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Digital Imaging and Communications in Medicine

Analytic Workflow: From Images to Reports

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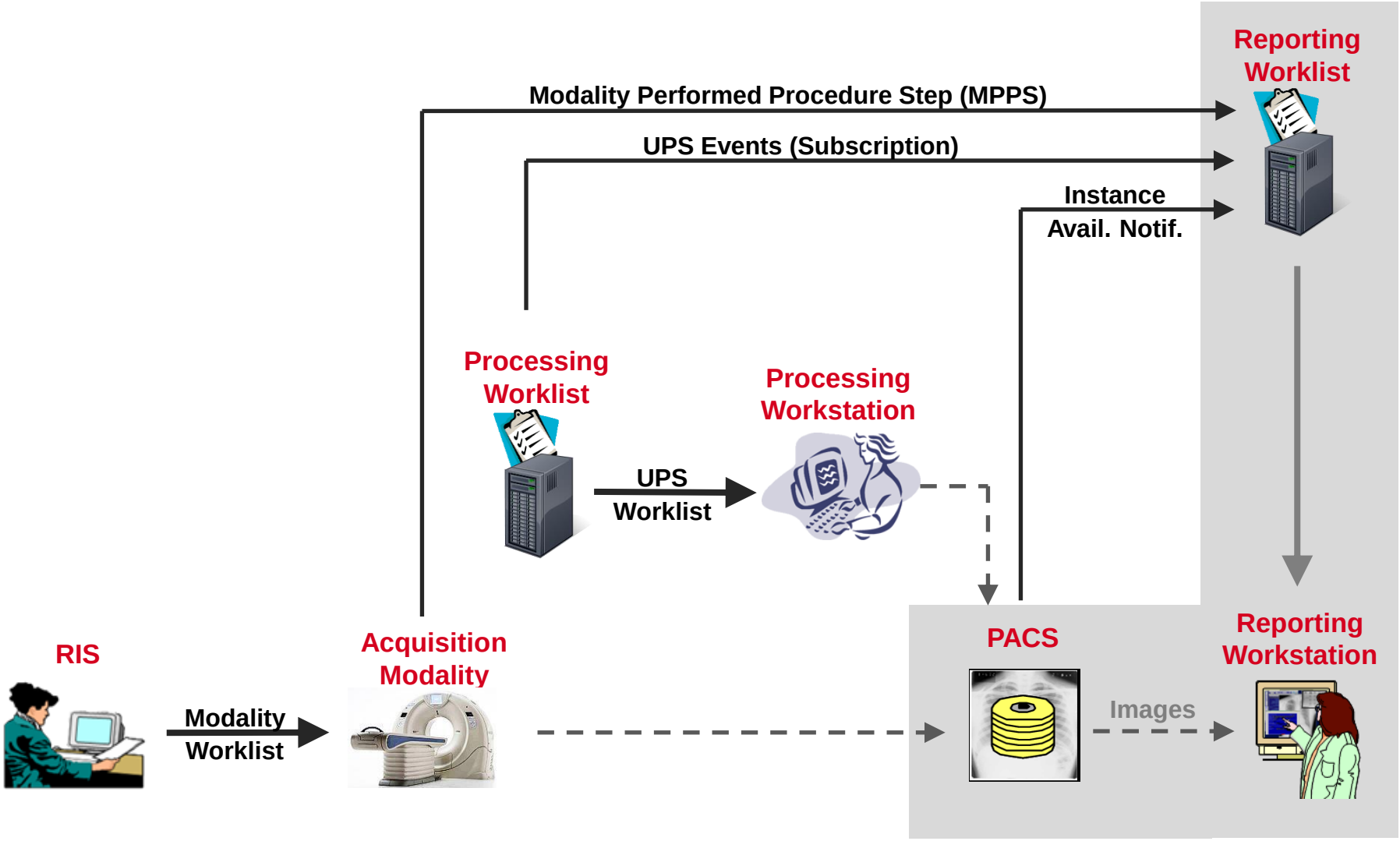
Leading Innovation

Dataflow & Workflow



“Post-Acquisition” Workflow

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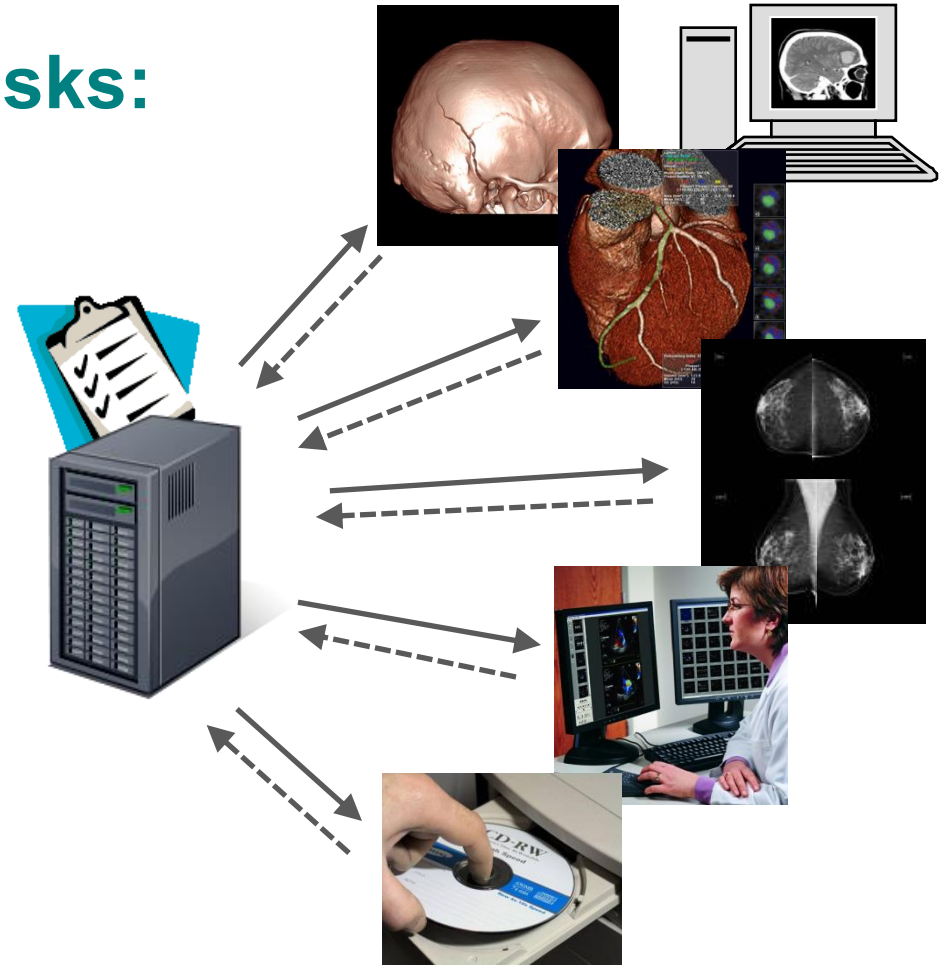
Example “Workitem” Tasks:

