teams, increasing risk and issue resolution time.** Outdated SACC guidelines confuse the terminologies of "patches" and "versions." Software testing time periods for beta testing and validation depends on the categorization of changes as a "patch" vs a "version." "Maintenance patches," "bug fix patches," and "functional enhancements" terminology are often unclear- increasing operational risks.

  "I tell them that your patch is not really defined as a patch. It is got enhancements in it so it will be more like a version." IHS Staffer

- **There are resource constraints that impact the availability of trained I/T/U and IHS support teams that can respond to tickets.** Resources are primarily focused on ongoing maintenance and operational support of the current system as opposed to updating them for future requirements.

  "Our biggest constraint is dollars, especially around support personnel. We only have 8-10 developers supporting RPMS." IHS Staffer

  "*If money and time were not an issue, RPMS could be modernized with the caveat that the agency is going to have to do a better job around governance because right now my feeling is, it is the wild west out there."* IHS Staffer

- **A typical RPMS "patch" that makes a GUI change will contain a Server software component and Microsoft Windows Client Software component that need to be installed separately.** There is only one server to upgrade; but there are a multiple client computers to upgrade. Not completing all the client upgrades leads to a block on using the program which is frustrating to users. This is not true for RPMS-EHR, as these updates, when loaded, are automatically delivered to both server and client.

4.7.4 Database Development and Support

What's Working	Areas of Concern	Recommendations
• dB works and is extensible	• RPMS Sites extend individual site databases through namespaces leading to further roadblocks to interoperability.	• Upgrade all dB to an RPMS gold dB • Upgrade to WIndows Server 2012
Assessment Score: 0 Inadequate Not fulfilling all basic requirements. Needs significant work to become operative.		

There are multiple, separate instances of RPMS running across the country and their configurations vary on a site-by-site basis. SQL performance results of a benchmark test run on Intersystems Cache versions 2017-2019 on a virtual machine of Windows Server 2012 shows how these latest versions can improve single-instance SQL processing. However, implementing InterSystems releases with RPMS releases can be problematic due to the need for testing coordination.[40]

> *"...the newest version of Cache and Windows is being tested but hasn't been cleared yet. Cache 2012 and Windows 7 is what is currently supported." - IHS Staffer*

The client-server configuration of RPMS creates issues when desktop operating system (OS) upgrades become available. When Windows 10 became available, for example, RPMS was certified to run on Windows 7. The transition to Windows 10 required careful testing and remediation of certain issues that became apparent during that testing, before the Windows version could be updated. When sites are not aware of this risk and install OS updates before they are certified by the IHS Office of Information Technology, significant support issues can arise.

[40] https://www.intersystems.com/resources/detail/sql-performance-benchmark-of-intersystems-iris-data-platform/

The transition to Windows 10 was further complicated by VistA Imaging, the image archiving application managed exclusively by VA because it is an FDA-certified medical device. Extensive testing was required, with results sent to VA which had to verify with FDA that no impacts on certification occurred with Windows 10. A similar process will have to occur as the agency prepares for server upgrades to Windows 2016 Server.

Support tickets and vulnerability scans provide insight on how different sites are maintaining their respective databases; although some sustain operations by meeting SAC guidelines, custom modifications can lead to future performance constraints.

- **Sites create new databases and tables through designated namespaces.** To accommodate limitations, some sites have workarounds where developers maintain individual site databases by extending namespaces.

  "Those changes are only as good as people keep on top of them and keep them updated so that if you have an enterprise solution that you release and you write over their changes, and the person who did those changes is no longer there, it is going to have an impact on the site, either with dangle data or files." IHS Staffer

- **Performance problems are common across sites.** Refactoring of core MUMPS code to improve its performance is an activity undertaken by developers. The end result is often tightly coupled data and applications.

4.7.5 Current Overlap Between VistA and RPMS

What's Working	Areas of Concern	Recommendations
• VA application support available to IHS • VA support for specific	• Loss of VHA support and development teams	• Evaluate each VHA application used by RPMS and develop appropriate support and/or

applications such as BCMA		replacement plan

Assessment Score: 1 Operative
Functional, but needs significant effort and workarounds. Making workload more difficult.

RPMS has a number of dependencies on VistA; VA's decision to transition from VistA to a COTS HIT system creates an eventual risk for IHS. The VA project is expected to take about ten years; during this time period, VistA must continue to be supported for VA facilities. At some point, support for VistA from VA will cease. At the same time, VistA has been widely adopted outside of VA; open source communities and commercial vendors provide active support for non VHA-based VistA deployments.

Appendix F tabulates the VistA packages that are presently part of RPMS. There are three categories:

1. VistA packages that have been extensively modified by IHS for use in RPMS (6 packages)
2. VistA packages that are used in RPMS with little or no modification (20 packages)
3. VistA packages that are installed at all RPMS EHR sites because they were prerequisites for installation of the Order Entry/Results Reporting (OE/RR) application but have no adaptation to or functionality in RPMS (10 packages)

The last major update of VistA packages in a release of RPMS-EHR was for 2014 certification, and included VistA patches up to January 2010. Some VA packages such as the National Drug File (NDF) and Lexicon are updated monthly by VA and ported to RPMS. Occasionally, certain desirable VA releases have been selectively incorporated into the appropriate package or EHR component. Other packages unrelated to the EHR, such as FileMan v22, are patched as needed, with the last VHA patch deployed within IHS in 2016 (VA continues to release FileMan updates).

The majority of the VA applications used in RPMS have been stable for many years and new development and releases are done by the VA and shared with Indian Health Service. Current significant dependencies include the annual releases of the NDF and Lexicon. NDF supplies the full array of updated drug information, including drug names, NDC codes, interaction data, etc., all of which is critical

to patient safety. Other major clinical application dependencies are Bar Code Medication Administration (BCMA) and VistA Imaging.

4.8 Security and Compliance

Because the RPMS database is hosted locally or in an Area Office, and managed by local site managers, there is little ability for IHS Headquarters to actively manage or monitor the dB. Backup practices vary widely across the enterprise and include physical backup to tapes/drives that are manually transported to other locations per policy. There are instances of Area Offices taking copies of production databases and using them to extract data and perform analytics on a regional level. While these practices are well-intended and serve an important business need, they also increase the risk for inappropriate access to and breaches of PII/PHI. A system that allows organizations to access consolidated data stores for approved business analytics, epidemiologic investigations or research, without such workarounds, would be preferred.

What's Working	Areas of Concern	Recommendations
• All systems have an audit trail • All sites have physical and logical security policies • Access to EHR is limited to those who have been cleared for access	• The process of assigning security keys is complicated and prone to error. Due to the local assignment of security keys, there is wide variation in access controls across the agency.	• Develop enterprise role based access guidance • Support Single Sign On
Assessment Score: 0 Inadequate Not fulfilling all basic requirements. Needs significant work to become operative.		

There is no functionality supporting single sign-on (SSO), which means that the person logging into the EHR can be a different person than is logged on to the desktop.

A review of the network security architecture shows software security measures adequately implemented for data at rest and data in transit.

4.9 Regulatory Compliance

What's Working	Areas of Concern	Recommendations
• Ability to produce GPRA, UDS and other performance measures • Compliance with federal mandates	• RPMS is no longer current with ONC certification requirements • Frequent changes in clinical and performance measures • Changing guidelines and regulations require new development/testing cycles	• Development or acquisition to meet 2015 certification • Acquisitions or new development must meet accessibility standards
Assessment Score: 0 Inadequate Not fulfilling all basic requirements. Needs significant work to become operative.		

5.0 Opportunities

5.1 A Human-Centered Process for the Next Generation of Health IT

Health IT applications (and enterprise software in general) provide a notoriously poor user experience across the board. Software that has been developed before Human-Centered Design (HCD) practices tend to use business requirements and data schemas as guidelines for interfaces instead of natural human workflows. This forces users to change their workflows, frequently slowing them down.

A modern Health IT system should follow an iterative HCD process where end users, their workflows, and mental models are the optimal software design. Such processes can result in high quality data, efficient workflows, fewer workarounds, happier users and, ultimately, healthy patients. An HCD process and framework to pursue should include:

- Product teams that include product managers, designers, user researchers, engineers, and subject matter experts with clearly defined roles and responsibilities;
- Creation and maintenance of design personas with needs, goals, pain points, attitudes, aptitudes and abilities based on organizational roles and the specific needs of the AI/AN communities and population. These should be based on rigorous qualitative user research with real end-users;
- Organizational goals based on I/T/U leadership and health care team input as well as community and population health needs guide needs and goals of system;
- Creation and maintenance of service blueprints and journey maps to guide requirements based on the context and different, sometimes conflicting needs. These are centered on both end-user needs and organizational goals, and based on rigorous user qualitative research;
- Incorporation of regulations into the workflow following service blueprints and journey maps;
- Creation and maintenance of libraries based on iterative user research: APIs, design systems, component libraries, taxonomies;

- A prioritized feature roadmap prioritized based on user needs and goals as well as organizational goals;
- Iterative development sprints incorporating user research, testing, formal quality assurance (QA) for continuous product improvement.

5.2 Modular Design

Predicting the future is an arduous and difficult task, prone to error both in terms of frequency and magnitude. A systems' architecture that takes into account what will likely not change over the expected lifetime of the system produces positive outcomes for users of the system. In practical terms, this means designing an extensible system that is modular in nature, leverages APIs or other forms of service-oriented architecture principles. Expected outcomes usually include an ability to incorporate design changes, new features, and removing functionality that is no longer needed. Strategic outcomes of a modular design include improved organizational agility, cost-optimization, and support for evolving operating contexts and requirements.

A modern modular design incorporates the following design principles:

- Implementations are environment-specific; they are constrained or enabled by context and must be prescribed by that context;
- Implemented systems will conform to defined standards that support interoperability for data, applications, and technology
- Subsystem interfaces are developed to enable legacy applications to interoperate with applications and operating environments within the architecture;
- Data is defined consistently throughout the system;
- Data is protected from unauthorized use, modification, and disclosure;
- Service representation utilizes descriptions to provide context and implements services using service orchestration

5.3 One Approach to Modernize RPMS

Many modernization efforts around aging, monolithic systems follow a pattern of wrapping the central systems with modern interfaces for an extended period of time. This provides the organization with the necessary time and technology support to phase out the core system instead of the commonly used rip-and-replace approach.

The consequences of rip-and-replace approaches are well documented; the system replacement projects tend to be costly and time consuming, usually with massive cost and schedule overruns.

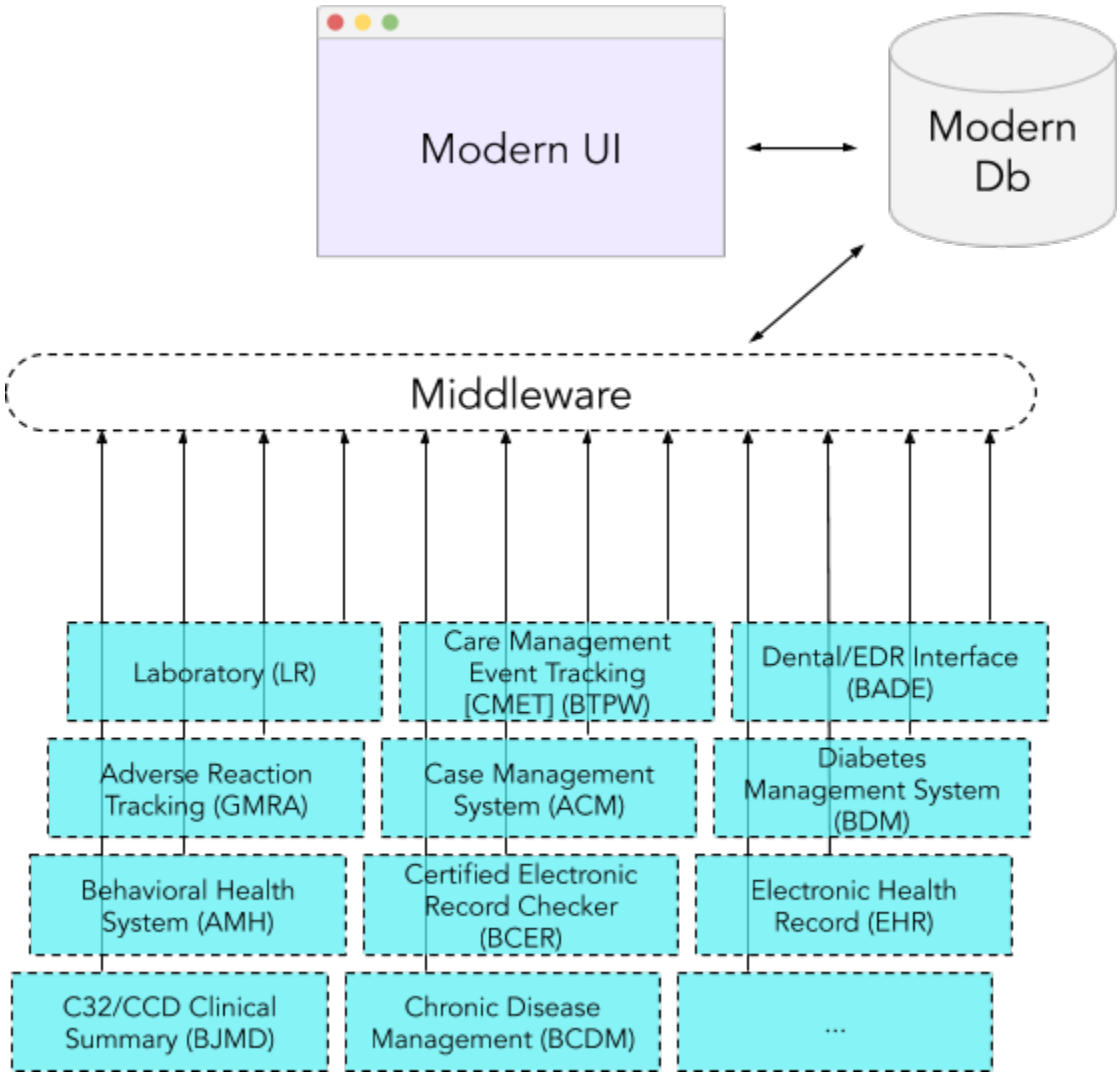
While not used frequently enough to be considered common, emerging trends around wrap and renew methodologies are demonstrating improved performance of modernization efforts in a number of settings including the finance and airline industries. There are also examples of success with this approach in large enterprise healthcare settings within the US over the last ten years. Most organizations that have previously relied upon legacy MUMPS applications, including one of the current large scale HIT vendors with a solution used by top healthcare enterprises including FQHCs, have gone through similar incremental transformations.

