Northwestern University Neuroimaging Data Archive (NUNDA)

"Great Leap Forward"

Lei Wang

Feinberg School of Medicine

Departments of Psychiatry and Behavioral Sciences, Radiology

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People

- Washington University XNAT Team
  - Dan Marcus
  - Mohana Ramaratnam
  - Tim Olsen
- Todd Parrish / CTI (formerly known as CAMRI)
- NU XNAT Team
  - Kate Alpert
  - Alex Kogan
- NU QUEST Team
  - Bruce Foster

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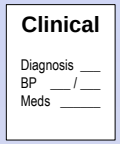
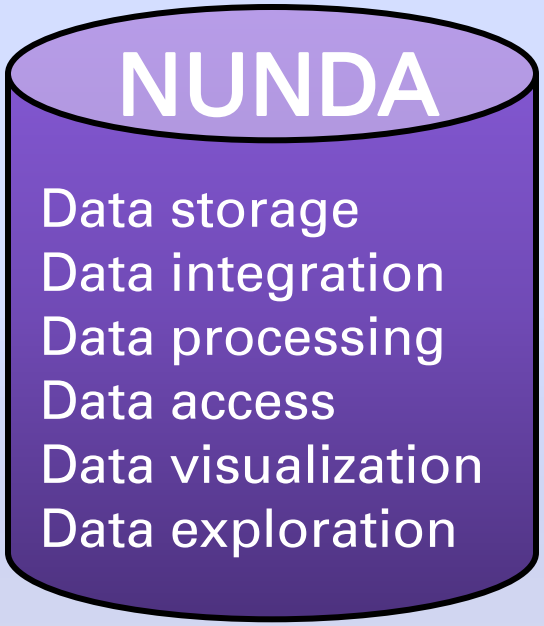
NUNDA

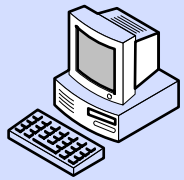
Neuroimaging

Processing & analysis

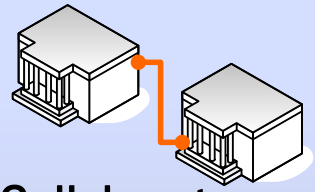


Related data





Local users



Collaborators

Community

- Archive of MR Sessions
  - Secure
  - Redundant
  - Backed up
- Pooling controls
- Common Anatomic Protocol (NUCAP)
  - T1, T2, DTI, Resting-State
- Standard processing pipeline

- Linking NUNDA with other neuroimaging centers via federated, disease-oriented databases

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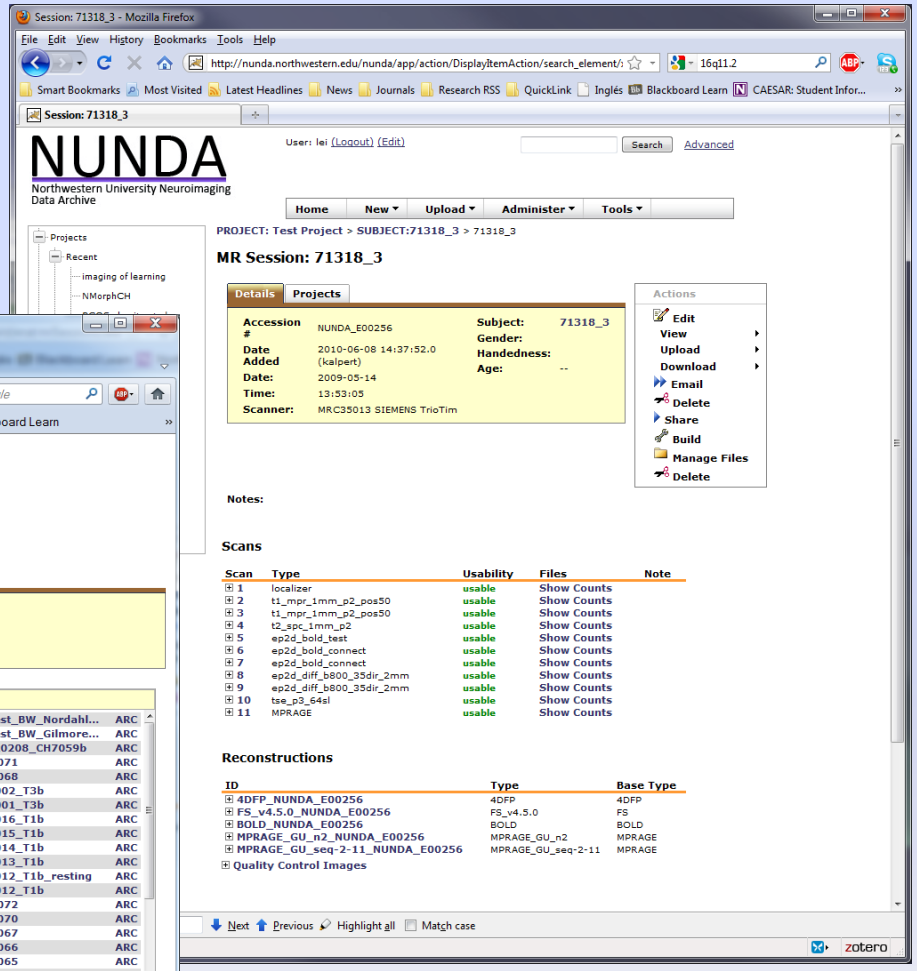
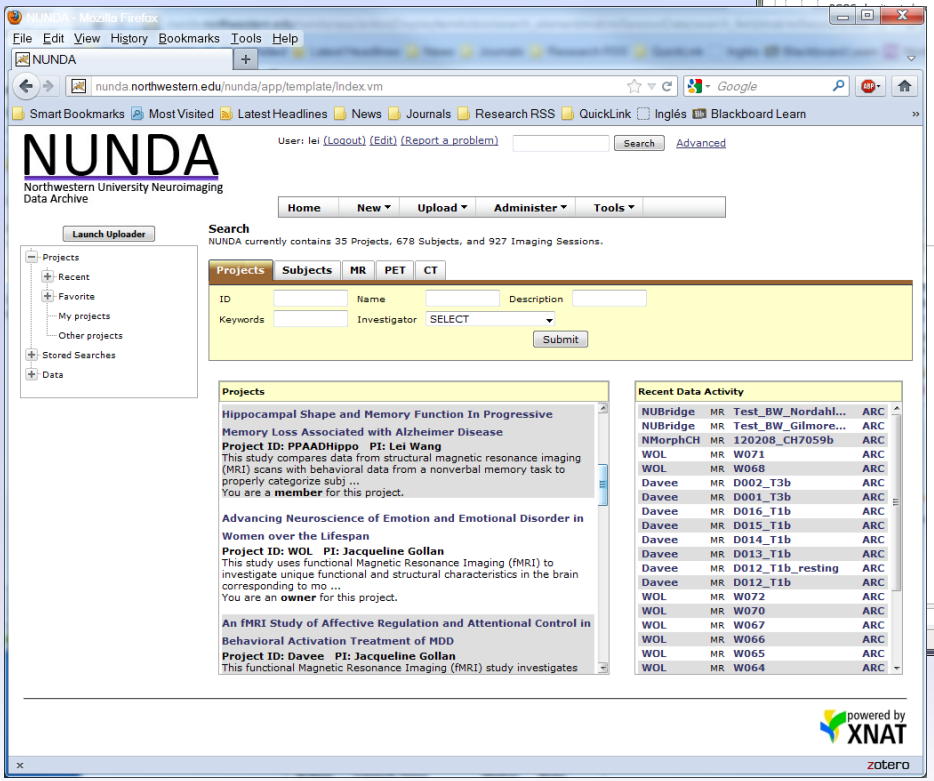
NUNDA

- Launched in 2009
- 35 Projects, 684 Subjects, and 935 Imaging Sessions
- 60 registered users





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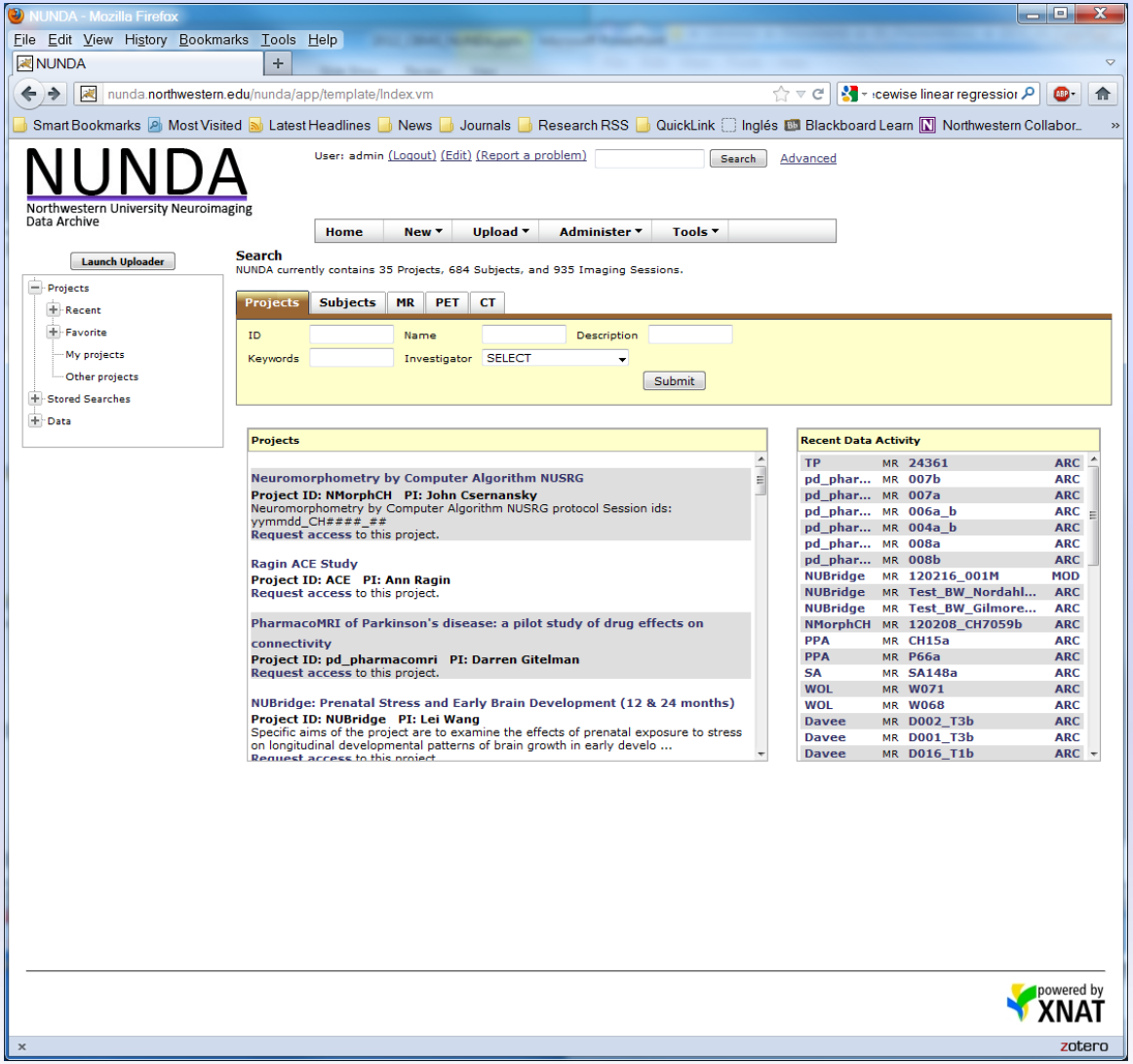

- Project (35)
  - Psychiatry (8)
  - Radiology (8)
  - Neurology (3)
  - Physiology (3)
  - CNADC (2)
  - CMH, MSS, Endocrinology

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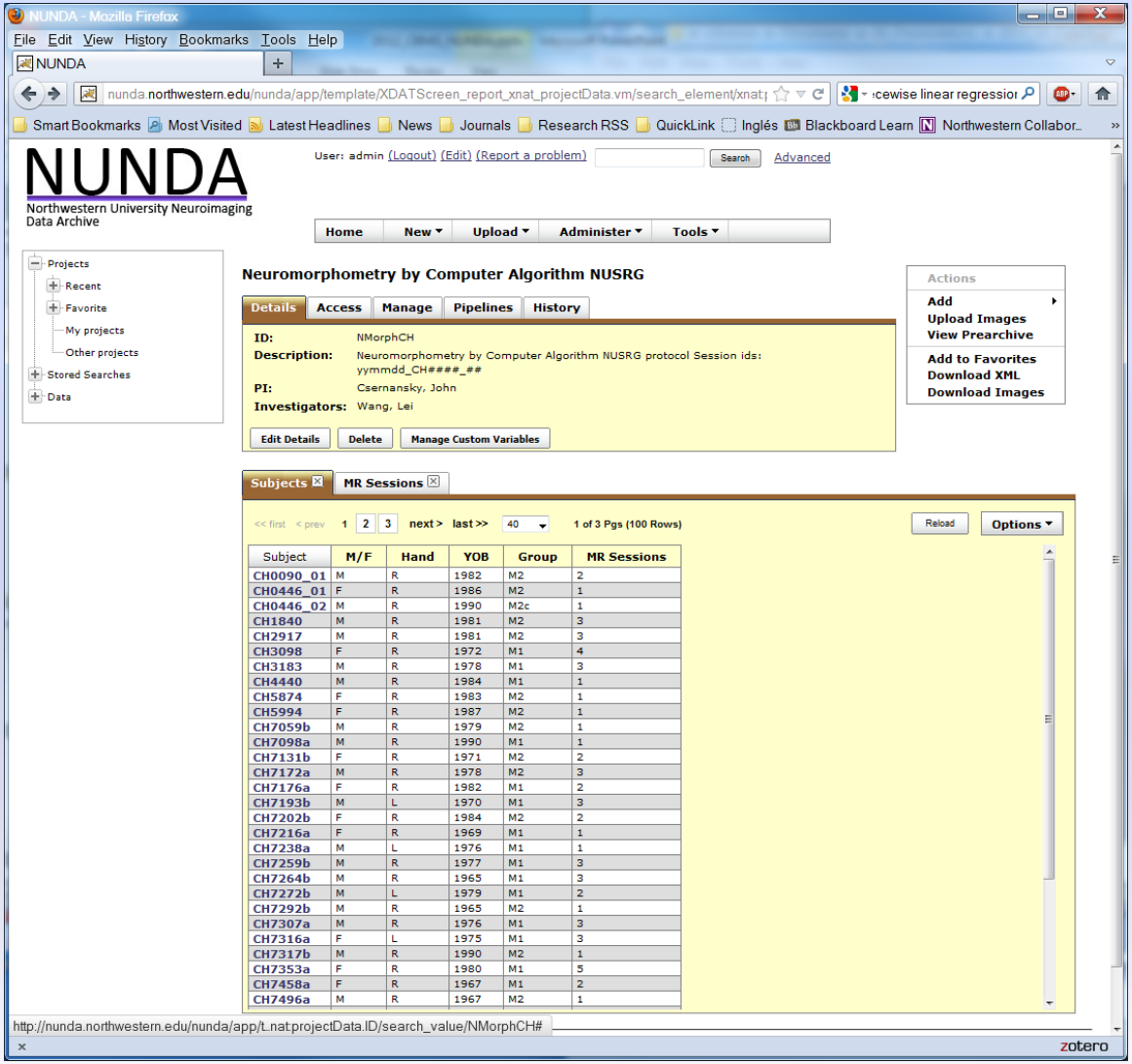

