RADIOLOGICAL SERVICE TRAINING INSTITUTE

Introduction to Servicing Cardiovascular & Interventional Radiology Systems



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Intro to Servicing Cardio & IVR

- What is IVR?
- Types of procedures
- Who?
- System Fundamentals
  - Exam Room
  - Control Room
  - Equipment Room
- Service Challenges

Intro to Servicing Cardio & IVR

- Fun Facts:
  - A normal heart valve is about the size of a quarter
  - The first heart pacemakers had to be plugged into a wall socket
  - Your heart is about the size of your two hands clasped together
  - Your heart beats an average of 100,000 times a day
    - 2.5 billion times in the average lifespan
  - The heart pumps blood through >60,000 miles of blood vessels
    - Earth circumference 24,901 miles at equator

What is IVR?

- IVR – Interventional Radiology
  - Minimally invasive (non-surgical) image guided procedures
  - (2) main objectives:
    1. Diagnostic: Identify the cause of an illness or disorder
    2. Therapeutic/Intervention: Provide treatment of an illness or disorder
  - Includes vascular & non-vascular procedures
  - Less risk/pain/recovery than open surgery

What is IVR?

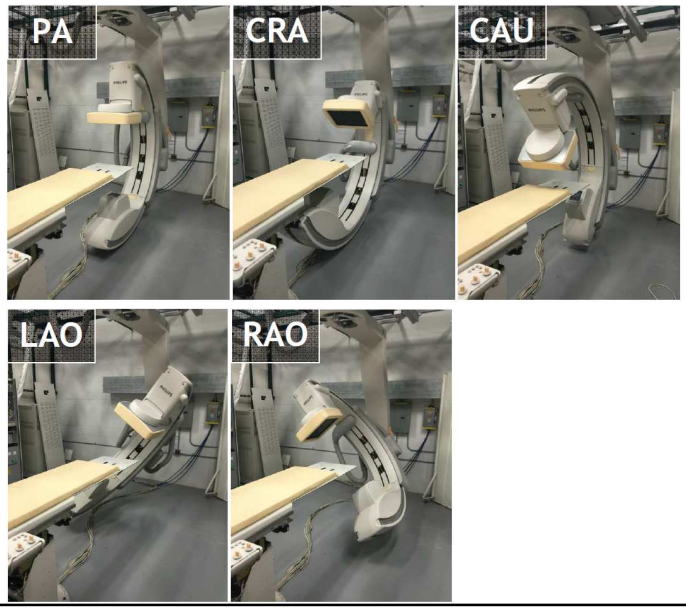
- IVR systems (Cardiac & Angiography) are similar to traditional fluoroscopy systems, but with procedure-specific design features that allow for imaging from various angles

What is IVR?



What is IVR?

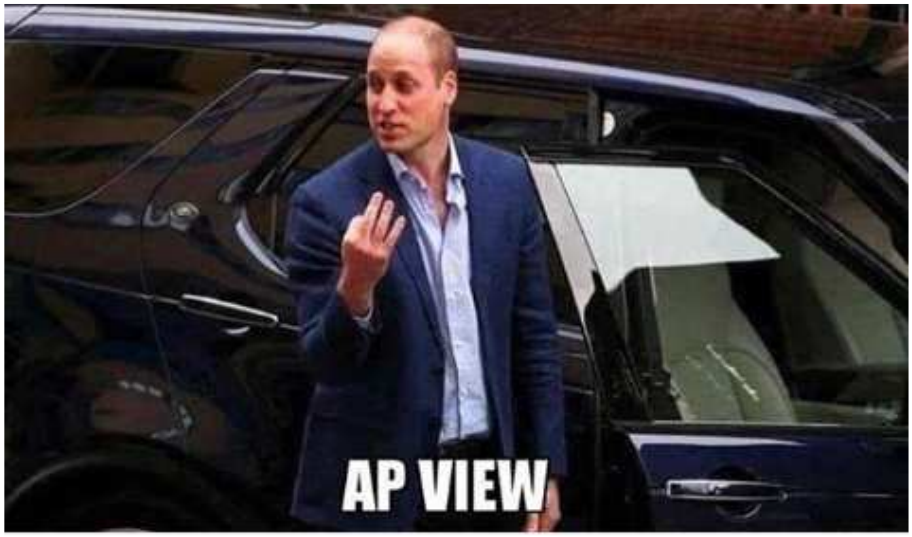
- Views



What is IVR?



What is IVR?



IVR Procedures

- Types of procedures, based on objectives:
  - Diagnostic: Identify the cause of an illness or disorder
  - Therapeutic/Intervention: Provide treatment of an illness or disorder

IVR Procedures

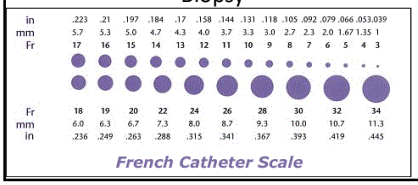
- Types of procedures, based on objectives:
  - Diagnostic: Identify the cause of an illness or disorder
    - Vascular (w/in the vascular system)
      - Angiography & Cardiac
    - Non-Vascular (Outside of the vascular system)
      - Urinary system
      - Bile ducts
      - Abscess drainages

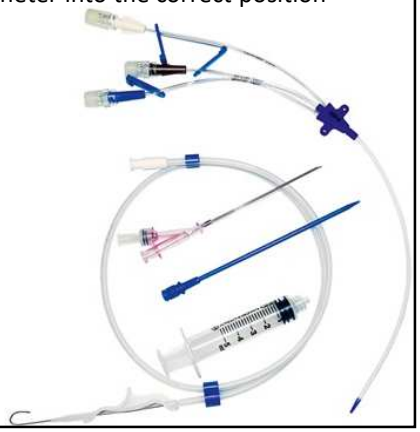
IVR Procedures

- Types of procedures, based on objectives:
  - Therapeutic/Intervention: Provide treatment of an illness or disorder
    - Balloon angioplasty & stent (Restore blood flow)
    - Deliver medication (treat or cut off blood flow)
    - Pacemaker/Central Line Placement
      - Venous access for pacemaker lead placement
      - Central port and PICC lines for long term IV therapy
    - Vascular & Non-Vascular
    - Open Surgical (if can't be treated endovascularly: performed through catheter)