In general terms, the wrap and renew approach uses web services, APIs and other integration patterns to allow users to access disparate systems through a single, unified web app. This methodology also increases application agility by leveraging service oriented architecture. In the specific case of RPMS, the enterprise would follow a process of:

1. Transitioning to the use of ObjectScript (a language that is designed to be familiar to modern software developers)
2. Mapping the existing data model to provide object and relational access; separating applications into UI, business logic, and data tiers consistent with modern architectural principles (with the business logic exposed as RESTful or SOAP services to allow the use of modern user interfaces with modern technologies)
3. Exposing existing legacy code as services via standard APIs

4. Refactoring or rewriting portions of existing code where doing so provides tangible enterprise wide benefits
5. Developing new, object oriented application modules in ObjectScript or use other modules developed using the exposed APIs and healthcare standards such as HL7, IHE or the merging FHIR standard.

Wrap and Renew Legacy RPMS



6.0 Required Steps for IHS Modernization

6.1 Recommendations from User Research

Through listening sessions, shadowing, and interviews, the Legacy Assessment team sought to understand how, when, and where RPMS enables or hinders the work of facility staff, and how it impacts the health and lives of patients and the greater population. All patient feedback came through the lens of IHS staff who are also patients. Our goal was to understand the current state of RPMS, and to provide guidance on where it might be modernized, considering patients, providers, community, and population.

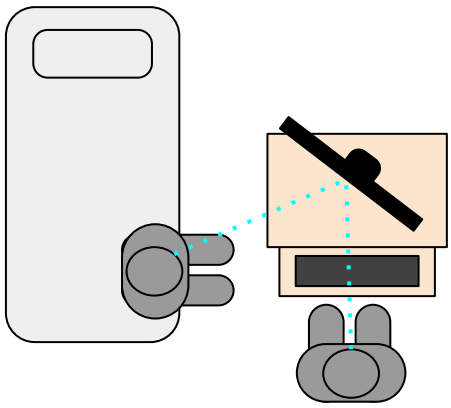
Below are our recommendations for where the RPMS user experience should be modernized.

Core User Experience Principles

- **Reduce cognitive load.** The current system places an enormous onus on each user. For example, in some interfaces, the user must remember TO USE CAPITAL LETTERS, or to take step X before step Y, or to take note of key information before it disappears in the next step. High cognitive load leads to increased user errors and interferes with the user's primary task. Good UX should aim for the lowest possible cognitive load.
- **Reusable components.** The user interface becomes dynamic, extensible, and easy to learn when design patterns are established and consistently used.
- **Effective use of color and interaction.** All design elements should be chosen with intention. Color and interaction should be utilized to aid facility staff in performing their jobs more effectively and efficiently.
- **Accessible to all.** All facility staff should be able to use RPMS regardless of ability.

Patient Experience

- **Bring education into the patient encounter by optimizing the notes interface to be reviewed together.** By physically moving the orientation of the computer monitor, the process of entering notes during a patient visit can transform into an educational experience for the patient. If the provider explains their entry, the patient will be prepared to understand their terminology later on, either when receiving their results online or through the mail. Studies have shown that this greatly improves the patient-provider interaction, as the doctor is engaging with the patient throughout the encounter. [41]



- **Improve the patient portal.** Much of the burden of work currently done by admin staff can be handed off to tech savvy patients with minor improvements to the patient portal. A few features might include:
    - Schedule appointments
        - By sending a message with preferred times to scheduling (easy),
        - Or by full integration with Moonwalk (hard);
    - Lab reports should include a note to help the patient interpret their results;
    - Extend content available in the PHR portal to include full access to clinician note (consistent with the Open Notes initiative)
    - Message provider;
    - Release of Information (ROI);
    - Upload records (e.g., notes from other providers) which flow directly into RPMS for providers to view;
    - Simpler account setup;

[41] https://www.opennotes.org/

- View PHR and submit modifications to their registration information (name, address, employment status, insurance, etc.).

Standardization

- **Reduce customizations of RPMS to make it easier to learn and support.** Unnecessary changes to interface colors and layouts make it difficult to troubleshoot over the phone and build how-to documentation that applies from site to site. Additionally, it forces staff to learn RPMS all over again whenever they move to another facility.
- **Create interfaces based on workflows guided by standardization of care practices.** Because RPMS layouts are customizable, the optimal configuration for each workflow should be determined, and those should be set as the preferred standard across sites.
- **Continue efforts to standardize clinical data entry.** Includes adoption of universal notes templates. Build pathways for data entry to flow from notes into relevant PHR data fields to eliminate duplicate entry whenever possible. Distribute this implementation to all I/T/U facilities and provide training on how to use new notes templates and how the data is linked to PHR.
- **Create and standardize reporting templates across facilities.** This will enable facilities to compare relevant and consistent information and reduce the burden on administrative staff and leadership in generating reports.

Usability

- **Interoperability.** Make RPMS data available in health information exchanges. Develop standard approaches to extract and share appropriate data.
- **Semantic search for notes and other data pieces.** Adding the ability to search within a patient's health record, labs, and notes would give doctors the ability to proactively seek information from patient history that might be relevant to their diagnosis.
- **Design and adopt consistent navigation patterns.** Reduce cognitive load by eliminating inconsistent patterns and by presenting the right information to the user, when they need it. This will allow users to use all areas of the system without requiring additional training.

- **Adopt keyboard shortcuts.** Keyboard shortcuts are a great way to expedite workflow and reduce click load. The adoption of roll and scroll indicates high likelihood of adoption of keyboard shortcuts if trained.
- **Provide ability to view multiple pieces of information at once and switch contexts easily.** For instance, providers should be able to reference other content while writing notes.
- **Provide contextual help within the interface.** By including tooltips or links to how-to, self-motivated users will learn to perform workflows in a consistent way without requiring support.
- **Single Sign-On.** Users save time when they do not have to separately log in into multiple systems, and manage different passwords.
- **Prioritize and personalize information displays based on the user's goals and needs at each moment of their workflow.** Include relevant and prioritized information in orders, notifications, referrals, and other types of communications. Track user patterns and behavior in the system to learn and improve flows.
- **Improve communication between staff with better alerts.** Allow users to prioritize what they want to see in each moment with functionality like "Dismiss," "Remind me later," and others.
- **Fully accessible interface.** Make RPMS accessible in ways that meet or exceed applicable regulatory requirements (e.g., Section 508), by enabling keyboard shortcuts for motor accessibility, allowing increased font sizes, and a screen reader for low vision accessibility.

Compatibility

- **Consider web-based interfaces.** A single user interface using a web-based library allows for a consistent and extensible UI, compatible with all major browsers, and hardware-agnostic.
- **Interoperable within facilities running RPMS.** Develop a way to push and pull data to and from external RPMS facilities.
- **Maintain legacy data.** Current access to data for population health reporting is very valuable and should be maintained.

Support and Training

- **Implement one centralized ticketing system at all sites, service areas, and at the national office.** By implementing a centralized ticketing system, IHS support can standardize the process of tracking issues, elevating complex tickets to higher tiers and eliminating leaks. Adoption across all tiers of support is critical, and it should be included in the performance requirements of sites. This might include features such as:
    - HIPAA compliance
    - Direct communication between support staff and users, via email, phone, and screen share
    - Photo and screen capture sharing (in ways that do not violate HIPAA)
    - Notifications to keep users updated on ticket status and requests for action
- **Move training material to a centralized, searchable platform.** Manuals, training videos, and answers to tickets should exist in a searchable, user-friendly platform that is easy for staff to access on a computer or mobile device. Ensure that staff is aware of the existence of this support platform via internal messaging and by referencing it during all training sessions.
- **Provide searchable forum functionality for peer-to-peer help.** In addition to searchable support tickets, users should be able to post questions to a forum and comment for answers, which facilitates inter-Tribal communication around how to best use RPMS.

6.2 Recommendations from Technical Review

Stabilize

Successful modernization efforts begin with a period of stabilization and consolidation. For executing any change methodology, this period creates the space required to address fundamental issues necessary for modernization. Work related to this consolidation phase needs to be focused on:

- Establishment of a consistent software development life cycle and patching process (even if a COTS solution is envisioned)
- Upgrades to infrastructure
- Incremental improvements to client systems (EHR/VueCentric, iCare, etc)
- Identification of interface and middleware requirements
- Security assessment of existing code base
- Development and transition of gold RPMS dB and application suite (borrowing from work done by VA)
- Develop and enable API's that can use healthcare standards such as HL7, IHE profiles and emerging standards such as FHIR

Create Response Team from outgoing VA VistA Developers

The VA is stopping development of VistA, a partnership that has benefited RPMS greatly as packages built by the VA are leveraged for RPMS. The loss of personnel with extensive experience programming in the MUMPS language, experience building and maintaining the VistA system, and experience working with systems like Caché presents a huge risk to the viability of RPMS sustainment and even for a KTLO (keep the lights on) maintenance mode. One approach to minimizing this risk could be to recapture skilled personnel who may be leaving VistA and create a centralized response team within IHS that can continue to provide maintenance support, patches, emergency support, and foundational development for RPMS deployments across I/T/U Sites.

Short Term

After the execution of consolidation, early efforts of the wrap and renew methodology are focused on the development of interface and middleware requirements for ensuring application stability through the renewal process. Efforts focus on:

- Development of architecture vision
- Definition of system interface requirements
- Database architecture definition
- Development of plan of action and milestones
    - Development methodology
    - Establishment of application, business, data access, and data storage design principles
- Map existing data to provide object and relational access
- Evaluate transition to use of ObjectScript
- Initial deployment of targeted updated packages

Long Term

- **Hire and Empower Agile Software Engineering Teams.** RPMS cannot be mapped in a typical waterfall model that outlines everything that needs to be done to modernize the system. The complexities of RPMS are too great and the specific environments of the I/T/U sites are too unique for a waterfall exercise to be useful. Instead, modern software engineering teams should be brought in and empowered with the authority to propose and implement incremental refactoring of the core RPMS applications utilizing more efficient and modern software programming languages and frameworks. Progress should be measured by short timeframe milestones that incrementally build upon a Minimum Viable Product (MVP). Oversight of these teams should be conducted only by experienced software engineering management with past hands-on experience in large, modern, software development.

- **Security:** Conduct ongoing security reviews and penetration testing. During the review of RPMS, some areas were discovered that warrant a deeper security review and proper penetration testing. It appears that areas of the architecture allow data to be shared in plain text over unsafe protocols like HTTP and FTP.

- **Enforce proper separation of concerns and begin decoupling tightly coupled application logic and RPMS packages.** RPMS's application and UI logic, business logic, data access, and data storage functions are all very tightly coupled into the same software layer and mixed with all other functions because of software design principles that MUMPS allows and promulgates. Separation of concerns[42] is crucial for numerous software engineering properties," and the decoupling of this logic and separation of concerns into components may enhance speed and flexibility (in both design and implementation), reusability, and configurability.[43]

[42] https://en.wikipedia.org/wiki/Separation_of_concerns

[43] Separation of Concerns, Erik Ernst, Dept. of Computer Science, University of Aarhus, Denmark, https://pdfs.semanticscholar.org/c052/f9d0e7e4c89a9d7abd36ffed4051ec59bb64.pdf

- **Increase Automated Testing.** There is little to no automated testing. Implementing automation, specifically functional automated testing, ensures that modernization efforts in the future do not create regressions and break crucial business functionality. Automated testing reduces risks overall and should be a critical investment for any healthcare system.