- Project
  - Subject

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NUNDA

- Project
  - Subject
    - MR Session

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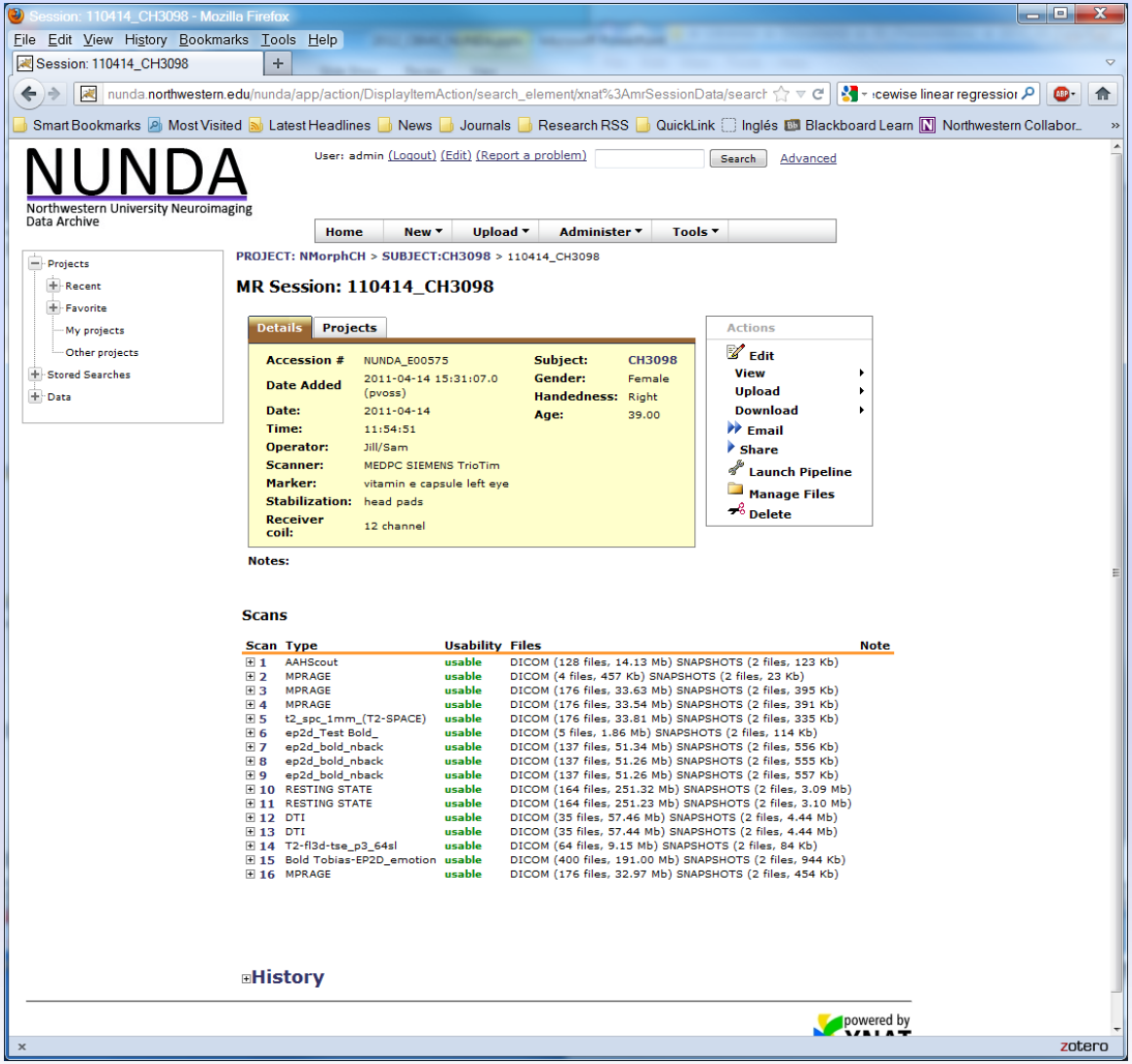

- Project
  - Subject
    - MR Session
      - Scan

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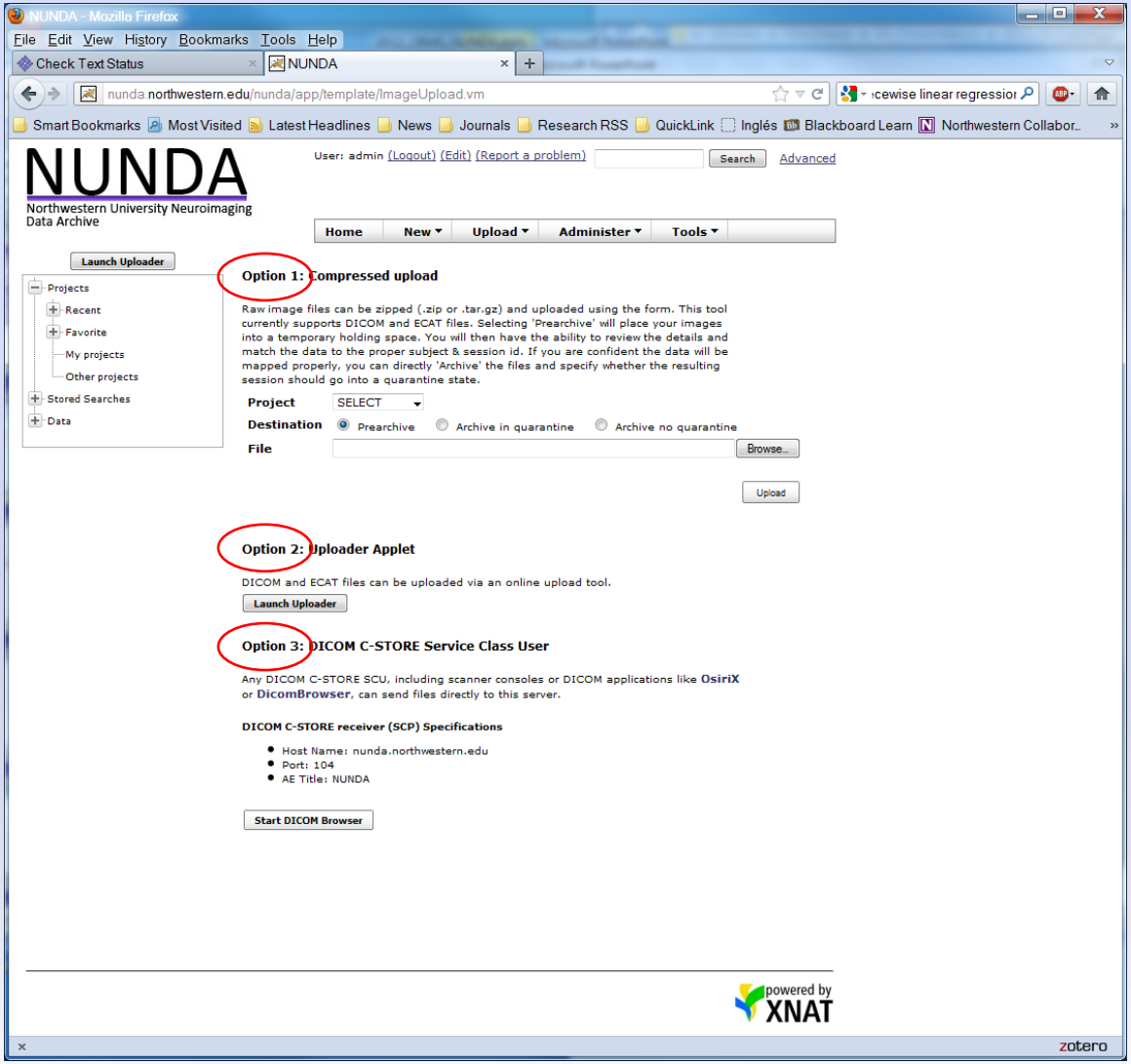
NUNDA



1. Data capture
   - Push from CAMRI
   - Web upload

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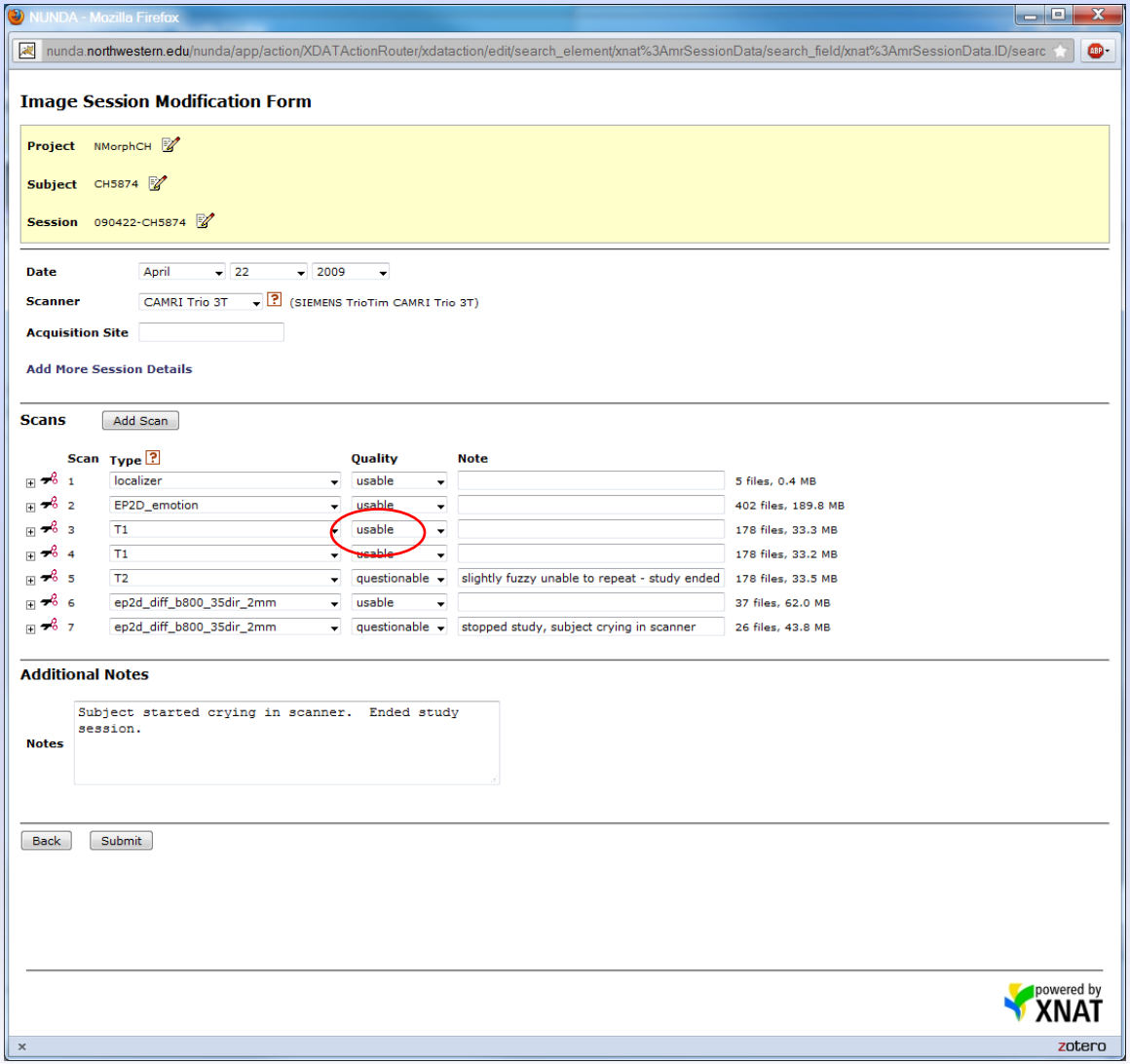
NUNDA



