

***The National Digital  
Mammography Archive***

***Phase II Final Briefing***

***Presented by  
Mitchell D. Schnall, M.D., PhD  
Department of Radiology  
University of Pennsylvania***

***Presented to  
National Library of Medicine***

***August 26, 2003***

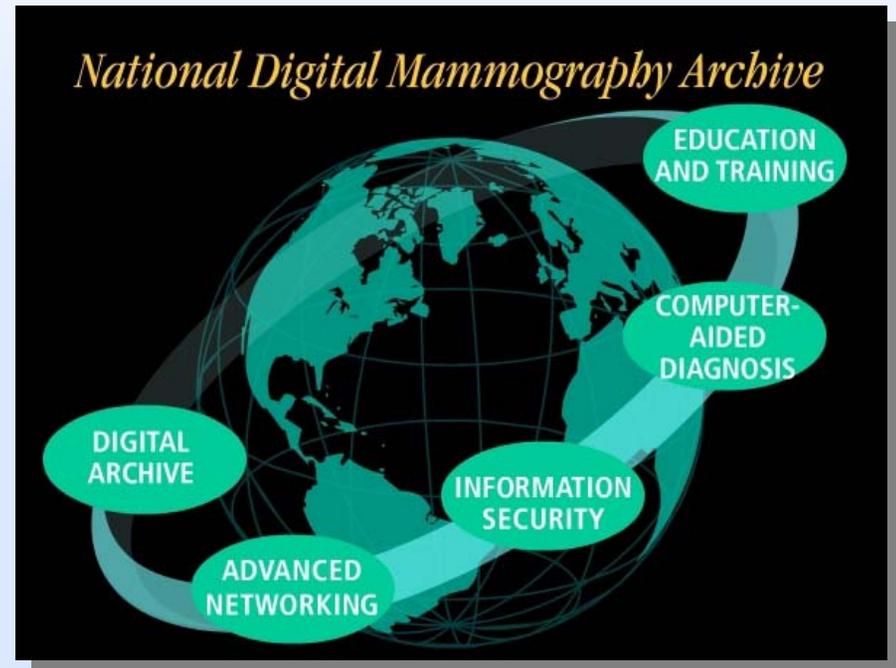
## What is NDMA?

A fully integrated test bed demonstrating the feasibility of a national breast imaging archive

Network infrastructure to support digital mammography using NGI technologies

A system that allows access to prior mammograms and appropriate records no matter where the prior exams were performed

A system that collects, processes, stores, manages, indexes and retrieves records



## **Test Bed Goals**

**Build an infrastructure that would allow patient records to be available wherever the patient was being treated**

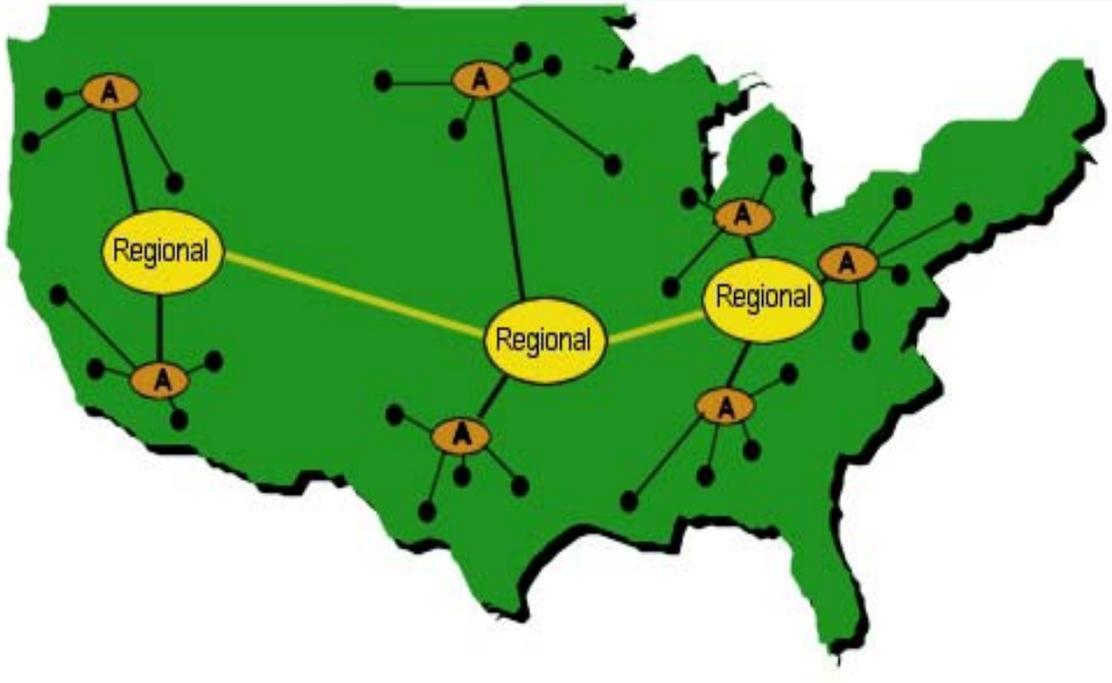
**Build an infrastructure that would allow large digital mammograms to be moved efficiently**

**Build the infrastructure to be scalable to a national level and useful for all medical modalities**

**Ensure that we meet the clinical needs while protecting patient privacy**



## The NDMA Concept



Area Archives would serve several local facilities

Regional Archives would serve as back-up and long term storage for several Area Archives

Regional Archives could serve as back-up for each other and also route and/or manage requests at a national level

With this concept implemented, a facility in California would have access to patient records in Texas virtually instantly.



*The request would originate in the Texas facility, and be forwarded from the South Area Archive to the Mid Regional.*

*The request would then be forwarded from the Mid Regional to the West Regional, which locates the record from the West Area Archive. The records would be returned via the same route.*

## Archive Storage

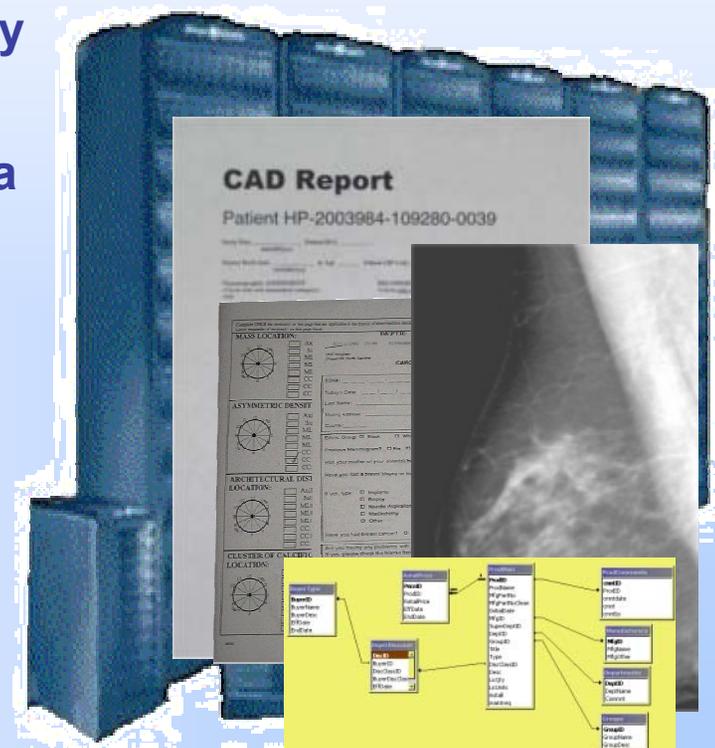
### *When DICOM objects are sent to the Archive:*