- **Enable the strategic use of COTS products.** The review of RPMS has led to the conclusion that a big-bang "rip and replace" approach with a COTS product is unlikely to work well in many of the RPMS deployments. However, the clinical and engineering teams should be empowered to evaluate COTS products as potential components in a hybrid solution, and allowed to examine where it may be appropriate to replace selective functionality of RPMS and encapsulate previous functionality. This could be at a package level, or an application level, or at a more conceptual functionality level. Any COTS products should seamlessly integrate with the rest of RPMS or require minimal refactoring, implementing appropriate layers of abstractions[44] that hide away the actual implementation on the other side.

[44] https://en.wikipedia.org/wiki/Abstraction_layer

Cloud Deployability

> *"' 'Cloud native technologies and cloud native applications are growing,'… Over the next 18 months, there will be a 100 percent increase in the number of cloud native applications organizations are writing and using… 'This means you can no longer just invest in IT,' but need to in cloud and cloud technologies as well."*
>
> —Abby Kearns, Executive Director of Cloud Foundry Foundation[45]

Cloud-based, and even more so cloud-native, applications are seen as the panacea for the hosting and development of modern software systems. The prevailing theory of the application development community is that it is best to embark on new Greenfield application development with a cloud-native approach and to move as much existing computation as possible to the cloud. As applied to RPMS, any modernization efforts that result in the development of new applications should consider a cloud-native approach. Deploying the existing RPMS infrastructure as-is in the cloud would also result in some benefits, albeit ones that are more limited than a full cloud-native re-architecture. The advantages of utilizing cloud providers over traditional data centers or on-premise hosting include:

- Lower total operational costs, as well as the reduction of large upfront capital expenditures in favor of more flexible monthly operating expenses.[46]
- Elasticity: the ability to scale systems—and costs—up or down based on need. This reduces the risks of capacity planning, and eliminates the need for large upfront capital expenditures and over-provisioning of hardware in order to meet peak demand.
- Lower IT staffing needs: outsourcing the infrastructure maintenance to cloud hosting providers reduces the amount of traditional onsite IT staff that is required to keep systems operational.

Given the pecuniary and staffing challenges of the various IHS sites that were examined, the move to a cloud hosting environment would seem to be easily justified.

[45] https://www.linuxfoundation.org/blog/2018/08/building-a-cloud-native-future/
[46] https://www.cio.com/article/2387672/how-cloud-computing-helps-cut-costs--boost-profits.html

However, in examining the information technology landscape of the I/T/U health delivery system we have uncovered some barriers to the viability of adopting any cloud solutions. **Two key barriers** would need to be addressed in order for a cloud-based RPMS, or its successor system, to be viable.

- **Cloud-hosted solutions would increase network demands on already saturated ISP circuits.** An analysis of 284 I/T/U sites' circuits found that 32% show a "Medium" or "High" utilization rate. Shifting more of RPMS's workload to the cloud, or using cloud-based solutions to include COTS, would push the bandwidth demands of the sites even higher. Additionally, 56% of the sites surveyed had provisioned bandwidth that was at or lower than 10 Mb/s, and the mode across all sites was only 1.45 Mb/s. By contrast, the average broadband connection speed across the United States was 25.86 Mb/s in 2018 as reported by M-Lab, a partnership between Google, Princeton, and New America's Open Technology Institute.[47]
- **Concerns regarding tribal sovereignty and data residency, ownership, control, and access shape decisions to adopt cloud solutions.** Sovereignty is always an important topic for tribes and tribal governments. The common fear is that tribal data in the cloud is out of the tribe's control and that institutions other than the tribes will have access to data stored in the cloud. This project encountered this hesitation around cloud solutions and concerns around data residency as it relates to tribal sovereignty and governance. When data is stored on physical hardware that exists within the geographical confines of tribal lands, the question of who owns and has access to that data is easier to answer. Mainstream cloud providers do offer some choice in where data will be physically stored, but this is only as far as a specific region and city within the Continental United States (CONUS) or abroad. Data sovereignty and data ownership issues reflect basic protection concerns about data.

Cloud Recommendations

- **In order to make any cloud solution feasible, supporting I/T/U sites by increasing the bandwidth and reliability available at each site is essential.** There are considerable barriers to

[47] https://www.cable.co.uk/broadband/speed/worldwide-speed-league/#regions

getting any internet connection at all, so increasing bandwidth is a considerable challenge. *"Due to the unique political status of sovereign Tribes and their economic history of disenfranchisement, Tribal [information and communication technologies] champions have had to work through a variety of social, economic, political, legal, and technical barriers to set up the infrastructure for ISPs on reservations."*[48] Given these limitations, sites with both higher bandwidth and a lower utilization rate could be the first to leverage a cloud-based solution with lower overall adverse effects on user-perceived performance and availability. Still, an architectural barrier remains to deploying RPMS specifically to the cloud as-is: the high number of RPC requests that constantly traverse the network for applications like the VueCentric EHR to work. This increase in network round-trips could be solved by refactoring the application, and introducing on-premise layers of caching. A detailed study of some of the more esoteric communications protocols that are used by RPMS would also be required to ascertain whether they can work on cloud providers' networks and leverage software-defined networking.

- **Contracts for application development that involves cloud hosting should include not only completion/delivery of software, but also evaluation criteria that include user-perceived performance.** Given the network challenges stated above, any new development should take into account not just system performance, but also user-perceived latency/performance as success criteria. The latest methods and techniques for delivering software to low-bandwidth end users, especially the reduction of network round trips, should be evaluated and implemented before considering a move of RPMS to the cloud.
- **More research is warranted on the legal question of how cloud providers could be utilized while protecting tribal sovereignty.** One specific technical approach that could be considered involves using data encryption in a specific way. Data could be uploaded encrypted (encryption at rest) to cloud providers, in any geographic region external to tribal lands. The encryption keys, however, could be stored and managed within the confines of a reservation. Now, healthcare data should always be stored encrypted, but this specific example uses "Customer-Provided

[48] Duarte, Marisa Elena. "Network Sovereignty: Understanding the Implications of Tribal Broadband Networks." University of Washington, 2013.

Encryption Keys" as supported by the majority of cloud providers, rather than those that are automatically provided and managed by the provider. This setup effectively ensures that tribal governments maintain full control and sole access to all data, even though it resides elsewhere.

- **Consider on-premise hosting with asynchronous data synchronization.** Given that there are hundreds of I/T/U sites and the challenges around network connectivity outlined above, a solution that allows for local LAN access (like much of RPMS does today) and synchronizes periodically with a cloud-hosted database could work best. This does not confer the same benefits of cloud-based solutions but still provides some data backup benefits. Given the limitations of many I/T/U sites, a full cloud deployment may not be feasible, so augmenting a local system with some limited cloud capabilities might be the most feasible.
- **Evaluate how a cloud based EHR operates with components that must remain on site, such as biomedical equipment that communicates directly with the EHR.**
- **Leverage lessons learned from other cloud based services that IHS uses, such as UFMS in the HHS cloud data center.**

6.3 Summary Statement

The goal of the Legacy Assessment has been to answer two questions:

1. **Can RPMS be modernized given its current state, functional scope, and known risks and constraints?**
2. **If RPMS can be modernized, what are the alternatives to achieving such modernization while protecting the confidentiality, integrity, and availability of the longitudinal patient healthcare data stored in the system?**

The answer to question 1 is an unequivocal "yes." We have gone into considerable detail to identify and describe issues with legacy RPMS and how those issues affect People, Processes and Technology performance at organizations that use the system. Those issues illustrate clearly why continuing the current path for RPMS development and support is not sustainable, and why a different approach should

be taken. Those issues do **not**, however, mean that RPMS cannot be modernized, using the methodologies we describe above. It can.

We also have laid out, in the document and its Appendices, the extremely broad scope of RPMS applications and functions. This scope is important because it underscores the complexity of complete replacement. The opportunity offered by a wrap and renew approach to stabilize RPMS **and** deliver enhanced usability, extensibility and efficiency of development in the relatively near term would allow for a more complete analysis of replacement options for high-priority modules to proceed. However, our research in the field repeatedly stressed **immediate** needs that are not being met. Developing and implementing a near term roadmap that can meet the highest priority needs is doable, and will help alleviate some of the angst that was reflected during the process of gathering data for this assessment.

Thus, in response to question 2, a wrap and renew approach to legacy modernization can be applied to several of the alternatives the project is considering. Moving the entirety of the RPMS suite into a modern tiered architecture as depicted in the Wrap and Renew Legacy RPMS figure above can certainly be one goal. On the other hand, if other factors compel IHS to move more quickly toward large-scale replacements, a wrap and renew modernization can be applied to subsets of RPMS that IHS may wish to maintain or are not readily available in the marketplace.

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Appendix A -- Historical View of RPMS Architecture

Year	Event	Technology
1974	PCIS – RPMS Forerunner	Cobol. Manual entry into systems
1986	RPMS Implementation	MUMPS
1990	1990 M Standard	Allowed for a better programming style
1996	BGU Broker	First TCP Broker that talked to RPMS. Allowed for Visual Basic Applications on Windows.
2001	BMX Broker	Broker with ADO.NET/minor SQL support & events
2002	CIA Broker	Broker with events and Component framework to allow decentralized development
2009	First Web Application (ED Dashboard)	Uses Cache Server Pages (a server side technology)
2012	Moonwalk Architecture	Use ORM/ADO.net to Access RPMS

Appendix B -- Additional History of RPMS

IHS was created in 1955 as a result of the Transfer Act of 1954, which moved responsibility for health care delivery on Indian reservations from the Department of the Interior Bureau of Indian Affairs to the Public Health Service, then under the Department of Health, Education and Welfare (now DHHS).

The co-location of IHS clinicians with computer scientists from the aerospace industry on the Papago (now Tohono O'odham) reservation in southern Arizona in December 1969 resulted in a decades-long clinical/technical collaboration that produced many "firsts" in the HIT industry. Among these were:

- First record with multi-facility, multidisciplinary data integration (1969)
- First electronic problem list, first health summary, and first integrated prescription list (1969)
- First health care reminders and alerts, and first population-based queries from an active data set (1970)
- First quality of care measurements from an active data set (1972)
- First inclusion of data from community outreach workers (CHR Program, 1972)
- First successful disease prevention program based on an active data set (eradication of infant gastroenteritis, 1973)
- First integration with telemedicine project (STARPAHC, 1975)
- First immunization management application (1975)
- First customizable/discipline-specific health summary (1980)
- First home health care application (1985)
- First epidemiology data system linked directly to online patient records (1988)
- First comprehensive query system for clinical end users (QMAN, 1988)

The original mainframe-based systems written in Cobol were migrated in the early 1980's to an architecture used by the Department of Veterans Affairs (VA) called the Decentralized Hospital Computer Program (DHCP), based in the MUMPS programming language developed by the Massachusetts General Hospital. Significant milestones in RPMS development and innovation in the current century include:

- 2002 - Release of the Clinical Reporting System (CRS)
- 2005-2008 - Release and nationwide deployment of the RPMS Electronic Health Record
- 2007 - Release of the iCare population management application
- 2007 - Certification of RPMS according to the requirements of CCHIT
- 2011 - Certification of the RPMS Suite according to the 2011 Edition criteria published by the Office of the National Coordinator for Health Information Technology (ONC) - RPMS became the first and to date only federal government health information system to be so certified
- 2014 - Certification of the RPMS Suite according to 2014 Edition ONC criteria

A fundamental aspect of RPMS has been access to the data at any time by any authorized user, applying simple but powerful querying techniques across virtually any field in PCC. These tools have been key to the public health mission of IHS, allowing insights into data at the population level and supporting case management, flexible disease registries and performance measurement.

Appendix C -- Core RPMS Technology and Applications

Current Architecture: Summary

RPMS evolved principally as an ambulatory electronic medical record system with inpatient capabilities designed to meet the needs of small hospitals. RPMS was developed by the IHS for its own use, and it contains workflows (such as Purchased and Referred Care) and reports such as the Government Performance and Results Act of 1993 (GPRA) that are legally required of the IHS.

RPMS is a decentralized system. Every instance of RPMS is hosted separately. There are at least 243 production instances of RPMS running throughout the Indian healthcare system. A key differentiator of RPMS from other health information systems is its strong focus on population health.

The core of RPMS is written in M (formerly known as MUMPS, though this document will continue to refer to it as MUMPS for clarity) using the VA VistA Architecture. MUMPS is a programming language and database designed to be used in the healthcare industry. It currently runs on InterSystems Ensemble, which consists of a Caché database that runs the MUMPS portion of RPMS and Ensemble, which is an integration engine. Small parts of RPMS are written in Caché Objectscript, which is InterSystems' backwards-compatible successor to MUMPS that layers object-oriented programming concepts on top of MUMPS.