- 3D View Generation
- Computer Aided Detection
- Clinical Applications
- Pre-fetching
- Image Routing
- CD Burning
- Image Importing
- …



Unified Procedure Step (UPS)

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Add “Create Workitem” & “Push Workflow”

- Request another system to add item to worklist
- Replacement for implicit workflow (“push to a box and hope for the best”)

Simplify Implementation

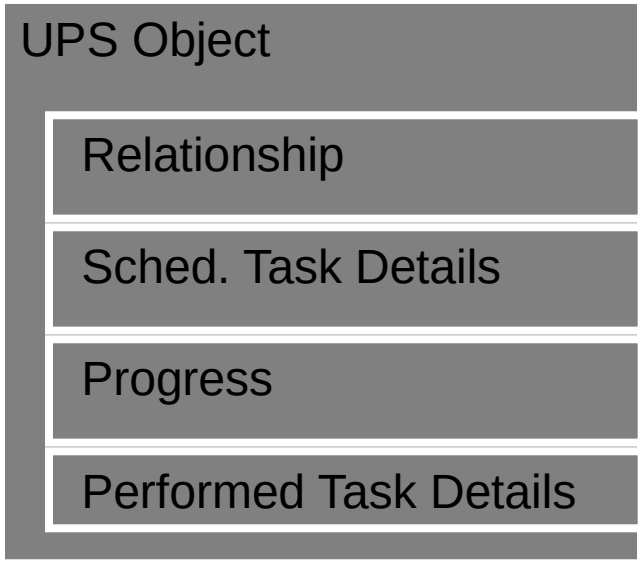
- GPWL had N:M relation of SPS:PPS
- State diagram was very complex

Add “Cancel Request”

Improve Status/Result Monitoring

- Getting PPS feed was awkward; required configuration and forwarding

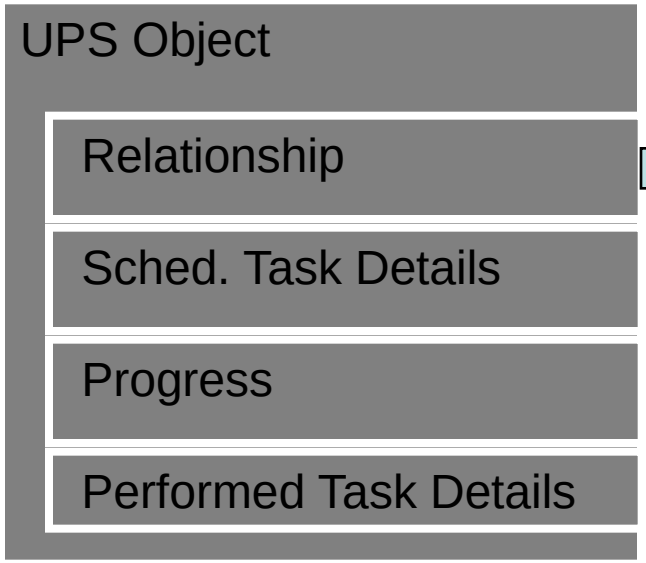
UPS Workitem Structure



A Workitem has its attributes grouped into 4 Modules:

(this does not affect processing;
just for logical organization)

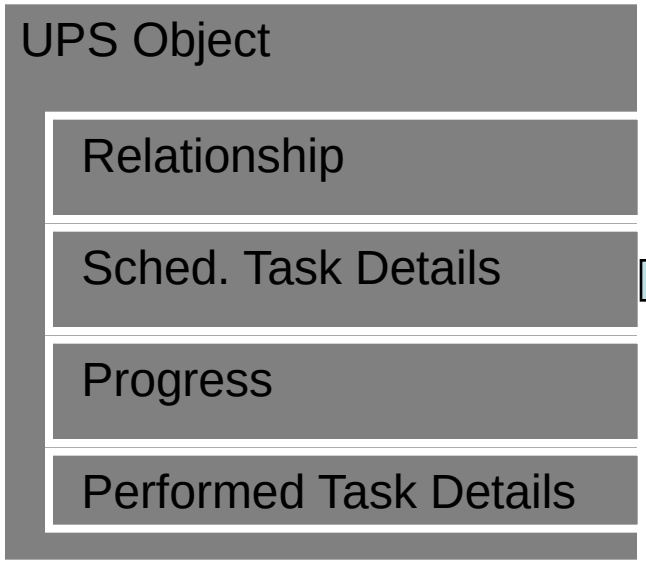
UPS Workitem Structure



Relationship Module

- Patient demographics
- Admission details
    - Order details
    - Requested Procedure
    - Accession #
    - Reason for Requested Procedure
    - Requesting physician/department
    - etc…