1. Data capture
2. Quality control

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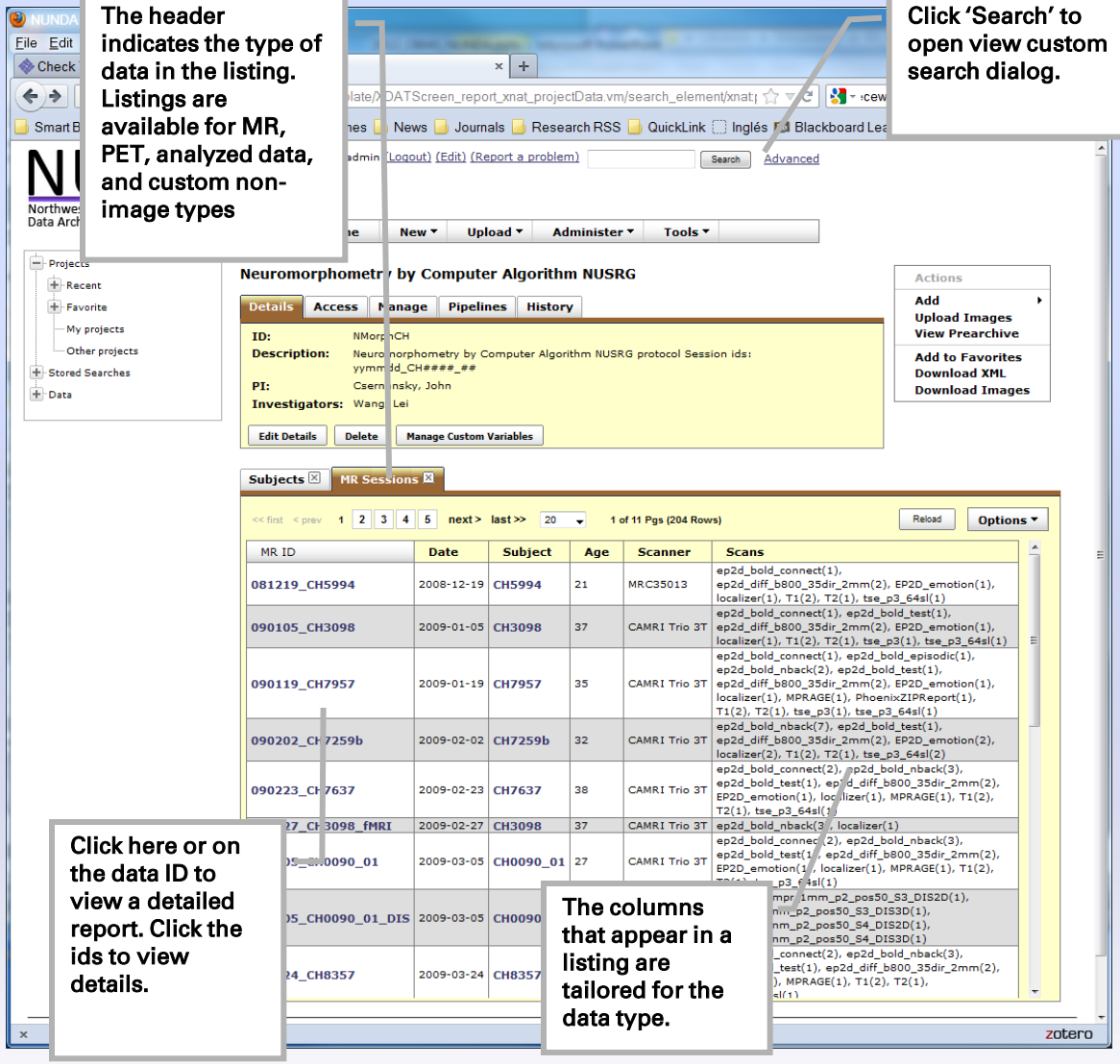

1. Data capture
2. Quality control
3. Data exploration & download

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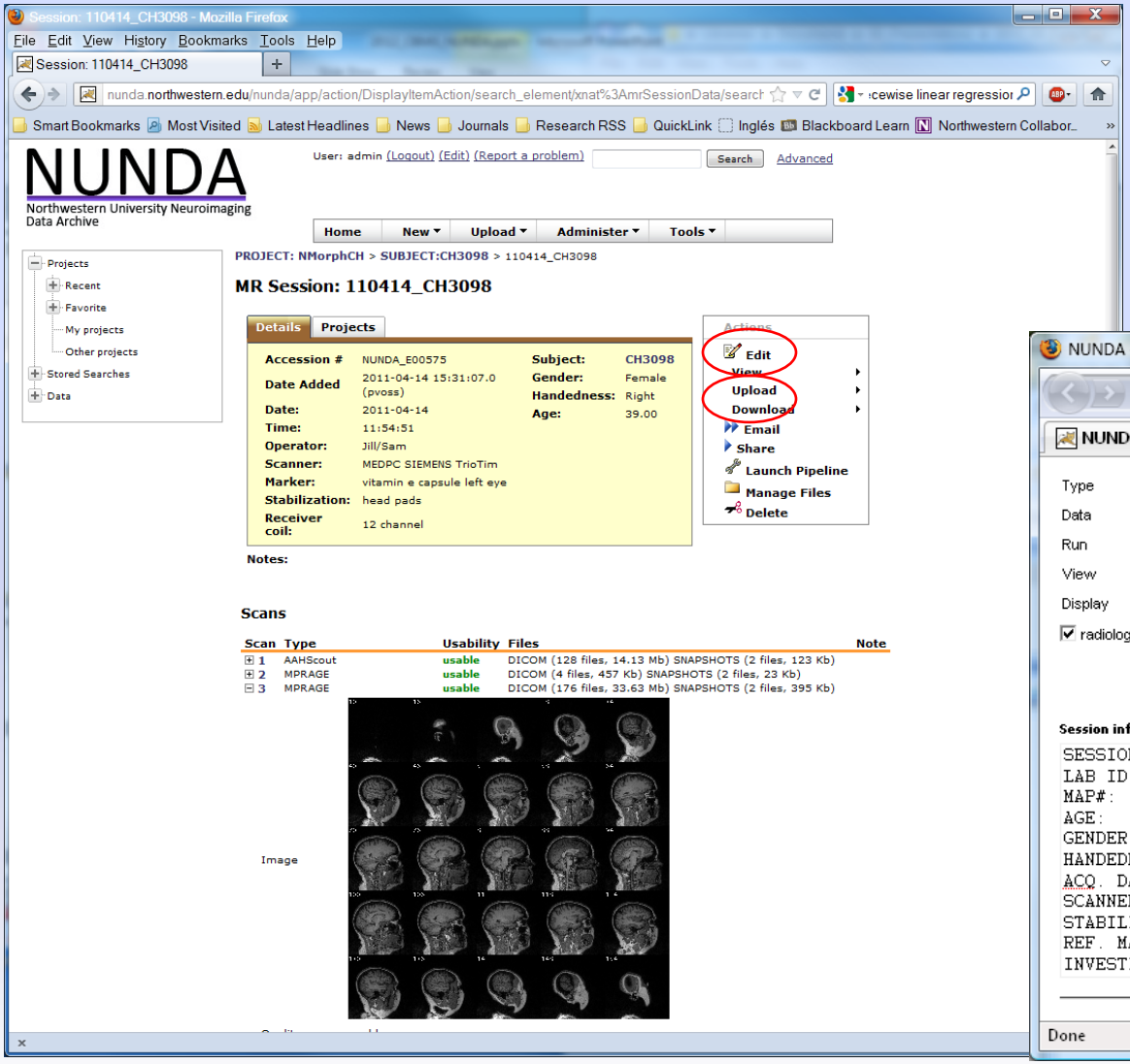
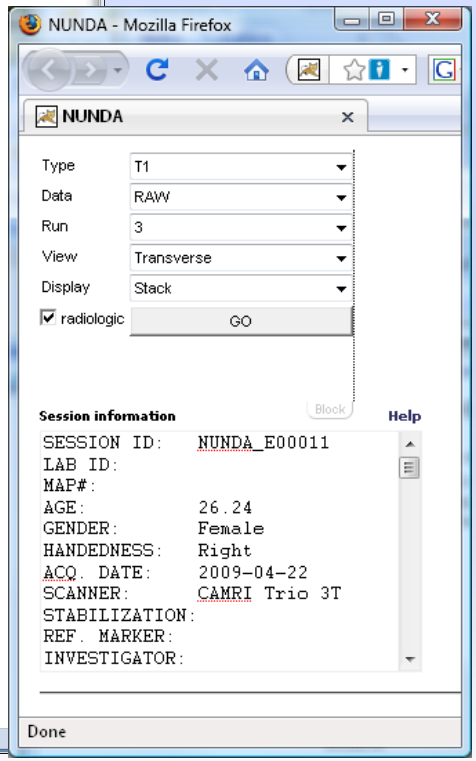
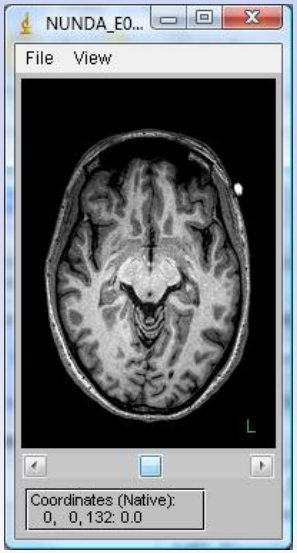
NUNDA

1. Data capture
2. Quality control
3. Data exploration & download







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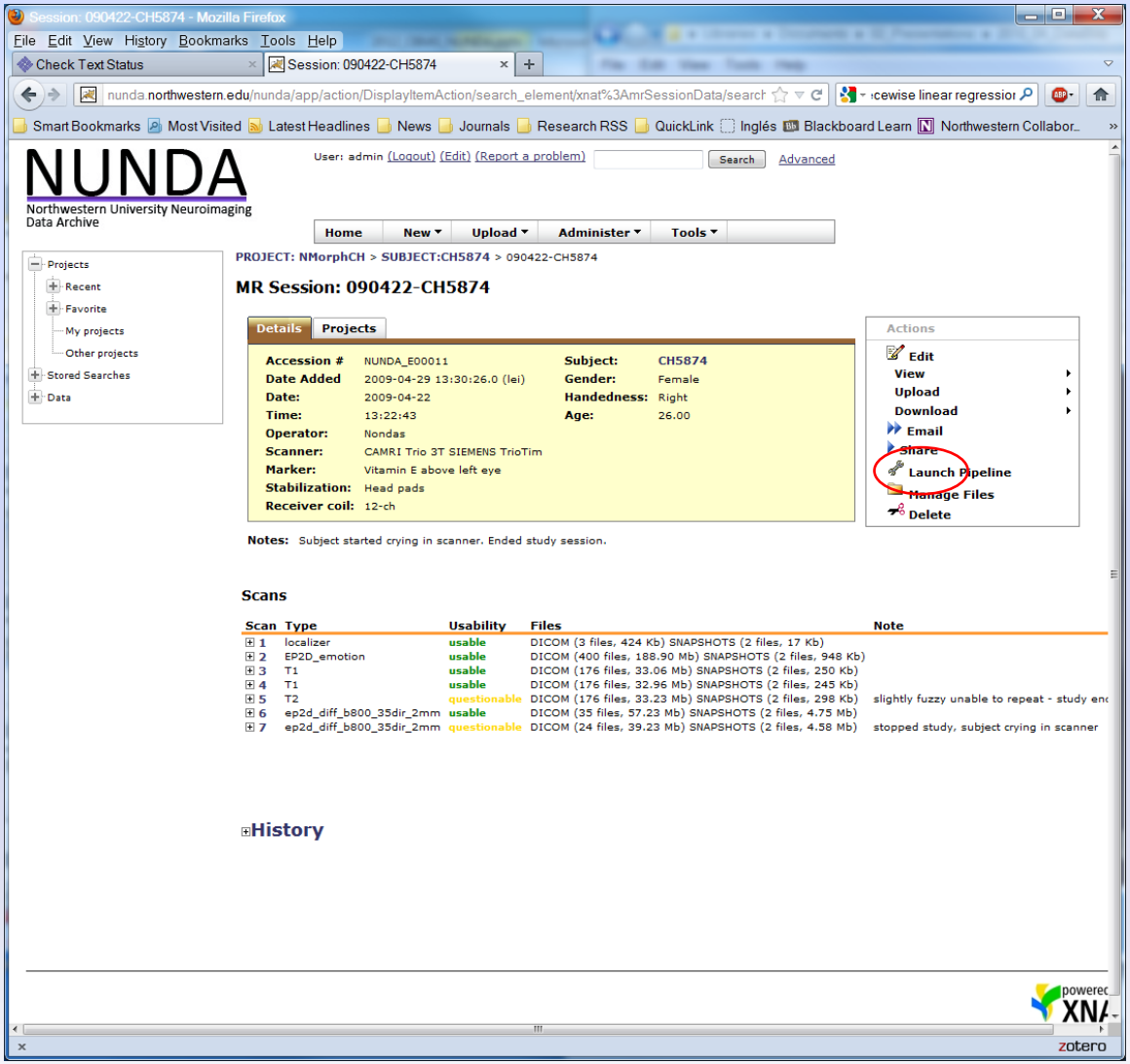
NUNDA Pipelines



1. Data capture
2. Quality control
3. Data exploration & download
4. Image processing pipelines

NUNDA PIPELINES

Process Your Data

NUNDA Pipelines

- Currently Available Pipelines
- The Front-End (How to Launch a Pipeline)
- The Back-End (How the Pipeline Engine Works)
- Live Demo (NUNDA Cooking Show)

Currently Available Pipelines

- Standard Structural Preprocessing (StdBuildNunda)
  - DICOM → Analyze reconstruction
  - MPRAGE averaging
- FreeSurfer Segmentation and Surface Generation (FSBuild)
- FSL Tissue Segmentation (FSLSeg)
  - Image segmentation into gray, white, CSF, tissue types
- Resting-State Preprocessing (GenericBoldPreprocessingNunda)
  - Resting-state BOLD scan preprocessing
  - Includes QC outputs

Currently Available Pipelines

- Standard Structural Preprocessing (StdBuildNunda)
  - DICOM → Analyze reconstruction (16-bit 4dint)
  - T1 MPRAGE averaging
    - Geometric distortion correction
    - Averaging multiple acquisitions
    - Gain field correction
  - T2W/TSE
    - Geometric distortion correction

Currently Available Pipelines

- Standard Structural Preprocessing (StdBuildNunda)
- FreeSurfer Segmentation and Surface Generation (FSBuild)
  - recon-all –all
    - Subcortical segmentation and volume
    - Cortical parcellation and volume, surface area, cortical thickness
    - Currently requires pre-processed MPRAGE image as input, will soon accept DICOMs

Currently Available Pipelines

- Standard Structural Preprocessing (StdBuildNunda)
- FreeSurfer Segmentation and Surface Generation (FSBuild)
- FSL G/W/CSF Tissue Segmentation (FSLSeg)
  - Segmenting MPRAGE with FSL
    - Requires pre-processed MPRAGE image as input
    - FSL BET – deletes non-brain tissue from input image
    - FSL FAST – corrects for spatial intensity variations – bias field or RF inhomogeneities
    - FSL FAST – segments image into gray, white, CSF, tissue types, provides volume

Currently Available Pipelines

- Standard Structural Preprocessing (StdBuildNunda)
- FreeSurfer Segmentation and Surface Generation (FSBuild)
- FSL G/W/CSF Tissue Segmentation (FSLSeg)
- Resting-State Preprocessing (GenericBoldPreprocessingNunda)
  - Pipeline to pre-process BOLD scan types
    - Frame alignment to correct for asynchronous slice acquisition
    - Correction for odd-even slice intensity differences
    - Movement correction
    - Average of all the first frames
    - Transformations to standard atlas space
  - Includes QC
    - Intensity histogram of the normalized bold image
    - Movement plot (from motion correction)