The database is a schemaless database with SQL projections. The data dictionary is stored in a core component of RPMS known as FileMan. FileMan provides data meaning to the stored data and also provides data integrity, preventing the saving of bad data. FileMan provides a text-based user interface for adding/editing/removing the data defined in its data dictionary.

RPMS's interface is accessed through a VT-220 terminal emulation (popularly known as either the "roll and scroll" and "DOS"). Code-wise, most code can only be run from here.

RPMS also contains a variety of graphical user interfaces (GUI), most of which are usable only on Microsoft Windows desktops. The graphical user interfaces exchange data with RPMS using a variety of Transmission Control Protocol (TCP)-based protocols, which are detailed in the subsection The Broker Based GUI Applications Architecture.

RPMS talks to various external (outside of the immediate RPMS database but excluding the Windows GUI clients) systems, including billing systems, laboratory instruments, reference lab interfaces, pharmacy dispensing machines, immunization registries, and health data exchanges. Most of these systems use the HL7 standard for data exchange (most commonly v2.3 and v2.4), and most now use TCP as the communication protocol, but there exist several file-transfer-based interfaces (i.e., a file gets written out to disk and uploaded to the receiver via SFTP or HTTPS). These systems are numerous and use a variety of interfaces.

The Three Architectures of RPMS

RPMS can be divided into three different architectures, which differ significantly from each other:

- The Classic VA VistA Architecture
- The Broker-Based GUI Applications Architecture
- The SQL Projection/Object-Relational Mapping (ORM) Architecture

FileMan is the Database Management System (DBMS) for RPMS, and it is responsible for defining the data schema and the storage locations for the data between the architectures.

Classic VA VistA Architecture

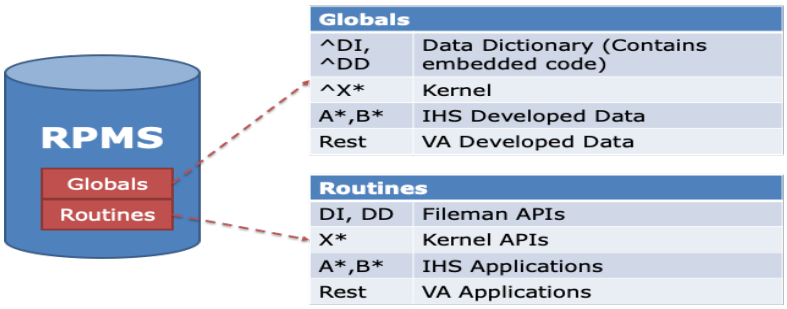
The Classic VA VistA Architecture was developed over the late 1970s into the mid-1990s. It uses the 1995 ANSI standard version of MUMPS to provide an integrated database system for medical applications. Four other commercially available systems – Epic, Meditech, GE Healthcare, and Allscripts – share similar architectural dependencies on components that are built on a MUMPS database, but do not use FileMan.

A MUMPS database consists of two portions: Routines and Globals (see figure below).

- **Routines** are the code;
- **Globals** are the permanent data stored on disk. =/+
- MUMPS routines are not organized into packages like other languages (e.g., Java classes) and, therefore, need a different mechanism to avoid name conflicts. In MUMPS, routines and globals are organized based on the first few letters of their name. This is known as a Namespace.

By convention, all of the IHS programs start with the letter B; although some historic IHS programs were initially stored in namespaces beginning with A. The choice of the letters was developed in conjunction with Veterans Affairs. In Figure 1 below, DI, DD, and X* are all VA-developed MUMPS programs.

RPMS Architecture at a very high level



The MUMPS database layer is a schemaless database, similar to NoSQL databases. It does not provide any form of access control or user interface. These were components built by the VA and IHS over many years. A listing of the most important components can be found in the section **VistA MUMPS**

Applications Parts Lists. **FileMan** is a framework over the database that provides a schema for the data and is where the data is stored. FileMan also provides a user interface to interact with the data.

A component called the **Kernel** adds security controls (authentication and a permission system). The Kernel also provides a character-based **Menu System** that allows various applications to be grouped in a hierarchical fashion. Access to menus is done with hierarchical permissions using what is known as "**Security Keys**." Security keys are database elements stored in the SECURITY KEY file. An example of a security key is LRSUPER, which gives the user access to advanced Lab Configuration functions. The figure below is an example of a menu.

Sample Menu

```
Select IHS Core <TEST ACCOUNT> Option:  Laboratory DHCP Menu
   1        Phlebotomy                    menu                    ...
   2        Accessioning                   menu                   ...
   3        Process      data      in       lab      menu        ...
   4        Quality           control            menu             ...
   5        Results                      menu                     ...
   6        Information-help                menu                  ...
   7        Ward              lab              menu               ...
   8        Anatomic                   pathology                  ...
   9        Blood                       bank                      ...
   10       Microbiology                   menu                   ...
   11       Supervisor                    menu                    ...
   BLR      IHS      Lab      Main      Support      Menu          ...
   LSM      Lab Shipping Menu ...
Select Laboratory DHCP Menu <TEST ACCOUNT> Option:
```

Options 8-11 in the graphic above are protected using security keys, and access to them and their descendants is allowed only for those users who have the appropriate keys.

Menus eventually end at an option to perform a task. For example, the first option in the "Phlebotomy menu" is "Add tests to a given accession." This calls the routine ADD^LRTSTJAM. Since the routine name begins with "LR," it is a VA-developed lab routine.

The menu system is mainly hierarchical in nature. Users are typically assigned a "primary menu" for their job functions. The example menu above would be a suitable primary menu for a lab technician. The menu system also allows system administrators to give users what are known as "secondary menus," which are other functions allocated to a user on an individual basis. For example, a lab technician may need to query certain files in FileMan directly; and so the option to query these files may be assigned as a secondary menu.

The Kernel also provides MUMPS vendor independence. MUMPS is a mostly standardized language; but it allows leeway for MUMPS language implementers to implement specific commands or parameters that are specific to the vendor. The Kernel abstracts those custom commands; if any application needs to use these commands, they can call a standard Kernel API rather than write a vendor-specific command inside the application code. That was very helpful over RPMS history, as RPMS ran on MSM (most sites) and DSM (Alaska), and later migrated to OpenM, which was later branded as InterSystems Caché. RPMS currently runs on InterSystems Ensemble, which includes Caché as the database.

Data Layout

Data is stored in MUMPS in what is known as a "global," which is like a file on disk. This is a line of sample data that is stored in MUMPS data files (also known as a " data node"):

```
^DPT(2,0)="USER,TEST^M^2850505^^2^^^^^^^^^^^^^^1"
```

This data by itself is meaningless without a schema describing how to interpret it. As the MUMPS storage engine is schema-less, FileMan provides that schema. As with any schema, it can be quite detailed.

FileMan has a global map schema that indicates what fields are stored on a specific node. In this case, it is the following:

```
^DPT(D0,0)= (#.01) NAME [1F] ^ (#.02) SEX [2S] ^ (#.03) DATE OF BIRTH [3D] ^
     ==>^ (#.05) MARITAL STATUS [5P:11] ^ (#.06) RACE [6P:10] ^ (#.07)
     ==>OCCUPATION [7F] ^ (#.08) RELIGIOUS PREFERENCE [8P:13] ^ (#.09)
     ==>SOCIAL SECURITY NUMBER [9F] ^ (#.091) REMARKS [10F] ^ (#.092)
     ==>PLACE OF BIRTH [CITY] [11F] ^ (#.093) PLACE OF BIRTH [STATE]
     ==>[12P:5] ^ ^ (#.14) CURRENT MEANS TEST STATUS [14P:408.32] ^
     ==>(#.096) WHO ENTERED PATIENT [15P:200] ^ (#.097) DATE ENTERED INTO
     ==>FILE [16D] ^ (#.098) HOW WAS PATIENT ENTERED? [17S] ^ ^ (#.082)
     ==>PATIENT MERGED TO [19P:2] ^ (#.083) CHECK FOR DUPLICATE [20S] ^
     ==>(#.6) TEST PATIENT INDICATOR [21S] ^
```

In this example, FileMan describes the patient demographics that are stored in the ^DPT global: the second entry (also known as Internal Entry Number--IEN) is for a patient called USER,TEST; who is male (M); who was born on May 5, 1985 (2850505); who is Married (2, a pointer to entry 2 in file MARITAL STATUS which means “Married”). The last “1” is an administrative piece of data saying that the record was checked for duplication.

Knowing what a data item means requires looking at the detailed schema. Two examples include the SEX field and the MARITAL STATUS field (only the data definition is shown, not the cross references—with the exception that a single cross-reference for SEX is shown. Cross-references are data-dictionary items that index the data for searching or that monitor the data for changes in order to trigger events).

```
2,.02        SEX                 0;2                 SET                 (Required)
                                 'M'                   FOR                    MALE;
                                 'F'                  FOR                   FEMALE;
                                 'U'                 FOR                   UNKNOWN;
             LAST EDITED:        APR                   19,                    2013
             HELP-PROMPT:        Enter   'M'   for   MALE,   'F'   for   FEMALE,   or
                                 'U'                   if                    UNKNOWN.
             DESCRIPTION:        Enter   'M'   if   this   applicant   is   a   male,
                                 'F'    if    female,    or    'U'    if    unknown.
```

```
             GROUP:              IHS
             CROSS-REFERENCE:                                                2^ASX
                                 1)=          S          ^DPT("ASX",$E(X,1,30),DA)=""
                                 2)=            K           ^DPT("ASX",$E(X,1,30),DA)
2,.05        MARITAL STATUS      0;5     POINTER     TO     MARITAL     STATUS     FILE
                                 (#11) (Required)

             LAST EDITED:        AUG                     25,                     2000
             HELP-PROMPT:        Select    from    the    available    listing    this
                                 patients        current        marital        status.
             DESCRIPTION:        Select    from    the    available    listing    this
                                 applicant's current marital status.
```

The schema is actually stored in the global ^DD. For example, the schema for the SEX field in the ^DD looks like this (NB: This is condensed; the actual DD is much bigger as most cross references have been removed from the listing).

```
^DD(2,.02,0)="SEX^RS^M:MALE;F:FEMALE;U:UNKNOWN;^0;2^Q"
^DD(2,.02,1,0)="^.1"
^DD(2,.02,1,1,0)="2^ASX"
^DD(2,.02,1,1,1)="S                                    ^DPT(""ASX"",$E(X,1,30),DA)="""""
^DD(2,.02,1,1,2)="K                                         ^DPT(""ASX"",$E(X,1,30),DA)"
^DD(2,.02,3)="Enter   'M'   for   MALE,   'F'   for   FEMALE,   or   'U'   if   UNKNOWN."
^DD(2,.02,20,0)="^.3LA^2^2"
^DD(2,.02,20,1,0)="DEMOG^"
```

```
^DD(2,.02,20,2,0)="IHS"
^DD(2,.02,21,0)="^^1^1^3130419^"
^DD(2,.02,21,1,0)="Enter 'M' if this applicant is a male, 'F' if female, or 'U' if
unknown."
^DD(2,.02,"AUDIT")=""
^DD(2,.02,"DT")=3130419
```

The above was a look at how data is actually stored. Moving up a level to the level of files, each file has a file number, a global location where the data is stored, and a file name. Sample FileMan files are displayed in the table below.

Sample Files in FileMan

File Number	File Name	Global Location	Description
2	VA PATIENT	^DPT(	Main Patient File
11	MARITAL STATUS	^DIC(11,	Marital Statuses
9000010.11	V IMMUNIZATION	^AUPNVIMM(	Patient Immunization Records

Each file can be considered to be analogous to a table in a traditional relational database, with the exception that files can contain subfiles. An example of a subfile is the appointments “multiple” in the patient file. In SQL Projections of FileMan files, which are accomplished by third-party tools (RPMS uses those provided by InterSystems in their Fileman To Class product), subfiles are usually projected as separate tables where the data in the subfile points back to the parent file using a foreign key.

In the August 2018 FOIA version of RPMS, there are 3059 files stored in 1903 globals (a global can store multiple files—for example, ^DIC can have ^DIC(10, which is RACE; and ^DIC(11, which is MARITAL STATUS).

A full listing of the RPMS files in the latest FOIA as of the time of this writing can be found on DOX on the OSEHRA website here: https://code.osehra.org/vivianr/files/dox/filemanfiles.html.

Relationships Among RPMS Applications

ViViaN, a visualization software produced by the Open Source Electronic Health Record Alliance (OSEHRA, www.osehra.org), contains an interactive display of the applications and their relationships with each other: https://code.osehra.org/vivianr/vista_pkg_dep.php.

VistA MUMPS Applications Parts Lists

This section is a parts list of the components that are used to create a full application. FileMan components and Kernel components are displayed in the tables below.