The DICOM Objects are stored exactly as they were received

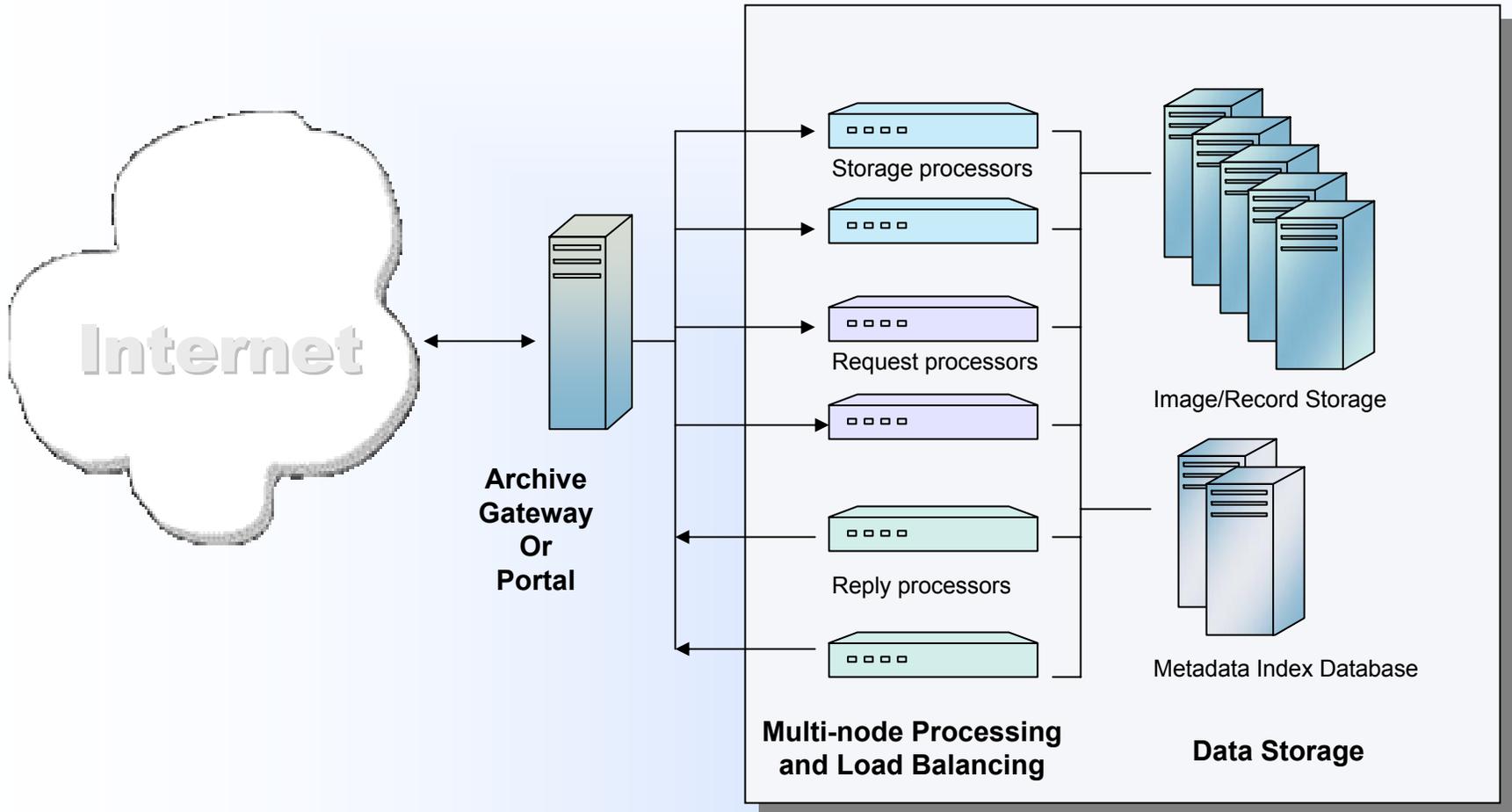
Information about those objects is stored in a central metadata index

The indexes contain both patient demographical data and clinical history and findings characteristics

This allows the Archive to search all records by either patient information or clinical characteristics



