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# Advance NXi

## Whole-Body Positron Emission Tomography System

## S9111NE/ S9111ND

### System Description:

The GE Advance Whole Body PET System is a state-of-the-art Positron Emission Tomography scanner. The system is optimized for routine 2D and 3D clinical studies, yet powerful and flexible enough for numerous research applications, making it the ideal solution for all your PET imaging needs.

The Advance is ideal for imaging all PET tracers and provides excellent image quality, high throughput, easy operator interaction and proven reliability. It also includes powerful built-in remote diagnostics and is backed by traditional GE service quality.

The uncompromising design of Advance's high-speed detection system provides highest resolution image quality without sacrificing the sensitivity and count rate performance necessary for fast whole body acquisitions. The wide bandwidth of the Advance NXi overcomes the need for data reduction techniques such as "mashing" which degrade resolution and quantitative accuracy.

To ensure long-term investment protection, the Advance NXi has a large portfolio of innovative upgrades including DICOM compatible image registration and fusion (MR and CT), DICOM connectivity and workflow tools. An outstanding upgrade option exists to upgrade the Advance NXi scanner onsite to a Discovery LS state-of-the-art PET/CT scanner. All features come equipped with a warranty and are backed by GE service.

### System Components:

The GE Advance Scanner consists of:

- A gantry containing eighteen detector rings of bismuth germanate (BGO) crystals
- A patient imaging table with head holder, patient security straps and comfort accessories
- High speed acquisition electronics
- A data management and reconstruction system including a scaleable high performance array processor system
- An operator workstation with flexible multitasking capabilities, hard disk storage, digital audio tape (DAT) archive storage and Ethernet network connections, optional optical disk drive (MOD)
- Comprehensive operator manuals for acquisition, processing and image analysis operations
- Options for enhancing the acquisition system and reconstruction processors
- Options for laser filming, color hardcopy, and optical disk storage

### System Operation:

The operator can easily position the patient from either side of the gantry with the dual table and gantry motion control panels. Acquisition and reconstruction protocols are defined and controlled by the operator's workstation (OWS). Display, image analysis, filming and archiving can be controlled from the operator's workstation (OWS) or from an optional independent workstation (AWS).

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### Summary of System Features

#### Acquisition Features:

- Static, dynamic, and gated emission acquisition modes
- Transaxial transmission acquisition with masking of acquired transmission data to reduce scatter and allow acquisition of attenuation correction data
- Interleaved transmission and emission acquisitions at multiple table positions with automatic table incrementation
- "High resolution" 2D and "high sensitivity" 2D coincidence acquisition
- High sensitivity 3D volume acquisition
- Direct measurement of dead-time information for all emission acquisitions
- Byte or word-mode storage of events
- Start on count rate, stop on counts
- Prescan monitor of per slice count rates for accurate patient positioning
- Real-time display of total true and random coincidence countrates during acquisition

#### Reconstruction Features:

- Transaxial images reconstructed from emission or transmission measurements
- Transaxial images reconstructed using OS-EM Iterative Reconstruction Algorithm
- Fully three-dimensional volume reconstruction without data reduction using the following algorithms:
- Reprojection (3DRP)
- Fourier Rebinning (FORE) plus Filtered Backprojection (FBP)
- FORE plus Iterative Reconstruction
- Targeted and off-center reconstruction (Pan & Zoom acquisition using (field-of-view from 6.4 to 55 cm)
- Operator selectable reconstruction filters for 2D FBP or 3DRP reconstructions including selectable cut-off frequencies: Hanning, Butterworth, Ramp or Shepp-Logan
- Attenuation correction using measured transmission data or calculated methods (automated, elliptical, polyline). Variable filtration transmission processing
- Segmented attenuation correction using transmission data
- Correction for post-injection transmission scanning ("T+E")
- Additional corrections integrated into tomographic reconstruction including:
  - Detector normalization
  - Blank scan correction (transmission scans)
  - Deadtime correction
  - Scatter correction
    2D: Bergström Method
    3D: Model-Based
  - Decay correction
- Prospective reconstruction of acquired data during acquisition for maximum throughput
- Reconstruction from remote workstations
- Transaxial image matrix sizes of 64 x 64, 128 x 128, or 256 x 256
- Calibrated (specific activity) images in nanoCi/cc or kBq/cc