FileMan Components

Part	Description
File	Contains the data whose structure is dictated by a corresponding data dictionary.
Fields	An individual data element; multiple data types are supported (text, numeric, pointer, MUMPS code, etc.).
Record	A single item of information composed as individual fields.
Print Template	Provides formatting logic for a user-friendly representation of a record.
Input Template	Template defining a list of fields from a given file for purposes of data entry.
Sort Template	Logic for the sorting and filtering of records;. Usually used with a Print Template.
Form	Like an Input Template, but allows you to use a form-based user interface for the entry of data. Compare this with a List Manager Template shown in the next table.

Kernel Components

Part	Description
Option	Menus and code to execute for that menu. This is the main role authorization system in the classic VA MUMPS architecture. Uses Security Keys (see below) to control access to menu trees.
Dialog	Translation of static text. Used for internationalization. Rarely used in clinical applications, where all text strings are typically hardcoded inside the source code.
Function	Standard code to execute on FileMan Data. An example is the YEAR function, which extracts the year from a date.
Help Frame	A help system for users
Security Key	The authorization permissions token system that VistA and RPMS use. Security keys are used throughout the system to know what kind of permissions a user has. For example, a user with the ORES key has the ability to place orders for patients. Keys are used in the menu system as well to control access to menu trees. Some are restrictive, as opposed to permissive. Others are mutually exclusive, meaning one key holder cannot hold a specific other key.
List Manager Template	A component for the creation of Text Based User Interface. Compare to Form in the table above. Unlike Forms, which usually operate on a single record, a List Manager Template operates on a group of records. A well known example is the Pharmacy User Interface, which uses these to allow the viewing and operating on a single patient's multiple prescriptions.
Protocol	A critical component with multiple uses • Event Drivers (e.g., I scheduled a patient; now what?) • HL7 Configuration Parameters (for VistA HL7 engine) • Specific Prompts in the Ordering System • List Manager Actions
Remote Procedure	Defines a piece of code that an external TCP based application (which will be discussed in the next section) can execute. Most GUI applications use these named Remote Procedures in order to interact with the RPMS database.
Device	Defines the communication protocols for an external device. This is most commonly a printer, but can also be a lab instrument, or a file on a file system.

The Broker-Based GUI Applications Architecture

By the late 1990s, "personal" computers running Microsoft Windows became the dominant workstations for government employees. The IHS, in concert with VA but writing code separately from them, developed Windows programs that talked to the RPMS database via the Transmission Control Protocol/Internet Protocol (TCP/IP).[49] RPMS does this using what is known as a Remote Procedure Call Broker (RPC Broker): The MUMPS program that mediates the communication between the client and the server using a proprietary protocol, and handles authentication and authorization. The RPC Broker sends RPC invocation requests from the client to the server and receives the responses. Today, the majority of users who interact with RPMS do so via a Microsoft Windows program that talks to the underlying RPMS system via TCP using a broker.

The IHS initially wrote code in the "BGU-" namespace (a naming convention for M routines that uses a package-assigned unique prefix to avoid naming collisions) for the IHS version of the broker in the mid to late 1990s. The IHS later wrote a new, improved version of the broker specifically for .Net applications called BMXNet. With the development of RPMS-EHR (the main clinical GUI used in RPMS), RPMS used the Clinical Informatics Associates (CIA) broker. When the IHS needed to use VA GUI applications from the VA (Imaging and Barcode Medication Administration [BCMA]), the IHS acquired two more broker protocols, the classic XWB (BCMA) and the new XWB broker (Imaging). Imaging brought another broker, called M2M, which is only used between RPMS and the Imaging Gateways.

BGU has been decommissioned and the old Visual Basic 6 applications that used it are no longer in use. Its successor is the BMXNet broker for the rewritten versions of these applications.

The last few paragraphs show all the different brokers in use in RPMS. The brokers have the following in common:

- All communicate via TCP.

[49] https://en.wikipedia.org/wiki/Transmission_Control_Protocol

- All communicate using proprietary, primarily text-based, incompatible protocols.
- All rely on the REMOTE PROCEDURE file that maps an RPC name to its execution point in MUMPS code.
- All rely on the OPTION file to determine if the user is authorized to execute a specific REMOTE PROCEDURE.

The brokers differ in the following respects:

- The old XWB broker does a "call-back," similar to the classic File Transfer Protocol (FTP).[50] One of the main reasons the new XWB broker exists is to eliminate that call-back, as call-backs do not work through firewalls or routers. BCMA is the only application that uses the old XWB broker; the latest version of BCMA from the VA has deprecated that and only uses the new XWB broker.
- CIA and BMX brokers support events (where a client can get notified that something it is interested in has occurred on the server). Both accomplish this by polling the server for events.
- CIA broker supports asynchronous execution of Remote Procedures.
- BMX broker supports projecting a FileMan file as an ADO.Net datatable, modifying it, and writing it back.
- BMX broker supports limited SQL queries against FileMan data.
- CIA broker has a logging capability for tracking broker calls via a Windows UI. All of the others are lacking in that regard.
- CIA broker has good integration with the VistA Authorization System (Security Keys). The other brokers do not have that capability.

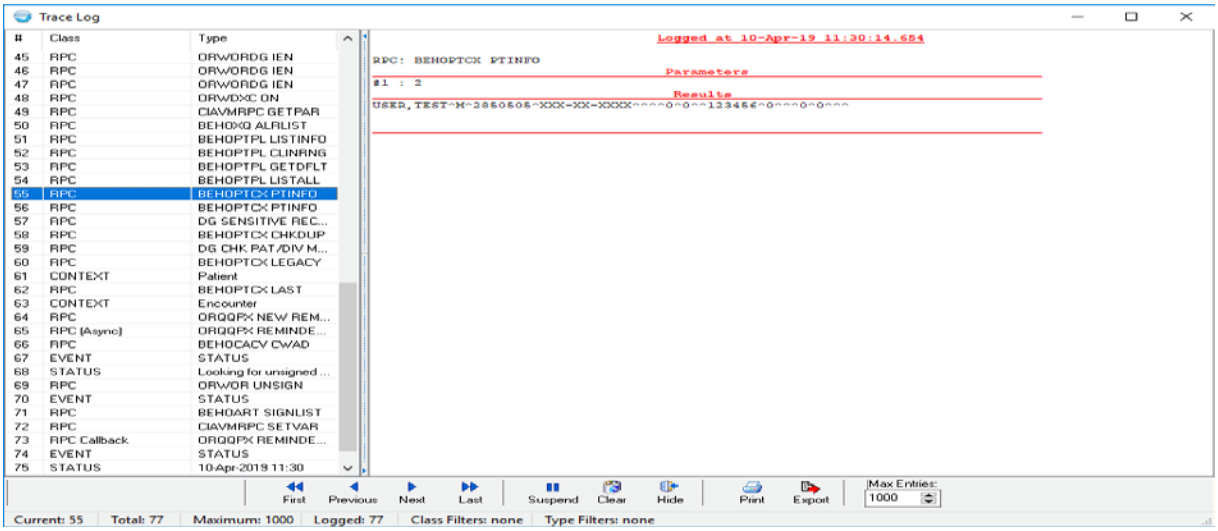
[50] https://en.wikipedia.org/wiki/File_Transfer_Protocol

- CIA broker is utilized by a GUI framework called VueCentric that allows developers to author COM components that are loaded at run time.[51] The VueCentric framework is the basis of RPMS EHR which is the most commonly used program in all of RPMS.

Typical Broker Communication

The figure below displays how a typical broker functions. This is a screenshot from the CIA Broker Tracer.

CIA Broker Trace



Brokers talk to RPMS by sending named Remote Procedure Calls (RPC) with a list of parameters. In this screenshot, we are sending the Remote Procedure named BEHOPTCX PTINFO with a single parameter with a value of 2. The RPC returns the result "USER,TEST^M^2850505^XXX-XX-XXXX^^^^0^0^^123456^0^^^0^0^^^". In general, for most Remote Procedures, input parameters and the output format are largely ad hoc and do not follow a common pattern or standard convention. This means that knowing the output of one RPC will not help you with the output of other RPCs; and every

[51] https://en.wikipedia.org/wiki/Component_Object_Model

RPC needs its own parsing code, both on the server and client side. Thus, the consumer of an RPC response is responsible for understanding and parsing the data that is returned.

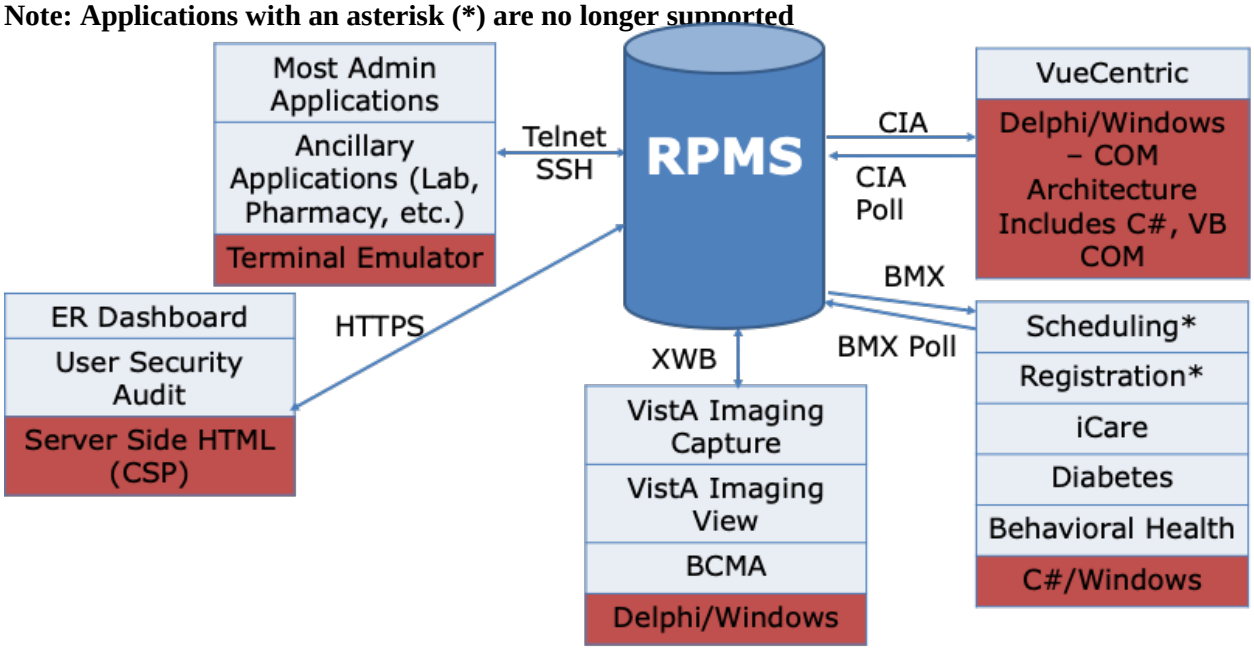
RPMS Applications That Use Brokers

The figures below display the most important RPMS applications as diagrams. The first figure includes the most important RPMS GUI applications that use brokers. The table in Appendix C is a full listing of all of the separate RPMS GUI applications at the time of this writing. The table shows the brokers and protocols used by each, and the programming languages they are written in. As VueCentric is a framework and contains multiple applications inside of it written in various languages, a table has been prepared in Appendix D, which lists all the clinical components in the VueCentric framework. It includes the programming languages each of the COM components was written in if the source code was available for examination.

The ER Dashboard and the User Security Audit applications do not use brokers, but rather they use a technology called Caché Server Pages (CSP) developed by InterSystems. These will be discussed in the next section.

RPMS GUI Applications, part 1

Note: Applications with an asterisk (*) are no longer supported



The SQL Projection/ORM/Service Oriented Architecture

History of the Architecture Development

In the early 2010s, there were several parallel efforts to create web accessible applications. IHS elected to use technologies offered by InterSystems, while still ensuring that all data was stored in a FileMan compatible format so that other applications in RPMS could continue to access the data.

The Emergency Department Dashboard was developed by Chickasaw Nation before 2009 and acquired by IHS in 2009. It pre-dates the SQL Projection Architecture; but is an important stepping stone on the road to it. It was written using Caché Server Pages, which is a technology similar to other server side rendering technologies, like Active Server Pages (ASP) or Java Server Pages (JSP). This was also the first project to start using Caché Objectscript, InterSystems' enhancement to the MUMPS language.

Later projects took advantage of InterSystems' FM2Class Product, which added metadata in order to be able to expose Fileman data to SQL; and allows access to Fileman data using Caché Objectscript class syntax, allowing a new paradigm of object-oriented programming using FileMan data structures. In the early 2010s, the Continuity of Care Document (CCD) C32 extractor project used the FM2Class capabilities. The entire package was written in Caché Objectscript.