## Archive Design

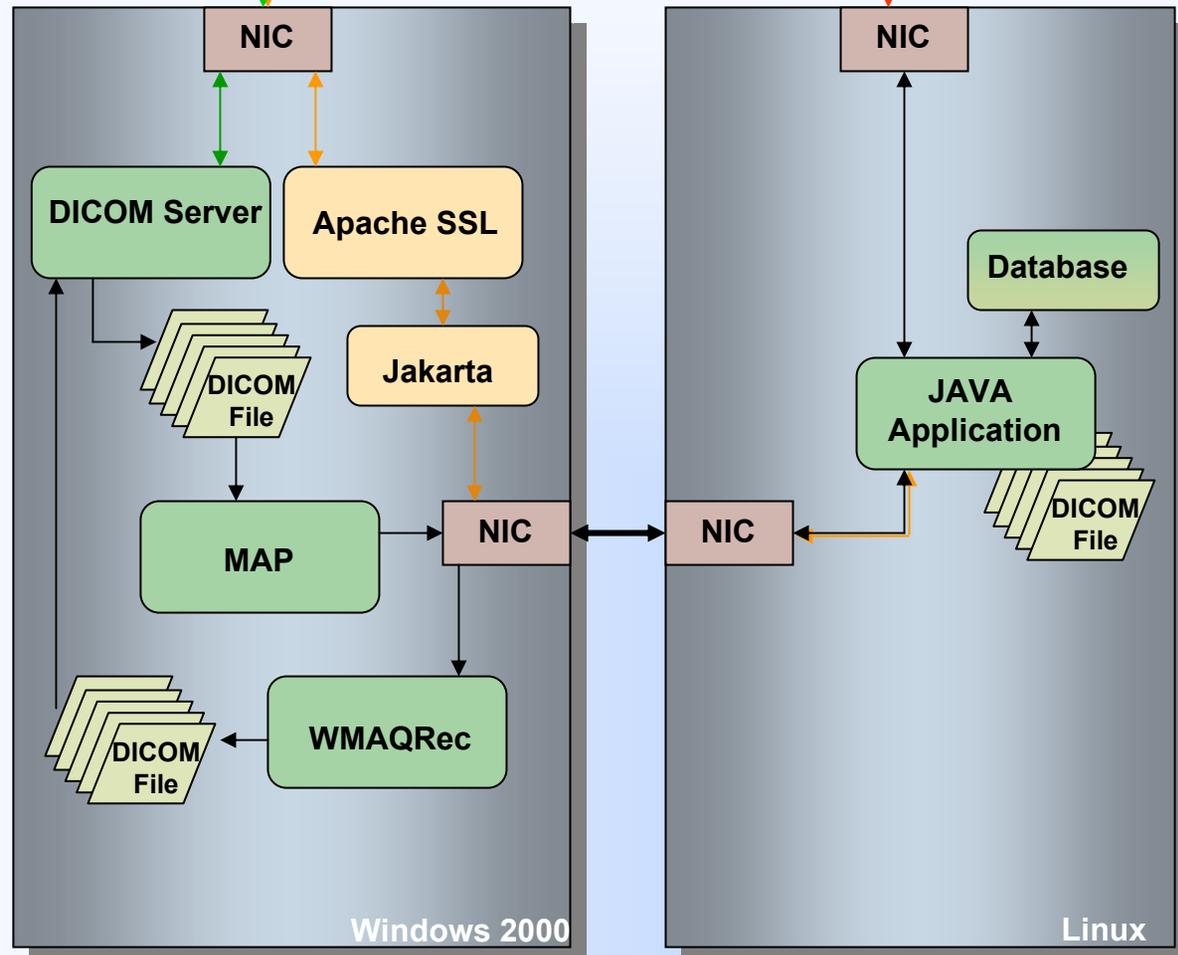


## Hospital WAN

Only DICOM  
or HTTPS  
Allowed

Only VPN  
Between Portal  
and Archive

## Portal Design



# Clinical Views

**Mini Mammo Module 2.01 (1.40)**

Report Date: August 14, 2003

Radiologist ID: lppayne Radiologist Facility: ORDEV

**NDMA: Main Menu - Netscape**

**National Digital Mammography Archive**

**OF CURRENT REQUESTS FOR CLINICAL RECORDS**

Patient Name	Date of Birth	Patient MRN	Study ID	Requested	Status
Bloomstone	Not specified	Not specified	Not specified	11/13/2002 13:05	Request

**Release Requests to the Archive**

These images are ready to send to the Archive for storage. Please check the box of the cases you want to send and then click on "Release".

Request ID/Request For	Request Date and Time	Requested By	Release/Stage
2063 Release/Robt*Way	11/05/2002 12:20	DWRKDC-AWS	<input type="checkbox"/> Stage
2066 Release/Robt*Way	11/05/2002 12:20	DWRKDC-AWS	<input type="checkbox"/> Stage
Class*Cheryl*Blas	11/05/2002 12:31	DWRKDC-AWS	<input type="checkbox"/> Stage
2069 Class*Cheryl*Blas	11/05/2002 12:31	DWRKDC-AWS	<input type="checkbox"/> Stage
2070 Class*Cheryl*Blas	11/05/2002 12:31	DWRKDC-AWS	<input type="checkbox"/> Stage
Orey*Ashley*Male	11/05/2002 12:32	DWRKDC-AWS	<input type="checkbox"/> Stage
2073 Orey*Ashley*Male	11/05/2002 12:32	DWRKDC-AWS	<input type="checkbox"/> Stage
2074 Orey*Ashley*Male	11/05/2002 12:32	DWRKDC-AWS	<input type="checkbox"/> Stage
Jaw*Fremet*Peggy	11/06/2002 13:43	9134667941032	<input type="checkbox"/> Stage
2152 Jaw*Fremet*Peggy	11/06/2002 13:43	9134667941032	<input type="checkbox"/> Stage
Fremet*Peggy*Jaw	11/06/2002 13:44	9134667941032	<input type="checkbox"/> Stage
2153 Fremet*Peggy*Jaw	11/06/2002 13:44	9134667941032	<input type="checkbox"/> Stage
White*Debbie*Delaney	11/02/2002 13:18	9134667941032	<input type="checkbox"/> Stage
2199 White*Debbie*Delaney	11/02/2002 13:18	9134667941032	<input type="checkbox"/> Stage
Bloomstone*Robt*Way	11/13/2002 12:20	9134667941032	<input type="checkbox"/> Stage
2207 Bloomstone*Robt*Way	11/13/2002 12:20	9134667941032	<input type="checkbox"/> Stage

**Clinical Request Status - Netscape**

**STATUS OF RECORDS RETURNED FOR:**

Request Number: 2402

Record #	Patient Name	Date of Birth	Patient ID	Study Date	Record Type	Record Owner	Expiration Date	Record Status
1 OF 7	Smith*Sarah*Lee	11/21/1954	1234567	10/23/2002	DICOM Image	ORDEV	11/21/2002	Records expired and will be deleted
2 OF 7	Chestnut*Lee*Mary	01/01/1000	TN-001	06/21/2000	DICOM Image	ORDEV	11/21/2002	Records expired and will be deleted
3 OF 7	Chestnut*Lee*Mary	01/01/1000	TN-001	06/21/2000	DICOM Image	ORDEV	11/21/2002	Records expired and will be deleted
4 OF 7	O'Connell*Annalee*Alice	12/01/1946	TN-036	08/03/2000	DICOM Image	ORDEV	11/21/2002	Records expired and will be deleted
5 OF 7	O'Connell*Annalee*Alice	12/01/1946	TN-036	08/03/2000	DICOM Image	ORDEV	11/21/2002	Records expired and will be deleted