#### Image Display and Analysis Capabilities:

- Acquisition, reconstruction, display and archival can all be performed simultaneously without interaction
- Corrected, uncorrected, and transmission images displayed as transaxial, sagittal, coronal, or combined displays
- Single and multiple image display of images and processed sinograms
- Maximal Intensity Projection images (MIP) with cine display
- Cinematic display of gated frame, slices in static measurement sets, individual images from dynamic measurements sets
- Protocols and support for user programmability
- Image text and graphic annotation
- Selection of stored and user defined color palettes
- Image manipulation (pan, zoom, flip, rotate)
- Vertical and horizontal activity profiles
- Screen labeling
- Image-to-Image arithmetic
- Image ROI statistical analysis
- Generation of graphs
- Distance measurement (in mm) between any two points in image
- Time activity curve generation and statistical analysis from region-of-interest (ROI)
- Sagittal, coronal, and oblique angle reorientation of transaxial tomographic images
- Special reformatting protocols for cardiac long and short axis images as well as polar plots.
- Realtime reformat for volume navigation
- FDG autoradiographic analysis

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### Dicom Features

- PET DICOM connectivity (Query, Retrieve, Send, Receive)
- Integrated DICOM connectivity for MR and CT
- DICOM Print
- DICOM Secondary Capture
- DICOM Modality Work-list (Option P5080SM)

### Other System Features:

- Data management (archive and deletion) of raw scan data, calibration files and image data
- Batch filming: operators may submit a number of patient images to be filmed in sequence
- Networking support: standard ftp and Dicom communications available for external analysis and review workstations
- Export and import tools for non-DICOM formats
- Automated calibration of detector and electronics
- Acquisition of normalization, blank, and well counter calibration data
- Simultaneity of acquisition, reconstruction, display, data archiving and batch filming
- Prospective reconstruction
- User-definable protocols for acquisition, reconstruction, and image analysis procedures
- Remote diagnostics/online service

### System Field of View:

Transaxial FOV: 55 cm
Axial FOV: 15.2 cm
Axial sampling interval: 4.25 mm
Number of detector rings: 18
Number of image planes: 35

### System Performance Specifications

The following specifications represent typical system performance, measured according to NEMA Standards. All measurements are performed using the standard Coincidence Window width ($2\tau$) of 12.5 nanoseconds. Separate energy windows are provided for 2D and 3D mode acquisitions. The 2D lower energy acceptance limit is set at 300 keV while the 3D lower energy limit can be configured at either 300 keV or the default value of 375 keV. For comparison, 3D NU2-1994 measurements represent performance at 300keV while NU2-2001 values represent 3D performance at 375 keV. 2D measurements use "standard mode" in which the "span" is±2 for direct slices, ±3 for cross slices. 3D measurements use the standard maximal "ring difference" of 11. Refer to NEMA Standards Publication NU-2, 2001 for further details. For comparison, measurements according to the NEMA NU2-1994 standard are also included.

### Spatial Resolution:

Resolution measurements in 2D imaging mode, and in 3D imaging mode at 1 cm, 10 cm and 20 cm from the central axis:

**2D - Nema NU2 2001**

| | | FWHM | FWTM |
|---|---|---|---|
| 1 cm | Transverse | 5.0 mm | 10.0mm |
| 1 cm | Axial | 6.3 mm | 11.2 mm |
| 10 cm | Tangential | 4.9 mm | 9.6 mm |
| 10 cm | Radial | 5.5 mm | 10.8 mm |
| 10 cm | Axial | 6.2 mm | 12.7 mm |

