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(54) Title: SMALL ANIMAL IMAGING CAPSULE AND BED SYSTEM

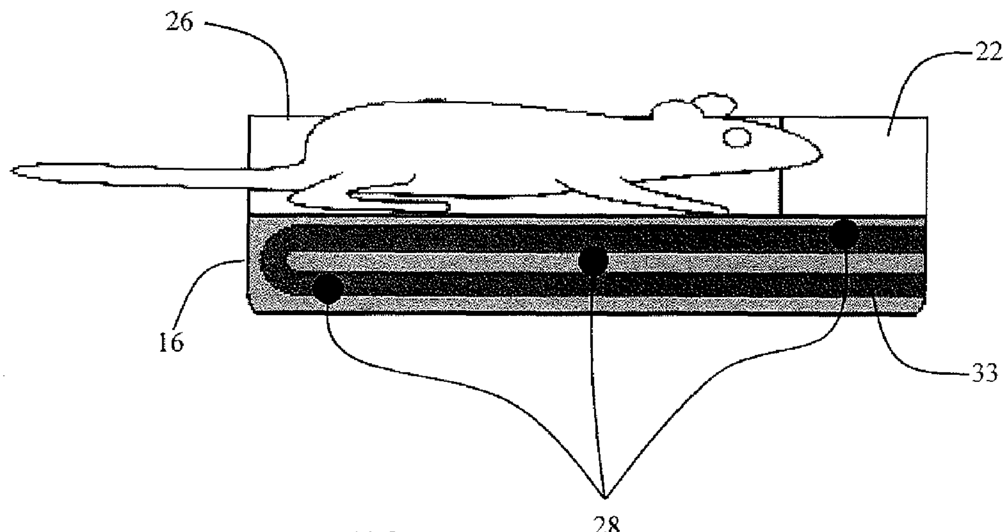


FIG. 5

**(57) Abstract:** In a small animal imaging system (10) at least one modality (12) and a docking station (36) are provided. The docking station (36) provides a workspace (47) and docking ports (48) for preparation and holding of anesthetized animals that are awaiting imaging. For the duplication of positions, a subject mold (26) is provided that holds the subject in a reproducible position on a subject bed (16). Vital signs monitoring is also provided for subjects awaiting scans. The bed (16) includes fiducials (28) to aid in registration of like modality images and different modality images. A capsule (14) can encapsulate a single bed (16), or for tandem imaging, the capsule can encapsulate multiple- bed configurations, such as two, three, or four beds (16). For better positioning and ease of user access, a positioner (34) positions the capsule (14) from the rear of the modality (12).

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# SMALL ANIMAL IMAGING CAPSULE AND BED SYSTEM

## DESCRIPTION

The present application relates to diagnostic imaging of small animals. More specifically, it relates to control of imaging variables across many scans to aid in the quantification and reproducibility of imaging studies, and will be described with particular reference thereto. It is to be understood, however, that the present application can also be applied to other diagnostic imaging applications.

Investigation of in vivo models of disease is enhanced if studies are conducted using reproducible imaging of individual or groups of subjects. Objective control over factors that affect the imaging is desired for quantification and validation of results. Various biological functions affect imaging and it is desirable to either control or monitor these functions through potentially long time periods and across heterogeneous imaging steps if the results are to be used in quantitative studies. Existing monitors and controls are tedious and error prone to set up and cannot be moved between imaging procedures.

Small animal imaging modalities, such as PET and CT, provide unique opportunities for imaging of models of disease implanted in genetically altered animals. Small animal PET for example, is a functional imaging modality that provides valuable insights into biochemical, physiological, and pharmacological processes in vivo. Current applications include perfusion, metabolism and substrate utilization in vital organs such as heart and brain, gene expression, tumor biology and angiogenesis, hypoxia and apoptosis, among many others. Small animal CT on the other hand, is a structural imaging modality that provides high bone to soft tissue contrast. It is used for screening of anatomical abnormalities, differentiation of tumors from normal tissues in angiogenesis, visualization of neo-vascularization with the aid of contrast agents, and etc.

Researchers working with small animal PET and small animal CT perform imaging of small animals such as mice and rats. The investigation and validation of in vivo models of disease require serial imaging of the same or groups of animals over time. A common goal of such studies is to compare and track the progression of disease by using the complementary information provided by the two imaging modalities. Consequently, quantification and accurate assessment of experimental results cannot be achieved without image registration that aligns the acquired volumes in the same coordinate space. Given the practical and logistical limitations of current small animal nuclear, CT, and MRI devices, it is customary to image a single animal at a time whereas it would be beneficial to be able to image multiple animals at the same time for the inclusion of one or more control animals and/or to process multiple animals in parallel for increased throughput.

The present application provides a new and improved small animal imaging handler which overcomes the above-referenced problems and others.

In accordance with one aspect, a diagnostic imaging system is provided. At least one imaging module acquires diagnostic imaging data of a subject in an imaging region of the module, the module having at least a first docking interface. A user prepares the subject at a docking station in preparation for imaging in the imaging module. The docking station has at least a second docking interface. At least one animal capsule encapsulates the subject and interfaces with the first and second docking interfaces. The capsule can come in different sizes and shapes, to accommodate different types of animals (e.g. rats, mice) additional animals in the same capsule (e.g. two rats, two, three or four mice) or different modalities.

In accordance with another aspect, a method of diagnostic imaging is provided. A conscious animal is placed in an induction chamber to anesthetize the animal. The anesthetized animal is mounted to a subject support. The animal is secured and positioned with a mold. A cover is placed about the support, encapsulating the animal. The support is docked at a docking interface of a docking station in a time period following preparation of the animal and before imaging of the animal. The support is removed from the docking station and docked with a docking interface of an imaging modality. At least one diagnostic imaging sequence of the animal on the support is initiated. The animal is then removed from the support after the imaging sequence is complete. The animal regains consciousness in a post-anesthesia chamber to allow the animal to recover from anesthesia.

One advantage is increased subject throughput.

Another advantage lies in the ability to control variables that affect the reproducibility or quantifiability of the study, such as but not limited to, body core temperature and depth of anesthesia.

Another advantage is the ability to image multiple animals at the same time to enable comparison studies.

Another advantage lies in improved monitoring of physiological parameters that may be used in evaluating the study results.

Another advantage lies in use of monitored parameters to raise alarms or alerts that may affect imaging results or subject health.

Another advantage lies in the ability of imaging researchers to move freely between imaging steps allowing a more effective use of the laboratory area.

Another advantage lies in more accurate registration of diagnostic images.

Another advantage lies in improved statistical confidence in the analysis of collected imaging data.

Another advantage lies in environmental control of animals awaiting imaging.

Still further advantages of the present invention will be appreciated to those of ordinary skill in the art upon reading and understand the following detailed description.

The invention may take form in various components and arrangements of components, and in various steps and arrangements of steps. The drawings are only for purposes of illustrating the preferred embodiments and are not to be construed as limiting the invention.

