There are four areas that would not necessarily be at the top of the list, but are areas where I think physicists can make contributions. These have to do with terminology, workflow, network architecture, and strategies for storage. With respect to terminology, radiology has evolved a standardized lexicon of terms to describe the body parts and procedures used in medical imaging examinations. An excellent reference for these terms is DICOM part 16 titled "Content Mapping Resource". This part has now over 300 pages and contains numerous tables defining important lexicon terms. These are referred to as context ID tables. Context ID 4 includes anatomic region terms where code values are identified in addition to code meanings. Context ID 4009 contains anatomy terms specific to digital radiography and specific to the DX object type. On the left column, the source of the terms, SNM3, is identified in these tables. In the case of the DX terms,

the view terms are also delineated with commonly recognized terms such as lateral oblique, medial oblique,as well as eponymous names. These are terms derived from person names where we recognize such things as Grashey for the shoulder view, Merchant for the knee view, and Towne for a particular view of the cranium. Terms are included that are specific to special imaging procedures, this being Ultrasound Beam Path. This being the isotopes used in radiopharmaceuticals. A separate context ID defines the pharmaceutical names. Tables are also included to define terms associated with interpretations. These are terms describing calcification types that are taking from the BIRADS documents where calcifications are described as eggshell calcification, punctate calcification and so on. Obviously, in each of these, I've selected only a very few entries. This last one has to do with abnormal findings in thoracic radiology.

Honeycomb pattern and Kerley B-line terms are common in chest x-ray interpretations. Part 16 includes terms that are derived from a multitude of sources. One of the most important sources is the Systematized NOmenclature of MEDicine clinical terms, referred to as SNOWMED. DICOM incorporates, under a license, the 1999 version from the College of American of Pathologists. BIRADS, as I noted, is included. In particular, terms from addendum 3.1 of the third addition of BIRADS. This is copyrighted by the American College of Radiology. In the case of the chest terms, the well recognized textbook by Frazier and Pare is used. Specific tables in that text book have terms used in chest radiology and terms used for CT of the lungs. The last that I'll note are certain ACR standards. The 'Performance of Pediatric and Adult Chest Radiography' includes terms as a part of the ACR standard, and the 'Performance of CT for the

Detection of Pulmonary Embolism in Adults'. So part 16 should be looked at as a collection of important terms and is therefore an important document in radiology. This use of consistent terminology within a department in a medical center allows studies to be accessed based on database entries that are derived from the DICOM object. The newer DICOM objects require the code value in addition to the meaning or description for terms associated with a context ID. The availability of these codes within the DICOM objects greatly facilitates database management where most database applications are going to be derived out of table driven code values. However, the persistence of older DICOM objects, a point that Donald Peck discussed, does in this particular case prevent the use of standard terminology because very few of these older objects were created at a time when part 16 existed. In our own center we use a work around for

the absence of these terms within the DICOM objects. When an imaging study is received by the

PACS archive the session number in the DICOM object is used along with a RIS orders table to match the incoming images with the order from the RIS system. Our order name, or pnemonic, for a radiograph of the orbits is ORBITS. Using a separate table (we refer to it as BMW table in that it's a table of body parts, modalities and work groups) we associate with that imaging study, the term ORBIT for the body part, CR for modality, and NEURO for the work group. If the images happen to be coming in with an ordered mnemonic of CTORBW, the W for with contrast, we would associate the same body part, and MRORBW again would have the same body part. And so, the PACS system now can access all orbit studies on a particular patient to identify of studies irrespective of the modality. Of course, the terms that we use in the BMW table are derived specifically to have a relationship to the part 16 table. Let me turn to workflow

improvements. Information technologies do offer opportunities to alter the work processes used in radiology and improve productivity. For a physicist to be involved in these areas, one needs to have some appreciation for the informatic processes in place and the technological opportunities that one has to intervene and produce change in those processes. Looked at macroscopically, diagnostic radiology practice involves the relatively small number of relatively well understood meta-processes: ordering, scheduling, examining, creating image records, interpreting the records, and reporting the records. A variety of players, as listed on the left, are involved in these Meta processes as are a variety of objects. In the case of electronics systems, the objects are computer files holding images, reports or other values. IHE defines specific profiles for improving workflow by integrating image and information systems in radiology.