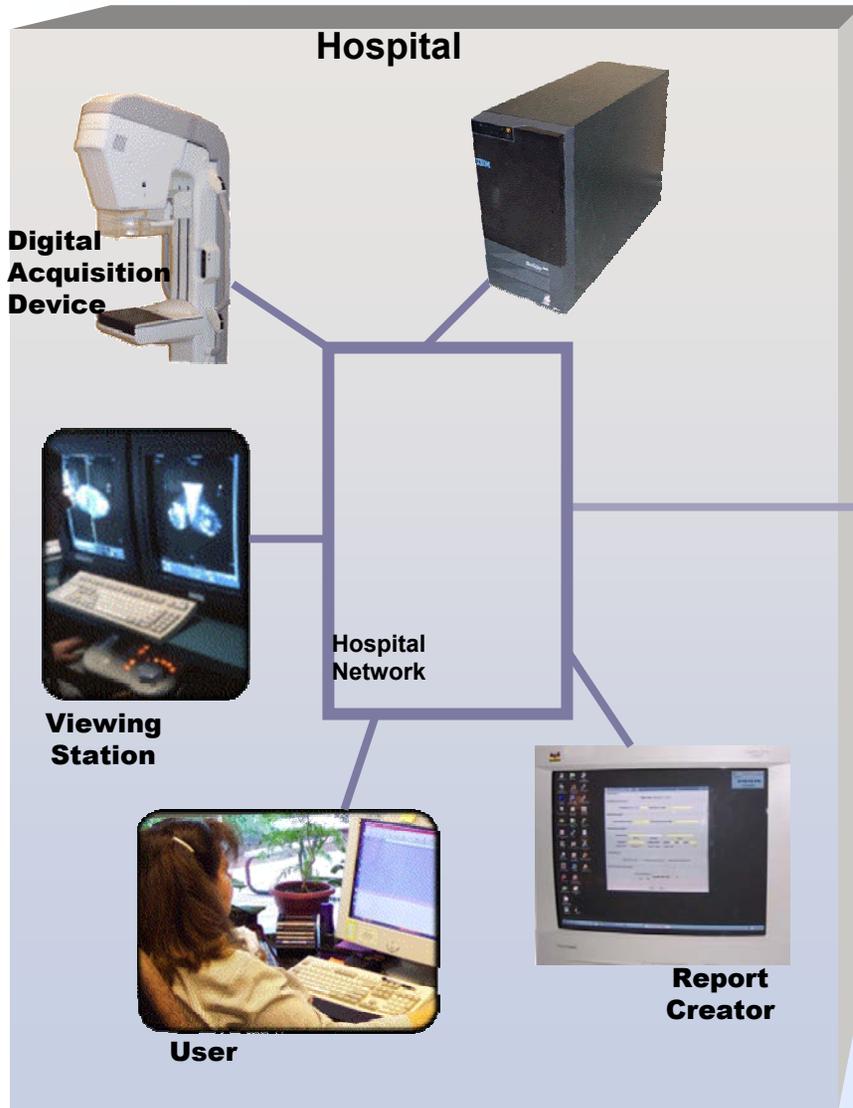
## Research Views

The image displays several overlapping screenshots of the NDMA website interface, illustrating different research views and search options. The main components shown are:

- Search Criteria (Section C):** A form for defining search parameters, including:
  - Assessment of the finding:** Radio buttons for AND and OR.
  - Overall breast:** Radio buttons for AND and OR.
  - Calcifications:** Checkboxes for various types: (C) Coarse, (E) Eggshell or rim, (M) Milk of calcium, (P) Punctate, (S) Skin, (V) Vascular, (F) Fine, linear, (H) Heterogenous or pleomorphic, (D) Dystrophic, (L) Large rod-like, (O) Lucent-centered, (R) Round, (U) Suture, (A) Amorphous or, (B) Fine, linear, br.
  - Pathology Codes:** Radio buttons for AND and OR, with checkboxes for (PA) Papiloma, (LA) Lactating Adenoma, (AA) Apocrine Adenoma, (TA) Tubular Adenoma, (FPN) Florid Papillary Hyperplasia (Adenoma) of the Nipple, (MTP) Papiloma - Microtubular (Pleomorphic adenoma), (FNS) Fibroadenoma NOS, (FA) Fibroadenoma, (HNS) Hemangioma NOS, (AM) Angiomatosis, and (NSH) Nonparenchymal Hemangioma.
- Research Request (Section A):** A form for query limitations, including:
  - Section A - Query Limitations:** Fields for "Limit of number of records to return" and "The year for which records are requested".
  - Specific Year:** A dropdown menu.
  - Year Range:** Fields for "Minimum" and "Maximum".
  - Section B - Demographic Criteria:** Fields for "Patient age at time of study" and "Specific Age", along with "Age Range" fields for "Minimum" and "Maximum".
- Results from Request 2137:** A table showing search results:
 

Request Case/Patient Visit	View Object	Object Type
<input type="checkbox"/>	<a href="#">View</a>	DIGM.DM
		1 Images
<input type="checkbox"/>	<a href="#">View</a>	DIGM.DM
		1 Images
<input type="checkbox"/>	<a href="#">View</a>	DIGM.DM
		0 Images
- Research Response Records - Netscape:** A detailed view of a research record with the following sections:
  - Patient Info:** Date of Birth (08141962), Sex (Female), Ethnic Group (Black).
  - Evaluation:** Overall Breast Composition (4 - Dense), Cyst Aspiration (Left), First Mammogram Ever, Overall Assessment (Suspicious abnormality).
  - Findings:** Finding[Calc] Assessment[Suspicious abnormality], Size (15).
  - Location:** Side (Left).
  - Calcification Specific Data:** Calcifications (Suture), Calc Distribution (Diffuse/scattered).
  - Biopsy:** Biopsy Date (11052002), Biopsy Technique (Core biopsy).
  - PathCodes:** Normal/Atrophic/Mild Ductal Hyperplasia, Finding[ArchDist] Assessment[Probably benign], Location (Right).

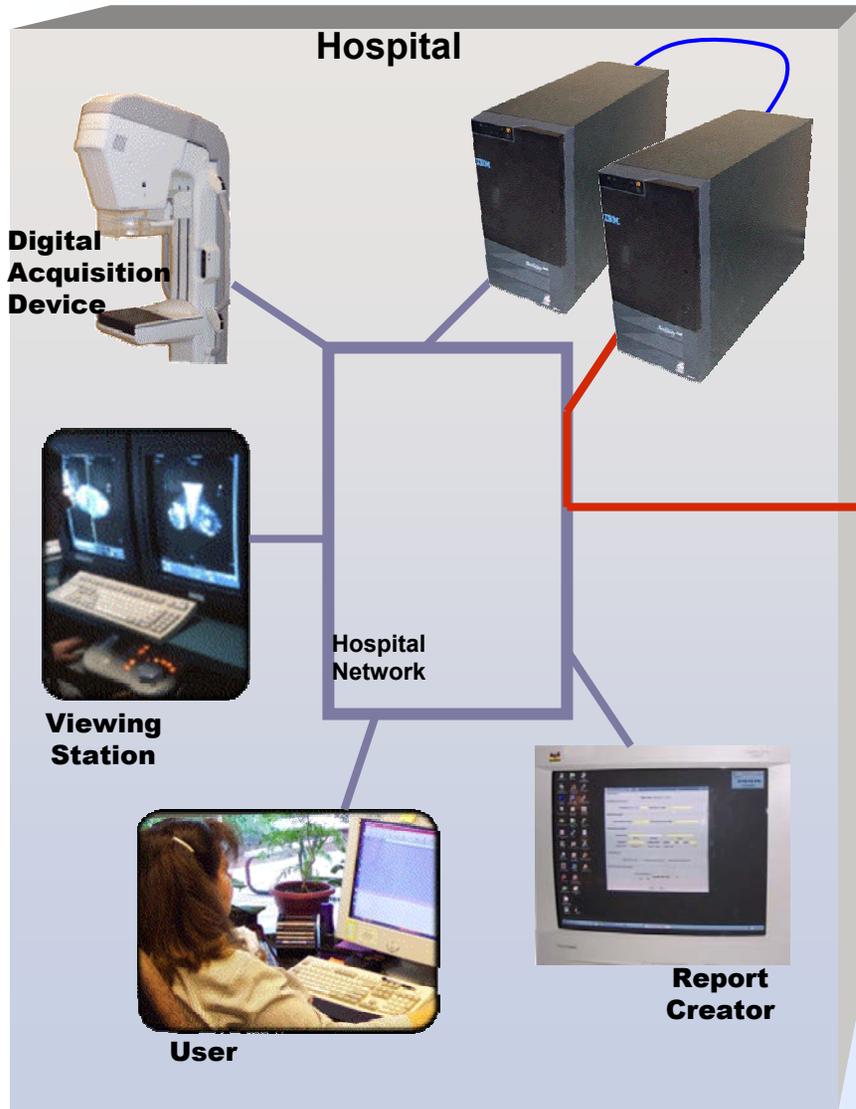
## Dual Host Configuration



The first component of a Portal is the **PERIMETER HOST**. It connects to the hospital network. This system is highly restricted as to what types of communication it allows.