At the same time that the CCD project was being developed, a research project was initiated to study the possibility of doing a Service Oriented Architecture consistent with what the commercial sector uses. It was called "Moonwalk" and namespaced into the "BMW-" namespace. According to the main architect, the objectives of the project were as follows:

- Provide Service Oriented Architecture
- Use commonly used programming languages and paradigms so that new developers can be easily trained to develop on the system and have an easier time grasping the concepts
- Have an SQL interface and and an Object Relational Mapping (ORM) system like Hibernate
- Provide a web-based interface.

In the end, the Moonwalk project proved successful, and is now the basis of the Practice Management suite.

Description of Architecture

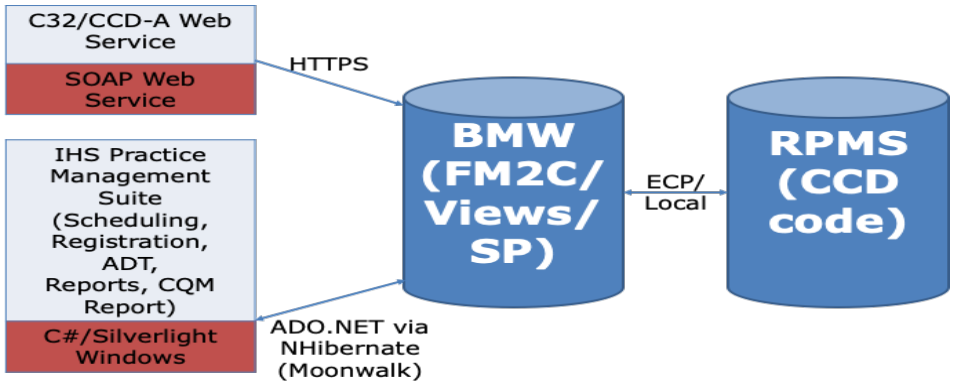
The final architecture uses Caché's ADO.Net adaptor to do Object Relational Mapping using NHibernate from a .Net Application. Silverlight was chosen as the front-end framework for that project. The Practice Management Suite contains the following applications:

- Scheduling
- Patient Registration
- Clinical Quality Measures
- Admission/Discharge/Transfer (ADT)

The architecture is somewhat modular, in that each of the applications is independent and was developed separately. The modularity concepts are not documented and are only known by the developers.

The successor to the C32, Consolidated Clinical Document Architecture (C-CDA) extractor project, started sharing some of the same infrastructure as the Moonwalk project. The architecture now looks like this:

RPMS GUI Applications, part 2



InterSystems Cache supports replicating a database over multiple machines; these machines can sync up their data using the InterSystems proprietary Enterprise Cache Protocol (ECP). The Moonwalk/BMW

database can be configured to either reside on a separate machine, enabling it to talk to the main RPMS database via the ECP protocol; or it can sit on the same machine as RPMS.

The BMW database contains the data definitions for projecting Fileman data into Cache Classes. It also contains a definition of Views of Fileman Data and Stored Procedures for various actions to perform on the data. The Stored Procedures are mostly MUMPS code written inside Cache ObjectScript wrappers that execute code on RPMS; as such, they very closely mirror remote procedures.

Practice Management is the first application to employ a stateless connection to RPMS, with state managed in the manner of modern web applications using session tokens. All other applications establish and sustain a single, stateful connection with a dedicated server process servicing and maintaining state for that connection.

RPMS Graphical Interfaces and Technologies

The list of the most important IHS Windows applications include:

- RPMS-EHR (built on the VueCentric Framework). This is the main program used by clinicians to deliver care to patients. It is an extensible framework that uses COM[52] technology allowing developers to extend the system without having to recompile the core. The framework is written using Delphi. The COM components are written in Delphi, Visual Basic 6, or C# (.net). The components were authored by different developers over a long period of time--as such, many are not visually consistent. RPMS-EHR uses the CIA broker.
- iCare. This unique RPMS population health program is written in C#, and uses the BMX broker.
- Practice Management Suite. This suite uses Silverlight and ADO.net[53] with ORM[54] on the RPMS database. ORM is provided by NHibernate, which uses a technology from Intersystems called "FileMan to Class" to expose FileMan data using ADO.net. Many operations are too complex for

[52] https://en.wikipedia.org/wiki/Component_Object_Model
[53] https://en.wikipedia.org/wiki/ADO.NET
[54] https://en.wikipedia.org/wiki/Object-relational_mapping

ORM, and as such they use Stored Procedures, which are very similar in character to Remote Procedures. Silverlight uses Windows Communication Foundation (WCF)[55] to communicate to RPMS.

The table below provides a listing of all the RPMS graphical applications, programming languages they are written in, and specific windowing framework (also known as Forms Technology) in use. It identifies all the different programs (defined as separate executables). All of the components in the VueCentric Framework which constitute the RPMS-EHR program can be seen in the table in Appendix D. There are some programs that do not interact directly with RPMS (e.g., VistA Imaging Background Processor and DICOM Gateway Managers), so these are not included in the listing.

[55] https://en.wikipedia.org/wiki/Windows_Communication_Foundation

RPMS GUI Applications Table

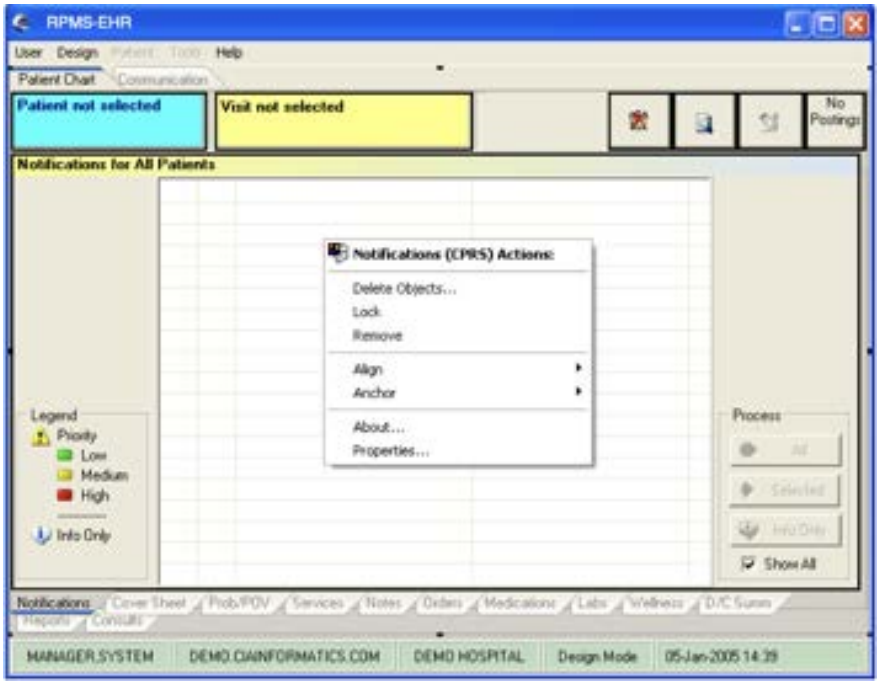
Applications with an asterisk (*) are no longer supported; applications with a dagger (†) are frameworks that have multiple applications under them.

Name	Namespace (M Code)	RPMS-EHR Component	Broker	Lang	Forms Technology
Patient Registration*	AGG	No	BMX	C#	Windows.Forms
Behavioral Health	AMH	No	BMX	C#	Windows.Forms
Visual Diabetes Management System	BDM	No	BMX	VB.net	Windows.Forms
Prenatal Care	BJPN	Yes	BMX/CIA	C#	Windows.Forms
Practice Management†	BPRM	No	None	C#	Silverlight
Visual CPHAD	BNI	No	BMX	VB.net	Windows.Forms
iCare	BQI	No	BMX	C#	Windows.Forms
Scheduling*	BSDX	No	BMX	C#	Windows.Forms
RPMS-EHR†	CIA, BEH, others	n/a	CIA	Delphi/C#/ VB6	Depending on component.
Well Child	VEN	Yes	BMX/CIA	C#	Windows.Forms
Generic Retrieval Utility	GRU	No	CIA	Delphi	VCL Delphi Framework
ER Dashboard	BEDD	No	None	CSP	HTML
User Security Audit	BUSA	No	None	CSP	HTML
VistA Imaging Capture	MAG	No	XWB	Delphi & C++	VCL Delphi Framework
VistA Imaging Display	MAG	No	XWB	Delphi & C++	VCL Delphi Framework
VistARad Radiology Diagnostic Workstation	MAG	No	XWB	Delphi & C++	VCL Delphi Framework
BCMA Site Parameters	PSB	No	XWB (old)	Delphi	VCL Delphi Framework
BCMA User	PSB	No	XWB (old)	Delphi	VCL Delphi Framework

For details of the applications in RPMS-EHR, see the table in Appendix D.

Appendix D -- The VueCentric Framework

The foundation of the RPMS-EHR, the VueCentric Framework, developed by Clinical Informatics Associates, Inc. (later acquired by Medsphere Systems Corporation, Inc.), provides a high level of extensibility and configurability. The VueCentric Framework is a composable, pluggable, domain-agnostic framework that enables the creation of complex applications from individual components (plugins) that may be visual elements and/or provide background services. Using a built-in composer (the Visual Interface Manager or VIM), a user may select and organize visual components to create a user interface that combines the functionalities and workflows required by a given clinical venue, specialty, role or individual user. The resulting composition (layout template) may be exported and shared across facilities. The following figure illustrates the use of the VIM in composing a layout template:



For the RPMS-EHR, over 80 visual components are packaged in the national distribution. These components provide wide-ranging clinical functionality such as problem list management, clinical documentation, result reporting, health maintenance, patient education and counseling, order entry,

medication prescribing, and decision support. The national distribution also provides a set of default layout templates that sites may use as is or modify to meet their needs. In addition to customizing layouts, some sites have created their own custom components to further extend the capabilities of the RPMS-EHR.

The VueCentric Framework is written in the Delphi programming language, an object-oriented extension of the better-known Pascal language. As such, it is a thick client application that runs exclusively on the Microsoft Windows platform. Plugin components may be written in any of several programming languages. Nationally distributed components have been written using Delphi, Visual Basic Classic, C# and Visual Basic.NET (in order of decreasing frequency). A full list of the plug-ins as of August 2018 can be found in the table at the end of this appendix. This choice of programming languages and software development tools is possible because VueCentric leverages Microsoft's Component Object Model (COM) specification to provide the necessary abstraction between plugin components and the Framework. Thus, any software development tool that can produce a COM-compliant component may be used.

The architecture of the VueCentric Framework and its relationship to the RPMS-EHR may be summarized by the following diagram:

The Visual Interface Manager (VIM) represents the top tier of the VueCentric architecture. It manages the composition and layout of the presentation layer. It allows the user to define the visual relationships among discrete components, provides the ability to compose complex interfaces from individual visual elements, supports the persistence of composed layouts to and from a central store, controls user-level access to components, and can interrogate components for the resources they require and automatically connect them to those resources.

The Component Support Services (CSS) comprises the middle tier and provides shared resources that all components may access and coordinates activities among individual components. The CSS supports the concept of plugin services that augment the functionality of the middle tier in a fully extensible manner. Natively available services include context management that exposes shared context objects that reflect the current state of the application, such as the currently selected patient, the user who is logged in, or the clinical encounter that is being referenced. Examples of plugin services include unified electronic signature, report generation, remote data views and clinical reminders. The CSS also provides support for

performing remote procedure calls to allow components to interact with the host system. The CSS is also a manager and producer of events that can notify components who choose to subscribe that, for example, the patient selection has changed. Finally, the CSS can also participate in context changes that originate outside the application. This is possible because the CSS automatically detects the presence of any CCOW-compliant context manager (see https://www.hl7.org/implement/standards/product_brief.cfm?product_id=1) and registers as a participant. In this manner, the VueCentric-based application may synchronize its context with other CCOW-compliant applications residing on the same desktop (e.g., VistA Imaging).

At the bottom tier is RPMS itself. The RPMS-EHR stores its data in RPMS utilizing, for the most part, existing RPMS files. Thus, existing applications (e.g., encounter tracking) will continue to function as before.

Critical to the interaction between the middle tier elements and the bottom tier host system is the Communication Service Layer (CSL). Its roles are to perform user authentication and to mediate both synchronous and asynchronous data exchange between the two tiers. The CSL is completely encapsulated by the CSS in order to facilitate the abstraction of the data access layer. This makes it possible to incorporate other data access components without adversely affecting existing consumers of the service.

Another key feature of the VueCentric Framework is the just-in-time deployment of components. The Component Management Service (CMS) performs this function. This service enforces version control, imposes access controls, interacts with the Updater Service to deploy updates from a central repository, and controls other aspects of a component's behavior at runtime.

In addition to the architectural elements described above, the VueCentric Framework also employs external data stores in the form of an Object Registry, a Template Registry, and an Object Repository.