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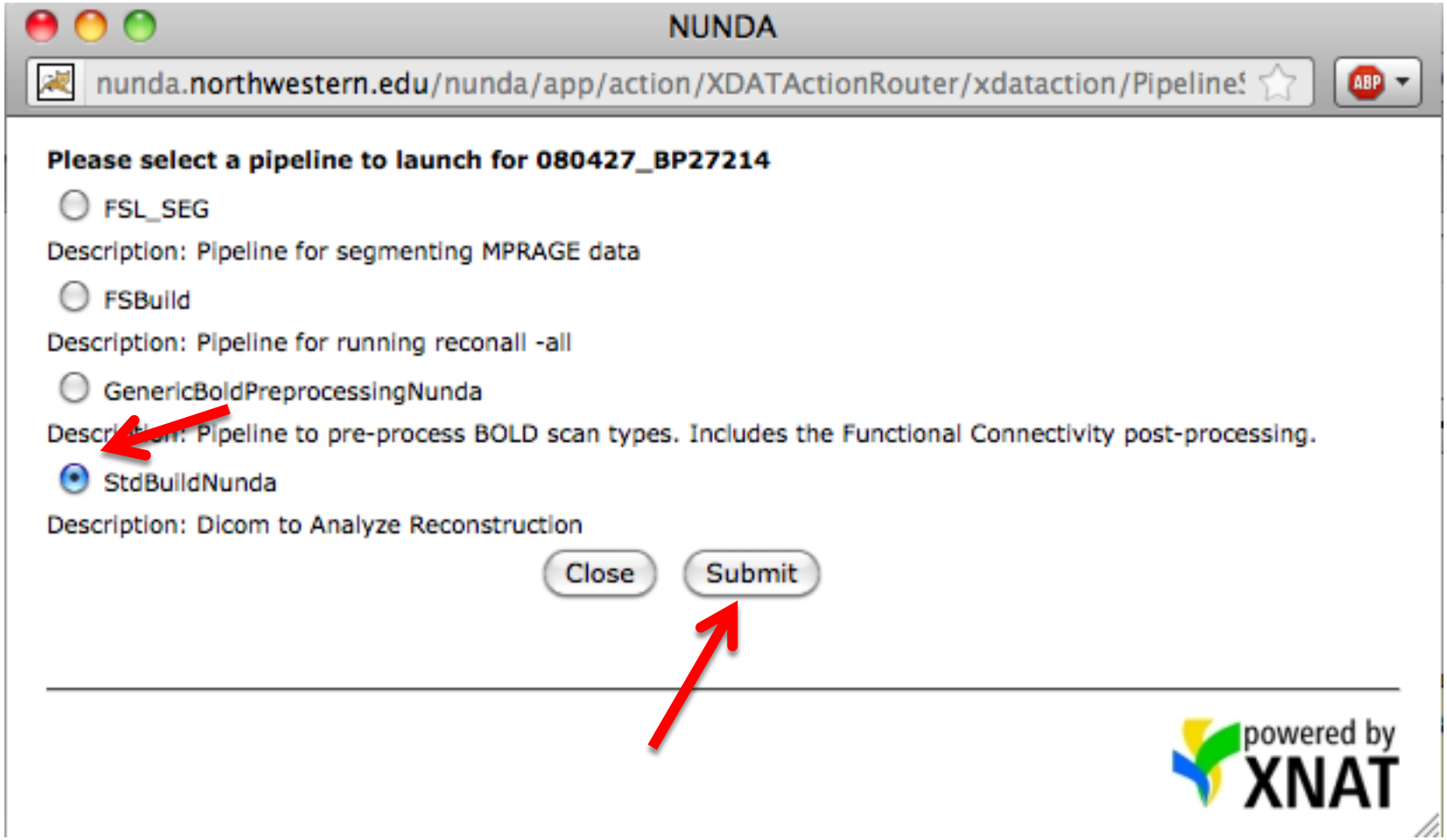
Launch Pipeline from NUNDA Web

Navigate to your MR Session page, select “Launch Pipeline” from the Actions Menu



Select the pipeline you wish to launch and click "Submit"

StdBuild Pipeline: Session Parameters

Subject: BP27214
Project: Test (Alex)

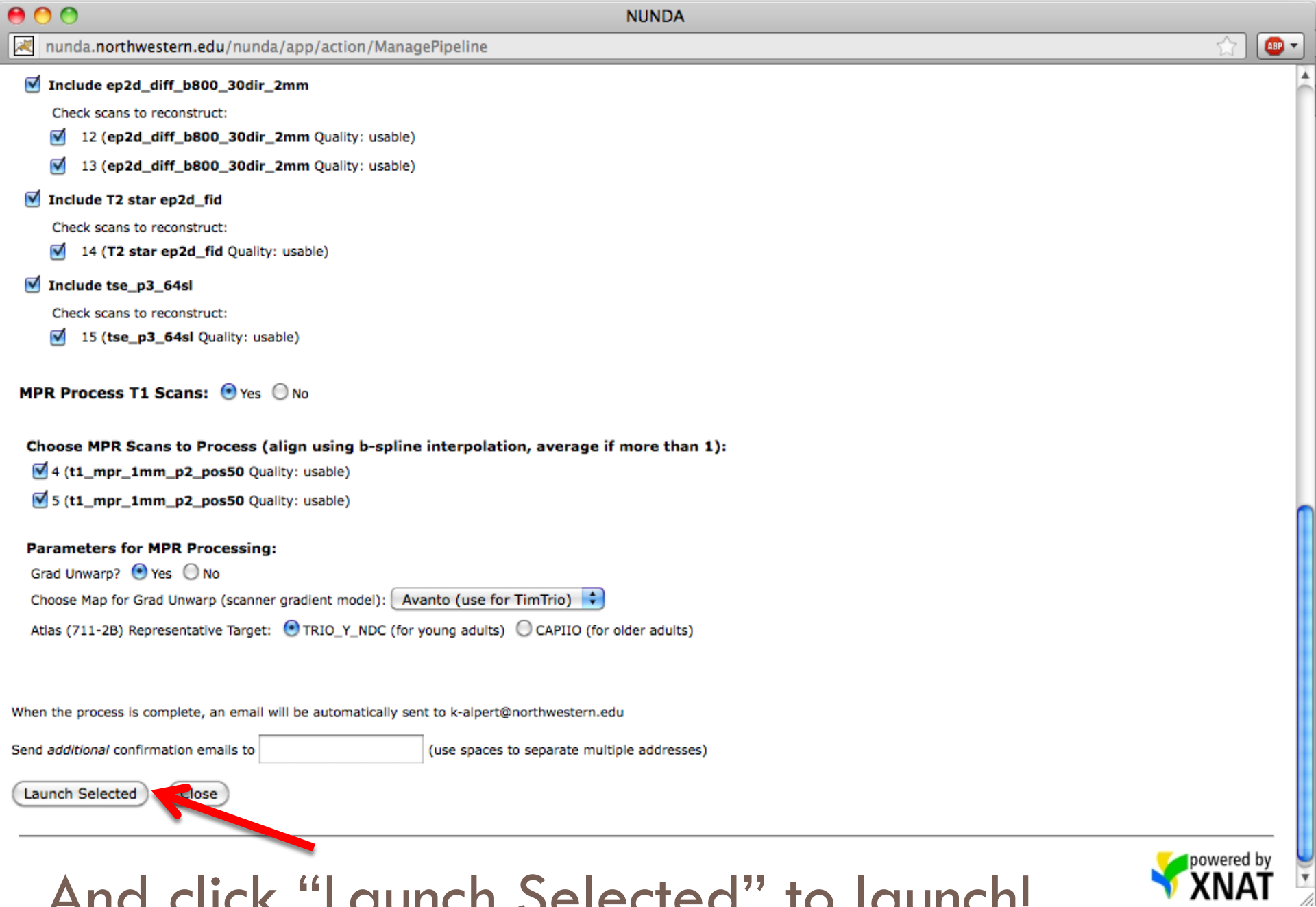
*****Warning: StdBuildNunda pipeline has been run already. A rerun will overwrite the following reconstructions: 4DFP_NUNDA_E00900, TSE_NUNDA_E00900, T2_NUNDA_E00900, and MPRAGE_*_NUNDA_E00900. *****

sessionId: 080427_BP27214

Min Number of Slices Needed to Reconstruct Sequence (changing this will change the sequences you can select below): 30

- ☐ **Include localizer**
(NOT ENOUGH FRAMES)
- ☑ **Include AAScout**
  - Check scans to reconstruct:
    - ☑ 2 (**AAScout** Quality: usable)
    - ☑ 7 (**AAScout** Quality: usable)
- ☐ **Include localizer_aligned**
(NOT ENOUGH FRAMES)
- ☑ **Include t1_mpr_1mm_p2_pos50**
  - Check scans to reconstruct:
    - ☑ 4 (**t1_mpr_1mm_p2_pos50** Quality: usable)
    - ☑ 5 (**t1_mpr_1mm_p2_pos50** Quality: usable)
- ☑ **Include t2_spc_1mm_p2**
  - Check scans to reconstruct:
    - ☑ 6 (**t2_spc_1mm_p2** Quality: usable)
- ☑ **Include tse_p3**
  - Check scans to reconstruct:
    - ☑ 8 (**tse_p3** Quality: usable)
- ☐ **Include ep2d_bold_test**
(NOT ENOUGH FRAMES)

Set session-specific parameters….



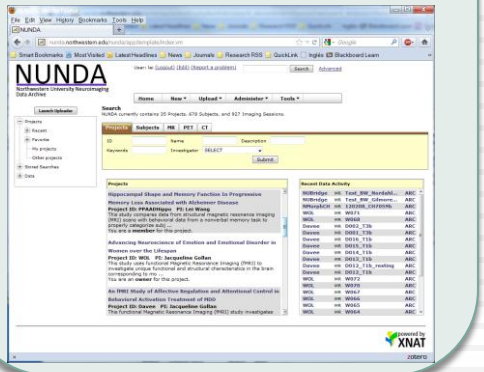
And click “Launch Selected” to launch!

powered by XNAT

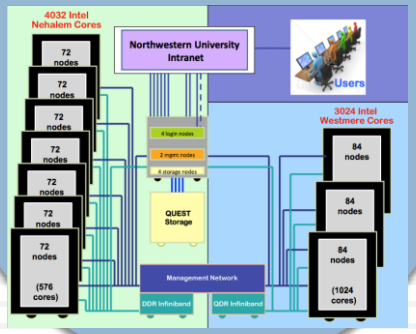
The Back-End

We harness the power of Quest, Northwestern's high performance computing cluster, to run NUNDA pipeline processes

NUNDA Server



Quest Cluster



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Quest Computing Cluster

NUIT Home › Research Computing Resources › Advanced Research Computing › High Performance Computing › **The Quest Cluster**

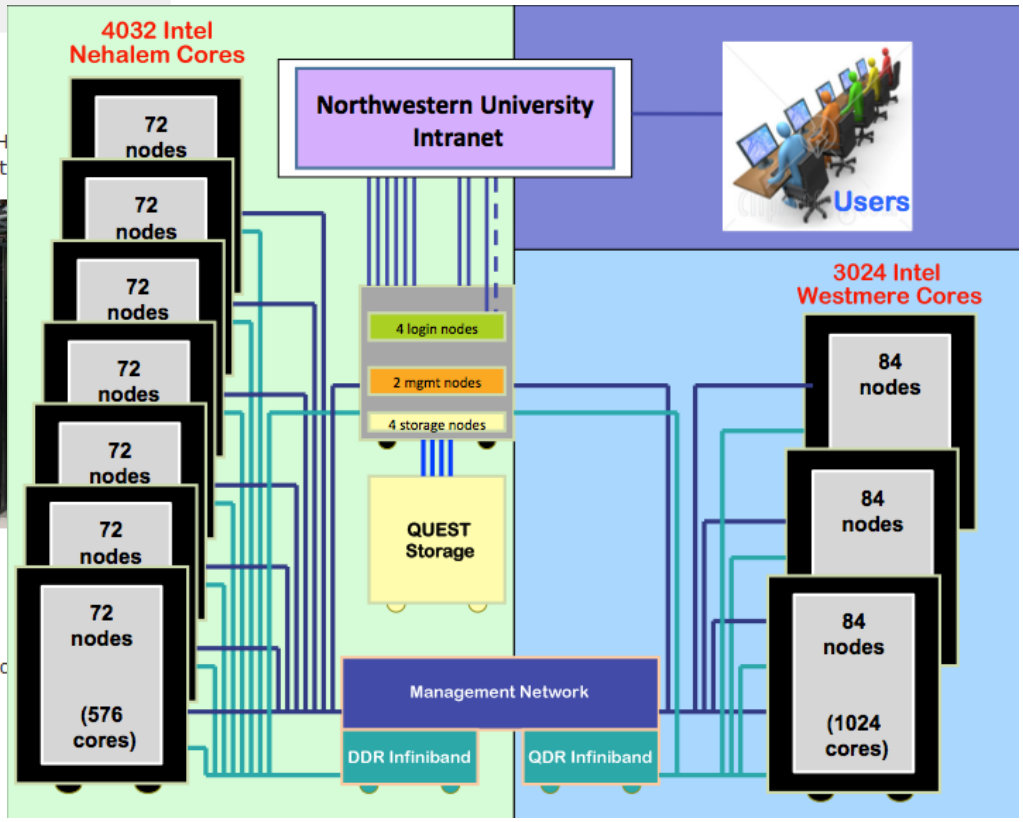
High Performance Computing System - Quest

The University's high performance computing (HPC) system is referred to as Quest. H
University's secure Data Center facilities, it offers a large shared computational facilit

Designed as a general use cluster, Quest supports the majority of HPC applications at Northwestern and is built to accommodate a wide variety of codes with great economy.

University researchers and educators, including postdoctoral researchers are eligible to apply for an account to request an allocation of time on Quest as computational investigators (CI's) for the purpose of research or education.

Information on the types of allocations supported by Quest, application deadlines, and required documentation can be found in the Allocation Submission and Review Guidelines.