Procedure Examples

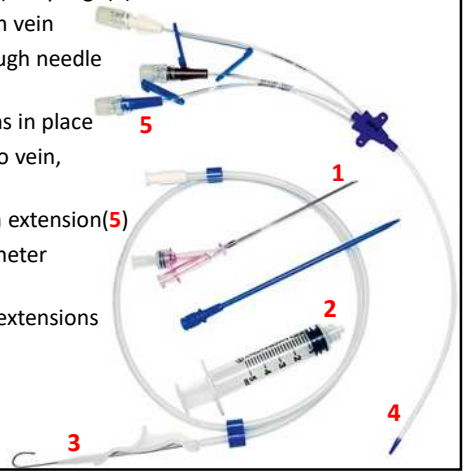
- Catheters
  - Small, flexible tube that is inserted into vessel
  - Guidewire can be steered through catheter into the correct position
  - Uses:
    - Contrast injection
    - Angioplasty (balloon)
    - Stent placement
    - Monitor pressures
    - IVUS
    - Biopsy





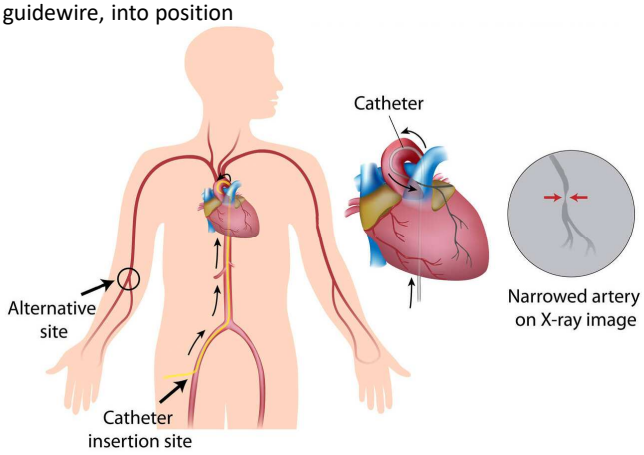
Procedure Examples

- Catheter Insertion:
  - US can be used to guide the needle(**1**) & syringe(**2**) into correct vein location
  - Syringe is removed, needle remains in vein
  - Flexible guidewire(**3**) is inserted through needle into vein, to required depth
  - Needle is removed, guidewire remains in place
  - Catheter(**4**) is slid over guidewire, into vein, using distance marks
  - Guidewire is removed through lumen extension(**5**)
  - Sterile dressing applied to secure catheter in place
  - Syringes can be connected to lumen extensions



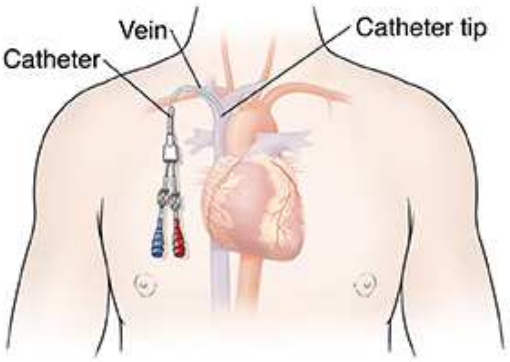
Procedure Examples

- Cardiac Catheterization
  - Catheter (small, flexible tube) inserted into vessel
  - Catheter slid over guidewire, into position



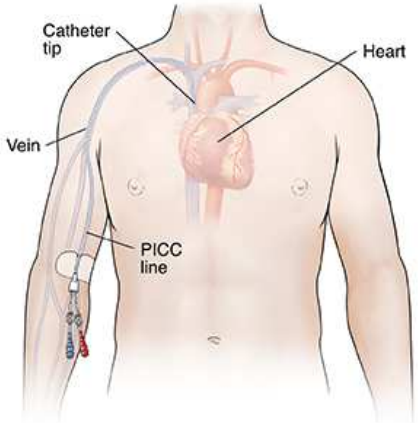
Procedure Examples

- Central Line
  - Long, flexible catheter empties near the heart, allowing treatment delivery within seconds



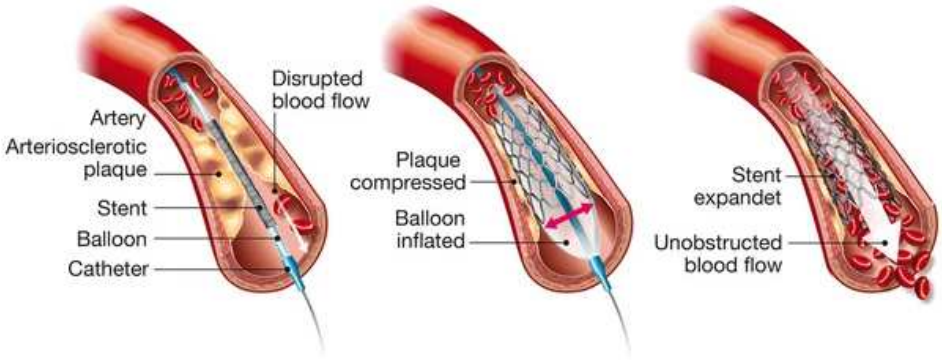
Procedure Examples

- PICC (Peripherally Inserted Central Catheter) Line
  - IV treatment or blood work is required performed over long period of time. Ex. Chemotherapy over multiple weeks



Procedure Examples

- Balloon Angioplasty & Stenting
  - Inflated using syringe pump



Who uses these systems?

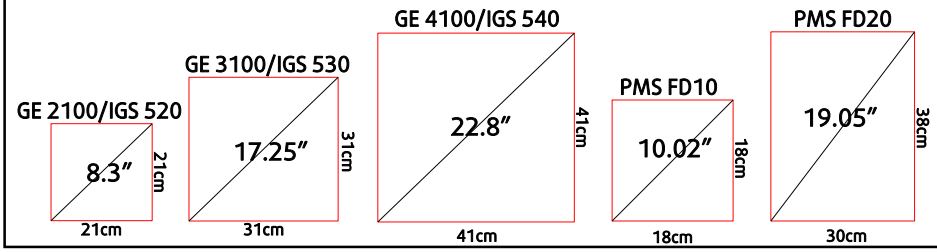
- Cardiologist
  - Cardiac Cath Lab Department
  - EP Department (Electrophysiology)
  - Surgery Department (Cardiac Intervention, TAVR: Transcatheter Aortic Valve Replacement)
- Neurosurgeon
  - Cardiac Cath Lab Department
  - Interventional Radiology Department
  - Surgery Department (Neuro Intervention, Spine)
- Vascular Surgeon
  - Cardiac Cath Lab Department
  - Interventional Radiology Department
  - Surgery Department (Endovascular Intervention, EVAR: Endovascular Aneurysm Repair)
- Interventional Radiologist
  - Vascular
  - Non-Vascular

Who uses these systems?

- Lines may be very blurred between departments.
  - For efficient room utilization and maximizing procedure scheduling: departments and physicians are “sharing” the imaging procedure rooms.