These profiles may have to do with acquisition, such as the scheduled workflow or consistent presentation profiles. They may have to do with the access to images, or may have to do with the final reporting processes, including billing, such as the charge posting profile. These IHE profiles are presently important. The integrating healthcare enterprise is where the IHE acronym is derived . It is an initiative which defines consensus effort and framework for integrating information systems in a healthcare environment. It is a joint effort of RSNA and HIMSS that has accomplished its objectives by demonstrations run at the annual meetings of the RSNA and HIMSS since 2000.In the context of the RIS PACS system at Henry Ford Hospital, Henry Ford Health System, the modality communication of processes that we currently have in place are the modality work list and the image delivery processes. All of our modalities, there are

approximately 90, do use the modality work list processes. I want to make one additional comment, in addition to what prior speakers have commented, and then discuss the communication processes that we're looking to support which have to do with perform procedures and key image notes. With respect to modality work list I do want to note that there are two options with respect to workflow that are important. One has been referred to as a patient oriented query. We currently use this workflow mechanism where either the accession number or the MRN is sent on a case by case basis to the RIS system to retrieve the further information about name and procedure. The alternative that Rick referred to would be a work list oriented query where all patients within a matching range of the key entries, usually a date range and a scheduled station identification or AE title, are returned and the technologist selects

from that list. Understanding the manner in which you're implementing a workflow is one of the

first steps in addressing that issue within a department. With respect to perform procedure step (PPS) this is a modality to RIS transaction, not a modality to PACS transaction. The two important components of it are procedure step in progress and procedure step completed. These are opportunities to eliminate a technologist going to a RIS station to notify the RIS system that they have started a procedure or that the procedure has been completed. The DICOM key object selection document is important with respect to the IHE key image note (KIN) profile. It is a modality to PACS transaction. The example I have noted here is one that I observed in which a technologist needed to attach a note to a chest two view study indicating that the patient had an amputated arm and the stub appears in the lateral view. This created an unusual appearance. There is a need for a technologist to communicate that to the radiologist. In the film screen environment this would have been done by a sticky note. This electronic version is often

referred to as the sticky note profile. In our department, the HIS communication are added to this chart where on the upper right we receive demographic information from our HIS system through what's commonly referred to as the ADT/HL7 feed. ADT is the admission discharge transaction, but is common to inpatients and outpatients. We also return reports to the HIS for the electronic medical record and that also is through the HL7 communication that Rick discussed. On the left we make available images from the RIS PACS system to a large number of clinical HIS stations. These, in this case, are done through a proprietary web delivery integrated with the HIS application. There are some emerging standard methods for this type of delivery, but for the most part many of these are delivered now through proprietary methodologies. In this chart, I've added on the right the important communication processes to

the radiologist where their work stations are obtaining lists of examinations associated with particular filters, and are receiving the images that they're requesting for studies they're looking to open, and returning the voice recognition reports to the RIS PACS system. We currently do our order and completion in our department through RIS stations. The very thing that I indicated we are looking to eliminate. That elimination would involve the modalities down on the bottom issuing the complete statement to the RIS PACS. Additionally, as is the case with many centers, we're looking to involve the HIS stations in the order entry process to make them more proactive in the ordering process. My third item has to do with <u>network</u> architecture. I recognize there are some abrupt shifts in topics as I go through these four areas. Here we want to consider the design and performance of computer networks and understand how dramatically that has

changed over the last ten years. Gartner well known analyst group recently published ten predictions that will impact enterprise businesses. At the top of their list was that bandwidth will be more cost effective then computing. They indicate that network capacity will increase faster then computing memory and storage capacity to produce a major shift in the relative costs of remote versus local computing. Cheap and plentiful bandwidth will catalyze a move towards more centralized network services using grid computing models and thin clients. This has catalyzed a change in the architecture of PACS systems, with newer systems using centralized archive and data base installations that acquire images from multiple locations and distribute images to multiple locations. We use such architecture and rely on a high speed wide area network using synchronous optical network or SONET services that are provided through local

communications providers in our region of Michigan. These rely on OC3 150 megabit per second services for which we use 100 megabits exclusively for the PACS system. We have around eight key facilities in the architecture of this wide area network. At the bottom, the main campus holds the database and archive. At the upper left, WBL is our West Bloomfield remote clinic, or suburban clinic facility, about 20 miles from downtown. If that direct line is interrupted for any reason we have available a line going up to the top to our corporate IT center and back down to the left to the West Bloomfield area. So by this interconnected mesh within the city we provide both high speed service as well as highly reliable service with redundant connections.Throughout those regions is an array of processors, with the PACS system now becoming rather amorphous. Out in the regions, devices are doing the DICOM reception at the