FIGURE 1 is a diagrammatic illustration of an animal imaging system, in accordance with the present application;

FIGURE 2 is a profile view of an animal imaging capsule;

FIGURE 3 is a perspective view of a two bed embodiment;

FIGURE 4 is a perspective view of a four bed embodiment;

FIGURE 5 is a profile view of an animal support bed with a corresponding positioning mold;

FIGURE 6 depicts an exemplary fiducial for the bed of FIGURE 5;

FIGURE 7 illustrates an exemplary workflow timeline;

FIGURE 8 illustrates relationships between the hardware aspects of the present application;

FIGURE 9 is a schematic diagram of one possible implementation of the system of FIGURE 1.

With reference to FIGURE 1, an exemplary small animal imaging system **10** is shown. The present application contemplates a system with modules for positron emission tomography (PET), Computed Tomography (CT), single photon emission computed tomography (SPECT), other diagnostic imaging modules, animal preparation, and a computer workstation for visualization, image registration, fusion, and analysis capabilities. The various modules are combined within a cover that allows flexible configurations with various combinations of side-by-side configurations, determined by space and throughput issues. A common animal positioner is also contemplated, as well as an animal holder that can be docked and undocked against the positioner. In a side-by side configuration, as shown in FIGURE 1, accurate image registration is achieved through the docking feature, which provides positional accuracy and repeatability when the animal holder is docked and undocked. Additional image registration can be obtained through the use of fiducial markers.

With reference to FIGURE 2 continuing reference to FIGURE 1, an imaging modality **12** is responsible for imaging data acquisition. As mentioned above, the modality **12** can be any imaging modality, including but not limited to one or more of PET, SPECT, CT, and MRI. Depicted in FIGURE 1 is a second modality **12'**, different than the first modality **12**. An animal capsule **14** holds one or more animals during imaging sessions. The capsule **14** typically includes one or more holders, or beds **16**, a cylindrical cover **18**, physiological parameter sensors **20**, provisions for anesthesia **22**, such as a nose cone into which the animal's nose fits, and a holder-side docking interface **24**. The docking interface **24** is preferably designed in such way that minimal insert/twist force is applied when the holder is inserted into the imaging modality **12**. It is preferable that the position of an animal is not disturbed when it is transferred from one modality to another. The docking interface **24** provides monitoring, heating and anesthesia interfaces to the capsule **14**. Detection of animal capsule **14** attachment and presence of animals inside the handlers can be done based on monitoring results. For example, if there are no ECG or respiration signals coming from a capsule **14**, it is assumed that there is no animal within the capsule. If no animal is detected within a capsule **14**, the capsule **14** can be considered disconnected. This check may result in e.g. adjusting user interface's properties so that all displayed/entered information is limited according to the number of detected animals. Also, this information may be used to recognize the current configuration of the modality **12**.

This interface **24** preferably supports up to four animals, but more interfaces are certainly contemplated. By configuring all the modalities and docking stations with a uniform docking interface **24**, the user can exchange the holder between different modalities and docking stations. Docking interface functionality includes providing monitoring, heating and anesthesia interface to the capsule **14**. For safety reasons, the anesthesia valves can be automatically shut off when the capsule **14** is detached and can be reopened when it is attached, e.g. check valves. The capsules are preferably constructed to withstand many cleanings and sterilizations, e.g., alcohol, steam, radiation, and the like.

A single animal capsule **14** can support several different bed **16** configurations. One capsule **14** can accommodate up to two (2) rat beds **16**, and alternatively, one capsule **14** can accommodate up to four (4) mouse beds **16**, that is, one two, three, or four mice could be accommodated in on capsule. A two-bed embodiment is shown in FIGURE 3, and a four-bed embodiment is shown in FIGURE 4. Apart from at least one bed mount, each of the capsule interfaces **24** also provides one or more sockets connected with the measurement sensors **20**, a fluid interface for air and anesthesia, and the like. The beds **16** can be either profiled beds or flat pallets. For increasing heating efficiency, it is preferable that separate and as small as possible cylinders **18** be used around each of the animals instead of one large cylinder **18** covering all the animals, although the latter embodiment is by no means unviable. The cylinders **18** are preferably easily removable. Holes are also provided, through which it is possible to insert or pull out catheters for isotope injection and/or optional measurements and physical interactions.

A flat pallet bed type allows animal technicians to work with non-standard measurements or with non-commonly used animals or animal configurations. The technicians can freely place different animals of different sizes and weights. The nosecone **22** on the pallet bed **16** preferably is interchangeable to accommodate different sizes of animals. The nosecone **22** is preferably radio-translucent and tightly covers the animal's head. Additionally, the nosecone **22** can be removed, e.g. if an injected anesthesia is used. The pallet bed **16** is equipped with holes at each side for mounting motion restraints.

In another embodiment, the bed **16** is a form fitting, profiled bed. The profiled bed **16** preferably comes in a few types, each adjusted to different animal category (rats, mice) and sizes (small, medium, large). The bed curves allows for easy and repeatable animal positioning, both with the same subject in temporally remote scans, or with different subjects. Motion restraints are integrated into the bed to prevent re-arrangement of the subject during or between scans. Restraints integrated with the bed **16** are also contemplated in lieu of traditional taping and un-taping.

With reference to FIGURE 5, for purposes of positioning subjects in reproducible positions, and to aid registration of images, a mold **26** is made of a subject. Silicone rubbers are contemporary materials available for making molds and have a very good chemical resistance and a high temperature resistance (205°C and higher). Small animals such as mice and rats are substantially standard in weight and have very small variation in size and shape. For example, the average body weight of an athymic mouse is 20 grams with a small standard deviation of 2 grams. By placing an animal on the larger end of the scale in a container of silicone rubber a technician can produce an external mold **26** of the animal body. The mold **26** is then cured and attached to the small animal imaging bed **16**. A set of molds custom fitted to general shape of the imaged animals (e.g. mice, rats, guinea pigs, etc.) can be prepared similarly and used interchangeably as needed. Imaging different animals placed in the same mold **26** on the imaging bed **16** keeps their shape, orientation, and position relatively similar, significantly simplifying intra-subject rigid or elastic matching of serially acquired volumes of the same animal as well as inter-subject registration.

To further aid registration of both intra- and inter-subject images, non-radioactive fiducial markers **28** are attached to the bed **16** to provide support for image based rigid or elastic registration techniques. An exemplary fiducial marker **28** is shown in FIGURE 6. Solid copper may serve as a fiducial marker in CT, PET, and SPECT. Small spheres or wires of copper **30** are visible in CT while neutron activation of these same markers produces positron-emitting Copper-64 for detection by PET and SPECT. Copper is easily machined into desirable shapes, and prior to activation, is easy and safe to handle. The center of fiducial markers **28** with spherical shapes is easily detected by a Hough transform or another image processing technique such as edge detection followed by a centroid calculation. The process is fully automatic, robust and reliable. After the centers of the fiducial markers **28** are detected, a least squares algorithm for rigid registration can be applied to serially acquired images to correct for a global rigid alignment. Once the partial images are brought into rough alignment, elastic matching can be applied to correct the non-rigid deformations between the volumes that in this case will be constrained by the holder mold **26** custom fitted to the shape of the imaged animal. A base **32** of the fiducial markers **28** can be made in such a way that allows the markers **28** to be attached only if needed. It is also preferred that the fiducials **28** are placed in non-linear and non-planar locations. Optionally, the fiducial **28** includes a hollow copper sphere filled with an MR imageable substance, such as copper sulfate, doped water, hydrogen containing gel or plastic, or the like.