**3D - Nema NU2 2001**

| | | FWHM | FWTM |
|---|---|---|---|
| 1 cm | Transverse | 4.8 mm | 9.1 mm |
| 1 cm | Axial | 6.5 mm | 12.9 mm |
| 10 cm | Tangential | 4.9 mm | 9.3 mm |
| 10 cm | Radial | 5.2 mm | 9.8 mm |
| 10 cm | Axial | 7.4 mm | 13.6 mm |

***2D - Nema NU2 1994***

*Transaxial (FWHM, Transverse values are average of radial and tangential)*

| | | |
|---|---|---|
| *1 cm* | *Transverse* | *4.8 mm* |
| *0 cm* | *Axial* | *4.0 mm* |
| *10 cm* | *Transverse* | *5.4 mm* |
| *10 cm* | *Axial* | *5.4 mm* |
| *20 cm* | *Transverse* | *6.2 mm* |
| *20 cm* | *Axial* | *6.6 mm* |

***3D - Nema NU2 1994***

*Transaxial (FWHM, Transverse values are average of radial and tangential)*

| | | |
|---|---|---|
| *1 cm* | *Transverse* | *4.8 mm* |
| *0 cm* | *Axial* | *6.0 mm* |
| *10 cm* | *Transverse* | *5.4 mm* |
| *10 cm* | *Axial* | *6.3 mm* |
| *20 cm* | *Transverse* | *6.2 mm* |
| *20 cm* | *Axial* | *6.6 mm* |

**Central Slices 11-25*

### Sensitivity:

**Nema NU2 2001 (cps/kBq)**

| | @ 1 cm | @ 10 cm |
|---|---|---|
| 2D | 1.25 cps/kBq | 1.25 cps/kBq |
| 3D | 6.50 cps/kBq | 6.50 cps/kBq |

***Nema NU2 1994 (cps/kBq/ml)***

| | *Trues + Scatter* | *Trues* |
|---|---|---|
| *2D Slice** | *180* | *160* |
| *2D System* | *5900* | *5400* |
| *3D System*** | *48,000* | *31,000* |

**Average for center 31 slices*
***Using a ring difference of ± 17*

### Scatter fraction:

**Nema NU2 2001**

| | |
|---|---|
| 2D | 10% |
| 3D | 43% |

***Nema NU2 1994***

| | |
|---|---|
| *2D* | *10%* |
| *3D* | *35%* |

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### Count Rate:

**2D - Nema NU2 2001**

| | | |
|---|---|---|
| Peak Trues | >180 kcps | to 150 kBq/ml |
| Peak NECR | 83.0 kcps | @ 108 kBq/ml |

*Peak Trues not reached with 150kBq/ml*

**3D - Nema NU2 2001**

| | | |
|---|---|---|
| Peak Trues | 141 kcps | @ 19.7 kBq/ml |
| Peak NECR | 27.6 kcps | @ 7.6 kBq/ml |

*Peak NECR without randoms variance reduction*

***2D - Nema NU2 1994***

| | | |
|---|---|---|
| *Trues @ 50% Deadtime* | *425 kcps* | *@ 160 kBq/ml* |
| *Peak Trues* | *470 kcps* | *@ 280 kBq/ml* |
| *Peak NECR* | *230 kcps* | *@ 140 kBq/ml* |

***3D - Nema NU2 1994***

| | | |
|---|---|---|
| *Trues @ 50% Deadtime* | *410 kcps* | *@ 26 kBq/ml* |
| *Peak Trues* | *460 kcps* | *@ 48 kBq/ml* |
| *Peak NECR* | *136 kcps* | *@ 21 kBq/ml* |