This computer accepts only Web requests for records over HTTPS and DICOM storage requests. It also moves returned records to the hospital devices via DICOM.



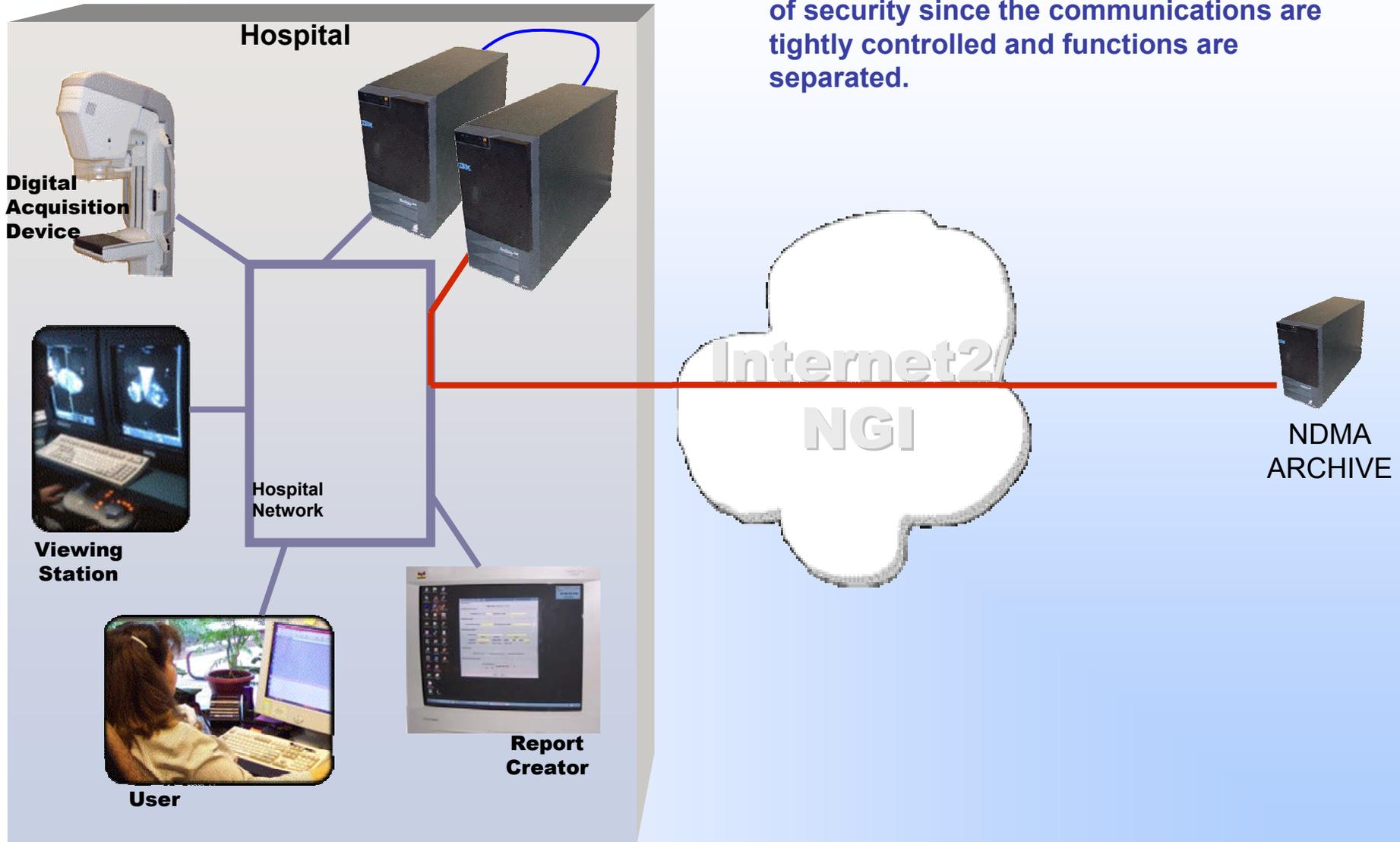
The second component is the Secure Host. It is also connected to the hospital network.

However, the ONLY communications allowed over this network interface is to the archive across the hospital system through the public network via a private tunnel (Virtual Private Network).



These two boxes communicate to each other via a private network between an additional set of network cards in each machine.

This configuration allows a high degree of security since the communications are tightly controlled and functions are separated.



### The Local Area Archive Design Supports the Capability to Provide Additional Services

#### Computer Aided Diagnosis (CAD) services

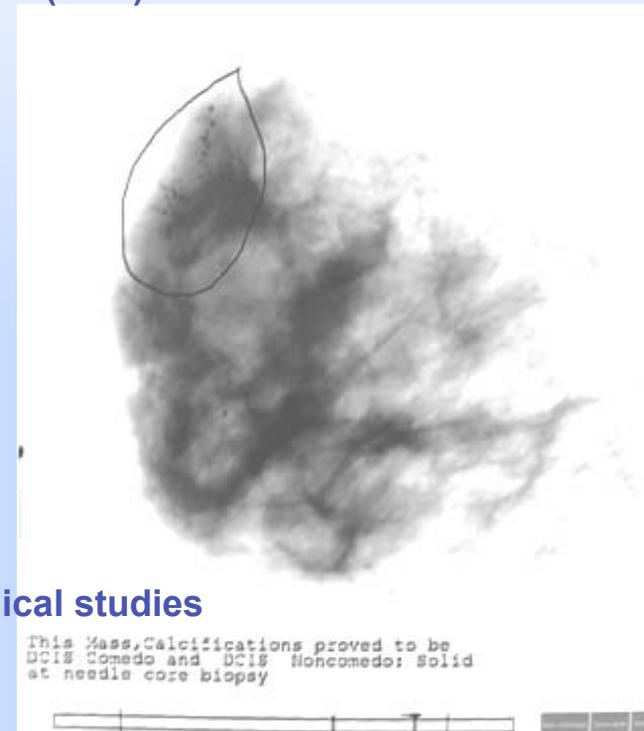
- Application of algorithms to reduce variability
- Front-end pre-processing using Focus-of-Attention Region (FAR) algorithms
- Potential centralized service over the network
- Auto-training of CAD algorithms