The sensors **20**, such as ECG and respiration probes are preferably integrated with the bed **16**. Alternately, sensors can be applied to the subject manually. $SpO_2$ and heating elements may also be parts of the bed **16**. Position marks on the bed (i.e. ruler-like markings) assist in reproducing positions when mounting subjects to the bed **16**. Given that exact repositioning is desirable in brain imaging, a stereotactic frame may be included. To allow access to the subject without disturbing the subject's position while it is fixed to the bed **16**, it is preferable to leave the animal's tail, legs, and eyes accessible while the animal is fixed to the bed **16**. It is desirable to autoclave elements that have been in contact with animals, so those particular components are preferably resistant to high temperature steam cleaning and disinfection.

The beds are independently removable to facilitate access to subjects in multi-animal configurations. With rat and mouse subjects, heated tail holders are preferable because they help prevent tail veins from contracting in a cold environment and altering blood flow rates. Moreover, the beds **16** include heating mechanisms **33** for controlling the subject's temperature while attached to the bed **16**. This can be built-in tubing for temperature control, such as embedded tubes in the base of the bed **16** that would allow for the circulation of heated water or air. In another embodiment the bed could include resistive coils and electrical connections. The temperature of the bed can be controlled by a thermostat that can turn on or off the heating of water, air, or resistive coils.

Absorbent materials can be included to handle excretion during imaging sessions; the bed design can accommodate disposable materials, or they can be integrated into the bed **16**. The bed **16** can be designed with all or most of desired probes embedded into the bed **16**. Alternately, the bed can be designed with all probes flexible enough to be placed wherever they are required by the operator. The integrated sensors **20** are useful for standardized imaging, specifically where throughput is an issue. External probes can be used, e.g., in complex research scenarios, where it is more desirable to execute a given scenario with maximum accuracy.

With reference again to FIGURE 1, the system **10** also includes an animal positioner **34** capable of receiving and docking the capsule **14**. The positioner **34** is used to position the animal capsule **14** optimally in an imaging region of the scanner **12** during an imaging session. The capsule **14** has an identifier to provide a unique holder identity to the system. The identity can be read when the capsule **14** is connected to the animal positioner **34**, e.g. a bar code that moves past a reader during insertion. Fixed laser devices can also be used to aid in registration. A docking station **36** provides anesthesia and monitoring while the animal capsule **14** is attached awaiting a scan. As shown, the docking station may include storage space **38** for storage of additional beds **16** cylinders **18** or other devices when not in use. Although the animal preparation and imaging modules are contemplated and shown side by side, animal preparation and imaging may be located in separate rooms.

A side-by-side configuration of the modules **12, 12', 36** is preferred because it facilitates ease of workflow. The user does not have to be constantly walking back and forth across a room, or between rooms. An exemplary workflow is depicted in FIGURE 7. In particular, it is a workflow for a PET imaging sequence. In such a workflow, there is potential for down time when the animal is actually being scanned. The radioisotope only decays so fast. In such a workflow, it becomes advantageous to prepare subsequent animals while one is being imaged, so that when the first scan is complete, a subsequent animal is ready to be imaged with no additional prep time. The workflow of FIGURE 7, or one similar to it, happens for each animal, but the docking station **36** allows these workflows to substantially overlap, reducing overall work time, and increasing subject throughput.

In an illustrative example, say a typical animal scan takes ten minutes, which includes five minutes of prep time, and five minutes of scan time. To scan six animals would take an hour, if the workflow were repeated from start to finish for each animal. This includes time when the scanner is not scanning. The docking station **36** allows pre-preparation of the animals. While the first animal is being scanned, the second animal will be prepped and held at the docking station **36**. Thus, the same task of scanning six animals is performed in only 35 minutes, with the only down time of the scanner being while the first animal is being prepped.

In the embodiment of FIGURE 1, the system **10** includes three modules, namely first and second acquisition modules **12, 12'** and the animal preparation module, that is, the docking station **36**. Of course, fewer or greater numbers of modules are contemplated. Preferably, the docking station **36** adds several aspects of functionality. With reference to FIGURE 8, an animal monitoring and anesthesia (AMA) system **40** is shown. An induction chamber **42** provides an area in which a conscious animal is placed so it can be anesthetized before it is mounted on the animal bed **16**. Before an imaging session can begin, the animal is placed in the induction chamber **42** where it is given preliminary anesthesia before further preparations will take place. Anesthetic agent is provided via a coarse anesthesia interface **44**. The subject's temperature is coarsely maintained with the use of heaters that rely on the environment or heater temperature. This control path is executed over a coarse temperature regulation interface **46**.

A physical workspace **47** is provided at the docking station **36** to attach the subject to a bed **16** and install the required sensors **20**, after the subject has been anesthetized in the induction chamber **40**. Docking ports **48** for continuation of life support and anesthesia of the subject between studies are provided at the docking station **36** within close proximity to the positioner **34**. Preferably, the number of docking ports **48** in the docking station matches the number of modalities available in the imaging facility (i.e. one docking slot per one available modality). Early preparation of a greater number of animals would not increase the imaging throughput, as imaging time is typically fixed, and is the factor that limits throughput. This way, the prepared animals spend no more time anesthetized than is necessary.

A post anesthesia chamber **50** or "wake up box" provides life support during wake-up of the subjects. Here, the subject's temperature is coarsely maintained via a coarse wakeup temperature regulator **52** in the same manner as it is done for subject in the induction chamber **42**. The post anesthesia chamber **50** is preferably well ventilated to speed the subject's recovery from anesthesia.

The preferred method of docking the capsule **14** to the receiving system is through a positive locking mechanism that is engaged through axial force applied by means of an actuator placed in the positioner **34**. Again, engagement of the actuator should not require disturbance of the animal. The docking interface **24** on each capsule **14** includes leads to engage the AMA system **40**, including electrical and gas connections. The anesthesia connection includes an "auto shut-off on disconnection" function to prevent loss of anesthesia to the environment.

During a procedure the subject is located on the imaging bed **16** and attached to either the docking station **36** or the imaging modality **12**. Its physiological parameters are monitored via a vital signs probes interface **54**. Anesthesia is supplied and controlled via an anesthesia interface **56**. This interface **56** can be a pneumatic interface that delivers anesthetic agent to the animal in the capsule **14** and extracts waste gases, but it can also include electrical (automatic) control of the agent concentration. Also the animal's core temperature is maintained with a temperature regulation interface **58** based on the current temperature measurement and desired target temperature value. The temperature regulation interface **58** preferably carries control signals that drive the heating elements working on per animal basis.

The AMA **40** also interfaces with one or more imaging modalities **12**. In the preferred embodiment, the modality's operation does not depend on the AMA **40**. For certain studies, however, physiological gating information is required in order to correctly build an image. A gating signal can be passed over a gating interface **60** that is the same for all imaging modalities. The gating interface **60** is preferably a TTL (0-12V) interface that accepts an active state as a gate event for image reconstruction.