The Object Registry provides information about available components and their capabilities. The CMS provides a read-only, object-oriented view of this information.

The Template Registry provides a globally accessible location for the storage of state-information in an exportable format. It is used to store layout templates composed using the VIM.

The Object Repository is a central store of components that are accessible to the VueCentric-based application. This repository allows an application to automatically update locally installed components from a trusted source. The repository may be implemented by a web server, an ftp server, any globally accessible directory, or any combination of all three. The VueCentric Framework employs a just-in-time deployment strategy. Under that paradigm, using its unique identifier and version, the Framework requests a component via the CMS. If the requested component is already deployed locally, that version is used. If it is not, the CMS retrieves the component from the Object Repository and deploys it with the help of the Updater Service. The Updater Service runs on the target workstation with elevated privileges that enable it to deploy and register components.

Complete Listing of all Clinical Objects in the VueCentric Framework, as of August 2018

Component Friendly Name	Programming Language	Windows Framework
Alerts	Delphi 7	VCL
Allergies	Delphi 7	VCL
Anticoagulation	C# 3.5	WinForms
C-CDA Request Tool	C# 3.5	WPF
C32 Viewer Launch Button	C# 3.5	WinForms
KMR NHIN Viewer Launcher Button	C# 3.5	WinForms
Chart Review	C# 3.5	WinForms
Community Info	C# 3.5	WinForms
Clinical Information Reconciliation	C# 3.5	WPF
Consult Order History	Delphi 7	VCL
Consults (CPRS)	Delphi 7	VCL
Crisis Alerts	Delphi 7	VCL
Crises/Warnings/Alerts/Directives	Delphi 7	VCL

Discharge Summary (CPRS)	Delphi 7	VCL
Dictate Note	Delphi 7	VCL
Direct Mail Button	C# 3.5	WinForms
Dosing Calc	C# 2.0	WinForms
Encounter Information Header	Delphi 7	VCL
Surescripts Renew Request Queue	Delphi 7	VCL
Integrated Signature Tool	Delphi 7	VCL
Health Summary Report	Delphi 7	VCL
Info Button Service	C# 3.5	WinForms
Level of Intervention	C# 2.0	WinForms
Integrated Problem List	C# 3.5	WPF
Lab Results	Delphi 7	VCL
Lab Orders	Delphi 7	VCL
Medications	Delphi 7	VCL
Medication Management	Delphi 7	VCL

Progress Notes	Delphi 7	VCL
Notifications	Delphi 7	VCL
Orders (CPRS)	Delphi 7	VCL
Patient Goals	C# 3.5	WPF
Patient Identification Header	Delphi 7	VCL
Primary Care Provider	C# 3.5	WinForms
Medication Counseling	Delphi 7	VCL
Primary Care Information Header	Delphi 7	VCL
Problem List	Delphi 7	VCL
Patient Detail View	Delphi 7	VCL
Quick Order Wizard	Delphi 7	VCL
Reminders (PCC)	Delphi 7	VCL
View Reminders (CPRS)	Delphi 7	VCL
Remote Data (CPRS)	Delphi 7	VCL
Reports (CPRS)	Delphi 7	VCL

Stroke Tool Button	C# 3.5	WPF
Stroke Tool	C# 3.5	WPF
Appointments	Delphi 7	VCL
Vital Measurement Entry	Delphi 7	VCL
Vital Measurement Display	Delphi 7	VCL
AMI Component	C# 3.5	WPF
AMI Component Button	C# 3.5	WPF
Lab Accession	Source not available	
IHS ImageViewer	Source not available	
Prenatal Pick List	C# 3.5	WinForms
Pregnancy Issues and Problems List	C# 3.5	WinForms
Well Child ASQ	C# 2.0	WinForms
Well Child Pediatric Growth Charts	C# 2.0	WinForms
Well Child Patient Education	C# 2.0	WinForms
Well Child Reminders List	C# 2.0	WinForms

Activity Time	VB 6	Source not available
Asthma Zones	C# 2.0	WinForms
Chief Complaint	VB 6	Win32
Evaluation and Management Coding	VB 6	Win32
Exams	VB 6	Win32
Eye Exam	C# 3.5	WinForms
Family History	VB 6	Win32
Health Factors	VB 6	Win32
Immunizations	VB 6	Win32
Infant Feeding	VB 6	Win32
Patient Education	VB 6	Win32
POV History	VB 6	Win32
Procedure Viewer	VB 6	Win32
Reproductive Factors	VB 6	Win32
Personal Health History	VB 6	Win32

Skin Tests	VB 6	Win32
SuperBill (New)	C# 3.5	WPF
Triage	VB 6	Win32
Triage Summary	VB 6	Win32
VCPT	VB 6	Win32
Visit Diagnosis (VPOV)	VB 6	Win32
Referral	C# 3.5	WinForms
ReferralView	C# 3.5	WinForms
IBH Suicide Form	C# 3.5	WinForms
Lab Point Of Care Data Entry	C# 3.5	WinForms
Patient Photo	Delphi 7	VCL
TIU Quick Note	Source not available	

Appendix E -- RPMS and VistA -- Dependencies and Key Differences

The following table lists application packages from VistA that are incorporated into RPMS.

VistA Packages used in RPMS with Substantial Modification	
Computerized Patient Record System	Delphi code componentized in RPMS EHR
Outpatient Pharmacy	111 of 430 routines modified
Laboratory	819 of 1132 routines modified
Scheduling	106 of 403 routines modified
Text Integration Utilities	78 of 367 routines modified
Adverse Reaction Tracking	19 of 116 routines modified
VistA Packages Used in RPMS with Little or No Modification	
Inpatient Pharmacy	6 of 218 routines modified
Radiology	28 of 344 routines modified
Consult Tracking	1 of 153 routines modified
Bar Code Medication Administration	IHS uses an outdated version of BCMA
National Drug File	Updated annually by VA for IHS
VA Lexicon	
VistA Imaging	
VistA RAD	
Order Entry / Results Reporting	
Clinical Reminders	
Patient Record Flags	
Consolidated Mail Order Pharmacy	

Controlled Substances	
Pharmacy Data Management	
VA Vitals	RPMS also has a separate vitals package
Admit/Discharge/Transfer	
FileMan	
MailMan	
Kernel	
HL7 Optimized	IHS uses other interfacing packages as well
VistA Packages Only Installed as Prerequisites for RPMS EHR	
Case Management	Nursing
Dietetics	Pharmacy Benefits Management
Foundations	Problem List
Intake and Output	Surgery
Medicine	VistALink

Appendix F -- External Interfaces and Central Services

The following table is a comprehensive listing of all the RPMS Interfaces that are known to exist.

Name	Purpose	Type	Real Time?	Format	Destination
Third-Party Billing	Transmit billing claims to clearinghouse or third party payer. Transmit transaction information to UFMS (Direct only).	Flat File	N	ASC X12N 837P	External to IHS
Pharmacy Point of Sale (POS)	Outpatient Prescriptions Billing	TCP	Y	NCPDP D.0	Emdeon
Contract Health	Purchase Order Data to BCBS FL & UFMS & visit data to NPIRS	Flat File	N	Custom	IHS Systems
Patient Registration	SSA Processing/CMS Eligibility	Flat File	N	Custom	IHS Systems
Master Patient Index	Patient Demographics for Master Patient Index	TCP	Y	HL7 2.X	NextGate EMPI (IHS System)
ScriptPro Interface	Outpatient Prescriptions Dispensing Automation	TCP	Y	Custom	Local ScriptPro machine
Electronic Dental Record	Transmit dental procedures from Dentrix to RPMS & transmit patient & provider changes from RPMS to Dentrix	TCP	Y	HL7 2.X	Local Dentrix System
Accounts Receivable	Receives adjudication information from clearinghouse or third party payers; Transmit transaction information to UFMS (Direct only)	Flat File	N	ASC X12N 837P & others	External to IHS
C32/C-CDA to HIE	Interoperability	TCP	N	HL7 C-CDA/C32 over HTTP	IHS HIE
Data Warehouse	Patient and Encounter Data for Statistical Analysis	Flat File	N	HL7 2.X	IHS System

E-Prescribing Controlled Substances Authentication	Authentication for electronic prescribing of controlled substances	TCP	Y	XML over HTTP	(not operational yet)
E-Prescribing	E-Prescription to send Outpatient Meds to Outside Pharmacies	TCP	Y	HL7 2.X	IHS System
Immunization Forecasting	Get the immunizations that are due for a patient based on their history	TCP	Y	Custom	Local TCH Forecaster
Joslin Vision Network	Transmit Orders/Receive Reports	TCP	Y	HL7 2.X/ DICOM	IHS System in Phoenix
Reference Lab Interface	Send reference lab orders & receive reports	TCP	Y	HL7 2.X	Reference Lab System
Referred Care Information System	Send C-CDA to Vendors for services	TCP	Y	HL7 C-CDA over HTTP	C-CDA emailed over Direct network
Medicaid Eligibility Download	Update patient info from state Medicaid	Flat File	N	Custom	File ingested into RPMS
Omnicell/Pyxis Interface	Allow patient and medication information to pass to either Pyxis or OmniCell pharmacy dispensing units located throughout a facility.	TCP	Y	HL7 2.X	Local Pyxis/ Omnicell at the facility
Direct Email	Send secure emails to providers on Direct Network	SMTP	N	Text	IHS SMTP Server
QRDA Extraction	Extract QRDA from RPMS for reporting purposes	File	N	QRDA	Manually submitted to HHS
Apelon DIT Terminology Server	Provide terminology services for certain parts of RPMS	TCP	Y	HTTP	Locally hosted Apelon DIT Terminology Server

Appendix G -- Sample RPMS Infrastructure Bandwidth Findings

Area	NOSC Site Name	Bandwidth (Mb/s)	Circuit Utilization	Visualization
Aberdeen	ABR-08: Ft. Yates	45	Medium	
Aberdeen	ABR-05: Elbowoods	45	Medium	
Aberdeen	ABR-13: Wagner	50	Medium	
Aberdeen	ABR-14: AAYRTC-Mobridge	3.09	High	
Aberdeen	ABR-31: Mobridge OEHE	3.09	High	
Aberdeen	ABR-51: Cannonball Health Station	1.54	High	
Aberdeen	ABR-29: Martin OEHE	3.09	High	
Aberdeen	ABR-22: Minot OEHE	6.18	High	
Aberdeen	ABR-04: Eagle Butte	50	High	
Aberdeen	ABR-35: Wanblee	30	High	
Aberdeen	ABR-32: Sioux City OEHE	20	Average	
Aberdeen	ABR-34: Kyle	30	Average	
Aberdeen	ABR-02: Belcourt	45	Average	
Aberdeen	ABR-16: Winnebago	45	Average	
Aberdeen	ABR-06: Ft. Thompson	45	Average	
Aberdeen	ABR-03: Sisseton	45	Average	
Aberdeen	ABR-59: L2L Bullhead Clinic	1	Average	
Aberdeen	ABR-07: Ft. Totten	45	Average	
Aberdeen	ABR-12: Rosebud	45	Average	
Aberdeen	ABR-10: Pine Ridge	100	Average	
Aberdeen	ABR-52: Wakpala Health Station	1.54	Average	
Aberdeen	ABR-23: McLaughlin	10	Average	

Aberdeen	ABR-27: Manderson Health Station	10	Average	
Aberdeen	ABR-60: La Creek	20	Average	
Aberdeen	ABR-18: Pierre OEHE	20	Average	
Aberdeen	ABR-53: Pierre Mammo	20	Average	
Aberdeen	ABR-17: Santee	45	Average	
Aberdeen	ABR-15: Carl T Curtis	45	Average	
Aberdeen	ABR-21: Trenton	45	Average	
Aberdeen	ABR-28: Flandreau	50	Average	
Aberdeen	ABR-46: SDUIH-Pierre	50	Average	
Aberdeen	ABR-47: SDUIH-Sioux-Falls	50	Average	
Aberdeen	ABR-30: Ponca	50	Average	
Aberdeen	ABR-55: Norfolk	50	Average	
Aberdeen	ABR-11: Rapid City	100	Average	
Aberdeen	ABR-36: Sioux Falls	500	Average	
Phoenix	PHX-17: RIVERSIDE	10	Medium	
Phoenix	PHX-34: L2L Desert Vision	20	Medium	
Phoenix	PHX-35: Hu Hu Kam	3.09	High	
Phoenix	PHX-16: PEACH SPRING	3.09	High	
Phoenix	PHX-21: Fort Duchesne	3.09	High	
Phoenix	PHX-31: EDO	1.54	High	
Phoenix	PHX-06: NEWE-ELY	1.54	High	
Phoenix	PHX-12: DUCKWATER	1.54	High	
Phoenix	PHX-29: Cibecue	1.54	High	
Phoenix	PHX-30: PIMC	50	High	
Phoenix	PHX-20: RENO-OEH/SCHURZ	4.63	High	
Phoenix	PHX-40: White River	45	High	
Phoenix	PHX-01: PHOENIX AREA OFFICE	50	High	
Phoenix	PHX-10: CHEMEHUEVI	1.54	High	

Phoenix	PHX-02: MOAPA	1.54	High	
Phoenix	PHX-09: AZTEC	20	High	
Phoenix	PHX-04: SUPAI	1.54	High	
Phoenix	PHX-47: RENO-SPARKS TRIBAL HEALTH	1.54	High	
Phoenix	PHX-24: Goshute	1.54	Average	
Phoenix	PHX-48: L2L Nevada Skies Youth RTC	10	Average	
Phoenix	PHX-15: Las Vegas	1.54	Average	
Phoenix	PHX-27: Yavapai Apache	1.54	Average	
Phoenix	PHX-42: SALT LAKE URBANS (IWIC)	1.54	Average	
Phoenix	PHX-13: WASSAJA	1.54	Average	
Phoenix	PHX-56: Battle Mountain	1.54	Average	
Phoenix	PHX-18: ELKO	20	Average	
Phoenix	PHX-26: WADO	20	Average	
Phoenix	PHX-33: San Carlos	45	Average	
Phoenix	PHX-39: Parker Indian Hospital	100	Average	

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Appendix H -- Analysis of Telemedicine

Telemedicine holds enormous opportunity for the IHS to assure that quality health care services are delivered where they are needed most, and that innovative and collaborative solutions can be implemented to address disparities and inequity. Telemedicine is an emerging set of tools that support the emergence of new, best practice clinical pathways to reshape expectations and opportunities in care. It encompasses clinical appointments and care provided remotely (both real-time and asynchronously), virtual consultation services with experts and specialists, and non-clinical services such as provider training and education.