### Count Rate Correction Accuracy:

**Nema NU2 2001**

Accuracy up to Peak NECR

| | |
|---|---|
| 2D | TBD |
| 3D | <2% |

***Nema NU2 1994***

*Accuracy up to 50% dead time*

| | |
|---|---|
| *2D* | *<3%* |
| *3D* | *<3%* |

### Image Quality Phantom:

See separate information sheet

### Average intra-slice uniformity:

***Nema NU2 1994***

| | |
|---|---|
| 2D | 8% |
| 3D | 10% |

### Reconstruction Times:

***Sample reconstruction times for one field-of-view (37 transaxial slices of 128x128 pixels, including all corrections, and with no data mashing).*** *Sample reconstruction times are measured using the image quality phantom specified in section 7 of the NEMA NU2-2001 standard.*

| *Algorithm* | *Standard 4-node array processor:* |
|---|---|
| *2D FBP/MAC* | *17 sec* |
| *2D OS-EM/SAC* | *62 sec* |
| *3DFORE/IR/SAC* | *3 min 22 Sec* |

| *Algorithm* | *Enhanced 8-node array processor:* |
|---|---|
| *2D FBP/MAC* | *10 sec* |
| *2D OS-EM/SAC* | *37 sec* |
| *3DFORE/IR/SAC* | *2 min 13 sec* |

| *Algorithm* | *Ultra 12-node array processor:* |
|---|---|
| *2D FBP/MAC* | *8 sec* |
| *2D OS-EM/SAC* | *27 sec* |
| *3DFORE/IR/SAC* | *1min 55 sec* |

## System Description

### Whole Body Scanning:

Maximum covered range: 280 cm

### Dynamic Histogram Acquisition:

Shortest frame time 1 second;
up to 100 dependent on acquisition parameters

### Gated Histogram Acquisition:

Number of frames: 2-20
Temporal resolution:1 ms
Collection modes: variable and fixed forward binning; bad beat rejection

### Detector/Gantry:

- Detector ring diameter: 92.7 cm
- Detector layout: 12,096 individual crystals arranged in 18 rings of 672 crystals each
- Crystal type/size: BGO, 4 mm transaxial, 8 mm axial, 30 mm radial
- Septa: 1 mm tungsten interplane septa, 11.7 cm long to minimize random and scattered coincidences
- Automatic retraction of interplane septa to switch from 2D to 3D mode or back in <30 seconds
- Patient port size: 59 cm diameter circle
- Low acoustic noise at gantry center: <50dBA
- Shielding of both the front and back of the detector units prevents detection of events from outside the scan planes
- Scan field of view located toward front of gantry for improved patient positioning access
- Large numerical display on gantry for indication of total system count rate at all times and to show elapsed time during acquisition
- Triple-axis laser alignment lights to indicate center of first image plane with $\pm$0.25 mm accuracy
- Operator controls and position indicators for gantry and table on each side of gantry

### Transmission and Normalization Sources:

- Automatic loading and storage of all rod sources used for calibration and attenuation correction (less than 30 seconds/pin to load or store)
- Shielded storage container located in gantry
- System operation requires two transmission measurement rod sources[1] ($^{68}$Ge, 10mCi maximum each) and one normalization rod source[1] ($^{68}$Ge, 1.5mCi maximum)

### Patient Imaging Table and Accessories:

- Single table, cantilever design includes large range of height adjustment to accommodate patient loading from ambulatory, gurney, or wheel-chair

[1] Rod sources are not included.

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- Vertical range: 52.8 cm to 104 cm
- Elevation speeds: 5mm/s and 20 mm/s
- Max 170cm horizontal table travel
- Horizontal speeds: 5 mm/s and 75 mm/s
- Positioning: 0.5 mm resolution with ±0.25 mm accuracy
- Table load capacity: 200 kg (450 lbs) maximum allowed with normal operation. Positional accuracy of ±0.25mm guaranteed up to 180 kg (400 bs).
- Maximum deflection: 16.5 mm max at scan field of view with 180 kg (400 lbs.) load
- Table position controlled from operator workstation for prescribed scans or from switches located on either side of the gantry
- Fixed offset headholder, armrests, patient security straps and patient positioning cushions are standard equipment
- 20 cm combination phantom with inserts provided for measuring system performance and cross-calibration with well-counter