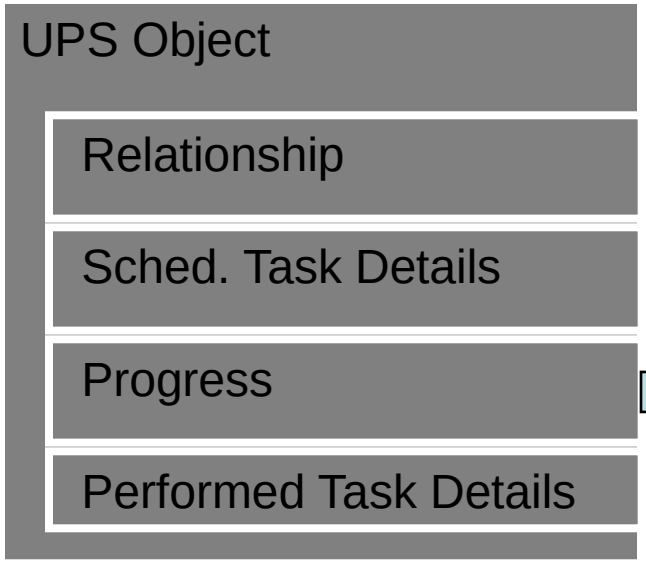
UPS Workitem Structure



Scheduled Proc. Info. Module

- Priority
- Requested perform/completion time
- Requested resources/location
- Requested Procedure descrip./codes
- Requested Processing parameters
- List of Input data IDs & Location
- Input Data Availability Flag
- etc…

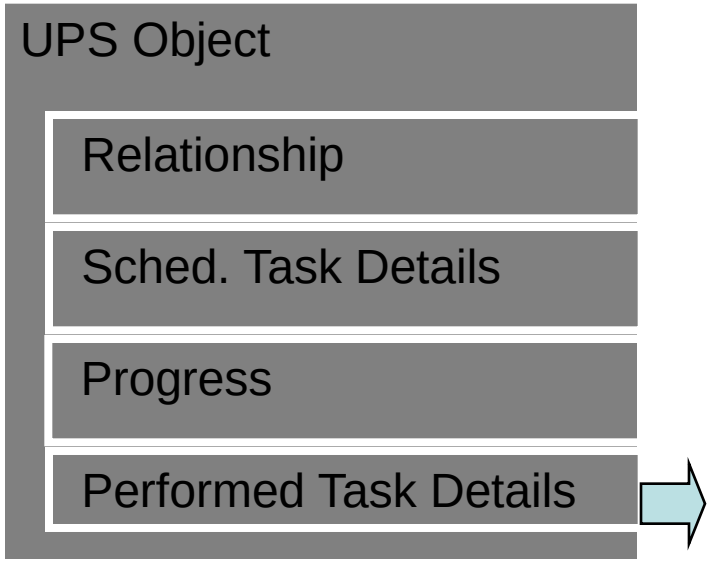
UPS Workitem Structure



Progress Module

- UPS State (Scheduled, In-Progress, Completed, Canceled)
- Progress Status – Numerical (e.g. % complete)
- Progress Status – Description (e.g. Annealing phase complete)
- Contact information for performer (e.g. phone #)
- etc…

UPS Workitem Structure



Performed Proc. Info. Module

- Time Performed/completed
- Performing resources/location
- Performed Procedure descrip./codes
- Performed Processing parameters
- List of Output data IDs & Location
- etc…

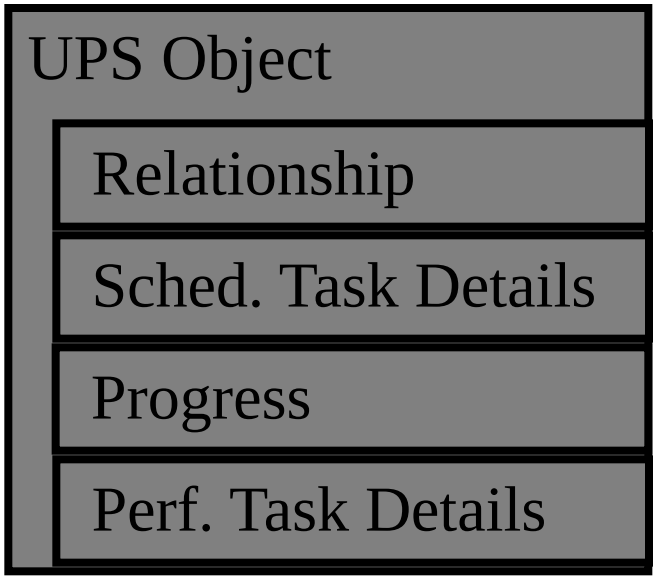
UPS SOP Classes

A UPS Object is managed by one SCP. (It doesn't move)

4 SOP Classes can be used to operate on a UPS object.

Each SOP Class supports a few related operations.

SCU/SCP not *required* to implement all the SOP Classes. Can implement SOP Classes based on the operations it needs.

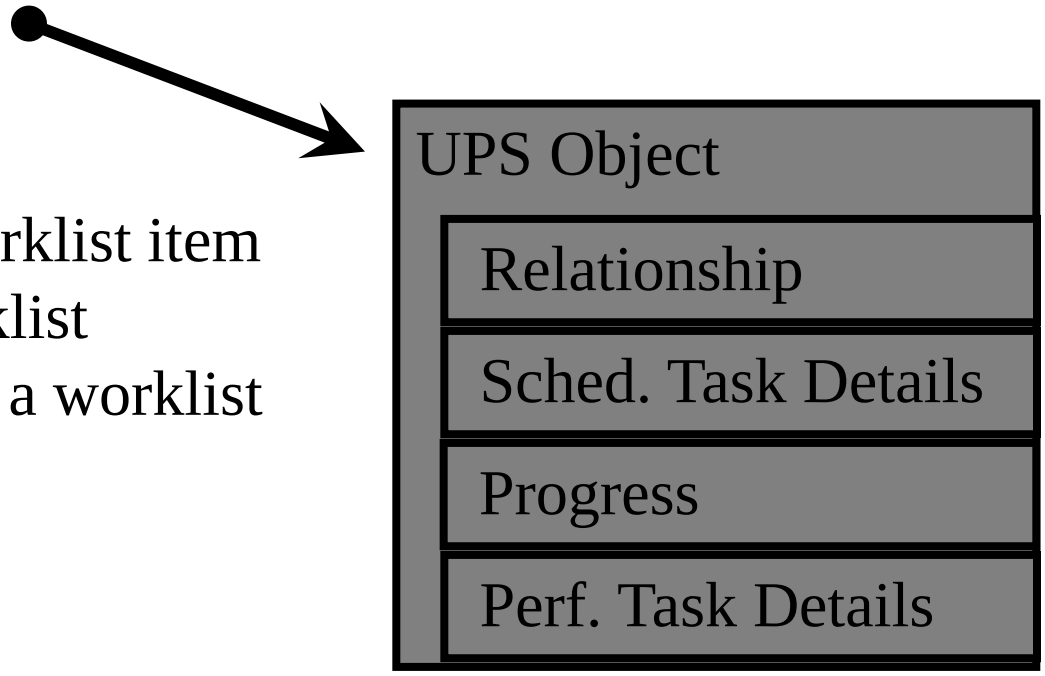


UPS SOP Classes

UPS Push SOP Class

allows SCU systems to:

* ***create (push)*** a new worklist item (i.e. instance) on a worklist
* ***request cancellation*** of a worklist item

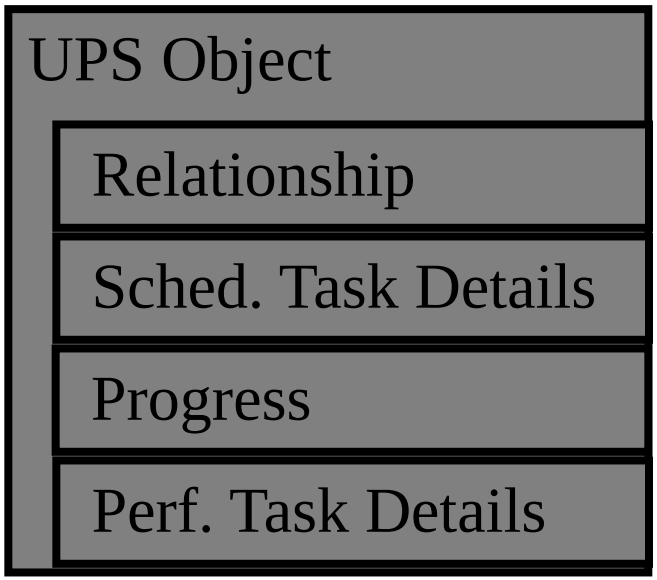


UPS SOP Classes

UPS Pull SOP Class

allows SCU systems to:

* ***query*** a worklist for matching items
* ***get details*** for a worklist item
* ***take ownership/control (pull)*** of a worklist item
* ***modify progress/status/result*** details for the worklist item
* ***finalize*** a controlled worklist item as Completed or Canceled.

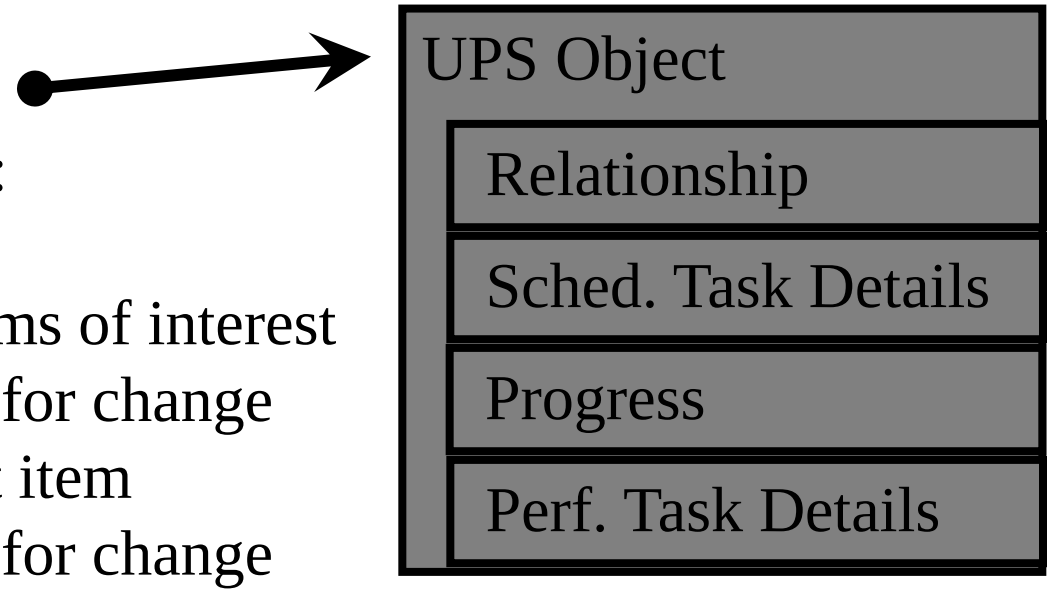


UPS SOP Classes

UPS Watch SOP Class

allows SCU systems to:

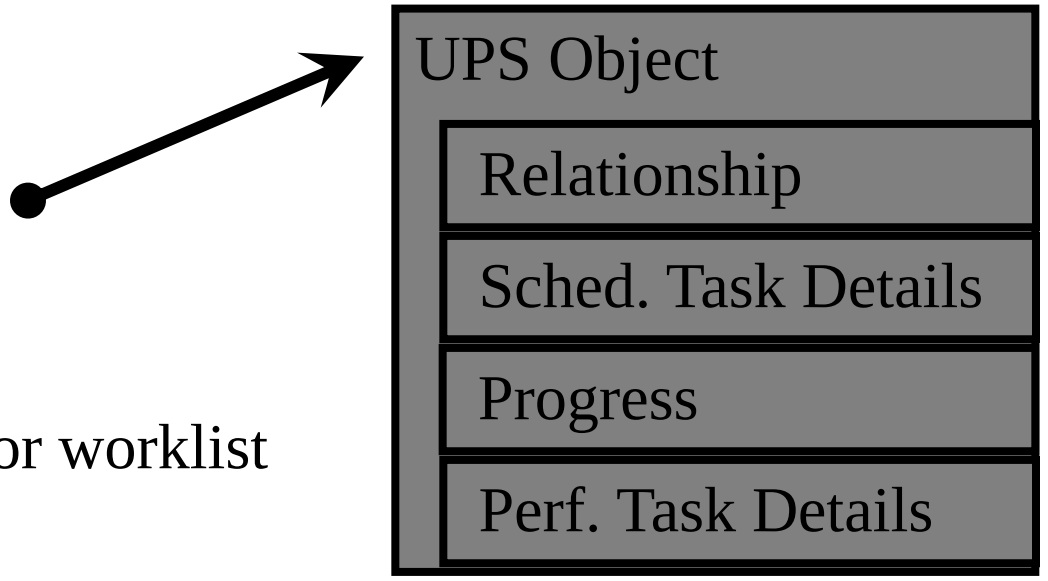
* ***query*** a worklist for items of interest
* ***subscribe/unsubscribe*** for change events for *one* worklist item
* ***subscribe/unsubscribe*** for change events for *all* worklist items
* ***get details*** for a worklist item
* ***request cancellation*** of a worklist item