Quest Facts

Ranked among the TOP500 list of the fastest computers world wide, Quest's architec

- Vendor: IBM iDataPlex
- Parallel Filesystem: IBM GPFS
- DDN DCS 9900 storage system: 100 TB available for projects on Quest
- **Interconnect: Infiniband DDR**
  - Number of Nodes: 504 (4032 cores)
  - Processor: Intel Nehalem E5520, 64-bit, 8M Cache, 2.26 GHz, 5.86 GT/s Intel® QPI, 1066Mhz FSB
  - Memory: Per node (Per Core) 48GB's (6GB's), Type: DDR3
- **Interconnect: Infiniband QDR**
  - Number of Nodes: 252 (3024 cores)
  - Processor: Intel Westmere X5650, 64-bit, 12MB Cache, 2.66 Ghz, 6.4 GT/s Intel® QPI, 1333Mhz FSB
  - Memory: Per node (Per Core) 48GB's (6GB's), Type: QDR

XNAT Pipeline Engine

- Installed and runs on Quest nodes, not on the NUNDA server
- It is a java-based engine that uses XML workflows to call local programs/scripts

XNAT Pipeline Engine

- Ins
- It i cal
  pr

```
<?xml version="1.0" encoding="UTF-8"?>
- <Pipeline xmlns:fileUtils="http://www.xnat.org/java/org.nrg.imagingtools.utils.FileUtils"
xmlns:nrgString="http://www.xnat.org/java/org.nrg.pipeline.utils.StringUtils"
xsi:schemaLocation="http://nrg.wustl.edu/pipeline ..\..\schema\pipeline.xsd"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xmlns="http://nrg.wustl.edu/pipeline">
    <name>StdBuildNunda</name>
    <location>/var/lib/nunda_pipeline/catalog/build-tools</location>
    <description>Dicom to Analyze Reconstruction</description>
  - <documentation>
    - <input-parameters>
      - <parameter>
          <name>sessionId</name>
        - <values>
            <schemalink>xnat:mrSessionData.label</schemalink>
          </values>
          <description>The MRSession Label</description>
        </parameter>
      </input-parameters>
    </documentation>
    <xnatInfo appliesTo="xnat:mrSessionData"/>
    <outputFileNamePrefix>^concat(/Pipeline/parameters/parameter[name='builddir']/values/unique/text
      (),'/', /Pipeline/parameters/parameter[name='sessionId']/values/unique/text
      (),'/', /Pipeline/parameters/parameter[name='sessionId']/values/unique/text())^</outputFileNamePrefix>
    <loop xpath="^/Pipeline/parameters/parameter[name='allstudies']/values/list^" id="alls"/>
    <loop xpath="^/Pipeline/parameters/parameter[name='studies']/values/list^" id="studys"/>
  - <parameters>
    - <parameter>
        <name>workdir</name>
      - <values>
          <unique>^concat(/Pipeline/parameters/parameter[name='builddir']/values/unique/text
            (),'/',/Pipeline/parameters/parameter[name='sessionId']/values/unique/text())^</unique>
        </values>
      </parameter>
    - <parameter>
        <name>processeddir</name>
      - <values>
          <unique>^concat(/Pipeline/parameters/parameter[name='workdir']/values/unique/text
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      </parameter>
```
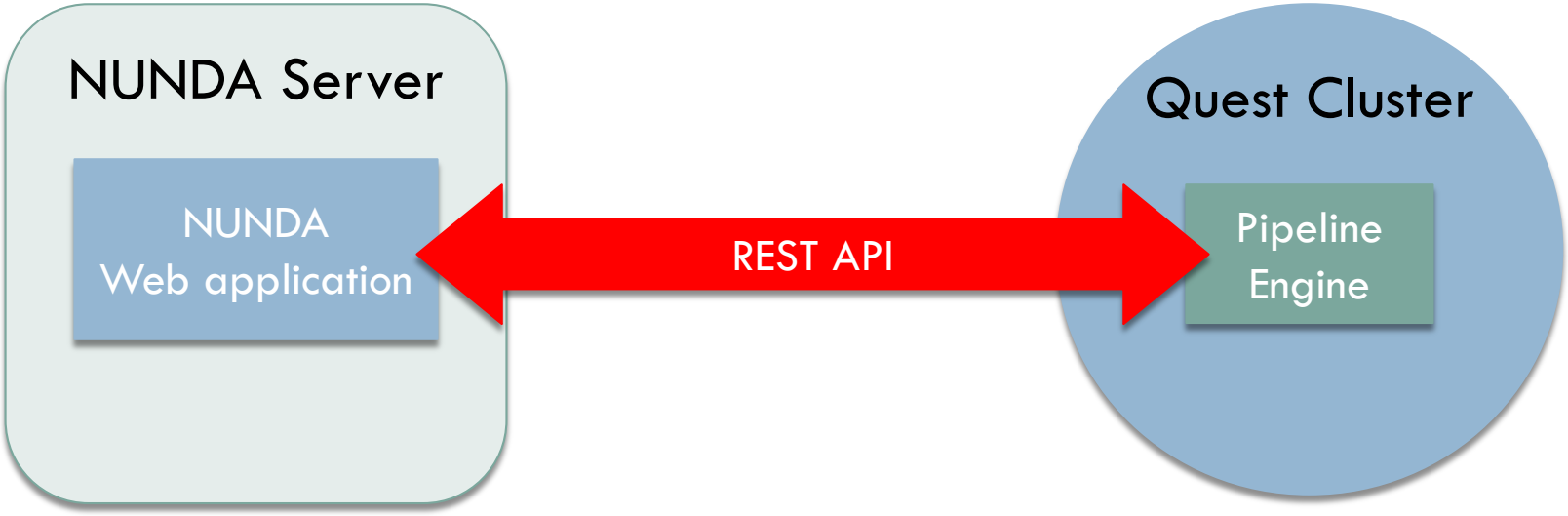

XML Workflow Example: StdBuild

XNAT Pipeline Engine

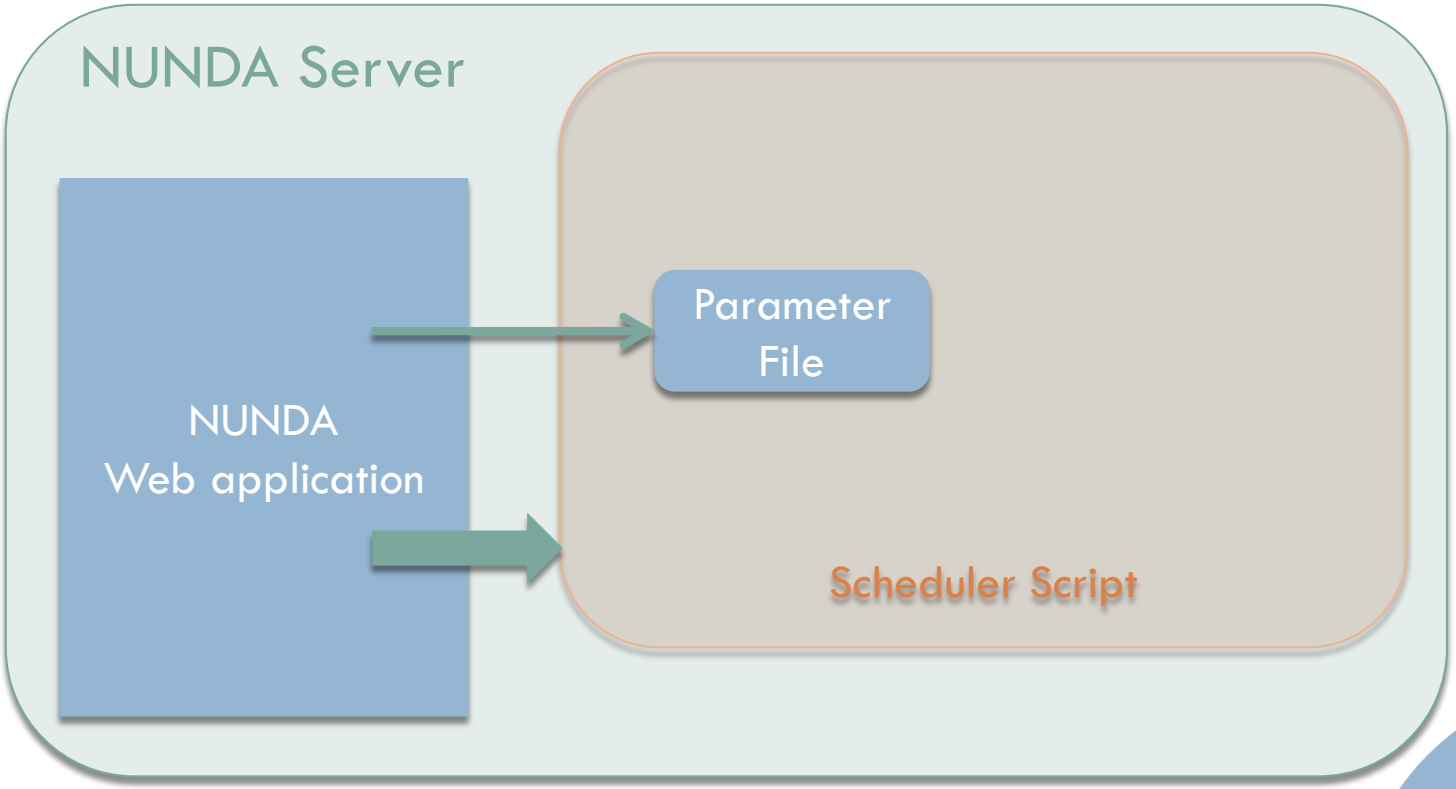


- Installed and runs on Quest nodes, not on the NUNDA server
- It is a java-based engine that uses XML workflows to call local programs/scripts
- It communicates with XNAT (NUNDA server) via the REST API

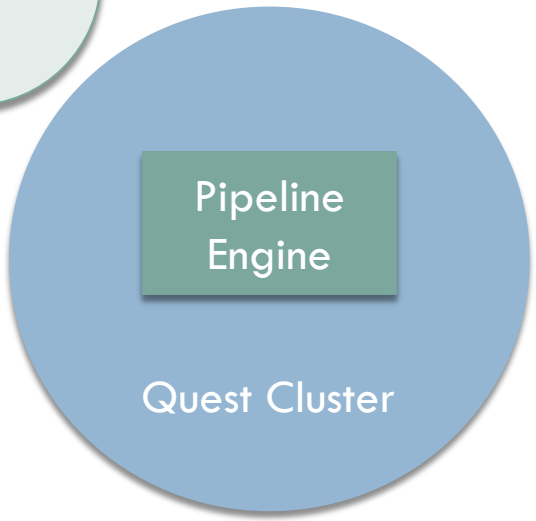
The REST (REpresentational State Transfer) API

- REST API enables a client to interact with the server in a standardized fashion
  - A client makes a request to the server, the server returns a response to the client
    - Requests can be GETs, POSTs, PUTs, DELETEs, etc.
  - Requests and responses are built around the transfer of representations of resources
  - A representation (for example, an XML document) communicates the state of a resource
    - E.g., a client GETs a resource XML, which represents an MRSession, from the server, changes the fields for scanner type and date, and then PUTs the updated resource XML back onto the server
      - A client (not on the server) is able to change the state of the MRSession resource
- This way, a client (with proper authentication!) can pull information from and push information to NUNDA → no need to run processing on the server

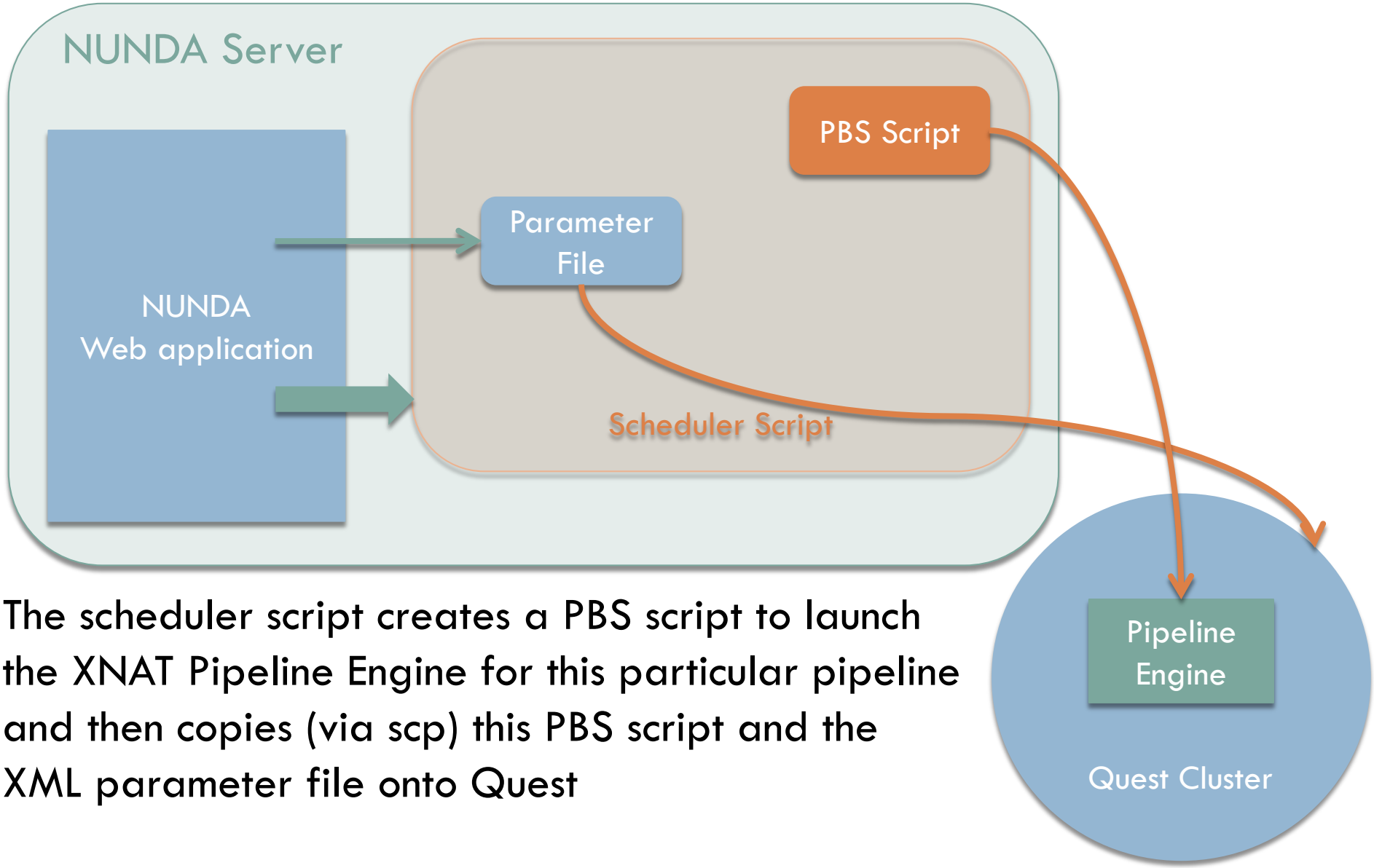
Communicating with Quest



When the user launches a pipeline, the NUNDA web application/web engine generates an XML parameter file, which stores all project and session parameters for the pipeline, and calls a scheduler script