**Event Detection and Processing:**

- Individual position mapping of each crystal to improve spatial resolution.
- No data "mashing"
- Individual energy mapping for each crystal to improve system energy resolution
- Deadtime measured directly during acquisition to improve correction accuracy

### System Dimensions & Weight:

Gantry weight: 2721 Kg (6000 lbs.)
Table weight: 544 Kg (1200 lbs.)
(when supporting a 200 Kg (450 lb.) Patient)

- System electronics customized for 3D volume imaging capability via Custom VLSI coincidence circuitry
- Random correction in real time or storage of separate prompt and delayed files

**Data Acquisition and Reconstruction System:**

- Dedicated real-time system controller
- Reconstruction array processor employing PowerPC 750 (375 MHz 32 Bit) processor nodes; 4 G3 nodes are standard. Optional upgrade to 8, or 12 node, G3 based array processor system is available for faster image reconstruction, providing up to 1600 Mflops single precision performance.
- 128 MB of dynamic histogram memory stores up to 40 separate 2D sinogram sets for gated or fast dynamic studies.
- Histogram memory expandable in 128 MB increments up to 512 MB (160 sinogram sets).
- System raw data maintained on SCSI high performance 18 GB disk.

**Operator Workstation:**

- Processor: Dual RISC 450MHz processors with 512MB RAM
- Data storage: Two internal 18 GB hard drive for system software and over 400K 128x128 images 16-bit images.

Data acquisition/reconstruction System: 272 Kg (600 lbs.)
Installation access: gantry envelope of 2025x 2363 /w x 978 /d mm (79.75" x 93" /w x 38.5" /d)

- Video display: 21" tilt and swivel high-resolution (1280 x 1024), color monitor supports 24-bit true color and gray scale
- Communications: ethernet with TCP/IP and NFS protocols
- Archival storage: 4mm digital audio tape (DAT) standard (12 GB storage capacity), and magneto optical disk (4.6 GB storage capacity)
- Unix operating system with X11/Motif user interface and industry standard ( Informix™) data base
- Image analysis and display software: See details under "Image Display and Analysis Capabilities," page 2.

**Optional and Accessory Items**:

- EKG synchronizer for acquiring gated frame cardiac studies.
- EKG strip chart recorder.
- 5.25" 2.6 GB read/write optical disk for removable data base and additional on-line storage.
- Additional acquisition memory (in 128MB increments, up to 512 Mbyte).
- GE color printer for 8-1/2" x 11". medical paper or transparency
- GE LaserCam HQ for 14" x 17". or 8" x 10". film formatting.
- Laser text printer
- Additional image display and analysis workstations for image processing.

Dimensions: reference attached illustrations.

### Environmental Requirements:

Operating temperature range:
18.3° – 24° C

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Operating humidity: 30%-60%

### Cooling Requirements:

| System Component | Watts/BTU/ hr |
|---|---|
| Gantry/table | 2900/9700 |
| Acq./recon. system | 3500/11900 |
| Operator workstation | 1600/5400 |
| Optional Laser Camera | 650/2200 |

### Power Requirements:

Voltage: 240 single phase or 208 three phase
Current: 75 A maximum
Frequency: 60 Hz/50 Hz
Voltage stability: +11%, -4%
Line regulation: 3%

### Regulatory Compliance:

This product was designed to comply with applicable standards under the Radiation Control for Health and Safety Act of 1968. Laser alignment devices contained within this product are appropriately labeled according to the requirements of the Center for Devices and Radiology Health.

### Certifications:

Complies with applicable IEC 601.1 requirements.
Listed as UL544 compliant. This product is EMC compliant and certified to meet all applicable requirements of 93/42/EEC and bears the CE mark of conformity.

This product has been designed to meet applicable CSA standards.

### Regulatory Compliance:

This product was designed to comply with applicable standards under the Radiation Control for Health and Safety Act of 1968. Laser alignment devices contained within this product are appropriately labeled according to the requirements of the Center for Devices and Radiology Health.