region, converting the images to compressed coefficients, and then moving them through cache units until they finally hit the final server or storage server in the downtown location at the right. At any moment in time, particularly for a new study, when images are retrieved they may in fact come from the distributed cache servers rather than the downtown storage server. For the suburban connections, the OC3 optical lines come in through the building conversion units, labeled S for the multi service switch, and then into routers that connect directly to the PACS switch unit and provide either 100 megabit/s or 1 gigabit/s service to the radiology devices. Our main campus becomes somewhat more complicated in that the router connects to two radiology routing units and each switch has redundant optical connections to those routers. In such a complex interconnected system it becomes very important to introduce active monitoring

processes and this, I think, in particular is an area where a physicist can become involved. SNMP, an FLA that I'm not sure Rick had in his list, stands for Simple Network Management Protocol. It is commonly supported in both network and computer server devices. It does enable administrators to manage performance, find, and solve problems as well as plan for future growth. I've illustrated at the bottom the network traffic for a 24 hour period from last Friday at the main radiology switch at Michigan State University, where the traffic level is averaged over five minute intervals. This is provided through the MRTG, or Multi Router Traffic Graph, application, which is a public domain and widely used application. I use this because, in this particular case, MSU lets anyone around the world see on any given day what their network is doing.In case you think that this is getting far from what a physicist should know, I point out this

article that was in Physical Review Letters where Argollo recently evaluated internet traffic dynamics in relations to other natural processes to demonstrate a unique scaling law that relates fluctuations to average flux. Here he has used the MRTG application to illustrate in figure one the internet traffic for four devices having different mean and standard deviation values. In this work he points out that the scaling relationship between noise and mean flow are the same as they are for the stream flow in rivers surveyed by the US Geologic survey, and in fact for other natural phenomena. A very fascinating paper and short if you should be inclined to take a look at that. Before I leave network monitoring, I think it's important to note that the network needs to be understood in terms of the final application, where one needs to look at how long it takes to get images from the modalities into the archive, and from the archive to the workstation. In our

case, for areas where we have radiology workstations, our monitors run between about 7-9

megabytes per second. That's in a byte unit, and means that for a typical CR it's about a half second delivery to the work station, which in reviewing cases is a delay that is unnoticed. At the three areas on the bottom, where we do not have radiologists reading at those locations, we use reduced bandwidth with about a 12-13 second time to deliver the acquired images to the archive. Finally, I'll very briefly comment on storage technology, where similarly rapid change in the design and performance of storage devices impacts our approach to long term archival.This graph I got from IBM about three years ago. It impressed me with respect to the persistent decline in the price per megabyte for both disk storage and memory storage. The rate averages about ½ per year. Down at the bottom, when I first used this at RSNA, I checked the price for IDE and SCSI devices and plotted these on the graph. They fit very nicely. For this presentation, I checked a week ago some pricing and sure enough for both the IDE and SCSI devices they fall

in a consistent position on this graph. so the rule of thumb that storage is going to decrease by ½ per year is one that, in general, can be relied on. Importantly the current pricing structure would indicate to any facility that there is essentially no role for CD or jukebox type of storage and most systems now are using entirely magnetic spinning disk storage. There has been similar improvement in computer performance. Several years ago, I used this example between 1982 and 2002 where the performance of a computer popular at that time and a current computer improves by 900 times with respect to CPU, 250 times with respect to memory, and 500 times with respect to storage, and all of that for 1/30th of the cost. Moravic just up the road at Carnegie Mellon produced this somewhat entertaining graph showing the evolution [of computer power] since the early part of the century and again shows this consistent improvement, this case in

terms of MIPS per 100 thousand dollars. Going back to Gartner, amongst the Gartner predictions were that Moore's law would continue to hold true through this decade. Moore's law being that which says that CPU power will double every 24 months. They further suggest that in 2008 the typical computer will have 4-8 processors running at 40 gigahertz, 4-12 gigabit of RAM, 1.5 terabytes of storage and by 2011 would have 6 terabytes of storage. So going back to what Rick said, in seven years from this summer we would expect the average desktop to be able to service a years PACS at the typical institution. Very interesting thought! I'm going to skip this, but it is another Gartner comment suggesting that IT is going to move back to what they call business units, what we would think of as departments, and we have seen this swing already with a decentralizing of IT services. I'll finish with a comment with respect to technology change. I

think that the continuous rapid improvement in price performance makes the computer technology areas, and the RIS-PACS areas we're speaking of, markedly different then other technologies. I don't think they are areas we should be awed by. We should not be awed by the fact a desktop in 2011 will service all RIS PACS needs. Rather these are extremely reliable trends. They've held true and there's every reason to believe they will hold true. So I think in every center somebody needs to be proactive in helping develop strategic plans that can take advantage of these changes.Thank you.