UPS SOP Classes

<u>UPS Event SOP Class</u>
allows SCU systems to:

* ***<u>receive</u>*** change events for worklist items



UPS Interfaces: DIMSE and RESTful

DIMSE (Traditional DICOM Protocol)

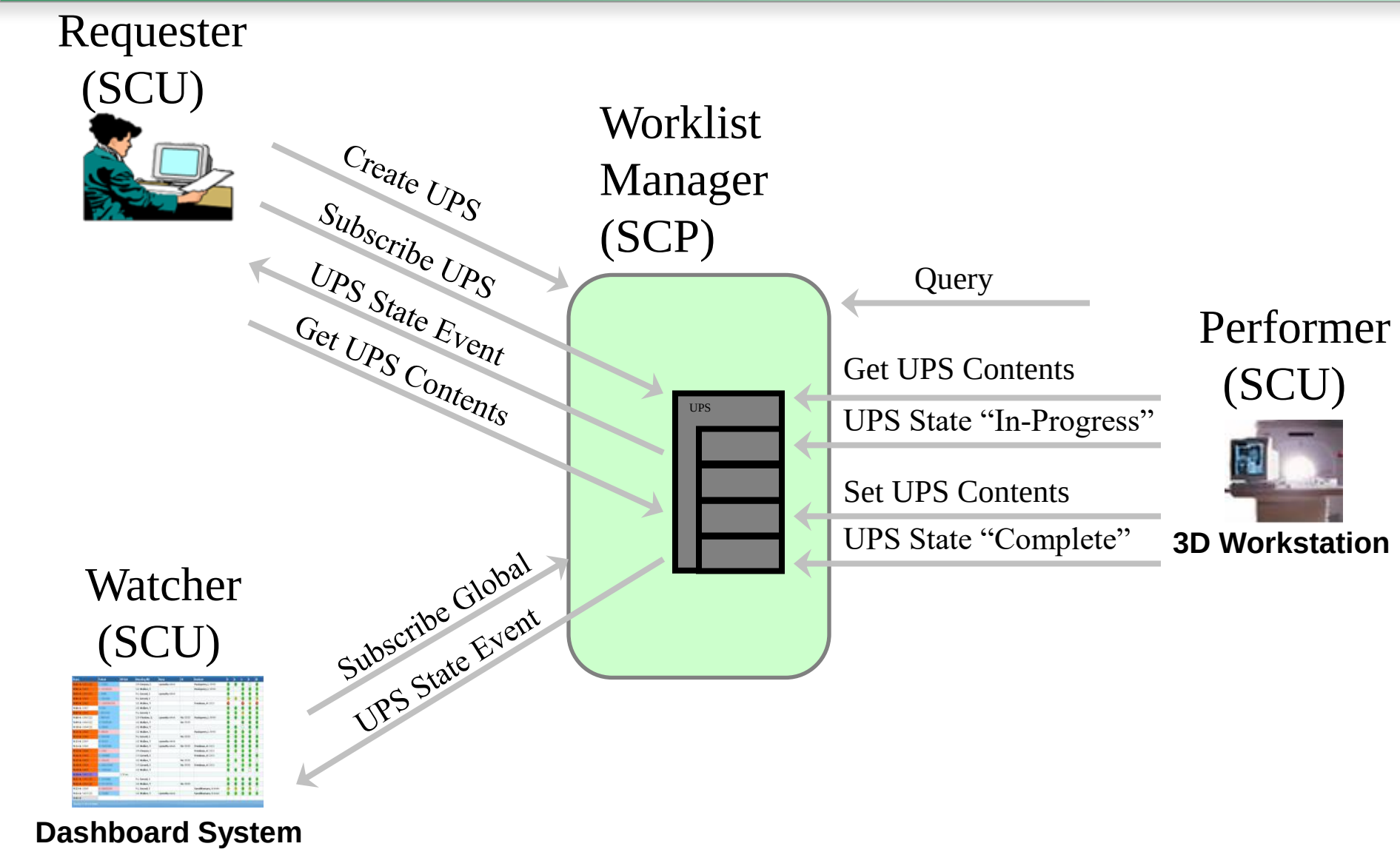
- Push/Pull/Watch/Event SOP Classes

RESTful (New Web Protocol)

- UPS-RS Supplement 171 (Public Comment)
- HTTP Interface to UPS Service
- Mostly Request/Response for each DIMSE message
- Uses WebSockets for Events

SCP can serve DIMSE clients & RESTful clients interacting with the same UPS workitems.

UPS Pull Workflow Example

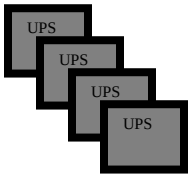


Pull Workflow

SCP

SCU

R I S



3D Workstation

Give me a list of tasks that need to be done
(C-FIND)

I will do that one
(N-ACTION Set to IN-PROGRESS)

Record these details in the UPS
(N-SET attribute values)

I am finished
(N-ACTION Set to COMPLETE)

Push Workflow

SCU

R I S

SCP

3D Workstation

UPS

Please perform this task
(N-CREATE with these attribute values)

Notify me about progress for that task
(N-ACTION Subscribe)

I have started to do that task
(N-EVENT it is IN-PROGRESS)

I have updated details in the UPS
(N-EVENT)

I am finished
(N-EVENT it is COMPLETE)

Give me the result details of the task
(N-GET these attribute values)

Watch Workflow

No central controller

- Workstation watches flow of N-EVENTs: "System X did A", "System Y did B"
- Workstation decides "Hmmm, I think I will do C"
- Workstation creates a UPS for itself
- Interested Subscribers are notified of Workstation activity via N-EVENT; N-GET details as needed