#### Education and Training

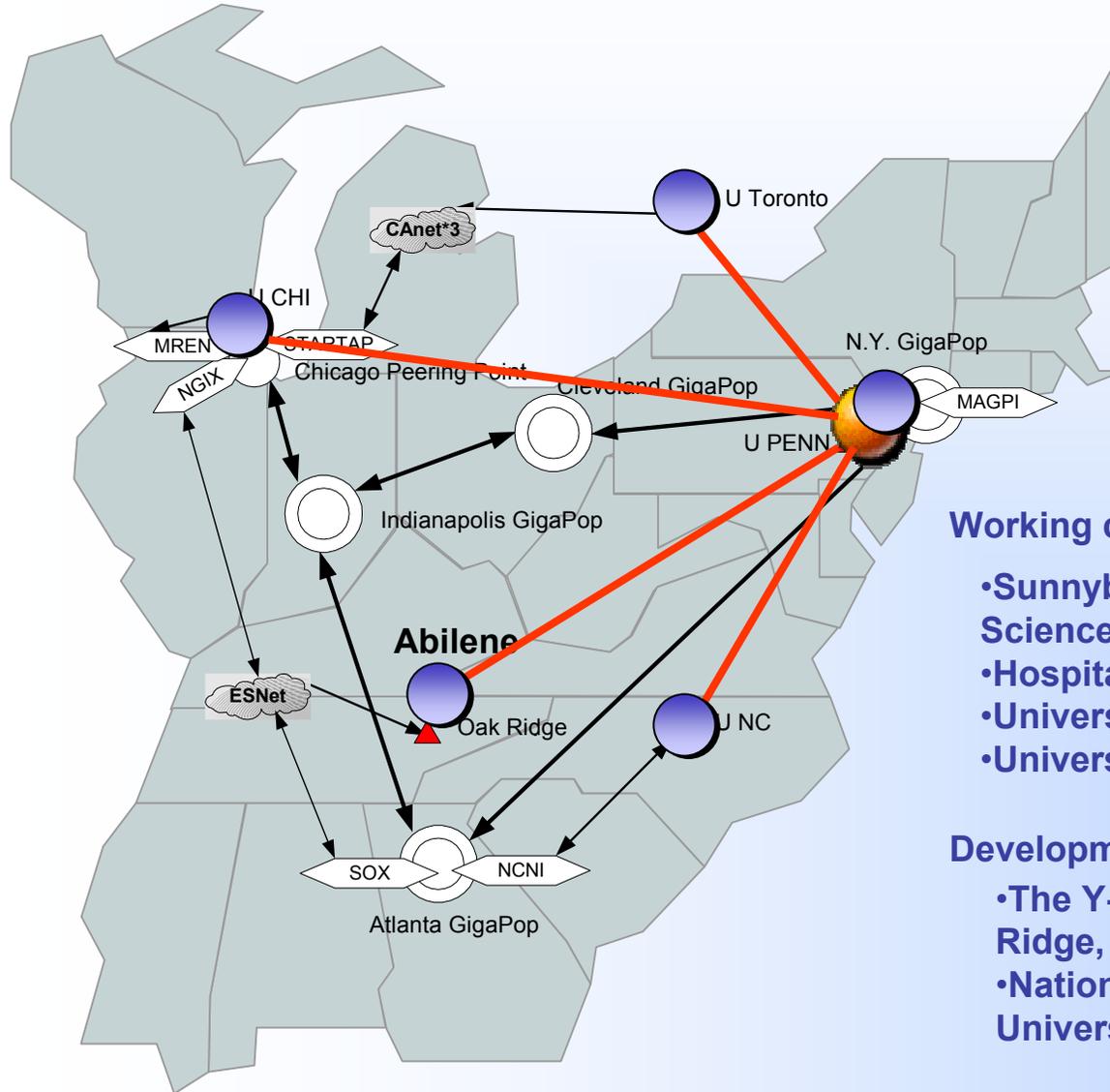
- Storing annotated cases for both clinical and research and training
- Future Archive management of teaching cases

#### Research

- Ability to search for records based on disease or history provides unique research opportunity
- NDMA database provides an opportunity for epidemiological studies to monitor the process of breast screening



## The NDMA System



We were able to connect six facilities to an Area Archive via the Internet2 system.

The Area Archive resides at the University of Pennsylvania

Working clinical portals are installed at:

- Sunnybrook and Women's College Health Sciences Centre in Toronto
- Hospital at the University of Pennsylvania
- University of North Carolina Hospital
- University of Chicago Hospital

Development portals are installed at:

- The Y-12 National Security Complex at Oak Ridge, Tennessee
- National Scalable Cluster Project at the University of Pennsylvania

## Accomplishments

### Delivered digital images over long distances expeditiously

Four test beds are operational over a large geographical distribution connected by Abilene, ESNet, and CA\*2

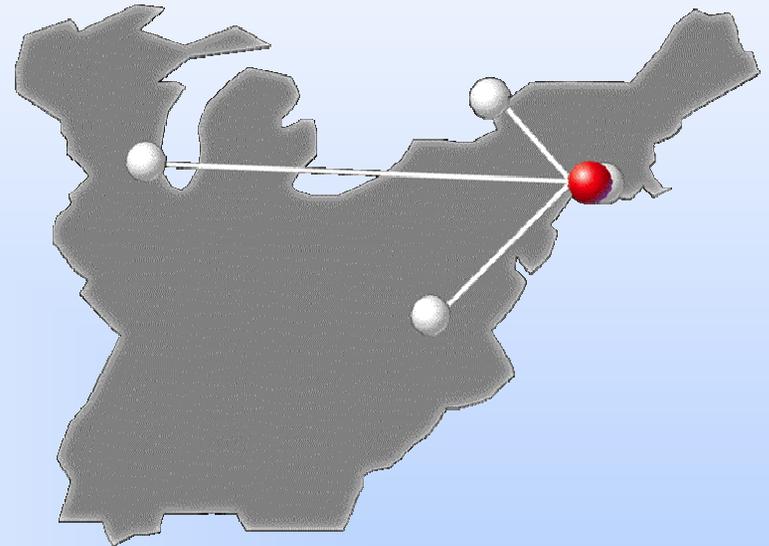
### Established a working Area Archive

From April – July the Area Archive stored 11,138 patient records

### Established a Regional Archive

During May the Regional Archive reached a goal of over a Terabyte per week of test record storage

### Ensured patient confidentiality throughout the system



## Highlights of the NDMA Implementation

### Security

Attention to patient privacy and compliance with HIPAA requirements was built in to the infrastructure and applications from concept to implementation

Use of VPN encryption over public networks, dual-host portal configuration, and secure application design were critical to the security of the system



## Communications Protocols

We wanted to design a messaging method that would allow the individual components to operate independently of the others.