Systems

- Hospitals or Out-Patient based labs
- OEM's typically offer 2 or 3 FPD size models
  - Cardiac: Visualize and measure functionality of the heart
    - ~20cm X 20cm
  - Angiography: Visualize vessels and organs of the body
    - ~40cm X 40cm or rectangular
  - "Hybrid" or "Swing"
    - Combination



System

- Cardiac rooms, typically:
  - Smaller FPD FOV: Smaller area of interest, not chasing contrast through small structures
    - Ex: PMS FD10: 10", 8", 6" FOV's
  - Shorter table: Movement is not necessary as imaging is focused on the heart
  - Lower resolution X-Ray tube: Larger focal spot (human heart: size of fists)
  - Lower resolution FPD: Larger pixel size (larger structures, heart)

System Fundamentals

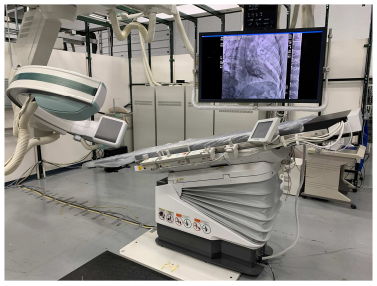
- Angiography rooms, typically:
  - Larger FPD FOV
    - Ex: PMS FD20: 20”, 17” 15”, 12”, 11”, 9, 7.5”, 6” FOV’s
    - Larger FPD FOV = Reduced dose for imaging larger areas of anatomy
  - Longer table: Motorized drive allows bolus chase runoffs
  - Higher resolution X-Ray tube: Smaller focal spot
  - Higher resolution FPD: Smaller pixel size (small veins/structures)

System Fundamentals

- Regardless of which type of room the system is designed for (cardiac/angio), some desirable features include:
  - Flexible Positioning
    - The ability to acquire images for all angles is critical, as you don’t want to disrupt the patient in the surgical position. Some systems are floor-mounted and may have less flexibility than the systems that are ceiling mounted. Some ceiling mounted systems have lateral movement to move even further away from the patient, when necessary. Space and flexibility can be an important commodity during a procedure.
  - Patient Access
    - Access to the patient's head is important for anesthesia. Conscious sedation can be administered through an IV. For conscious sedation, the patient is awake, can speak, but is very relaxed. Full anesthesia can be administered via IV or a breathing tube and requires an anesthesiologist.

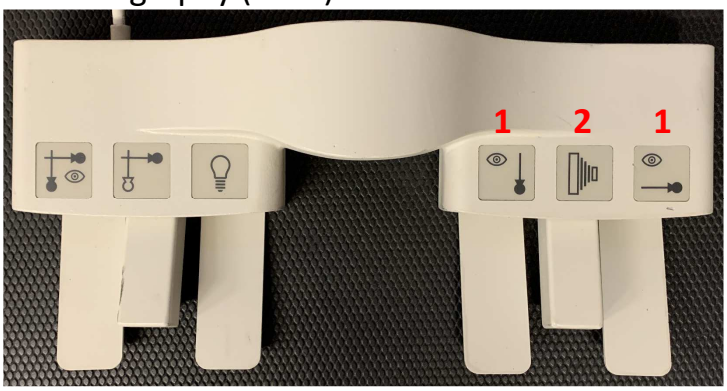
System Fundamentals

- Additional features:
  - Motorized longitudinal table (option):
    - "Bolus Chase" or "Runoff"
  - Tilting table (option)
    - Trendelenburg Position:
      - Minimize air embolism risk
      - Maximize vein distention (bulging)
  - Roll/Cradle (option)
    - CO2 contrast management
      - Dissolves quicker than iodinated contrast
      - CO2 only used below the waist (abdomen and extremities), to keep CO2 away from heart and brain

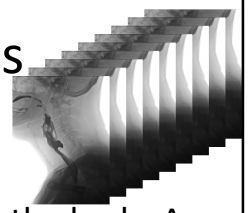


System Fundamentals

- Imaging modes/types:
  1. Fluoroscopy
  2. Radiography (CINE)

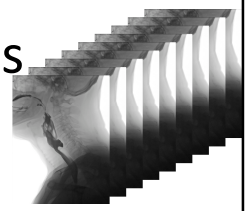


System Fundamentals

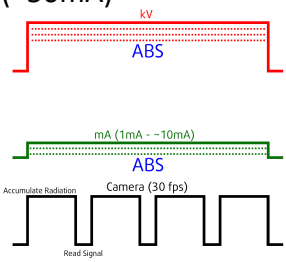


- Fluoroscopy:
  - Used to view moving structures within the body. A continuous or pulsed X-Ray beam is passed through the body part being examined.
  - Positioning
  - Lower dose
  - Not stored
    - By default

System Fundamentals

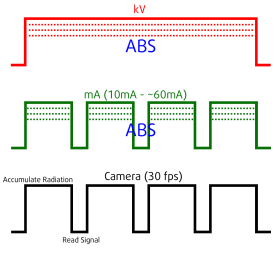


- Fluoroscopy:
  - Continuous (~10mA or less)
  - Pulsed (~50mA)



kV: Continuous
mA: Continuous
Camera: 30 fps
Exp Control: ABS

On-Time Waveform Representations: Fluoroscopy, Continuous



kV: Continuous
mA: Pulsed
FPD/Camera: 30 fps
Exp Control: ABS

On-Time Waveform Representations: Fluoroscopy, Pulsed (mA)

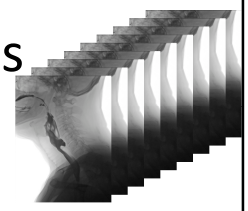
Pulse Rates

- What dictates pulse rates (or frame rates) selected by physician?
  - Pacemaker placement?
  - Pediatric Cardiology?
  - Angiography proximal/closer to the heart?
  - Angiography distal/further from the heart?
- Lower pulse rate = lower dose

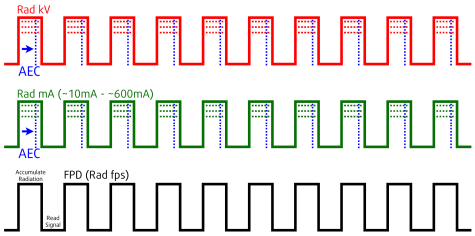
Fluoro Pulse Rates

- 1-2 pps: Not typically used, poor image quality, but physician who is very dose conscious may use.
  - Pacemaker lead placement
- 2-4 pps: Neurovascular.
  - Not chasing contrast but looking at site of blockage or leakage.
- 3-4 pps: Ablation studies.
  - Cauterization is used to disrupt electrical circuits that cause heart arrhythmias.
- 6 pps: Barium swallow studies
  - Contrast is swallowed at a slow rate.
- 7.5 pps: Distal vascular studies
  - Arteries/veins farther from the heart transport blood/contrast at a slower rate.
- Some systems can perform higher fluoro fps at lower resolution. For example, a modern cardiac cath lab with an FPD (Flat Panel Detector) might perform:
  - 1024 X 1024 - 15 & 30 fps
  - 2048 X 2048 - 0.5 fps - 6 fps