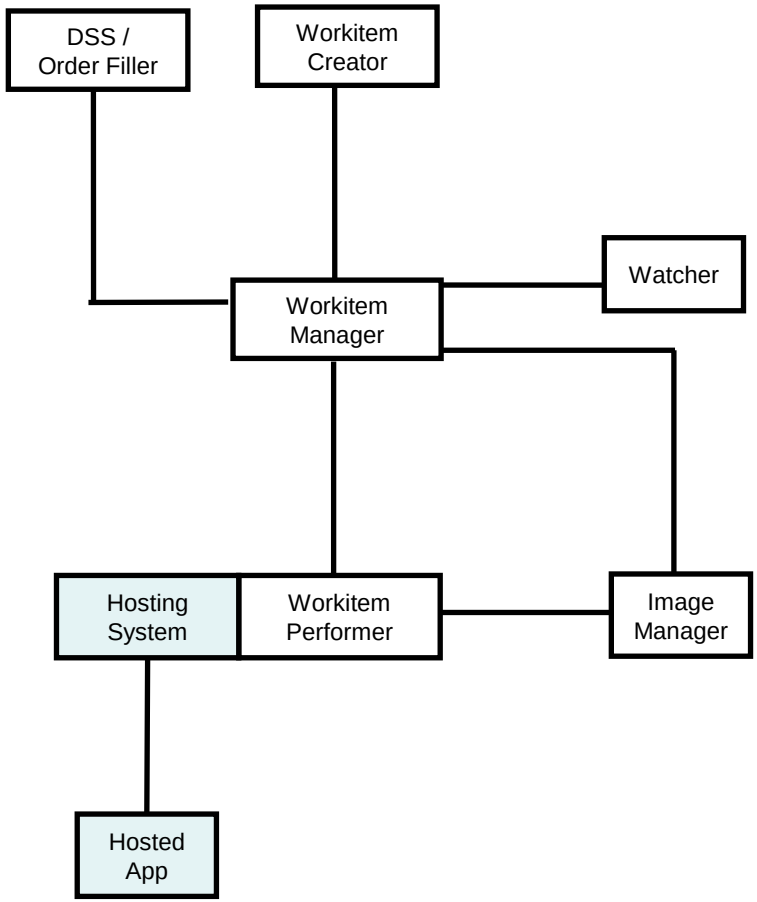
Similar to Ad hoc/Unscheduled Tasks

Examples:

- CAD workstation sees N-EVENT that Mammo Acq. is complete; decides to do CAD processing
- Reporting station sees N-EVENT that CAD is complete; decides to queue reading worklist for that study

IHE Post-Acquisition Workflow

- **IHE PAWF builds on DICOM UPS**
- **Essential Profile Features:**
  - **Worklist managed processing**
    - **Automated & manual**
  - **Progress notifications**
    - **Any interested system (RIS, Billing, Reading Worklist, Dashboard, Analytics)**
    - **Subscription-based**
  - **Cancelation requests**
    - **With reason & contact**
  - **Hosted applications ("DICOM plugins")**



DICOM Application Hosting

Separate the application from the infrastructure

- **Infrastructure (Hosting Systems) move and store data & results, and manage workflow**
- **Applications process and analyze that data, and provide results back to the infrastructure**

Minimize ‘reinvention of the wheel’.

(See DICOM PS3.19)

One App, Many Hosts

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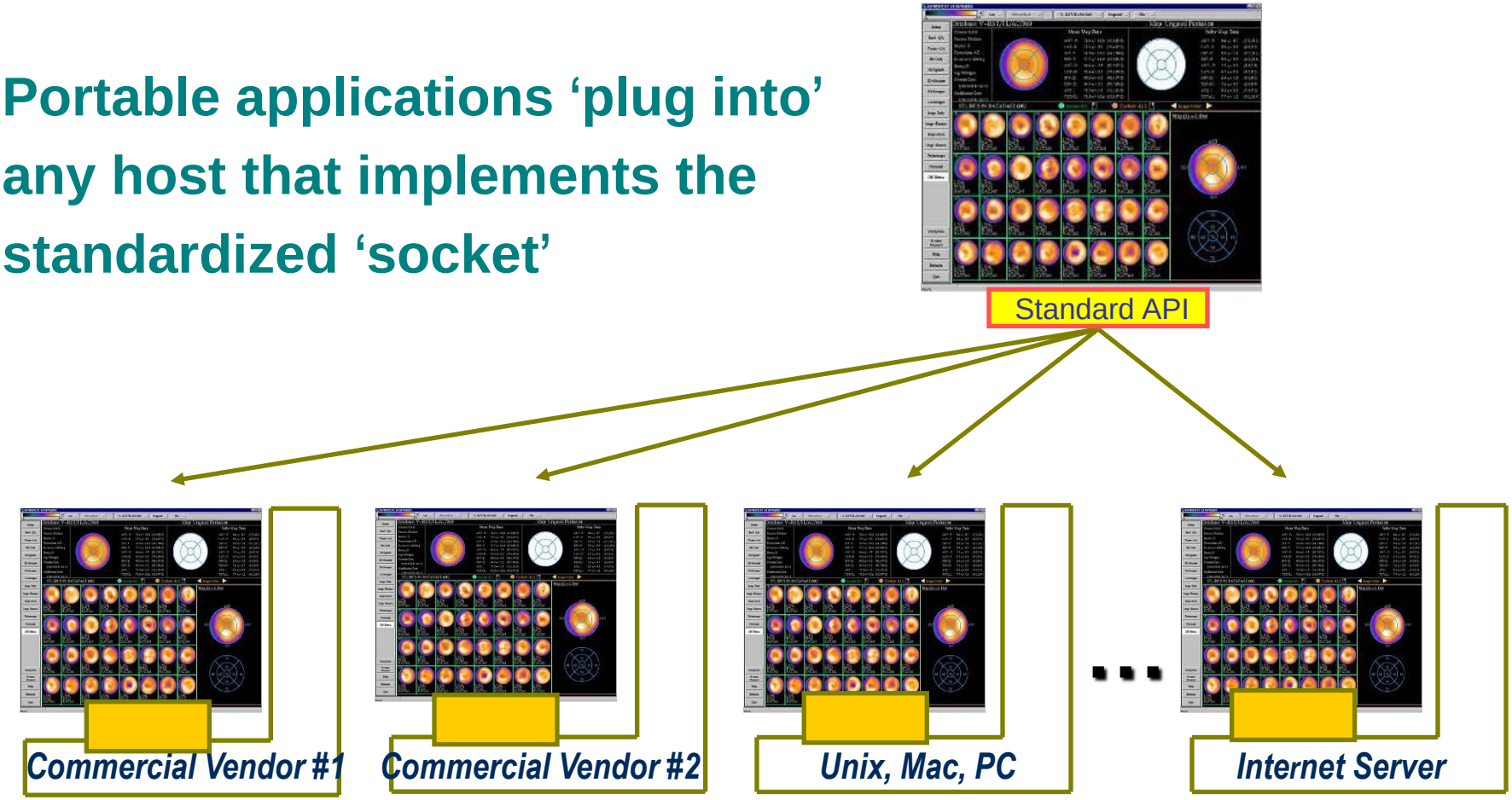
Portable applications 'plug into' any host that implements the standardized 'socket'