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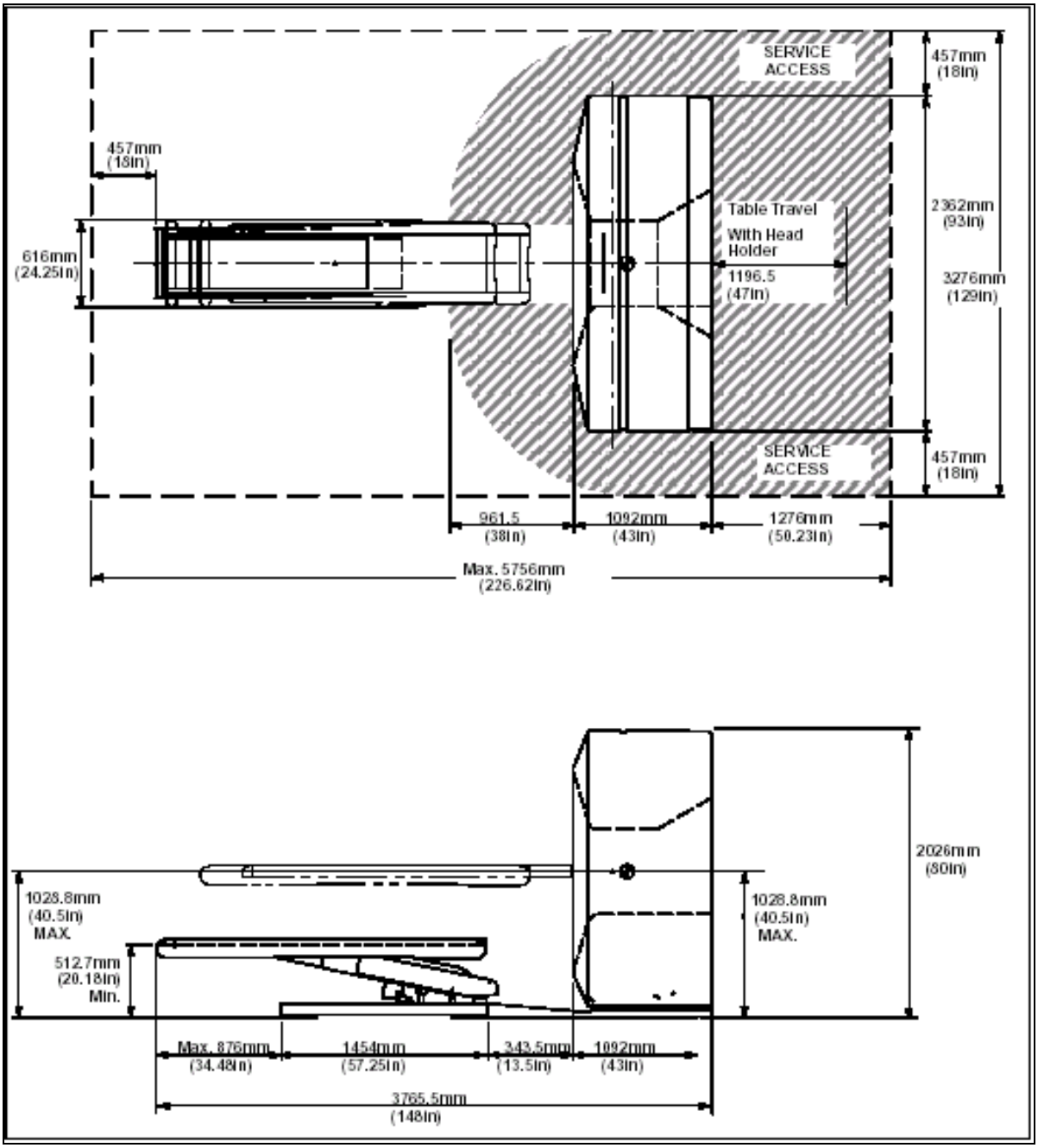