System Fundamentals



- Radiography ("Cine"):
  - Capture radiographic level (>1,000mA) exposures in rapid succession at various frame rates



kV: Pulsed (X-Ray tube or inverter)
mA: Pulsed
Camera: 30-60 fps
Exp Control: AEC

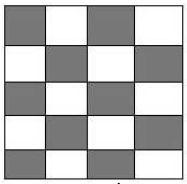
On-Time Waveform Representations:
Cine

Systems: Advanced Features

- Advanced Image Processing Features:
  - Mostly performed using Radiography/Cine images
  - Some very modern system can perform advanced applications on fluoro images, but these features are typically reserved for radiographic level cine
    - DSA
    - Roadmapping
    - Runoffs
    - 3D

Systems: Advanced Features

- DSA
  - Used to visualize blood vessels. Images that are acquired pre-contrast are used as the "mask". The mask image is then subtracted from subsequent images, which leaves only the contrast within the vessels to be displayed in the image.



Mask

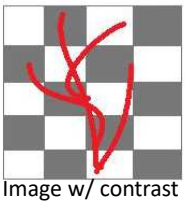
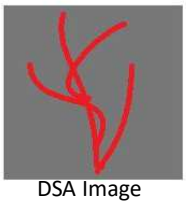
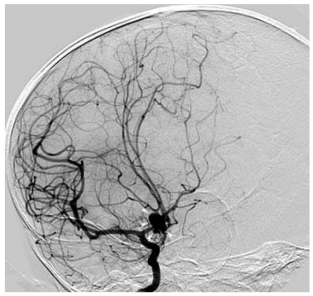


Image w/ contrast

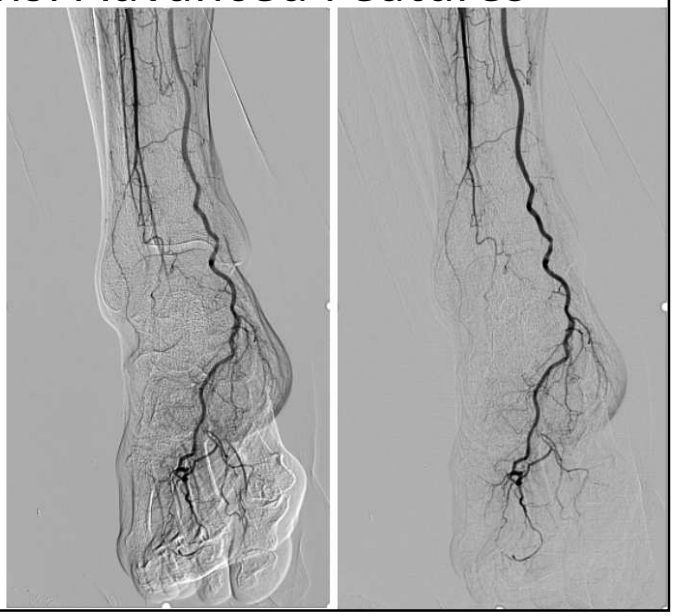


DSA Image



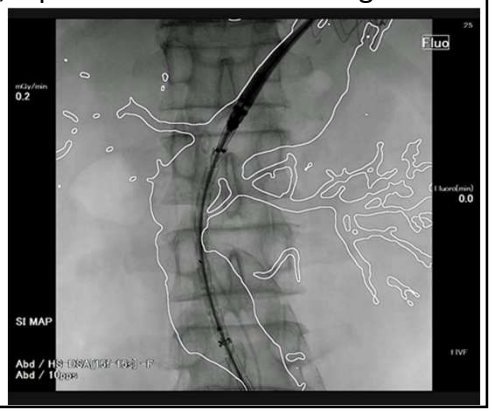
Systems: Advanced Features

- DSA
  - Not motion tolerant



Systems: Advanced Features

- Roadmap
  - DSA images can be used to create vessel map
  - Can be used during fluoro, if position remains unchanged



Systems: Advanced Features

- Peripheral Runoff
  - "Run Off", or "Bolus Chase"
  - Auto: Table long drive start/stop pre-programmed
  - Manual: Table is locked to float only longitudinal



Systems: Advanced Features

- 3D
  - Images acquired during rotational spin (~60°/sec) w/ CINE/Radiography
  - Images sent to 3D workstation for processing
  - C-Arm & table movement can be synchronized w/ 3D workstation
    - Send C-Arm & table back to exact position where acquisition occurred

Systems: Advanced Features

- 3D



Systems: Advanced Features

- 3D



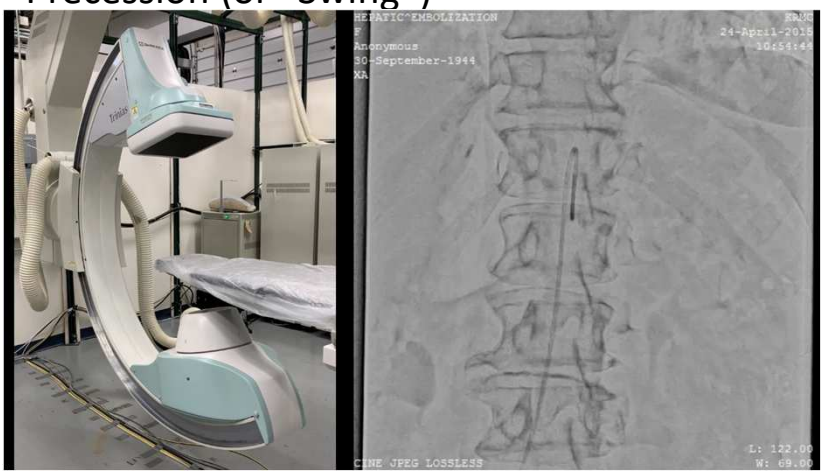
Systems: Advanced Features

- Pendulum



Systems: Advanced Features

- Precession (or “Swing”)