Benefits of Application Hosting

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Users
- **One workstation supports any needed functionality**
- **Mix and Match applications from multiple providers**

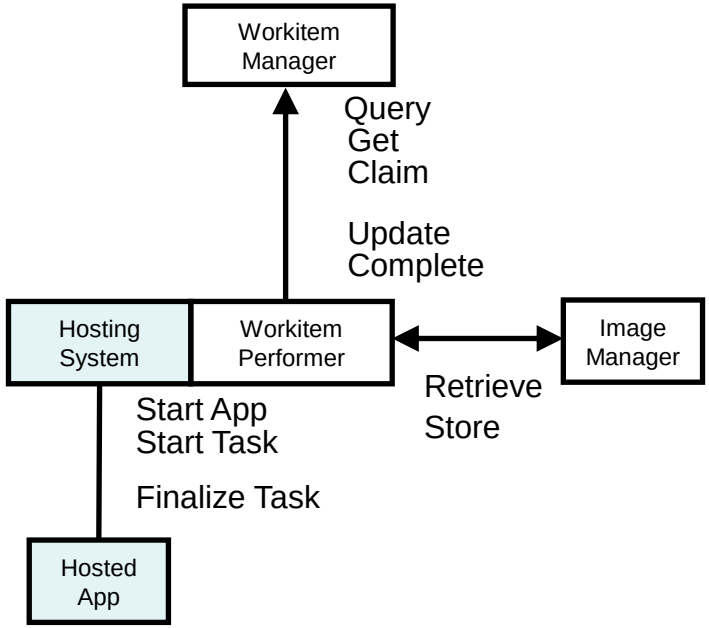
IT Administrators
- **Tired of changing infrastructure to accommodate new workstations simply to add functionality**

Application Developers
- **Don’t have to re-write applications for dozens of workstations in the market**

Workstation Vendors
- **Expand their list of offered applications without development effort**

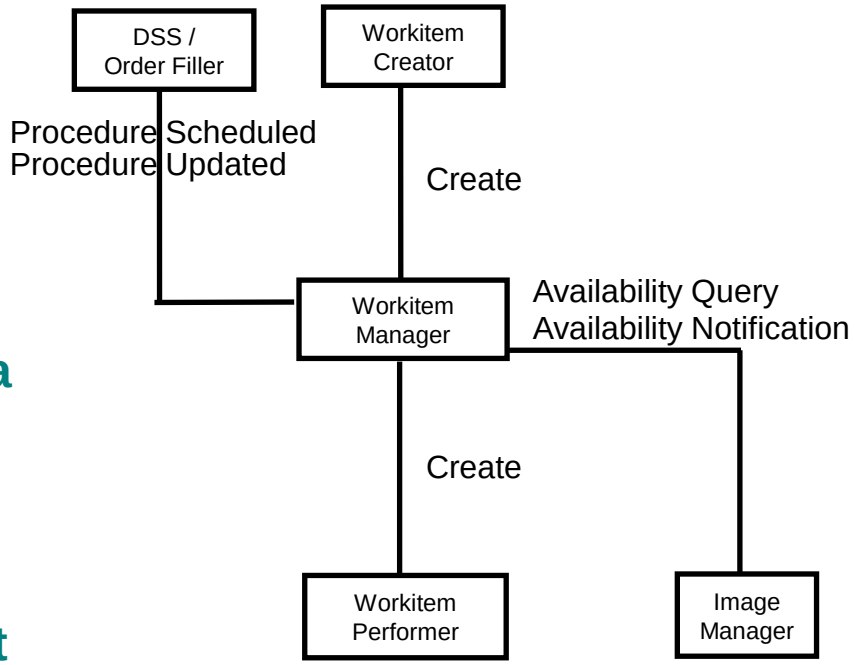
Perform UPS Workitems

- **Typical Pull Workflow**
  - **Query, Claim, Update, Complete**
- **Input / Output References**
  - **Local to Performer;**
    Local Image Manager;
    Other Image Manager
- **Hosted applications (plugins)**
  - **Performer may choose to be a Hosting System**
  - **Apps may be 3rd party**



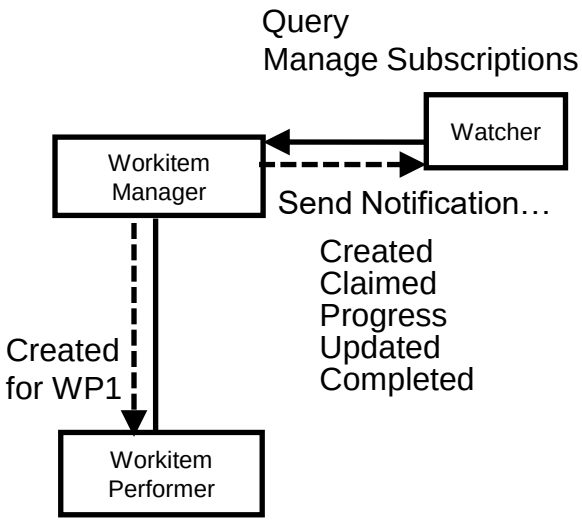
Create UPS Workitems

- **By Workitem Manager**
  - **Internal logic**
  - **Triggered by DSS/Order Filler scheduling**
  - **Triggered by Image Manager Data**
- **By Workitem Creator**
  - **Explicit create request**
  - **Can be grouped with any relevant system**
- **By Workitem Performer**
  - **Explicit create request**
  - **"Unscheduled"/Self-scheduled/Ad Hoc**