An acquisition, reconstruction and control subsystem **62** also interfaces with the AMA **40**. The subsystem **62** has at least two functions related to the AMA **40**. These functions include presentation and storage of acquired vital signs data, control of monitoring and anesthesia functions, image reconstruction, correlation of vital signs data with image data, and the like. These commands and data are sent over a monitoring status and control interface **64**. The interface **64** can handle all monitoring data, status and control commands. It is to be understood that acquisition, reconstruction, and control are logical components that are physically distributed over different parts of the system **10**. A power distribution unit **66** distributes electric power to all subsystems.

The system also includes a computer workstation **68**. The workstation **68** includes a computer that controls main system functions and provides an interface for a user to work with the image and vital signs data. The workstation **68** includes acquisition control to allow starting, pausing, resuming and stopping an image acquisition and showing status and progress info on the acquisition. The workstation **68** also interfaces with the AMA **40** in order to display vital signs for multiple animals scanned across several modalities and stages of animal preparation on the workstation. Additionally, acquisition control and a reconstruction user interface reside on the workstation **68**. Multimodality function is included on the workstation **68** such as PET-CT non-rigid registration. In such a situation, interfacing with a CT Acquisition control can to be done via the workstation **68**. It is preferable that the workstation **68** provides a migration path for all applications of the system **10** to use a common platform for infrastructure services and operation. Naturally, the workstation **68** can be upgraded as new preparation techniques, scanning techniques, software, hardware, and the like become available. Alternatively, the AMA **40** is capable of running without an associated workstation **68**; however, functionality and accessibility to the AMA **40** would be more limited.

The workstation **68** presents information to the user and allows the user to enter data into the system. Optionally, the workstation **68** itself does not process information, it merely passes and receives it to/from behind-the-scenes processing **70**, storing and retrieving data from databases **72**, and the like. The workstation's **68** tasks include presenting results of monitoring and anesthesia, entering animal identification and tracer injection times, configuring gating signal, and the like. For entering experiment information and configuration settings an input device, such as a keyboard or mouse, is used. The workstation need not be a PC; it could be, for example, a display **74** on the modality **12** such as a touch screen. FIGURE 9 shows, in schematic form, one possible implementation of the system **10**.

In another embodiment, a portable AMA can be provided. To increase docking station's usage flexibility it is preferable that function in this embodiment is limited to docking capabilities. Preparation stations may vary significantly by size and complexity between different imaging facilities, therefore, it is preferred that the facility organizes the station wherever it suits them and their own needs. Then, the docking station can be placed either aside the preparation station providing storage for prepared animals, or it can be placed aside modalities, which often can be in different rooms, offering temporary storage for longer studies or when animal is exchanged between different modalities. Portability of such a unit would allow it to be placed wherever it is convenient. Also, its functional similarity to the normal AMA unit would allow technicians for early detection of wrong animal setup or monitoring and anesthesia defects.

The invention has been described with reference to the preferred embodiments. Modifications and alterations may occur to others upon reading and understanding the preceding detailed description. It is intended that the invention be constructed as including all such modifications and alterations insofar as they come within the scope of the appended claims or the equivalents thereof.

## CLAIMS

Having thus described the preferred embodiments, the invention is now claimed to be:

1. An imaging system comprising:

at least one imaging module **(12)** for acquiring diagnostic imaging data of a subject in an imaging region of the module **(12)**, the module **(12)** having at least a first docking interface **(48)**;

a docking station **(36)** where subjects are prepared for imaging in the imaging module **(12)**, the docking station **(36)** having at least a second docking interface **(48)**;

at least one animal capsule **(14)** that encloses one or more subjects and interfaces with the first and second docking interfaces **(48)**.

2. The imaging system as set forth in claim 1, wherein the at least one imaging module **(12)** includes a small animal PET scanner, CT scanner, SPECT scanner, MRI scanner, and a hybrid scanner containing at least two imaging modalities.

3. The imaging system as set forth in claim 1, wherein the docking station **(36)** includes an induction chamber **(42)** for anesthetizing an animal before securing the animal in the capsule **(14)**.

4. The imaging system as set forth in claim 1, wherein the docking station **(36)** includes a post-anesthesia chamber **(50)** into which an anesthetized animal is placed after an imaging session to allow the animal to recover from anesthesia.

5. The imaging system as set forth in claim 1, wherein the docking station **(36)** includes a workspace **(47)** that allows a user to prepare an anesthetized animal for imaging.

6. The imaging system as set forth in claim 1, wherein the capsule **(14)** includes a docking interface **(24)** that mates with the docking interface **(48)** of the imaging module **(12)** or the docking station **(36)**.

7. The imaging system as set forth in claim 6, wherein the docking interface **(24)** of the capsule **(14)** includes electrical connections and fluid connections.

8. The imaging system as set forth in claim 7, wherein the capsule **(14)** includes a nosecone **(22)** that is supplied by the fluid connections to keep an animal in an anesthetized state during imaging, and holding in anticipation of imaging.

9. The imaging system as set forth in claim 1, wherein the capsule **(14)** includes a subject support **(16)** upon which an anesthetized animal rests during imaging and preparation.

10. The imaging system as set forth in claim 9, wherein the subject support **(16)** is a contoured support that assists in positioning and registration of an animal.

11. The imaging system as set forth in claim 9, wherein the subject support **(16)** includes at least one sensor device **(20)** that measures at least one biological process of the animal while it is mounted to the support **(16)**.

12. The imaging system as set forth in claim 11, further including:

an alarm system that alerts a user when at least one abnormal biological process is detected.

13. The imaging system as set forth in claim 11, wherein the support **(16)** includes electrical leads connected to the sensors **(20)** that supply the sensors **(20** with power and enable communication.

14. The imaging system as set forth in claim 9, wherein the subject support **(16)** includes a heating element **(33)** for controlling the environment within the capsule **(14)**.

15. The imaging system as set forth in claim 14, wherein the heating element **(33)** includes a tail warming portion that specifically warms the tail of the animal mounted to the support **(16)**.

16. The imaging system as set forth in claim 9, wherein the subject support **(16)** includes fiducials **(28)** imagable by the imaging module **(12)** to aid in registration of images.

17. The imaging system as set forth in claim 16, wherein the fiducials **(28)** are imageable in at least two imaging modalities.

18. The imaging system as set forth in claim 9, wherein the capsule **(14)** includes a removable cover **(18)** that encloses the support **(16)**.

19. The imaging system as set forth in claim 9, further including:

a mold **(26)** contoured to the size and shape of the subject for securing the subject in place and reproducing subject positions, aiding in inter-subject and intra-subject registrations.

20. The imaging system as set forth in claim 1, further including:

a positioner **(34)** connected to the first docking interface **(48)** for positioning the capsule **(14)** in the imaging modality **(12)**.

21. The imaging system as set forth in claim 20, wherein the positioner **(34)** positions the capsule from behind the modality **(12)**, relative to where a user attaches the capsule **(14)** to the docking interface **(48)**.