Cine Frame Rates

- Typical frame rates for cine can be up to 120 fps. Examples can include:
  - 1 - 3 fps: Slower blood flow (arterial embolization, peripheral arteriography, venography)
  - 1 - 7.5 fps: DSA (Digital Subtraction Angiography).
  - 7.5 fps: Faster blood flow. Closer to the heart typically means faster blood flow (carotid, aorta, neuro).
  - 15 fps: (requirements are based on how fast blood/contrast is pumped through the veins/arteries):
    - CO2 imaging
    - Neuro - Close to the heart
    - Angiography
    - Proximal vascular (arteries/veins closer to the heart transport blood/contrast at faster rate).
  - 30 fps: Cardiac (capturing the heart without heartbeat motion).
  - 60-120 fps: Cardiac Pediatric (capturing the infant heart without heartbeat motion)

Cine Frame Rates

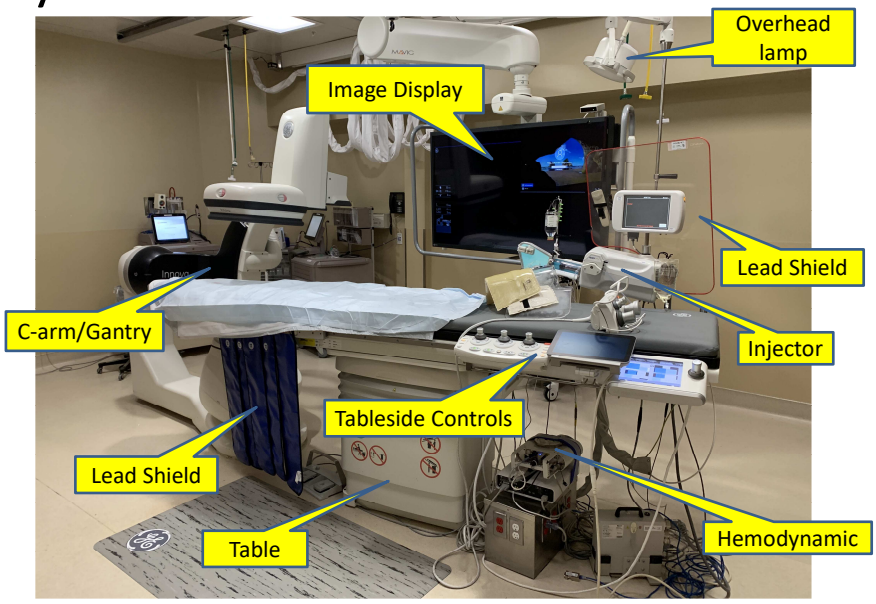
- Cine Frame Rates



System Fundamentals

- All systems:
  - Exam Room
  - Control Room
  - Equipment Room

System Fundamentals: Exam Room



System Fundamentals: Exam Room

- Gantry:
  - Floor mounted
  - Ceiling mounted
  - Biplane
- Table:
  - Basic designs:
    - Cardiac table
    - Angio table
    - Hybrid OR table (3rd party)
  - Geometry:
    - Elevating
    - Pivot
    - Tilting
    - Roll/cradle
    - Lateral movement
    - Longitudinal movement

System Fundamentals: Exam Room

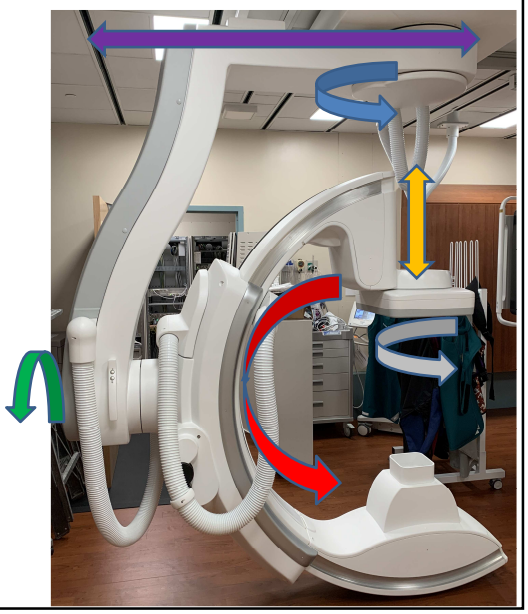
- Geometry:
  - Gantry: GE
    - L-Arm
    - C-Arc
    - Pivot
    - Detector Lift



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System Fundamentals: Exam Room

- Geometry:
  - Gantry: PMS
    - Beam Z-Rotation
    - C-Arm Rotation
    - Beam Propeller
    - Detector SID
    - Beam Longitudinal
    - FPD Rotation



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System Fundamentals: Exam Room

- Geometry:
  - Tableside Controls
    - GE: TSSC (Table Side Status Control)
      - Gotcha: GE ITU (Intelligent Touch Unit) has Hospital/WAN IP
    - PMS: TSO's (Table Side Operation Module)
      - Geometry Module
      - Imaging Module
    - Siemens:
      - CCM - Collimator Control Module
      - ECC - Examination Control Console
      - SCM - Stand Control Module
      - TCM - Table Control Module

System Fundamentals: Exam Room

- Tableside Controls: GE



GE Innova/IGS:
SmartBox



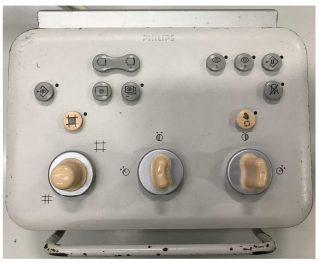
GE Innova/IGS:
TSSC

System Fundamentals: Exam Room

- Tableside Controls: PMS

Allura FD: Geo Module





Allura FD: Imaging Module

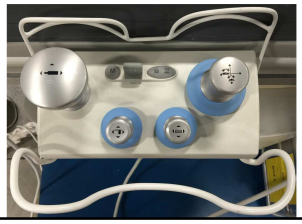


Azurion: Combined TSO

System Fundamentals: Exam Room

- Geometry Tip (Controls):
  - Drive the detector





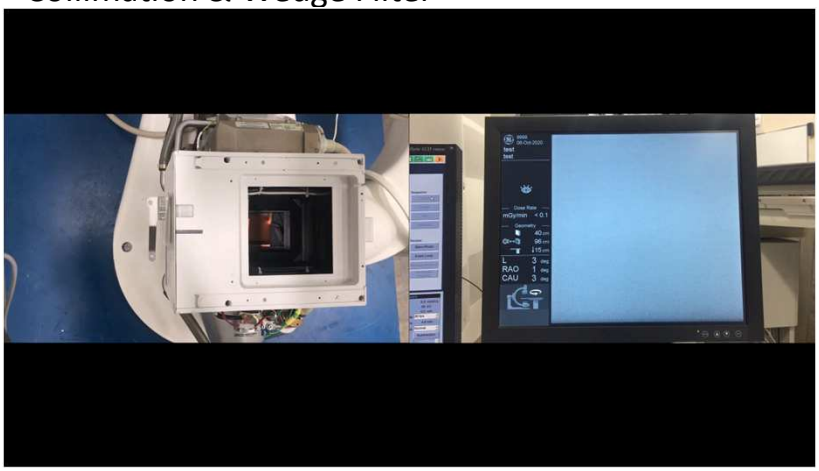


System Fundamentals: Exam Room

- Collimators
  - Typically contain multiple sets of wedge filters (or “contour filters”)
    - Partially attenuate the beam, moveable, independently controlled
    - Reduce patient dose and excessive image brightness, where patient attenuation in minimal.
      - Ex. lung fields, alongside legs in run-off procedure