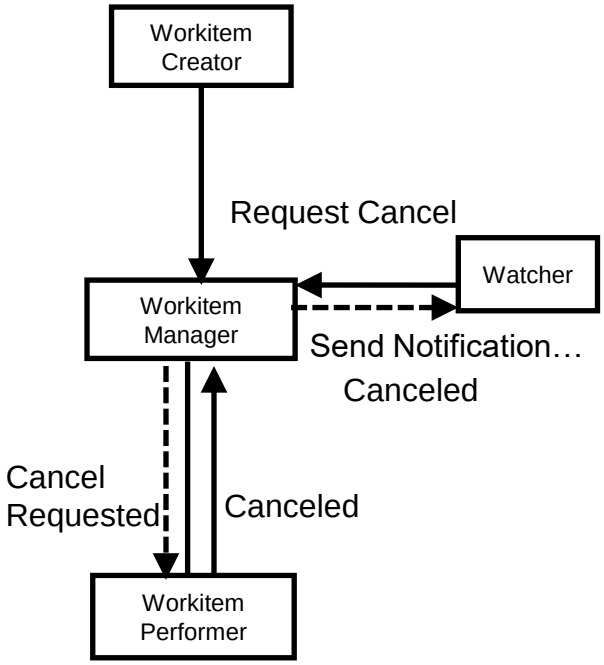
Monitor UPS Workitems

- **Subscribe / Unsubscribe**
  - **Globally or for Individual Workitems**
- **Applications/Usage**
  - **Schedule subsequent tasks**
  - **Report progress**
  - **Bill for performed tasks**
  - **Populate reading worklist**
  - **Drive dashboard**
  - **Analyze dept. performance**
  - **Claim assigned workitems**



Cancel UPS Workitems

- **Workitem Manager**
  - **Can directly cancel unclaimed workitems**
  - **Otherwise notifies Performer**
- **Workitem Performer**
  - **Cancels at its own discretion**
- **Watcher**
  - **Waits for Notification task was either Completed or Canceled**



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Applications

Scheduling Post-Processing

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Various co-existing patterns possible

Top-down

- Original order invokes full set of UPS
- E.g. Protocol code -> standard processing; dept. policy

Daisy chain

- Each step completion triggers next UPS
- Push, Pull & Watch variants

Ad Hoc Performance

- Performing system self-schedules own UPS
- E.g. human has initiated processing

Ad Hoc Request

- E.g. Radiologist decides additional work-up is required;
  Reporting system creates UPS

Feeding into Reporting

Notifications of processing tasks

- Both pre-planned and ad hoc
- Associate by accession #
- Can monitor UPS creation and completion

Processing outputs = Reporting inputs

- Full set of instances is identified
- Storage/retrieval location identified
- Input Readiness State flag

Billing for Post-processing

Billing System = Watcher

- Notifications of processing tasks
- What has (actually) been performed
- What has been canceled
- When was it done
- Linked to patient ID & accession #
- Who ordered it

UPS for Reporting Workflow

Possible future Profile

Same worklist model as post-processing

- Scheduled tasks
- Relationship to Patient, Order, Workflow
- Lists of inputs and outputs
- Progress/completion notifications

Linkages between post-acquisition and reporting

- Less falls through cracks
- Record of reported instances
- New data can result in notification to radiologist or scheduling of new reporting task

References

dicom.nema.org -> The DICOM Standard

- Part 4, Annex CC
- Part 3, C.30
- Part 17, Annex BBB

www.ihe.net -> Technical Frameworks

- (Supplement) Scheduled Workflow.b
- (Supplement) Post-Acquisition Workflow
- and many more…

UPS Deletion Locks

Reliable Watcher (SCU)

- **Problem: SCP might delete a completed UPS before SCU gets needed details**
- **(e.g. due to Network latency or outage)**
- **Missing a UPS could prevent Watcher from:**
  - monitoring completion
  - extracting details
  - creating subsequent UPS Instances,
  - referencing UPS 1 outputs as UPS 2 inputs

Mechanism

- **SCU Sets a Deletion Lock flag during subscription**
- **SCP can't delete UPS with outstanding Deletion Locks**
- **SCU removes Deletion Lock after retrieving final state of UPS**
- **SCP free to delete UPS after all deletion locks removed**
- **SCP documents how it handles orphans**

SWIM

UPS are transient but can be locked/logged

- Time scheduled
- Time started
- Time completed
- Even intermediate progress for some tasks

Track various activities

- Image import, special reconstructions, automated processing, QC, image export

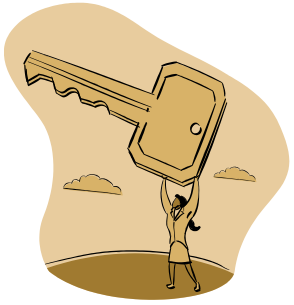
UPS Re-Assignment

If you've put it In-progress

- Cancel your workitem &
- Create a replacement workitem (copy the details from the original)

Alternatively (trickier)

- Communicate the Transaction ID ("secret key") to the system that is taking over.



UPS Profiling

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Use cases will drive configuration parameters

- **Codes for work tasks (RadLex, DICOM, Site, …)**
- **Object types to be provided as input and as output**
- **Names of worklists managed by worklist manager**

***Profiling* = Use case driven specification of use of standards**

- **First example is Radiotherapy, DICOM Part 17 Annex BBB**

Deployment

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Supported in some toolkits & open source

Radiotherapy

- **Incorporated in IHE RO Profiles**
- **Released in Products (see IHE Integration Statements)**

Radiology