We developed a messaging format with XML as a central communication standard which allowed the NDMA system to be very scalable and portable.

```

<?xml version="1.0" encoding="UTF-8"?>
<Message type="QueryResearch">
  <MessageID>
    <OriginalIP>192.168.201.1</OriginalIP>
    <Timestamp>1059754584</Timestamp>
    <MessageNum>24795</MessageNum>
  </MessageID>
  <Sender>
    <Certificate>F96617548972C259D39A0C38F37112E3</Certificate>
  </Sender>
  <Requestor>
    <Facility>ORDEV</Facility>
    <ID>Pat @ UT</ID>
    <Certificate>53A242EB07E1DB646D77087F1C15EEEE</Certificate>
  </Requestor>
  </Sender>
  <Receiver>
    <Certificate>0CF4AD70961C4683A012C9E0FB0BF8C4</Certificate>
    <Ip>130.91.50.151</Ip>
  </Receiver>
  <Request action="Query" type="Research">
    <ID>24795</ID>
    <Priority>LOW</Priority>
  </Request>
  <Request>
    <Payload>
      <CriteriaGroup operator="AND">
        <CriteriaItem operator="EQUAL">
          <Name>PathCodes</Name>
          <Value>CHC</Value>
        </CriteriaItem>
        <CriteriaItem operator="EQUAL">
          <Name>FindingType</Name>
          <Value>ArchDistortion</Value>
        </CriteriaItem>
      </CriteriaGroup>
    </Payload>
  </Request>
</Message>

<?xml version="1.0"?>
<Message type="RequestReply">
  <MessageID>
    <OriginalIP>130.91.50.210</OriginalIP>
    <Timestamp>2003-08-01-11.56.4</Timestamp>
    <MessageNum>6767</MessageNum>
  </MessageID>
  <Reply type="Query">
    <ID>6767</ID>
    <RequestID>24795</RequestID>
    <ItemNumber>1</ItemNumber>
    <ItemTotal>3</ItemTotal>
  </Reply>
  <Sender>
    <Certificate>BB9118189D5FA513</Certificate>
  </Sender>
  <Receiver>
    <Certificate>F96617548972C259D39A0C38F37112E3</Certificate>
    <IP>192.168.201.1</IP>
  </Receiver>
  <Payload>
    <Statistics>
      <NumberVisitFound>3</NumberVisitFound>
      <NumberVisitRequested>25</NumberVisitRequested>
    </Statistics>
    <PatientVisit>
      <VisitNumber>1</VisitNumber>
      <PatientName>024795*01*NDMA</PatientName>
      <ExamDate>1998-02-18</ExamDate>
      <ImageID>f7zPqbMhMD4Mx8xYDwG7saRdUQWUjHv9psemj/0V6uL86zOMXUSFXM</ImageID>
      <AssociatedNumberOfImages>12</AssociatedNumberOfImages>
      <AssociatedNumberOfReports>0</AssociatedNumberOfReports>
    </PatientVisit>
  </Payload>
</Message>

```



## Lessons Learned



**The concept of the NDMA is viable**

*This project generated a significant amount of interest, both from clinical and research professionals and from the radiology community as a whole*

**Commercialization seems a real possibility**

## Lessons Learned

### Use of Smart Cards

The technology worked well to provide the desired functionality

However, in the environment in which the test bed operated, it became a management problem

Users often forgot their PINs and many cards were locked with unsuccessful attempts

A biometric for unlocking the cards – or a biometric for authentication - would have been a better choice for this environment



## Lessons Learned

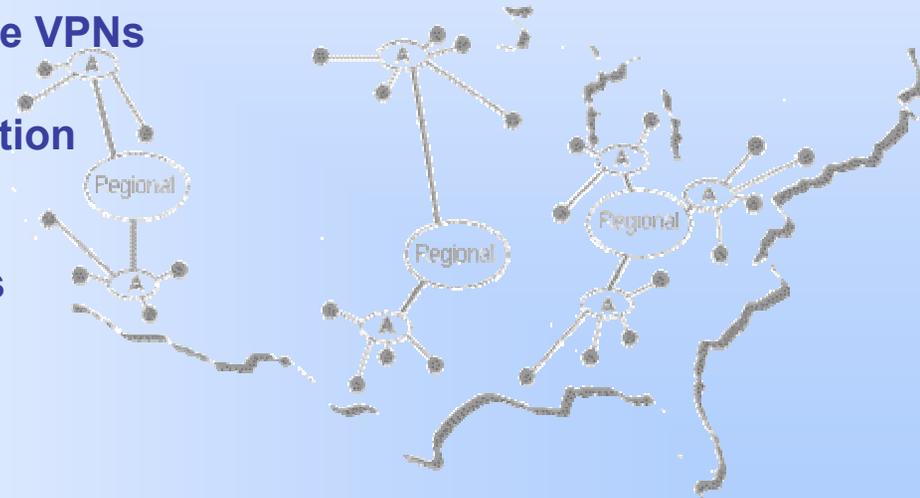
### VPN performance

Because the VPN was implemented on a network card, we were limited to the bandwidth that the card supported, which in this case was 100 Mbps.

Therefore, we were unable to take advantage of the higher speed ATM links (OCS-12, 622Mbps) several sites had to the Internet.

In practice, this was not an issue, as the VPNs achieved their purpose in providing confidential, authenticated communication between the sites.

Typical performance was up to 45Mbps between site due to congestion on the Internet, so the cards were not the limiting factor.



## Lessons Learned

### DICOM Structured Reports

We observed a change in prevailing expectations about the role of DICOM SR in diagnostic imaging.

DICOM SR's role will be more focused in specialty domains, while mainstream diagnostic reporting in radiology will more likely remain in information systems using primarily Health Level Seven (HL7) standards.

We solved many of the problems of storing coded data and using it to find reports and images, but more work is needed to clarify the handling of exam content in NDMA data.

Mini Mammo Module 2.01 (1.40)

General Info Mass Calcs

Mass Finding 1 for Rita Raye Redman

Side, Location, and Size

Side **Right** Location Size  mm

Mass Shape

Round  Oval  Lobular  Irregular

Mass Margin, check all that apply

Circumscribed  Microlobulated  Obscured  Indistinct  Spiculated

Associated Findings

Skin retraction  Nipple retraction  Skin thickening  
 Travecular thickening  Skin lesion  Axillary Adenopathy  
 Architectural distortion  Calcifications  Hematoma  
 Post-surgical scar

Changes Since Previous Exam

Assessment

**4 - Suspicious abnormality**

Biopsy and Pathology Codes

Has a biopsy been performed?  Yes  No

## Lessons Learned

### Standards Based Design

One reason we chose Mammography was that standards had already evolved for radiology and mammography (BiRADS and DICOM).

Use of these standards provided us a basis for design of storage and messaging components.

Our goal was to design a central lexicon based on these standards that would serve mammography but also support evolving standards as well as expansion to other modalities.