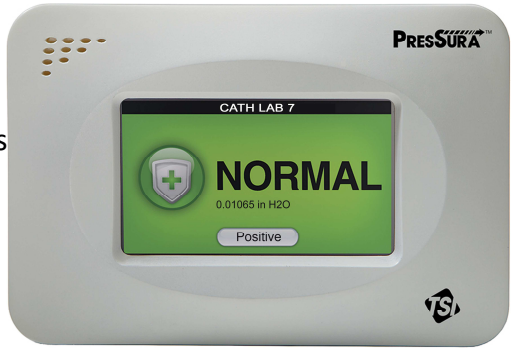
System Fundamentals: Exam Room

- Collimation & Wedge Filter



System Fundamentals: Exam Room

- Exam Room
  - Usually have positive pressure air handling system
    - Higher pressure in the exam room
      - Prevents pathogens from getting in
    - Goals have shifted: may be more appropriate to use negative pressure to keep the coronavirus from getting out.
    - Keep doors closed during service



System Fundamentals: Equipment Room

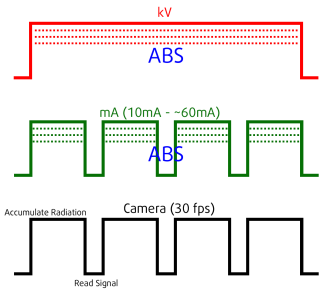
- Contains Cabinets, which house:
  - X-Ray Generator
    - Typically: 100kW, Grid controlled
      - GE: JEDI
      - PMS: Velera (Allura FD <= R8.1) or Certaray (Allura FD 8.2 & Azurion)
  - Host PC
    - GE: DL
    - PMS: Host PC
  - Image Processing
    - GE: RTAC
    - PMS: Image Proc PC

System Fundamentals: Equipment Room

- Contains Cabinets, cont'd:
  - Positioner Control
  - FPD Chiller
    - Some air-cooled FPD's
  - X-Ray Tube Chiller
  - Large Monitor Control
    - GE = LDM: Large Display Monitor
    - Philips = Flexvision
    - Shimadzu = LMM: Large Monitor Manager
  - Air conditioned, well ventilated

Sys Fundamentals: Gridded X-Ray Tubes

- Pulsed X-Ray Control = Reduced dose
  - Radiation pulsed during fluoro & CINE, synced w/ FPD
  - IVR system cables:
    - 25m - 50m

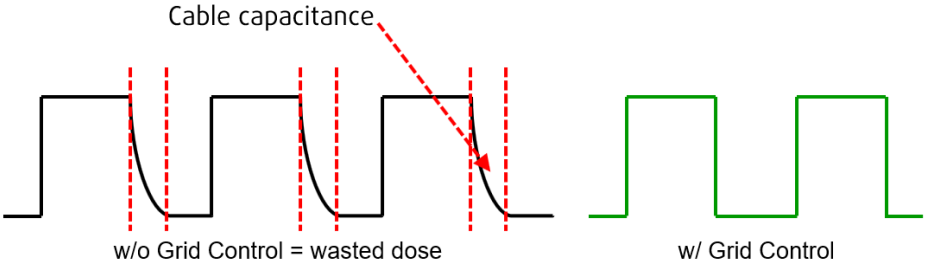


kV: Continuous
mA: Pulsed
FPD/Camera: 30 fps
Exp Control: ABS

On-Time Waveform Representations:
Fluoroscopy, Pulsed (mA)

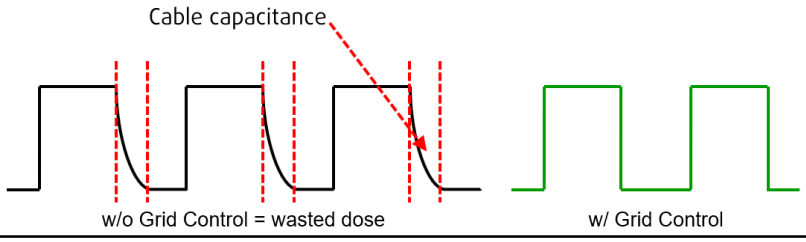
Sys Fundamentals: Gridded X-Ray Tubes

- Problem:
  - Long cable lengths
  - Low mA during fluoro = long discharge time
- Solution:



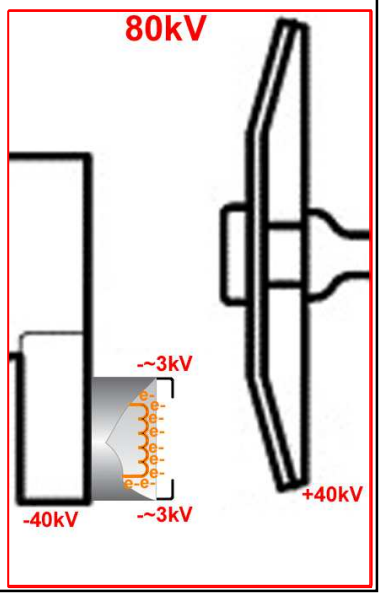
Sys Fundamentals: Gridded X-Ray Tubes

- Pulsed Fluoro:
  - Gridded X-Ray tubes control mA using grid bias at the cathode cup
  - Grid bias voltage is typically ~3kV, relative to the cathode cup.
  - Grid bias control methods:
    - Transformer in the X-Ray tube to turn mA on/off (Philips Cath, SFS only)
    - Transformer (InGrid) plugged into X-Ray tube to turn mA on/off (GE Cath, SFS only)
    - Transformer in the X-Ray generator cabinet to turn mA on/off (Shimadzu)