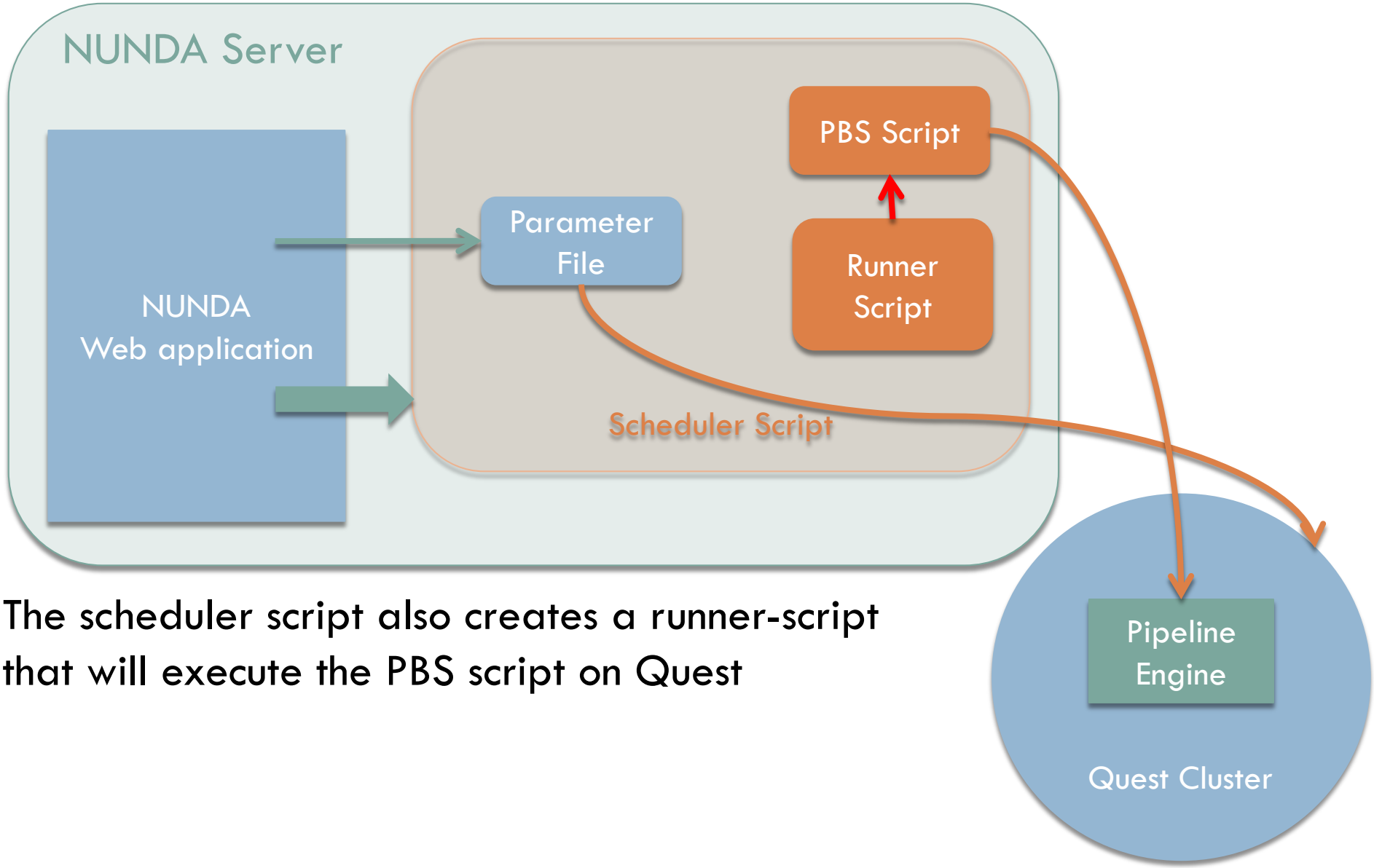


Communicating with Quest



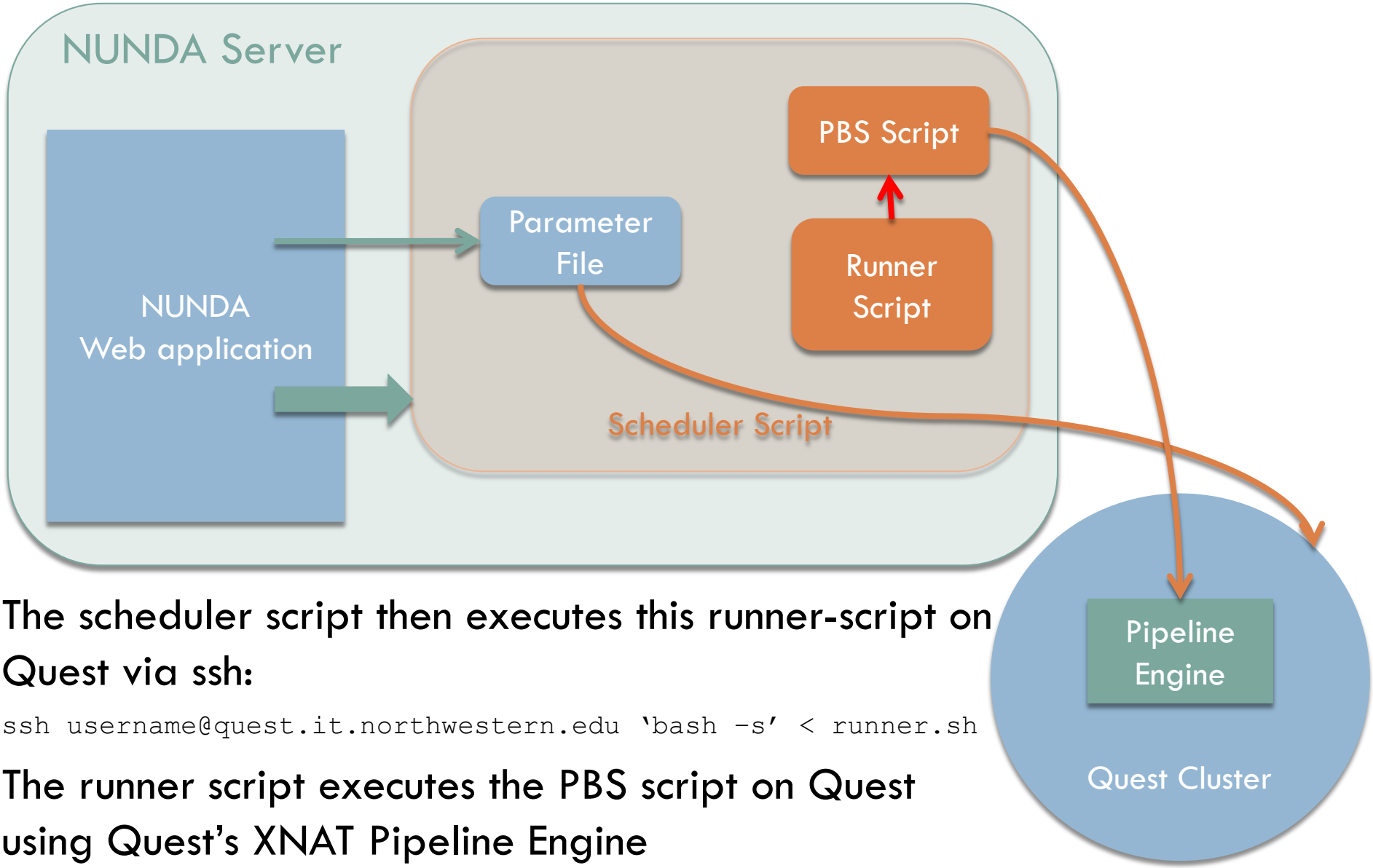
The scheduler script creates a PBS script to launch the XNAT Pipeline Engine for this particular pipeline and then copies (via scp) this PBS script and the XML parameter file onto Quest

Communicating with Quest



The scheduler script also creates a runner-script that will execute the PBS script on Quest

Communicating with Quest

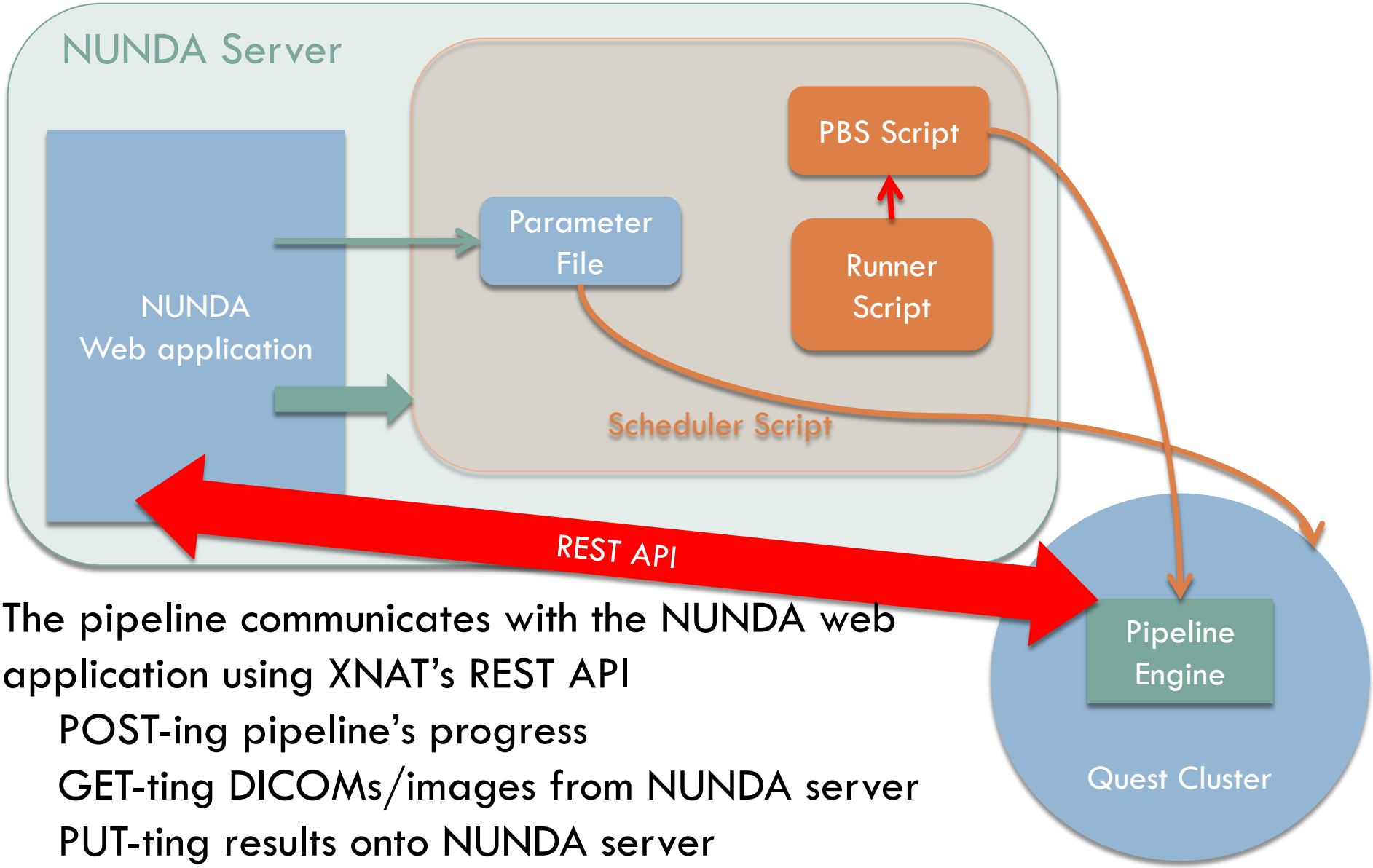


The scheduler script then executes this runner-script on Quest via ssh:

```
ssh username@quest.it.northwestern.edu 'bash -s' < runner.sh
```

The runner script executes the PBS script on Quest using Quest's XNAT Pipeline Engine

Communicating with Quest



The pipeline communicates with the NUNDA web application using XNAT's REST API

- POST-ing pipeline's progress
- GET-ting DICOMs/images from NUNDA server
- PUT-ting results onto NUNDA server