22. A docking system comprising:

an animal monitoring and anesthesia device **(40)** for providing anesthesia to subject animals and monitoring subject vital signs;

an induction chamber **(42)** that interfaces with the monitoring and anesthesia device **(40)** for providing coarse sedation to subject animals;

at least one docking interface **(48)** having electrical connections and pneumatic connections, for receiving an animal capsule **(14)**.

23. A method of imaging comprising:

placing a conscious animal in an induction chamber **(42)** to anesthetize the animal;

mounting the anesthetized animal to a subject support **(16)**;

positioning and securing the animal to the support **(16)**;

placing a cover **(18)** about the support **(16)** to enclose the animal;

docking the support **(16)** at a docking interface **(48)** of a docking station **(36)** in a time period following preparation of the animal and before imaging of the animal;

removing the support **(16)** from the docking station **(36)** and docking it with a positioner **(34)** of an imaging modality **(12)**;

initiating at least one diagnostic imaging sequence of the animal on the support **(16)**;

removing the animal from the support **(16)** after the imaging sequence is complete;

placing the animal in a post-anesthesia chamber **(50)** to allow the animal to recover from anesthesia.

24. The method as set forth in claim 23, further including controlling variables in the imaging, the controlling including at least:

monitoring physiological aspects of the animal after anesthetizing the animal with sensors **(20)** integrated within the support **(16)**;

regulating the temperature of the animal with at least one heating element **(33)** integrated within the support; and

regulating anesthesia to the animal prior to and during imaging.

25. The method as set forth in claim 23, wherein positioning includes placing the anesthetized animal in a support **(26)** contoured to a size and selected imaging position of the animal.

26. The method as set forth in claim 23, further including:

repeating the method with at least one of a plurality of animals, the same animal over time, and the same or plural animals in a plurality of imaging modalities **(12)**.

27. The method as set forth in claim 26, wherein the support **(16)** includes alignment fiducials **(28)** and further including:

using the fiducials **(28)** to align images of at least one of the plurality of animals, the same animal over time, or the same or plurality of animals generated by different imaging modalities **(12)**.

28. The method as set forth in claim 23, wherein the cover **(18)** is placed around a plurality of supports **(16)** such that a plurality of animals are imaged concurrently.

29. An imaging system comprising:

at least one imaging modality **(12)**;

at least one capsule **(14)** for holding a subject in an imaging region of the modality **(12)** during an imaging scan, and for holding the subject in a sedated state prior to the imaging scan;

a capsule positioner **(34)** that positions the capsule **(14)** in the imaging region.

30. The imaging system as set forth in claim 29, wherein the capsule positioner **(34)** transfers the capsule **(14)** from a docking interface **(48)** on a docking station **(38)** to docking interface **(48)** on the modality **(12)** before positioning the capsule **(14)**.

31. A capsule **(14)** for use in an imaging apparatus comprising:

at least two subject beds **(16)**, each bed **(16)** supporting a sedated subject for simultaneous imaging in the imaging apparatus;

a cover **(18)** that encapsulates the at least two subject beds **(16)**.

32. The capsule as set forth in claim 31, wherein the capsule includes at least three subject beds **(16)**.

33. The capsule as set forth in claim 31, wherein the capsule includes at least four subject beds **(16)**.

34. A capsule **(14)** for use in an imaging apparatus comprising:

at least one subject bed **(16)** for supporting a sedated subject during an imaging scan;

at least one sensor **(20)** integrated into the subject bed **(16)** for monitoring at least one biological function of the subject located on the subject bed **(16)**;

a docking interface **(24)** that includes electrical connections for facilitating communication of the at least one sensor **(20)**.

35. The capsule as set forth in claim 34, wherein the bed **(16)** includes a registration system for aiding in image registrations.

36. The capsule as set forth in claim 35, wherein the registration system includes a contoured bed **(16)** that conforms to a natural disposition of the subject, substantially reproducing subject position across imaging scans.

37. The capsule as set forth in claim 35, wherein the registration system includes a plurality of fiducials **(28)** associated with the bed **(16)** arranged in a non-linear fashion that are imagable by the imaging apparatus.

38. The capsule as set forth in claim 37, wherein the fiducials **(28)** include a material capable of being imaged in at least two different imaging modalities.

39. A method of imaging comprising:

anesthetizing at least one subject;

affixing the at least one subject to an imaging bed **(16)**;

encapsulating the subject and the bed **(16)** with a cover **(18)** forming a capsule **(14)**;

connecting the capsule **(14)** to a docking port **(48)** of a docking station **(36)**;

providing vital signs monitoring of the subject, continued anesthesia, and waste gas removal while the capsule **(14)** is docked to the docking station **(36)**;

removing the capsule **(14)** from the docking station **(36)** and connecting the capsule **(14)** to a docking port **(48)** of an imaging modality **(12)**;

positioning the capsule within an imaging region of the modality **(12)**;

performing an imaging scan of the subject within the capsule **(14)**;

providing vital signs monitoring of the subject, continued anesthesia, and waste gas removal while the capsule **(14)** is docked to the modality **(12)**.

40. The method as set forth in claim 39, wherein continued anesthesia and waste gas removal are provided through pneumatic connections located in a docking interface **(24)** of the capsule **(14)**, and vital signs monitoring is provided via electrical connections in the docking interface **(24)** of the capsule.

41. A method of performing an imaging test comprising:

placing a subject under general anesthesia;

affixing the subject to a subject support bed **(16)**;

placing the subject bed **(16)** within a cover **(18)** creating a subject capsule **(14)**;

connecting the capsule to a docking port **(48)** of an imaging modality **(12)**, the docking port interfacing with a docking interface **(24)** of the capsule **(14)**, creating electrical and pneumatic connections to the capsule **(14)**;

monitoring at least one condition in the capsule **(14)** via the connections while the capsule **(14)** is docked to the docking port **(48)**;

altering at least one imaging protocol performed by the modality **(12)** based on results of the monitoring.