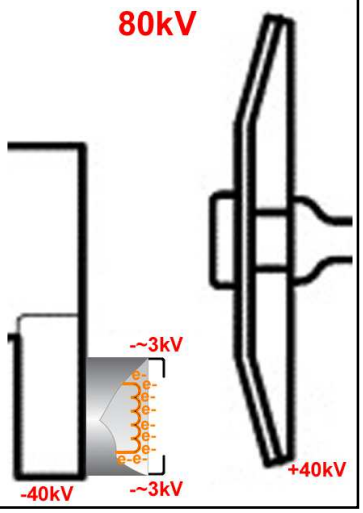
Sys Fundamentals: Gridded X-Ray Tubes

1. X-Ray OFF
   - kV: OFF
   - Fil i: OFF
   - **Tube i: OFF**
2. X-Ray OFF
   - kV: OFF
   - Fil i: ON
   - **Tube i: OFF**
3. X-Ray OFF
   - kV: ON
   - Fil i: OFF
   - **Tube i: OFF**
4. X-Ray ON
   - kV: ON
   - Fil i: ON
   - **Tube i: ON**
5. Grid Switched ON: X-Ray OFF
   - kV: ON
   - Fil i: ON
   - **Tube i: OFF**
6. Grid Switch Pulsed: X-Ray Pulsed
   - kV: ON
   - Fil i: ON
   - **Tube i: Pulsed**

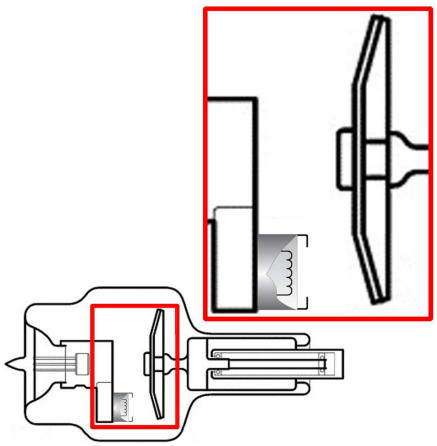


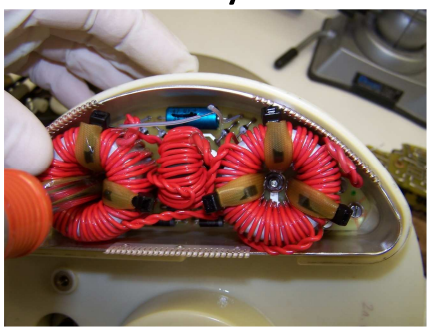
Sys Fundamentals: Gridded X-Ray Tubes

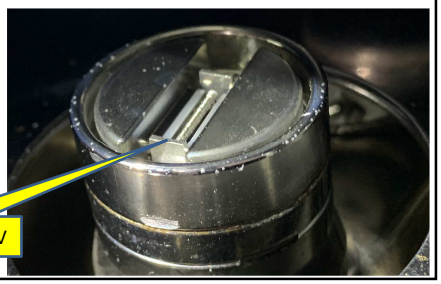
- Example: MRC200 LMB X-Ray Tube
  - 3.3kV Grid Bias V
  - Typically: ~10% of electrons bounce back from the anode
  - This deflection (µA) is routed back to HV Tank
  - Measured/Controlled by:
    - GSS (Velera)
    - XSC (CertaRay)
  - Only Fluoro SFS is gridded
    - CINE/Rad mA (up to 1,250mA) is higher than fluoro mA (60mA) = no cable discharge issue w/ CINE/Rad
  - Tube Fault:
    - GRID SWITCH NOT AVAILABLE



Sys Fundamentals: Gridded X-Ray Tubes







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Sys Fundamentals: Gridded X-Ray Tubes

- 15PPS Fluoro



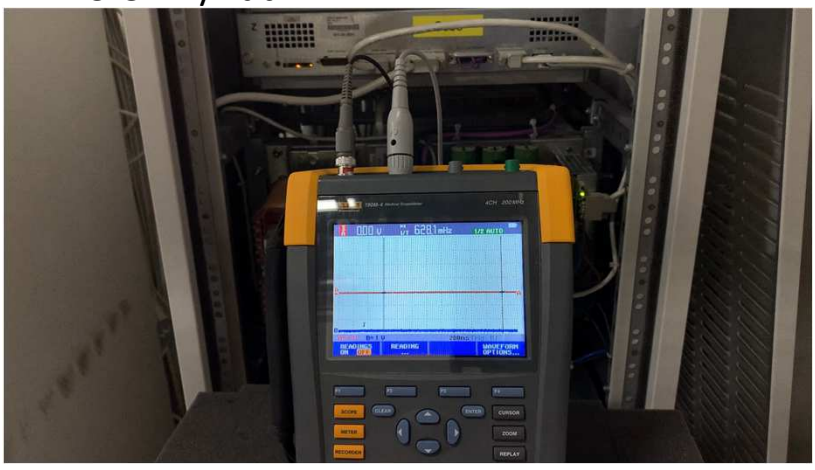
64

Sys Fundamentals: Gridded X-Ray Tubes

- Pulsed kV control
  - Used for Rad/CINE
  - Inverter is turned off
  - Cable capacitance not an issue, due to higher mA during CINE
  - mA examples:
    - FD 10/20:
      - Fluoro: 60mA
      - CINE/Rad: 1 – 1,250mA
    - GE IGS:
      - Fluoro: 1 - 140mA
      - CINE/Rad: 1 – 1,000mA

Sys Fundamentals: Gridded X-Ray Tubes

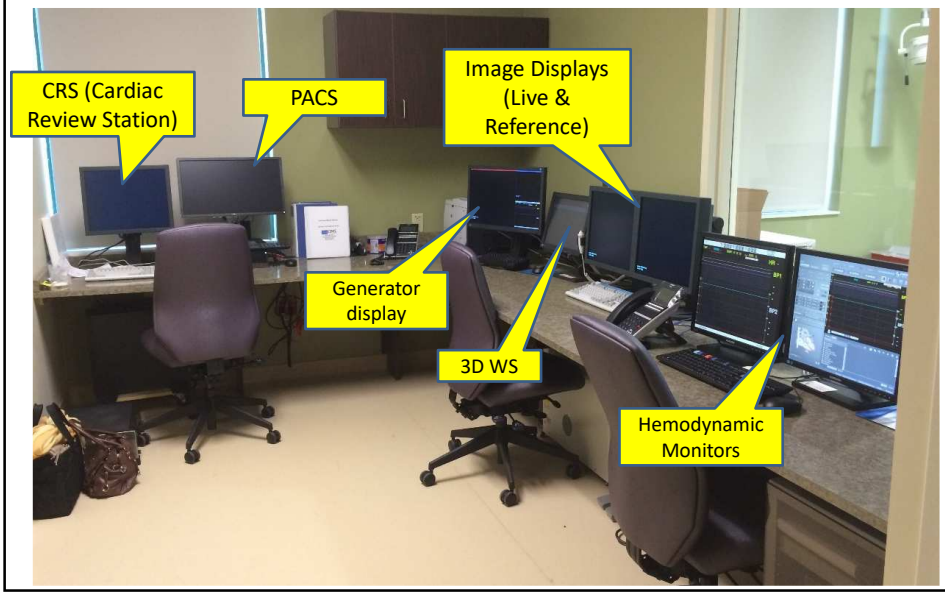
- 2FPS CINE/Rad



Sys Fundamentals: Gridded X-Ray Tubes

- Pulsed X-Ray Control, Summary:
  - Fluoro: Pulsed using gridded X-Ray tubes
  - CINE/Rad: Pulsed by switching inverter ON/OFF