For the patient, telemedicine offers Native American communities a truly patient-centered approach to care by providing care when, where, and how it is needed or preferred. With the more recent emergence of consumer health applications, patients are becoming more and more technologically advanced and expecting that technological offerings be well understood by their healthcare system and integrated into their delivery of care to advance their health. A PCP in the Phoenix area noted that due to a population that is more often located a far distance from the facility, and with many of them receiving chronic care management services, over 50% of her patients could be seen via telemedicine visits to help keep them engaged while they are unable to access the facility physically. Importantly, telemedicine visits will also be a core way that health care is expanded and extended for people with chronic conditions, augmenting care management in ways that fundamentally improve outcomes and patient satisfaction while helping avoid high cost ER visits and hospitalizations.

From the population health perspective, in order to truly impact an underserved population, patient engagement must be a priority and creative pathways for that engagement in care established. Consistent engagement with the healthcare system has been shown to have positive impact on adherence to treatment and improved outcomes, especially for chronic care patients. Consistent engagement is a health behavior that patients must be willing to adopt in order to positively affect their health. Health behavior change theories can be used to model a patient-centered pathway to support that adoption by providing insight into the patient's factors that lead to the adoption of a health behavior. For example, the Health Belief

Model suggests that a patient's beliefs about health problems, belief in benefit of action, perceived barriers to action, and self-efficacy determine their adoption of health behaviors, such as engagement. Telemedicine visits can mitigate some of these perceived barriers and increase the chance of consistent engagement – such as an inability to access their healthcare team due to time and distance. The use of emerging tools and innovation can enable and support the clinical relationships between patients and care teams, resulting in enhanced patient engagement and improved outcomes.

For the provider, telemedicine-enabled clinical pathways provide opportunities to deliver consistent care to those patients that have otherwise been intermittently seen, and to develop a different level of understanding of their patients' social determinants and influencers by being "present" in their living environments. Telemedicine also provides the opportunity to leverage a virtualized team-based approach among physicians, specialists, nurses, social workers, mental health specialists, community health workers, and other non-physician clinicians from anywhere in the United States. The team-based approach is becoming recognized as increasingly vital, particularly for chronic conditions, for improving coordination of care by spreading the responsibility of a patient's care across the team. Telemedicine visits become a one-stop engagement experience for the patient where they receive treatment from their PCP, get screenings from nurses, and visit with the social worker to address other determinants – all in their own environment. Cost savings have been found with the team-based model in the form of reduced emergency room visits, but could potentially reduce costs further when delivered through a telemedicine pathway due to reduced travel costs of the healthcare team, increased provider productivity, and improved wait times and access to specialty services.

With telemedicine, the potential of enhanced patient engagement and timeliness of interventions can improve patient outcomes, increase satisfaction, and save costs for both the healthcare system and the patient in both the near and longer term.

Appendix I -- Examples of MUMPS System Modernization in Healthcare

There are numerous examples in industry of MUMPS-based healthcare systems that have utilized variations of wrap and renew methodologies to extend and enhance their capabilities and enable integration with new systems, while retaining legacy data and functionality. Note that while most of the enterprises named below used InterSystems products to accomplish their modernization, this is not a product endorsement for InterSystems. These organizations were historically using InterSystems products and leveraged tools provided by the company as the most effective path toward modernization. The open source community has also successfully embraced MUMPS modernization independently of InterSystems, as illustrated in the last bullet.

- Veterans Administration - even though VA is on a migration path toward Cerner, it is utilizing HealthShare to facilitate its progress. VA is using the FM2Class-generated VistA object-relational data model to develop data services for VistA, perform the mapping of the legacy VistA data structures to the SDA data model, and transform VistA FileMan data to FHIR Resources. VA has plans to migrate more than 80 legacy applications to the HealthShare platform over the next couple of years.
- Kingdom of Jordan - Jordan and other international users of the open source GT.M version of MUMPS are utilizing other open source tools to accomplish modernization of their legacy systems. Most of the open source community using GT.M has converged on using QEWD[56] to provide new web-based user interfaces to VistA. Jordan also developed a new Dental package that uses QEWD.
- InterSystems TrakCare - this internationally-deployed EHR product was originally built in MUMPS and has since has since defined object/SQL mappings against the original globals; built a modern web-based framework to replace the older Visual Basic client; and added various new modules using object-oriented ObjectScript.

[56] Quality Enterprise Web Development - http://qewdjs.com/

- Partners Healthcare - started with its home-grown, roll-and-scroll DataTree MUMPS application code and built Visual Basic (VB) applications, web applications, and web services around it. New applications were developed with VB and web user interfaces and ObjectScript server-side code. These measures extended the life of the application by approximately 20 years until Partners moved their clinical operations to Epic in 2015.
- Epic Systems - Epic first modernized from a legacy roll and scroll application to a Visual Basic (VB) user interface utilizing the existing server-side code, and then from the VB UI to a modern Web UI. The company rewrote the user interfaces without changing the server-side code. The latter continues to evolve with incremental improvements and optimizations, instead of a rewrite or replatform.
- Ontario Systems - this revenue-cycle management company developed SQL data mappings to make data available via ODBC to external applications, then implemented a service-oriented architecture in which new functionality was always exposed as services available via API calls. That approach has since migrated to the cloud; the company developed its own REST framework, enabling their web services to be invoked as cloud services.
- New Century Health - this specialty third-party claims administrator modernized its legacy MUMPS application using Cache ObjectScript and exposing MUMPS code via SQL, web services, and other standard APIs. They routinely maintain, enhance and modernize an application that has evolved over the past 40 years.
- Sonic Healthcare (Australia) - this large pathology and radiology diagnostics company started with a roll and scroll MUMPS application that covers patient registration, episode of care management, test administration, reporting, instrument interfacing, among other functions. The original data model has been mapped to SQL and the company has developed new modules and services using various technologies.

Appendix J -- RPMS Outside of Indian Country

Although penetration of RPMS outside of the I/T/U is not as substantial as its VistA counterpart, there are nonetheless several organizations that have adopted RPMS as their preferred HIT solution over the years. These organizations are not supported by IHS, but provide their own support locally or through RPMS-knowledgeable contractors.

- In 2008 IHS signed a cooperative agreement with the Telecommunications and Information Policy Group (TIPG, now the Telecommunications and Social Informatics Research Program - TASI) of the University of **Hawaii**. Through this agreement TIPG supported RPMS implementations at hospitals and clinics on the Hawaiian Islands. Staff supporting these implementations are able to participate in RPMS listserv forums and RPMS related training on a space-available basis, but receive no other support. Since the original implementation IHS has released very significant changes to RPMS including both 2011 and 2014 certification and the transition to ICD-10. Some of the changes IHS released that would have been needed for 2014 certification and stage 2 meaningful use require connections to the centralized services of the RPMS Network, which are not available to these locations. The sites are believed to continue to use RPMS, but their current status is unknown.
- RPMS has been in use at the Northern and Southern Region Community Health Centers on the U.S. territory of **Guam** in the southern Pacific. Both of these are Federally Qualified Health Centers; their implementation of RPMS is supported by contracts with staff based at TASI in Hawaii as well as the U.S mainland.
- The Commonwealth Community Health Center (CCHC) on the island of **Saipan** in the Commonwealth of the Northern Marianas Islands (CNMI, also a U.S. territory) implemented RPMS in the mid-late 1990s, assisted by a former IHS employee, an RPMS technical expert. This implementation predated the EHR and all changes related to meaningful use. CHCC is a multi-specialty hospital with two satellite facilities and is the only health care provider on Saipan. Numerous customizations were made to the RPMS instance in those days which has created

challenges whenever the organization has sought to implement upgrades. CHCC was supported by TIPG for a few years but is extremely under-resourced and has not been able to have consistent support for its implementation.

- Many years ago the public health nursing program of the State of **Alaska** (SOA/PHN) stood up RPMS as the record system for patients served by their PHNs on a statewide level. The organization reports that it supports nearly 100 users on 22 instances of RPMS, which is the primary client record for all PHN activities in the state including immunization and tuberculosis tracking as well as general public health encounters. Over 21,000 clients were served in 2018. SOA/PHN has 2.5 programmers, 2 PHN informaticists, one application coordinator, one administrative support person and the equivalent of 10 FTEs for data entry. The organization is actively exploring its options for replacing the system.
- Others - **OSEHRA** and **industry** - While the Open Source Electronic Health Record Alliance (OSEHRA) is not a user of RPMS, the organization maintains a repository of RPMS code and has done considerable analysis on incorporating advanced features from RPMS into the more broadly used VistA. In addition, commercial VistA resellers such as Medsphere and DSS have incorporated RPMS capabilities into their offerings.

Appendix K -- Glossary of Acronyms

ADT	Admission Discharge Transfer
AI/AN	American Indian/Alaska Native
ARRA	American Recovery and Reinvestment Act
BCMA	Bar Code Medication Administration
C32	Technical specification by HITSP for Summary Documents Using HL7 Continuity of Care Document (CCD) Component
CAC	Clinical Application Coordinator
CCD	Continuity of Care Document
CCHIT	Certification Commission for Healthcare Information Technology
CIO	Chief Information Officer
CMS	Centers for Medicare and Medicaid Services
COTS	Commercial-off-the-Shelf
CPRS	Computerized Patient Record System (VA)
CRS	Clinical Reporting System
DEA	Drug Enforcement Administration
EHR	Electronic Health Record
EMPI	Enterprise Master Patient Index
EMR	Electronic Medical Record
FOIA	Freedom of Information Act
FQHC	Federally Qualified Health Center
GPRA	Government Performance and Results Act
GUI	Graphical User Interface
HHS	Department of Health and Human Services
HIE	Health Information Exchange
HIM	Health Information Management
HIPAA	Health Insurance Portability and Accountability Act
HIT	Health Information Technology
HITECH	Health Information Technology for Economic and Clinical Health Act
HITSP	Health Information Technology Standards Panel
HL7	Health Level Seven International
HRSA	Health Resources and Services Administration

ICD	International Classification of Diseases
IEN	Internal Entry Number
IHS	Indian Health Service
ISO	Information Security Officer
IT	Information Technology
ITAC	Information Technology Access Control
I/T/U	IHS/Tribal/Urban
LEDI	Laboratory Electronic Data Interchange
LOINC	Logical Observation Identifiers Names and Codes
MPI	Master Patient Index
NDW	National Data Warehouse
NPIRS	National Patient Information Reporting System
NIST	National Institute of Standards and Technology
NOSC	Network Operations Security Center
OE/RR	Order Entry/Results Reporting = Orders Package in EHR
OIT	Office of Information Technology
ONC	Office of the National Coordinator for Health Information Technology
PCC	Patient Care Component
PDF	Portable Document Format
PHI	Protected Health Information
PHN	Public Health Nurse
PHR	Personal Health Record
POS	Point of Sale
POV	Purpose of Visit
ROI	Release of Information
RPMS	Resource and Patient Management System
SOAP	Simple Object Access Protocol
SNOMED CT	Systematized Nomenclature of Medicine Clinical Terms
TIU	Text Integration Utilities
VA	Department of Veterans Affairs
VHA	Veterans Health Administration
VistA	Veterans Health Information Systems and Technology Architecture

VPN	Virtual Private Network