Because the final implementation was based on a strict interpretation of the standard, we validated the need for a common medical lexicon/data model.

```

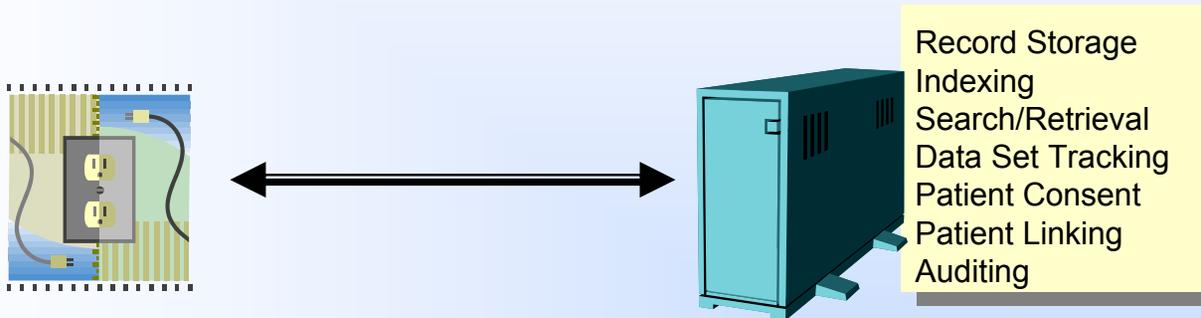
<?xml version="1.0" encoding="UTF-8" ?>
<MiniMammoReport version="2.0b3 (1.39b)">
  <BiradEdition>3.1</BiradEdition>
  <ReportDate>20030513</ReportDate>
  <ReportTime>135935</ReportTime>
  <Study>
    <StudyDate birad="D19" biradcode="03062003">Mammogram Study Date</StudyDate>
    <WhereDone>ORDEV</WhereDone>
    <StudyID>STUDYIDgoeshere</StudyID>
  </Study>
  <Patient>
    <PatientID>ORDEV-0011</PatientID>
    <PatientName>
      <First>Lora</First>
      <Middle>Lynn</Middle>
      <Last>Serridge</Last>
    </PatientName>
    <BirthDate birad="C9" biradcode="07131961">Patient Date of Birth</BirthDate>
    <Sex birad="C10" biradcode="F">Female</Sex>
    <EthnicGroup birad="C11" biradcode="1">White</EthnicGroup>
    <RiskFactors birad="D74">
      <Factor biradcode="N">Family history unknown</Factor>
    </RiskFactors>
  </Patient>
  </Study>
  <Evaluation>
    <RadiologistID>ppayne</RadiologistID>
    <FacilityName>ORDEV</FacilityName>
    <BreastComposition birad="E77" biradcode="1">1 - Fatty</BreastComposition>
    <HistologicBiopsyLeft birad="D47" biradcode="1">Needle biopsy in left breast</HistologicBiopsyLeft>
    <IndicatedProblems birad="D75">
      <Problem biradcode="A">
        Palpable abnormality
        <Side>Right</Side>
        <Quadrant>Lower Outer</Quadrant>
      </Problem>
    </IndicatedProblems>
    <FirstMammo birad="D73" biradcode="N">>false</FirstMammo>
    <PreviousMammoDate>2000</PreviousMammoDate>
    <OverallAssessment code="3">Probably benign</OverallAssessment>
  </Evaluation>
  <Findings>
    <Finding type="Other">
      <FindingSide birad="E98" biradcode="L">Left</FindingSide>
      <FindingSize birad="E95" biradcode="15">Size</FindingSize>
      <ChangeSincePrior birad="E79">
        <Change biradcode="+">Increase in size</Change>
      </ChangeSincePrior>
      <FindingAssessment birad="E100" biradcode="3">Probably benign</FindingAssessment>
      <OtherFinding>= other text is entered here</OtherFinding>
    </Finding>
    <AssociateFindings birad="A">
      <AssocFinding biradcode="A">Auxiliary Adenopathy</AssocFinding>
    </AssociateFindings>
    <BiopsyDate birad="F108" biradcode="05132003">Biopsy Date</BiopsyDate>
    <BiopsyTechnique birad="F109" biradcode="CB">
      Core biopsy
      <PathCode birad="F110">
        <PathCode biradcode="VH">Hemangioma: Venous hemangioma</PathCode>
      </PathCode>
    </BiopsyTechnique>
  </Findings>
  </Evaluation>
</MiniMammoReport>

```

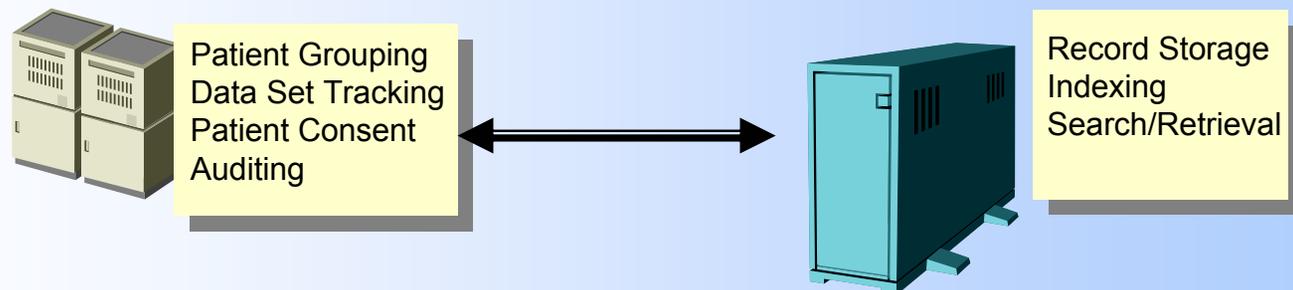
## Lessons Learned

### Portal Functionality

Original concept was simple “Wall Plug” Portals



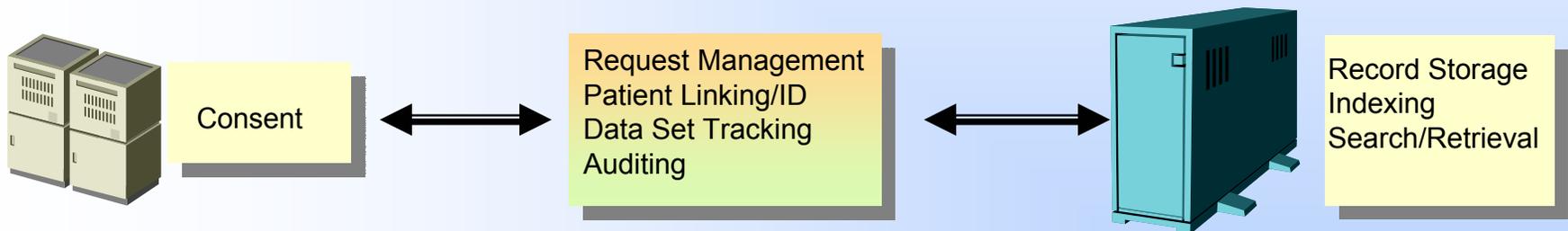
As development proceeded, requirements evolved to keep Archives simple. This resulted in functions being pushed down to Portals



## Lessons Learned

### Portal Functionality

What was needed was a solution such as a Web Service that would allow both Portals and Archives to remain simple with focused functionality.



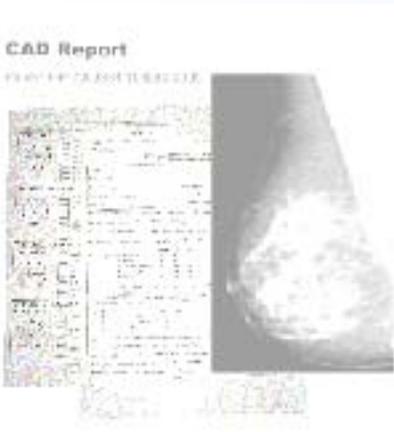
## What Sets NDMA Apart?

Records across geographically dispersed locations are instantly available wherever the patient is being treated

Report data is coded in a central metadata index so that searches are not limited to patient demographics but can be searched by finding characteristics

Images and reports are managed across healthcare enterprise boundaries

Security is integrated across the system to insure privacy and confidentiality



## The NDMA Team



THE UNIVERSITY OF CHICAGO  
HOSPITALS & HEALTH SYSTEM

This research is funded by The National Library of Medicine, under Contract #N01-LM-01-3512 with the University of Pennsylvania and under contract #Y1-LM-2015-0 with BWXT Y-12 L.L.C.

# Questions

***Mitchell D. Schnall, M.D., PhD***  
***schnall@oasis.rad.upenn.edu***