How to Launch a Pipeline

Once you have MR Sessions in a project on NUNDA, you can begin running pipelines

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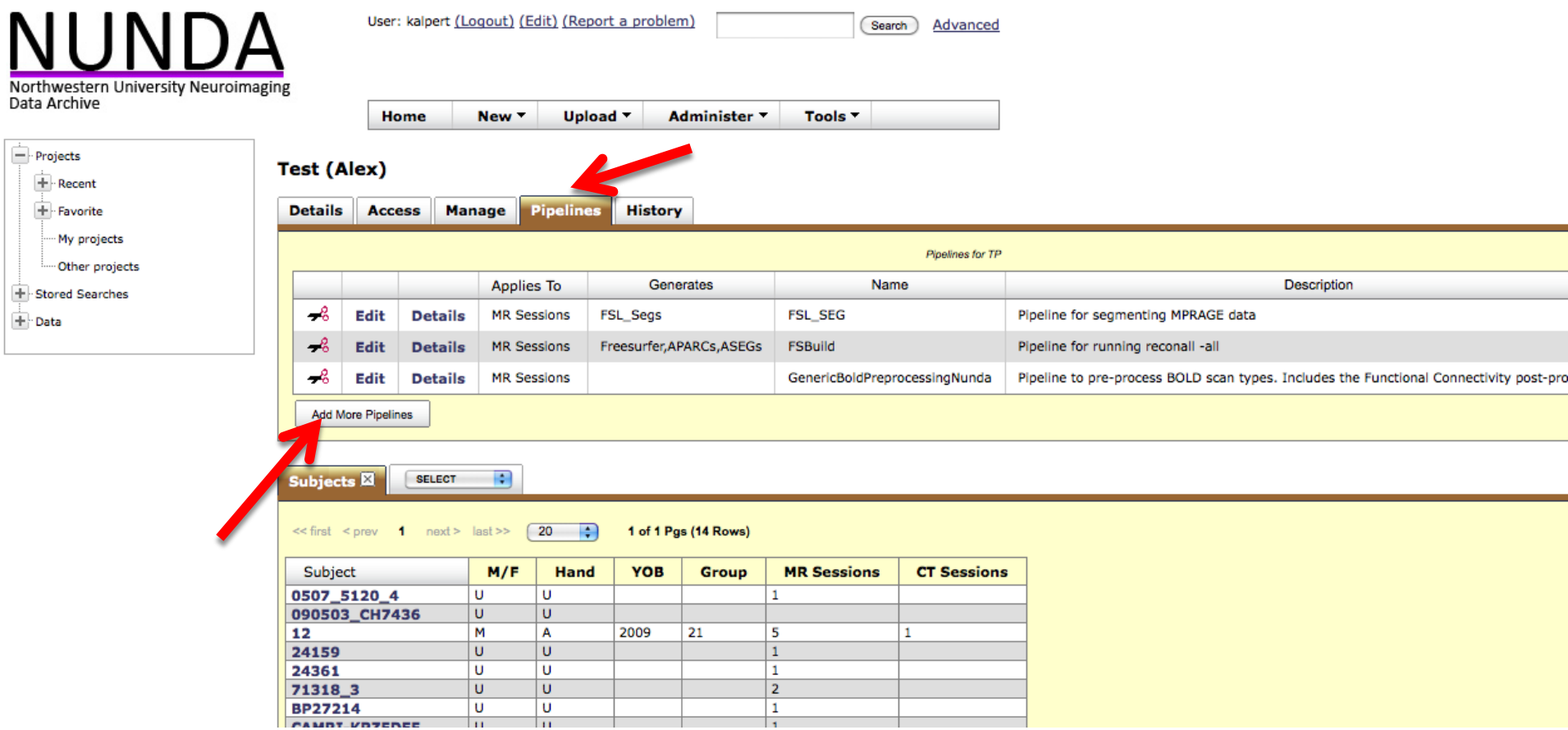
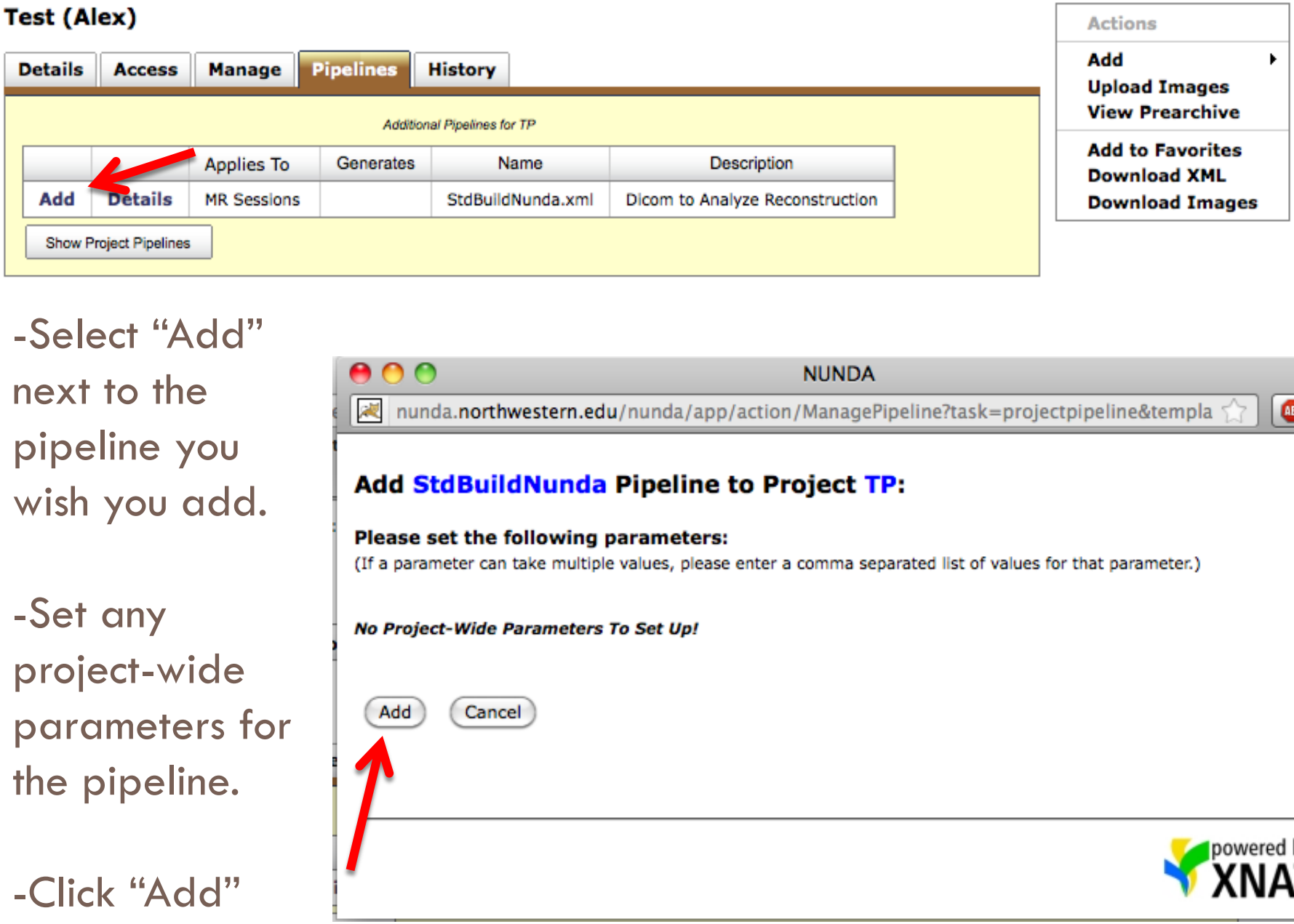
Step 1: Add Pipeline to Your Project



Navigate to your project page, select the "Pipelines" tab, and click "*Add* More Pipelines"

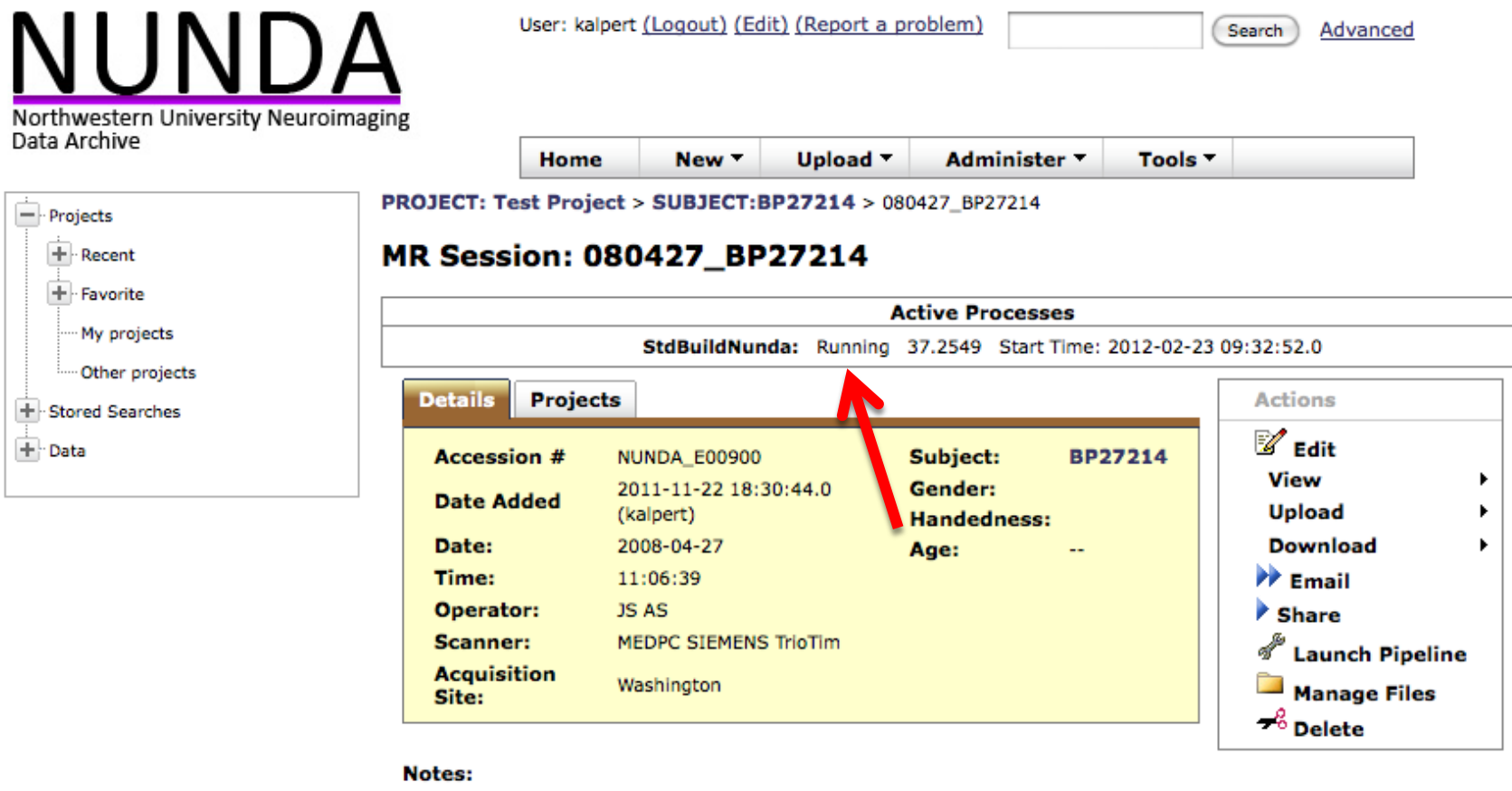

Test (Alex)
Details
Access
Manage
Pipelines
History
Additional Pipelines for TP
Applies To
Generates
Name
Description
Add
Details
MR Sessions
StdBuildNunda.xml
Dicom to Analyze Reconstruction
Show Project Pipelines
Actions
Add
Upload Images
View Prearchive
Add to Favorites
Download XML
Download Images
-Select "Add" next to the pipeline you wish you add.
-Set any project-wide parameters for the pipeline.
-Click "Add"
NUNDA
nunda.northwestern.edu/nunda/app/action/ManagePipeline?task=projectpipeline&templa
Add StdBuildNunda Pipeline to Project TP:
Please set the following parameters:
(If a parameter can take multiple values, please enter a comma separated list of values for that parameter.)
No Project-Wide Parameters To Set Up!
Add
Cancel
powered by XNAT

https://nunda.northwestern.edu/

Step 2: Launch Pipeline on MRSession

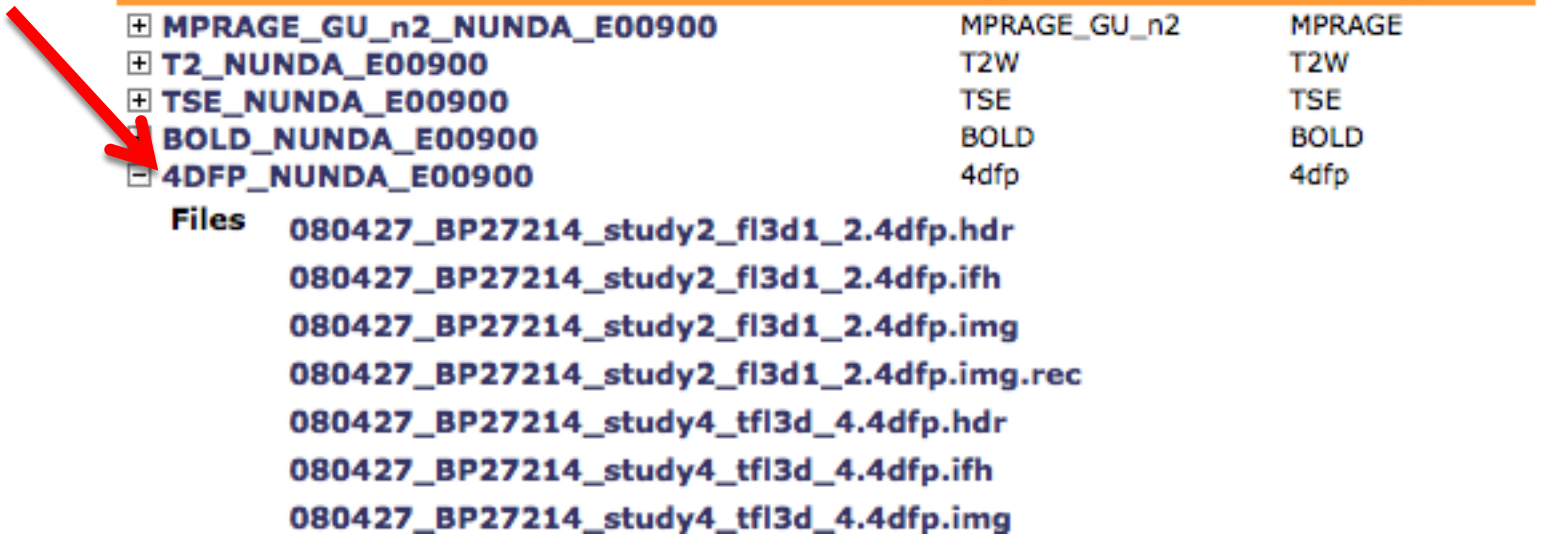
Navigate to your MR Session page, select “Launch Pipeline” from the Actions Menu

Step 3: Check Pipeline Status



Note the pipeline is listed as a “Running” Active Process.