*Figure 1: GANTRY & PATIENT TABLE*

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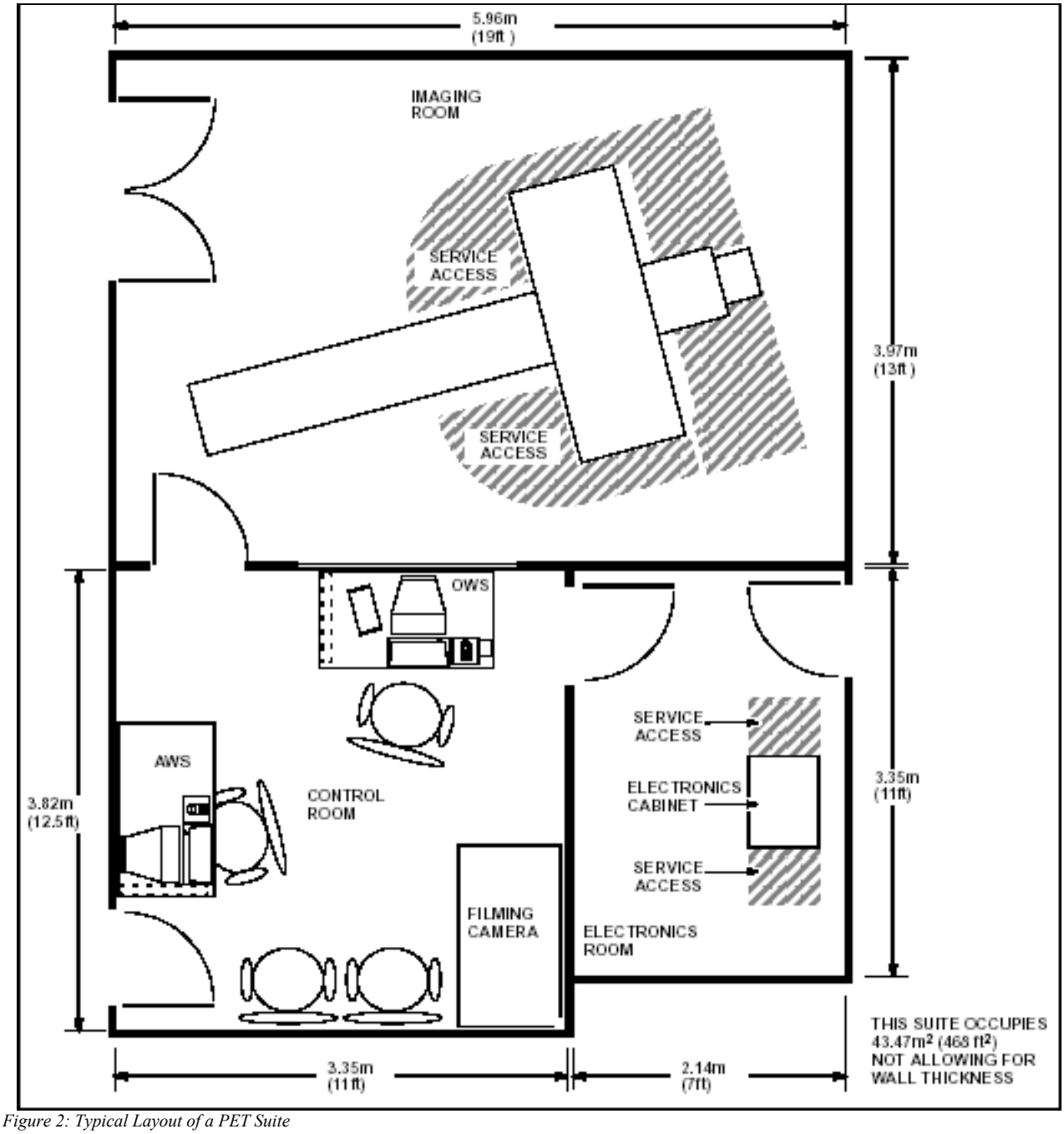