System Fundamentals: Control Room



System Fundamentals

- Bi-plane Cath Lab



Bi-Plane

- Biplane systems
  - Images acquired from (2) planes (frontal and lateral)
  - Frontal & Lateral planes pulse/alternate radiation.
    - Without pulsing:
      - Extreme radiation at isocenter
      - Large amounts of scatter radiation hitting the "non-targeted" FPD
  - Images from each plane are displayed on separate monitors.
  - A biplane system will have more cabinets in the equipment room:
    - (2) X-Ray tubes
    - (2) X-Ray generators
    - (2) FPD's
    - (2) Image processing computers
    - (2) Sets of monitors
    - (2) Positioner controllers



Bi-Plane

- Biplane common uses:
  - Neuro studies
    - Advantageous to view vessels in 2 different views, simultaneously
  - EP (Electrophysiology)
    - Record/measure electrical signals: “Electricians of the heart”
    - Electrical signals that control heartbeat can be manipulated by burning/cauterizing tissue to disrupt electrical “circuit”
    - Ablation procedures are used to correct heartbeat and heart arrhythmia conditions
- Biplane advantages:
  - Reduction in contrast usage
  - Contrast is extremely toxic to the kidneys



System Fundamentals

- Hybrid OR (Cleveland, OH)



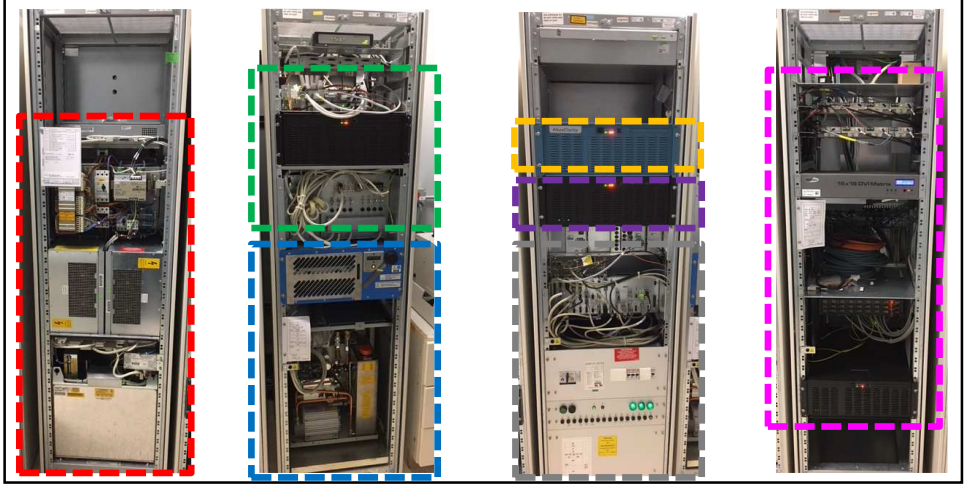
Service Challenges

- Room access & scheduling
- PPE Polices: Check w/ customer:
  - Bunny suits
  - Hair cover
  - Beard cover

Service Challenges

- Identify Major Subsystems: PMS Allura FD

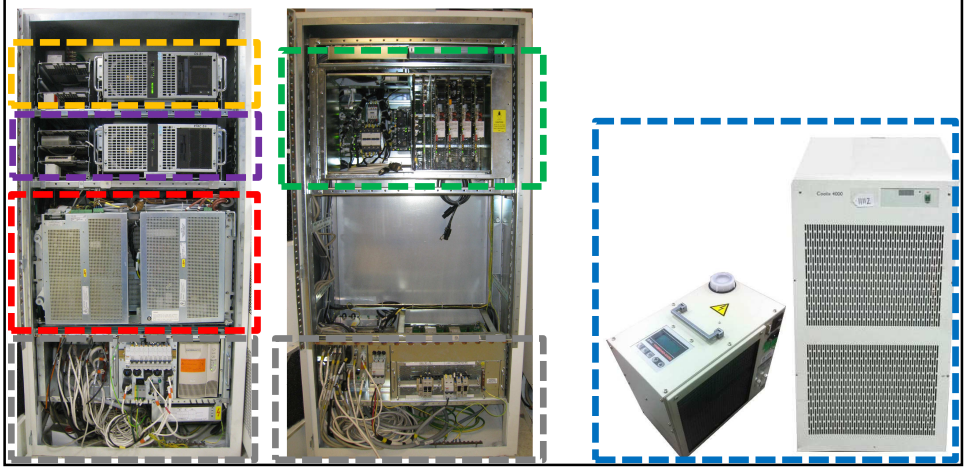
X-Ray Generator Cooling Geometry Image Processing Host PC Power Dist LM Support



Service Challenges

- Identify Major Subsystems: GE Innova/IGS

X-Ray Generator Cooling Geometry Image Processing Host PC Power Dist LM Support



Service Challenges

- Optional/Ancillary Equipment
  - Fluoro UPS
  - IVUS
    - Intravascular ultrasound, also known as a percutaneous echocardiogram is an imaging method using long, thin catheters attached to US equipment to visualize the lumen (inside of tube) and the interior wall of blood vessels.
      - GE: Boston Scientific
      - PMS: Volcano
      - Siemens: Volcano
  - Options: 3D, CT
  - How is the contract written?
    - Who's responsible for what?

Service Challenges

- Service Access?
  - 2579 Report of Assembly
  - AIAT: 21CFR 1020.30
    - (c) *Manufacturers' responsibility.* Manufacturers of products subject to 1020.30 through 1020.33 shall certify that each of their products meet all applicable requirements when installed into a diagnostic x-ray system according to instructions. This certification shall be made under the format specified in 1010.2 of this chapter. Manufacturers may certify a combination of two or more components if they obtain prior authorization in writing from the Director of the Office of Communication, Education, and Radiation Programs of the Center for Devices and Radiological Health. Manufacturers shall not be held responsible for noncompliance of their products if that noncompliance is due solely to the improper installation or assembly of that product by another person; however, manufacturers are responsible for providing assembly instructions adequate to assure compliance of their components with the applicable provisions of 1020.30 through 1020.33.
  - Contact me to discuss specifics

Thank You For Your Time

Todd Boyland, CEO, RSTI Training

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