Step 4a: View Reconstructions

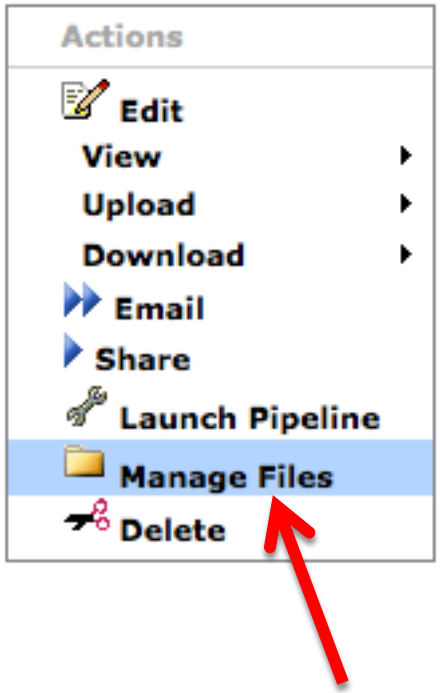


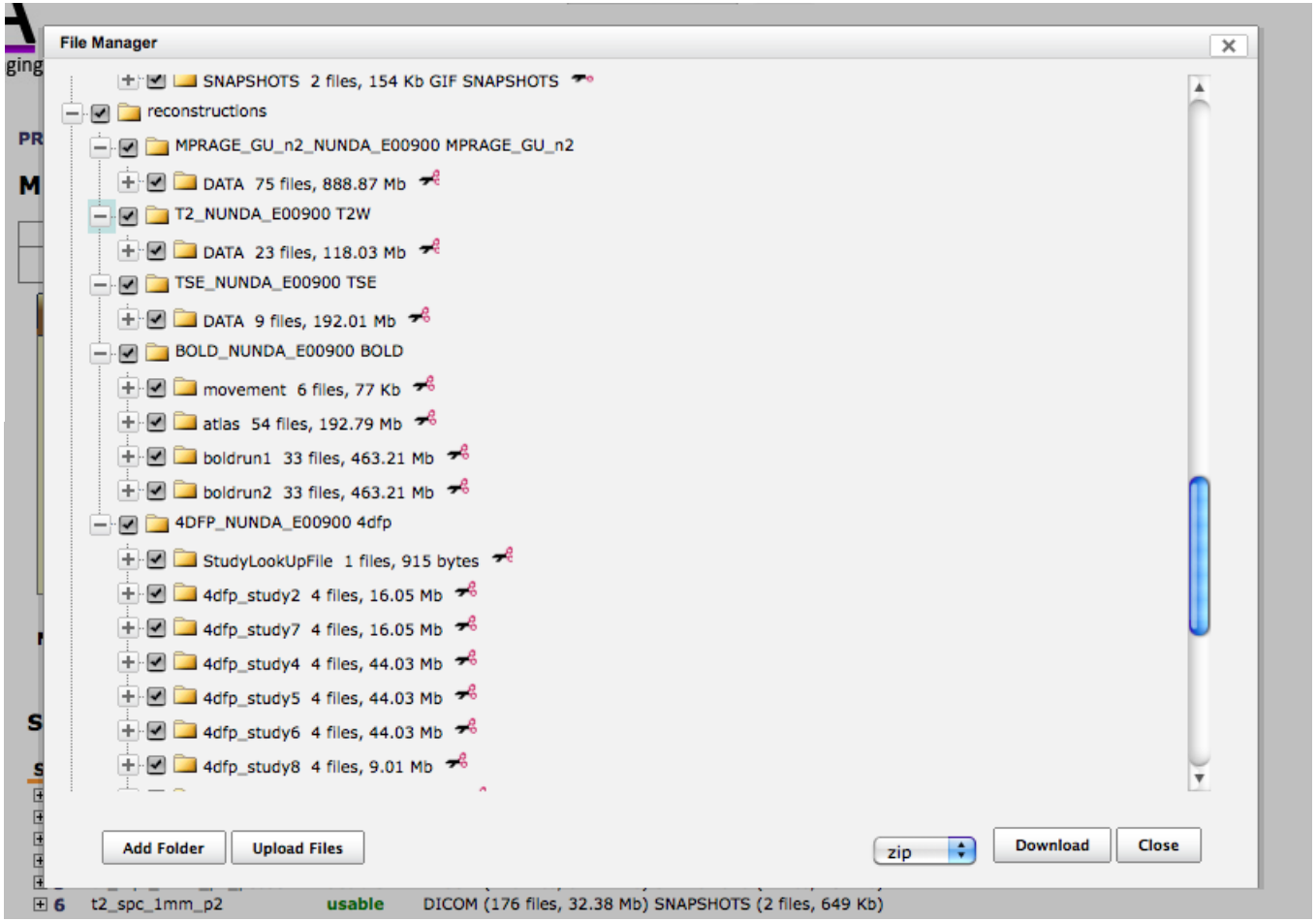
Reconstructions

ID	Type	Base Type
⊞ MPRAGE_GU_n2_NUNDA_E00900	MPRAGE_GU_n2	MPRAGE
⊞ T2_NUNDA_E00900	T2W	T2W
⊞ TSE_NUNDA_E00900	TSE	TSE
⊞ BOLD_NUNDA_E00900	BOLD	BOLD
⊟ 4DFP_NUNDA_E00900	4dfp	4dfp

Files
- 080427_BP27214_study2_fl3d1_2.4dfp.hdr
- 080427_BP27214_study2_fl3d1_2.4dfp.ifh
- 080427_BP27214_study2_fl3d1_2.4dfp.img
- 080427_BP27214_study2_fl3d1_2.4dfp.img.rec
- 080427_BP27214_study4_tfl3d_4.4dfp.hdr
- 080427_BP27214_study4_tfl3d_4.4dfp.ifh
- 080427_BP27214_study4_tfl3d_4.4dfp.img

Once the pipeline has finished, you can check for output files under the “Reconstructions” area of the MR Session report page…





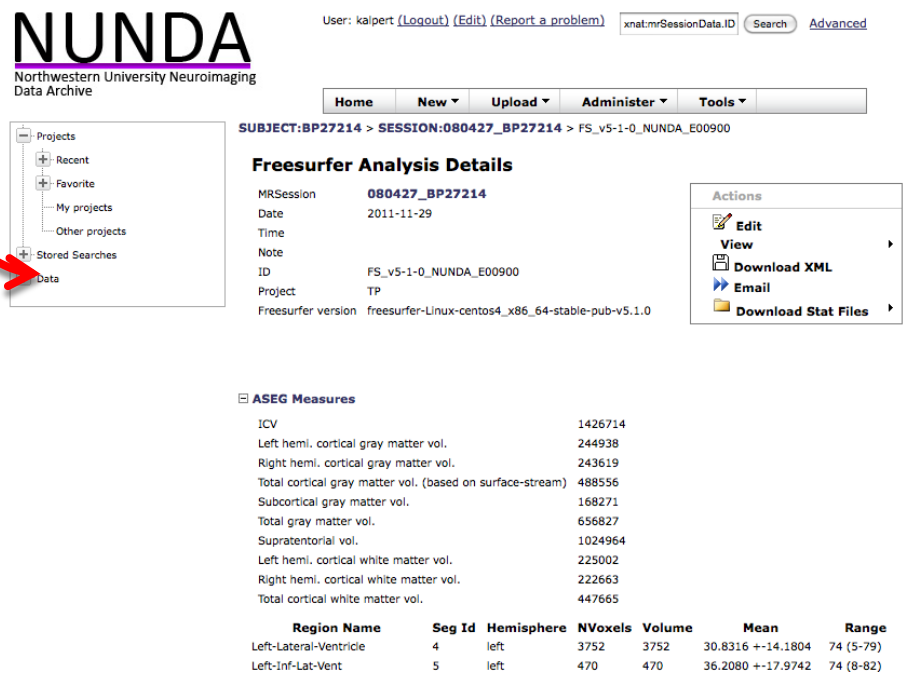
Or you can peruse the Reconstructions from the “Manage Files” section of the “Actions” menu.

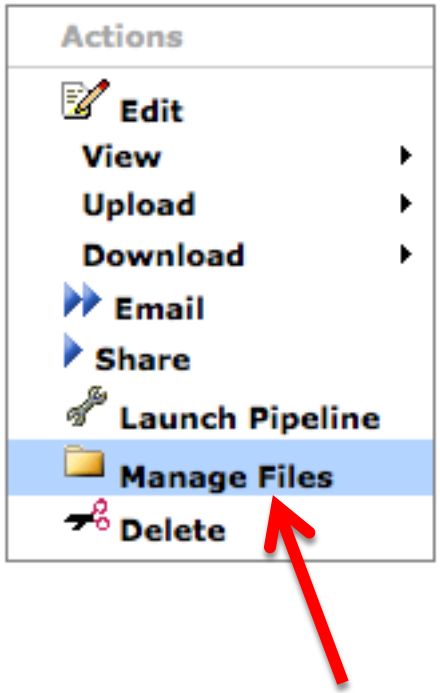
Step 4b: View Assessors

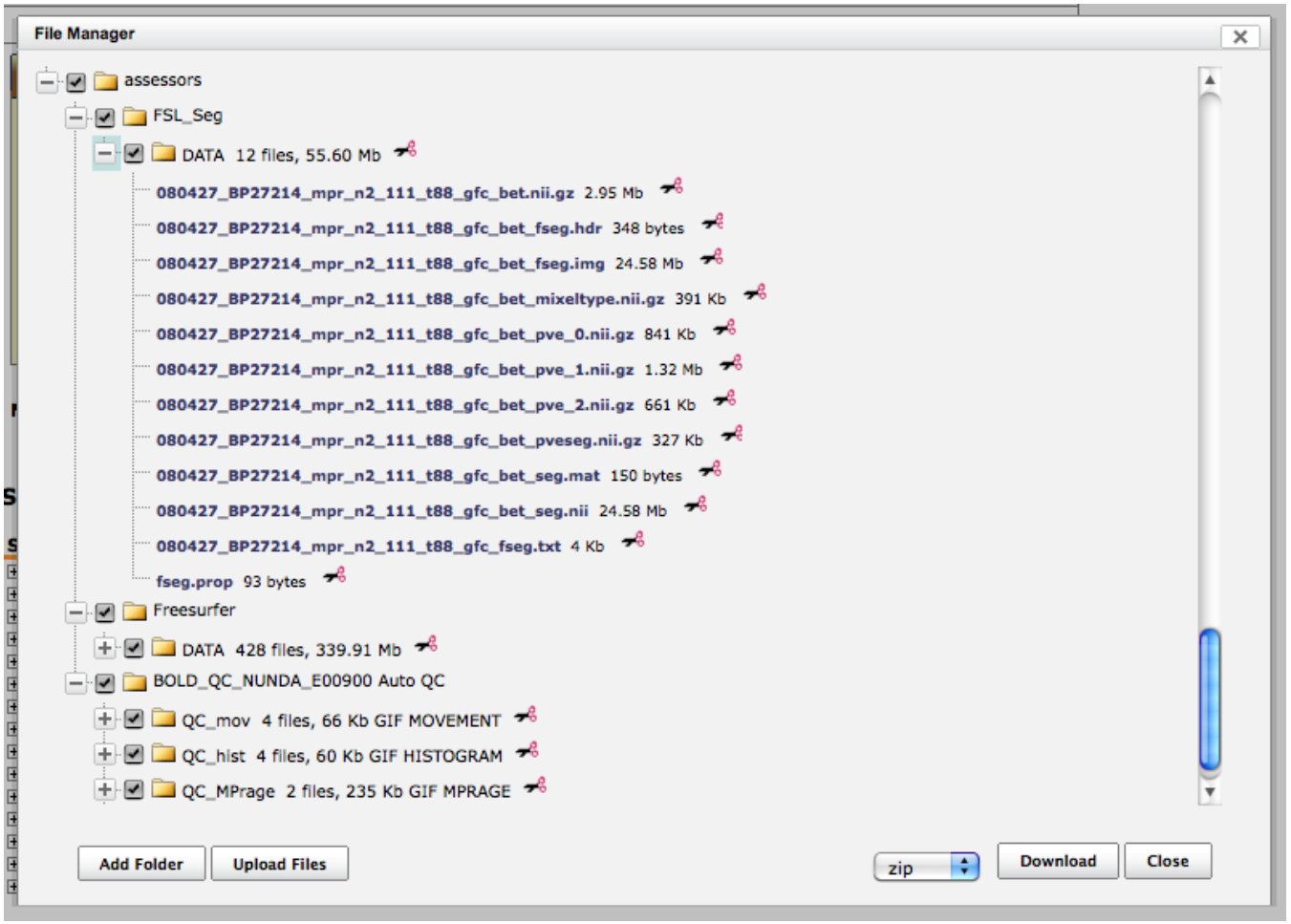
Assessments

Experiment	Label	Date	Project
FSL_Seg	FSEG_NUNDA_E00900	2011-11-23	Test Project
Freesurfer	FS_v5-1-0_NUNDA_E00900	2011-11-29	Test Project
Auto QC	BOLD_QC_NUNDA_E00900	2012-01-10	Test Project

Some pipelines output Assessors in addition to Reconstructions. You'll find these under the "Assessments" area of the MR Session report page, and clicking them will take you to an Assessor report page.







Or you can peruse the Assessors from the “Manage Files” section of the “Actions” menu.

NUND Live Demo

Kate Alpert

Future Directions

Where we are heading with NUNDA pipeline processing

Pipeline Release Date: May 1st

- While we have preliminary pipelines on NUNDA now, we're making some changes before we officially release the pipelines
  - Setting most preferences at the project-level as opposed to the session-level
  - Initializing the FreeSurfer Pipeline with DICOMs as well as reconstructed MPRAGE
- After we've implemented these changes, we plan to introduce the pipelines to the entire NUNDA community (Data Blitz / May 1st)

Automatic Pipeline Processing

- We are also hoping to implement an option for automatic pipeline processing by project
- NUNDA user would select "Run pipeline automatically on all sessions" within a project
  - All existing sessions and any sessions added after this point would automatically be run through the selected pipeline(s)
- Cron job would inspect the database for unprocessed sessions and shoot off pipelines as necessary
- ISSUE: we need all parameters to be set at the project level

New Pipelines

- We are excited to work with the NUNDA community to adapt processing streams into pipelines on NUNDA
- Request at NUNDA.Admin@northwestern.edu
- Register at https://nunda.northwestern.edu/