*Figure 2: Typical Layout of a PET Suite*

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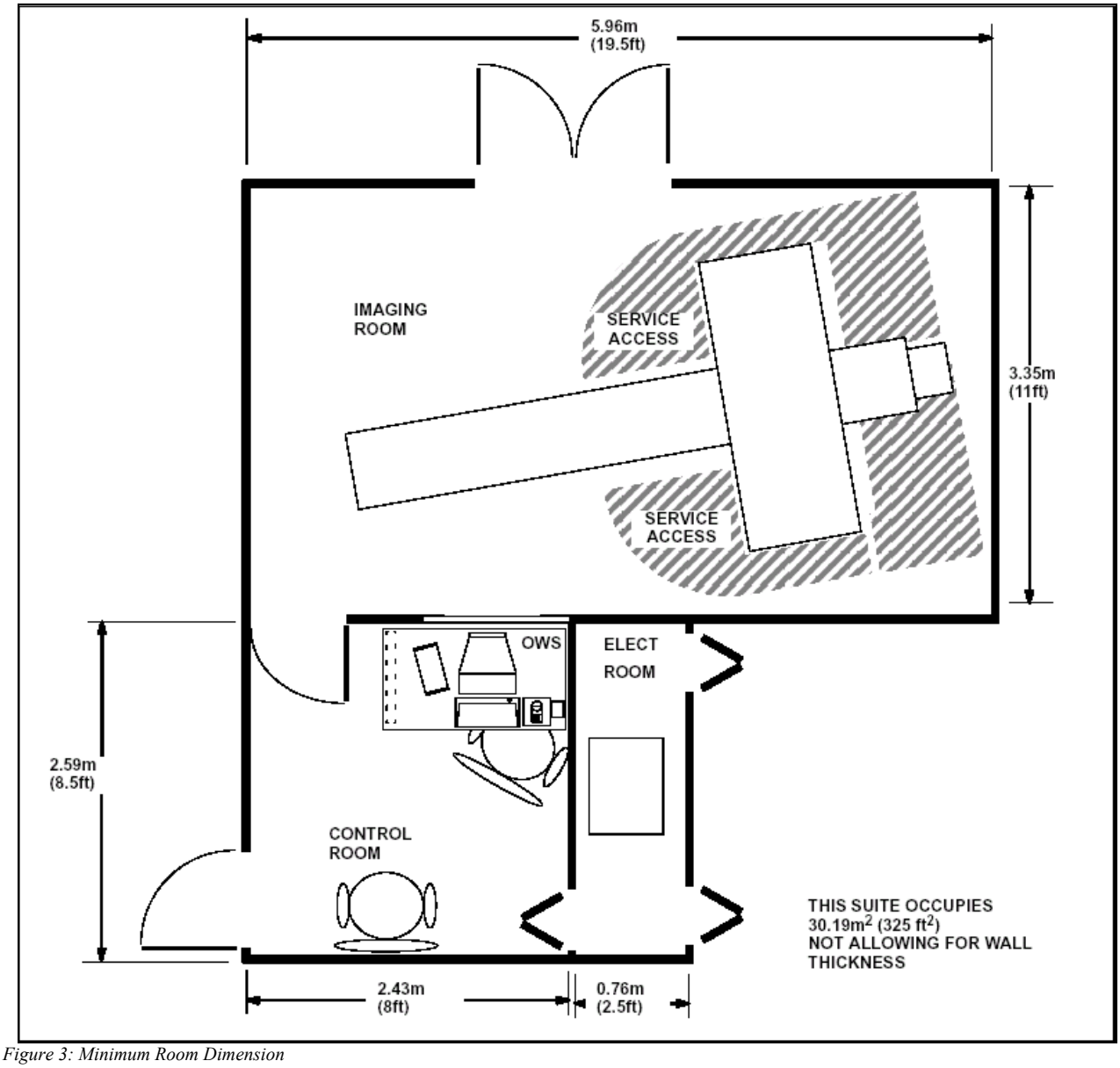


*Figure 3: Minimum Room Dimension*

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