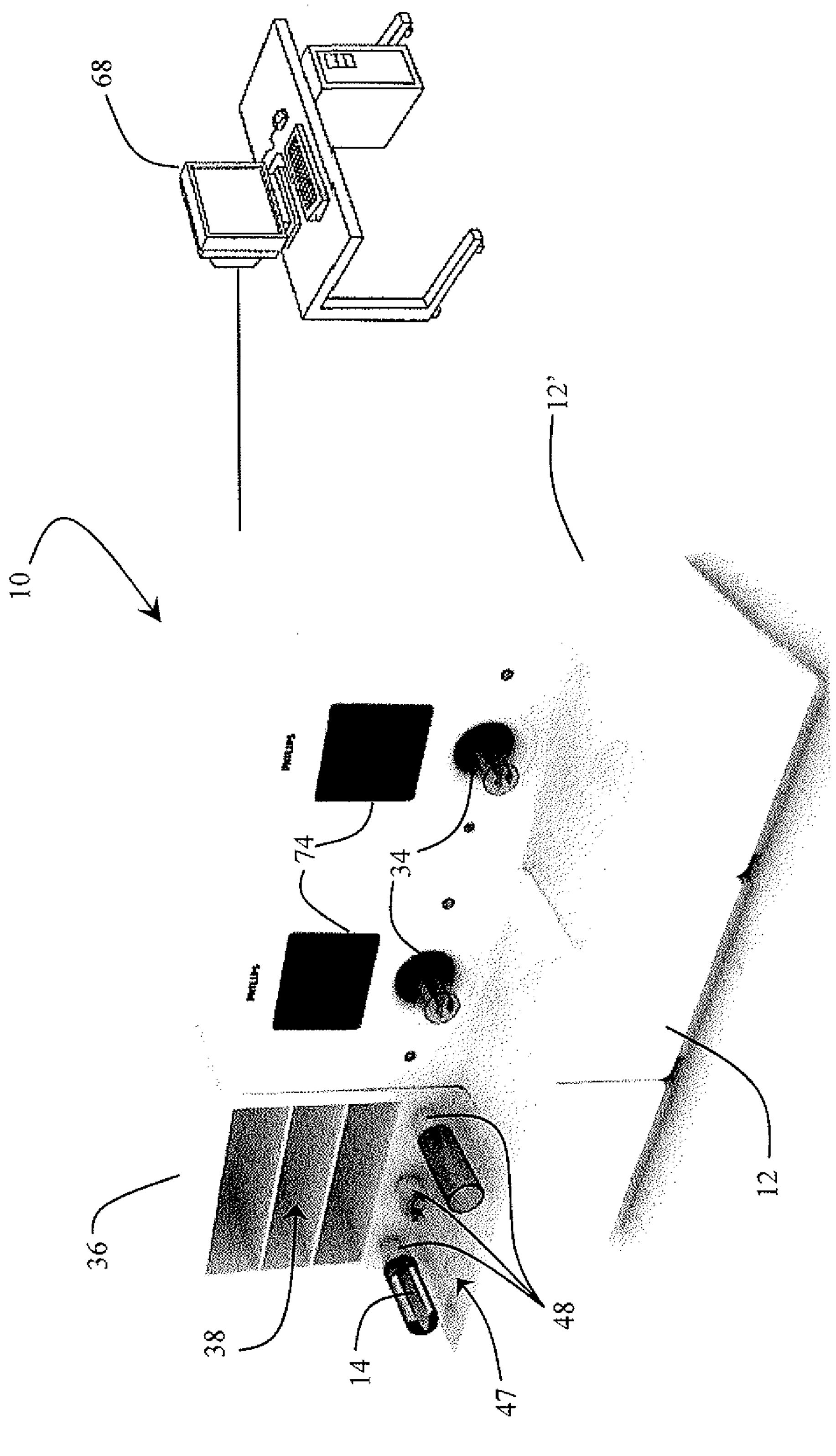


FIG. 1

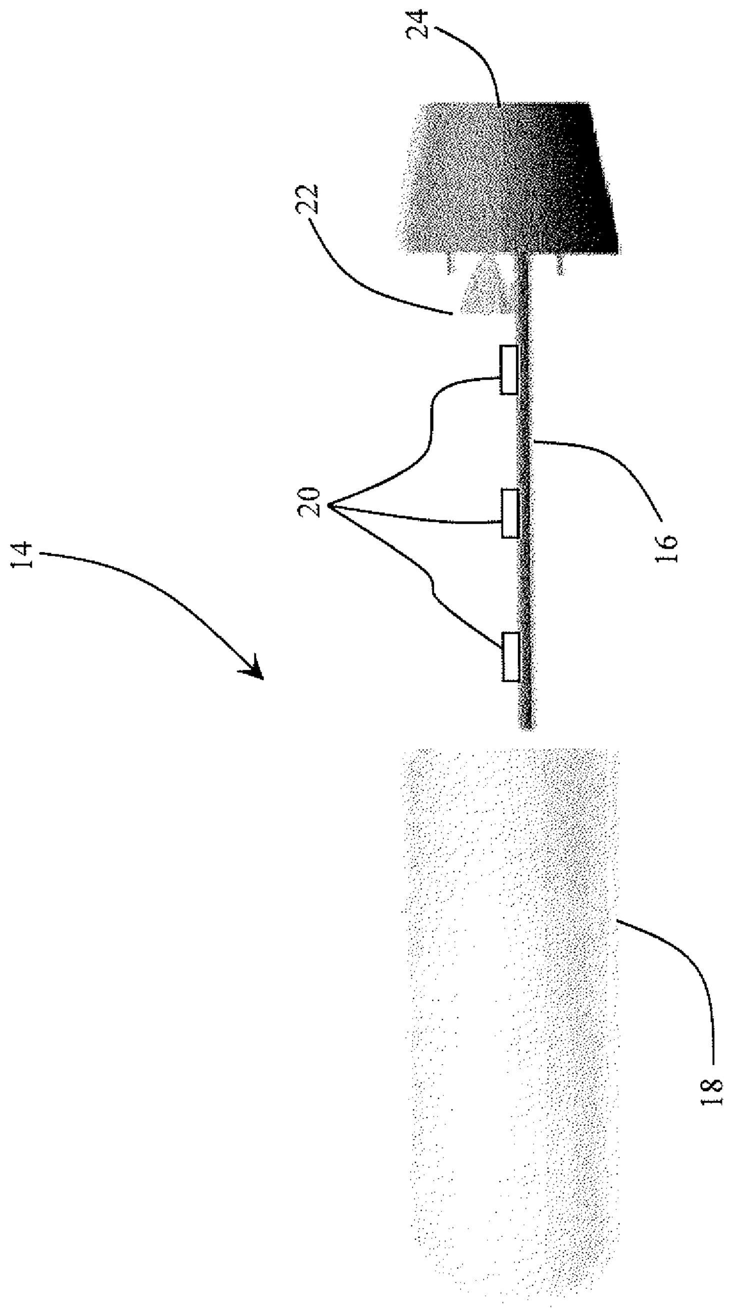


FIG. 2

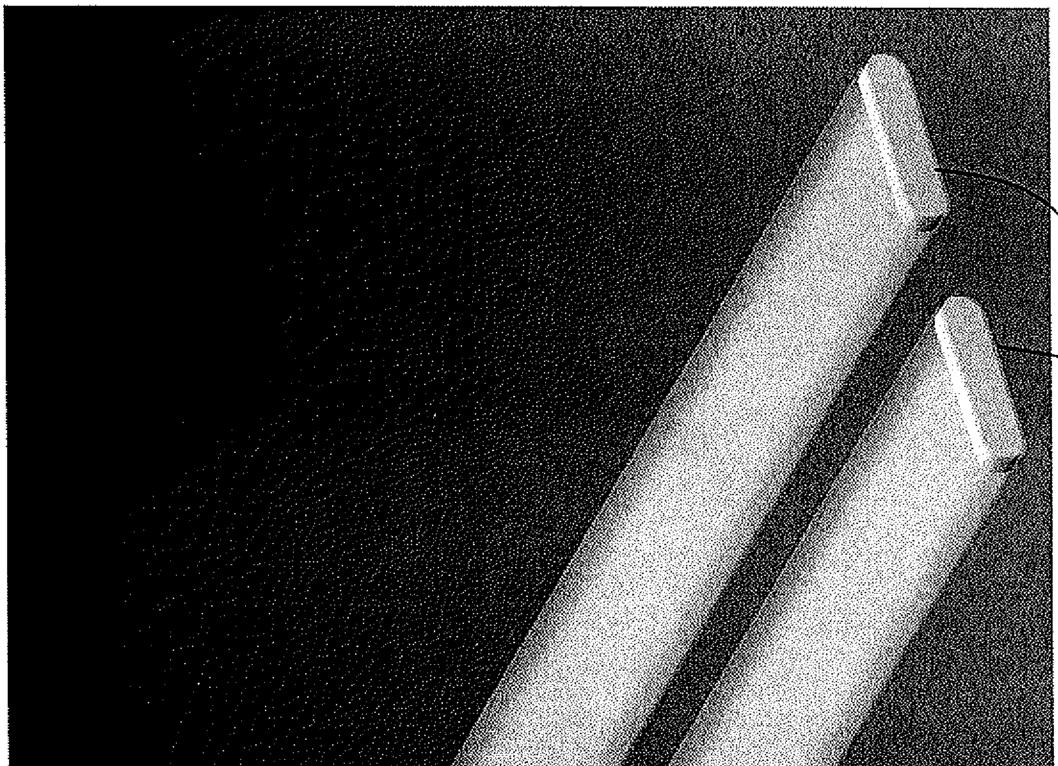


FIG. 3

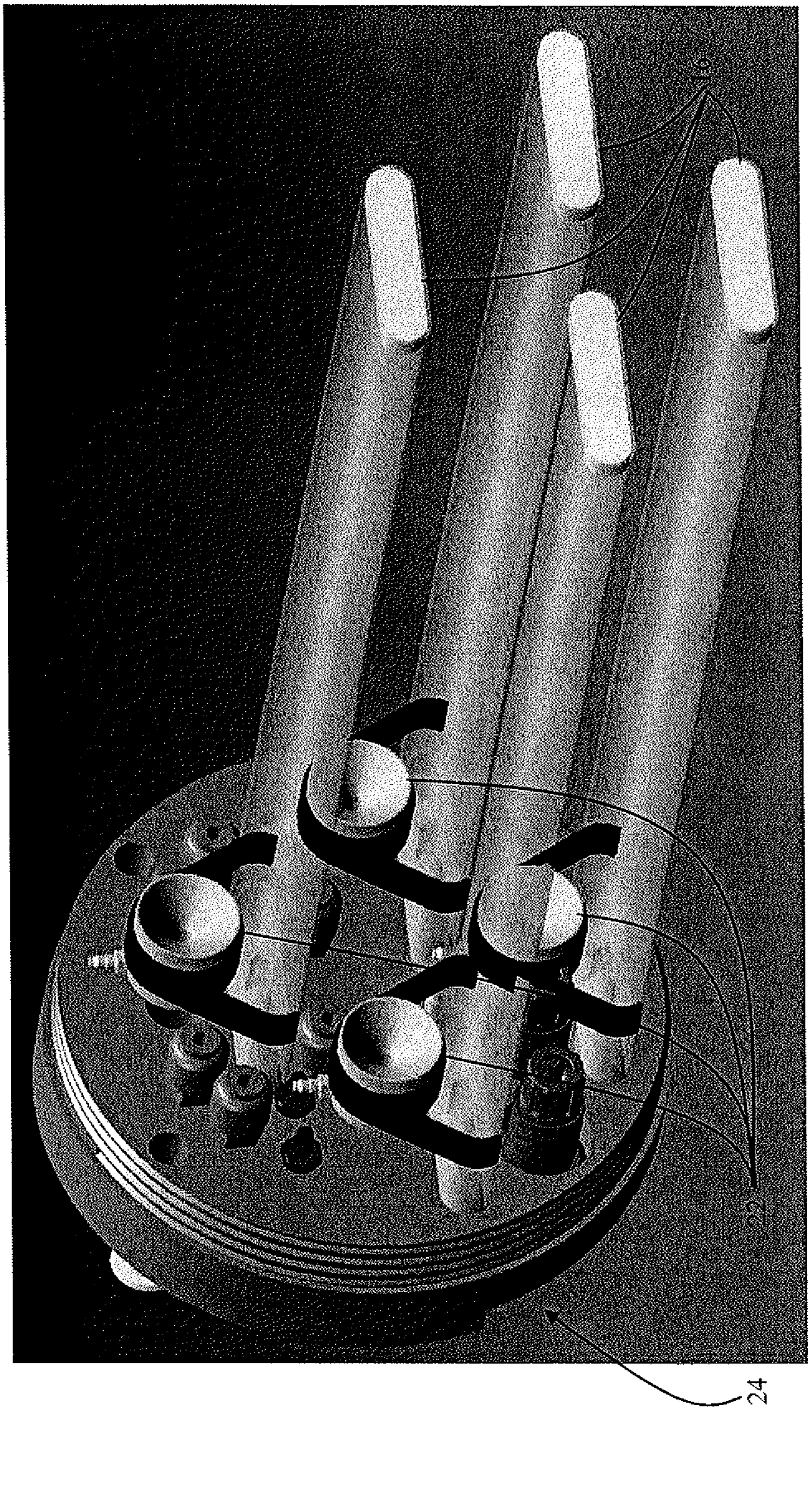


FIG. 4

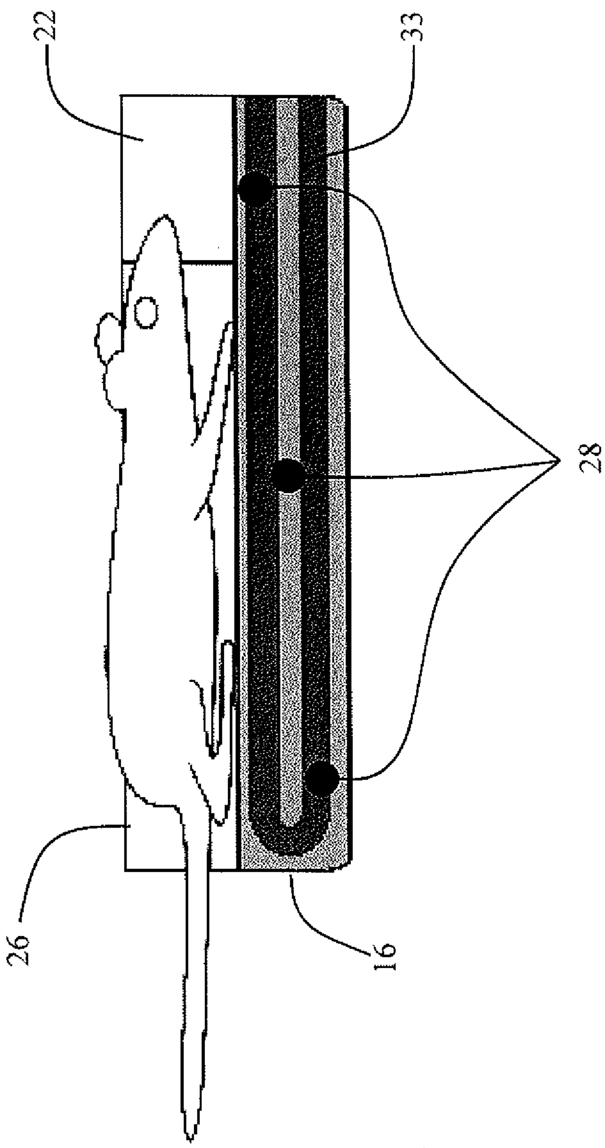


FIG. 5

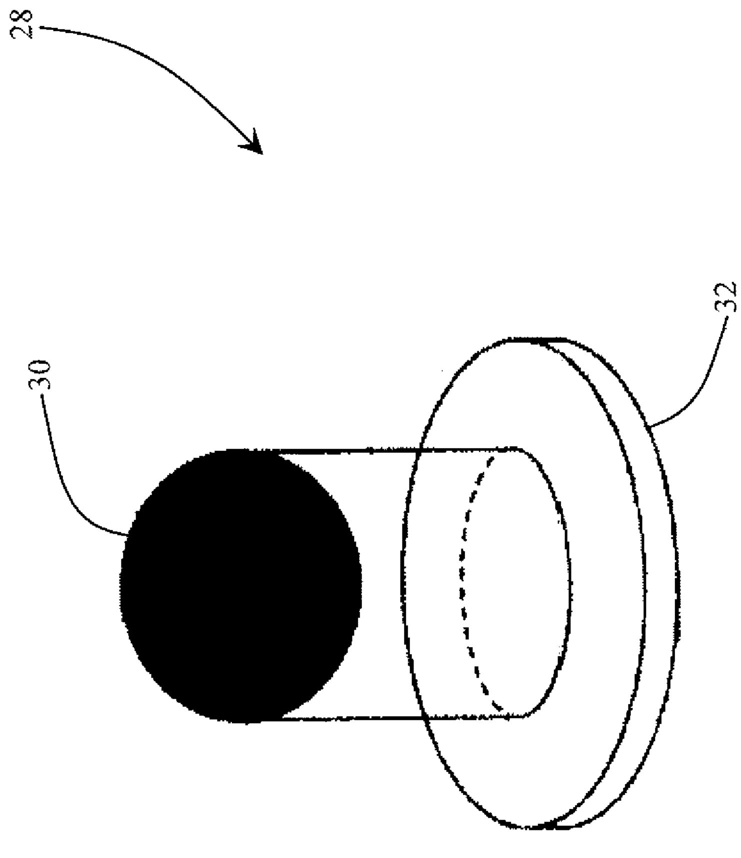


FIG. 6

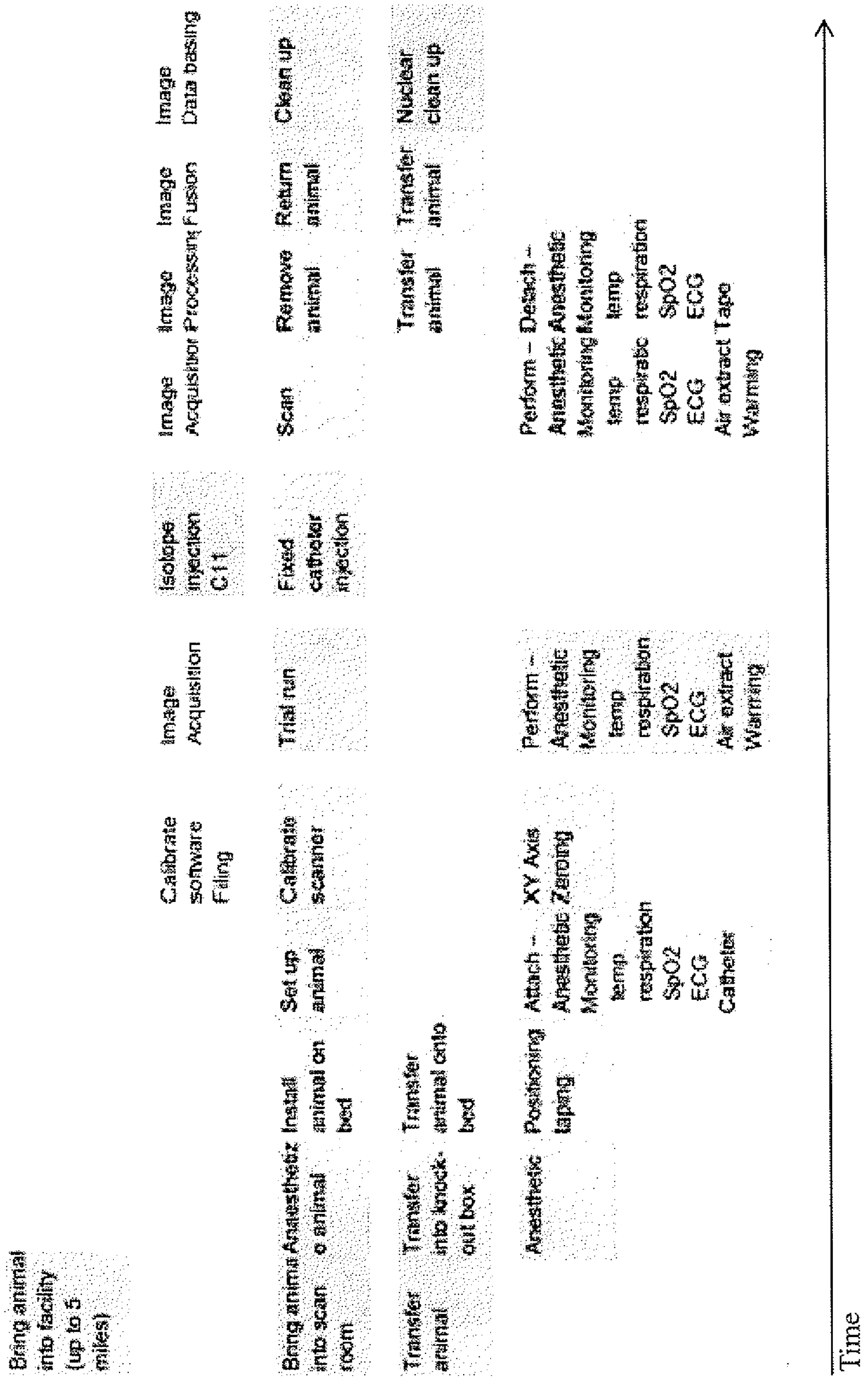
Bring animal into facility (up to 5 miles)
Calibrate software Filing
Image Acquisition
Isotope injection C11
Image Acquisitior
Image Processinç
Image Fusion
Image Data basing
Bring anima into scan room
Anaesthetiz o animal
Install animal on bed
Set up animal
Calibrate scanner
Trial run
Fixed catheter injection
Scan
Remove animal
Return animal
Clean up
Transfer animal
Transfer into knock-out box
Transfer animal onto bed
Transfer animal
Transfer animal
Nuclear clean up
Anesthetic
Positioning taping
Attach – Anesthetic Monitoring temp respiration SpO2 ECG Catheter
XY Axis Zeroing
Perform – Anesthetic Monitoring temp respiration SpO2 ECG Air extract Warming
Perform – Anesthetic Monitoring temp respiratio SpO2 ECG Air extract Warming
Detach – Anesthetic Monitoring temp respiration SpO2 ECG Tape
Time

FIG. 7

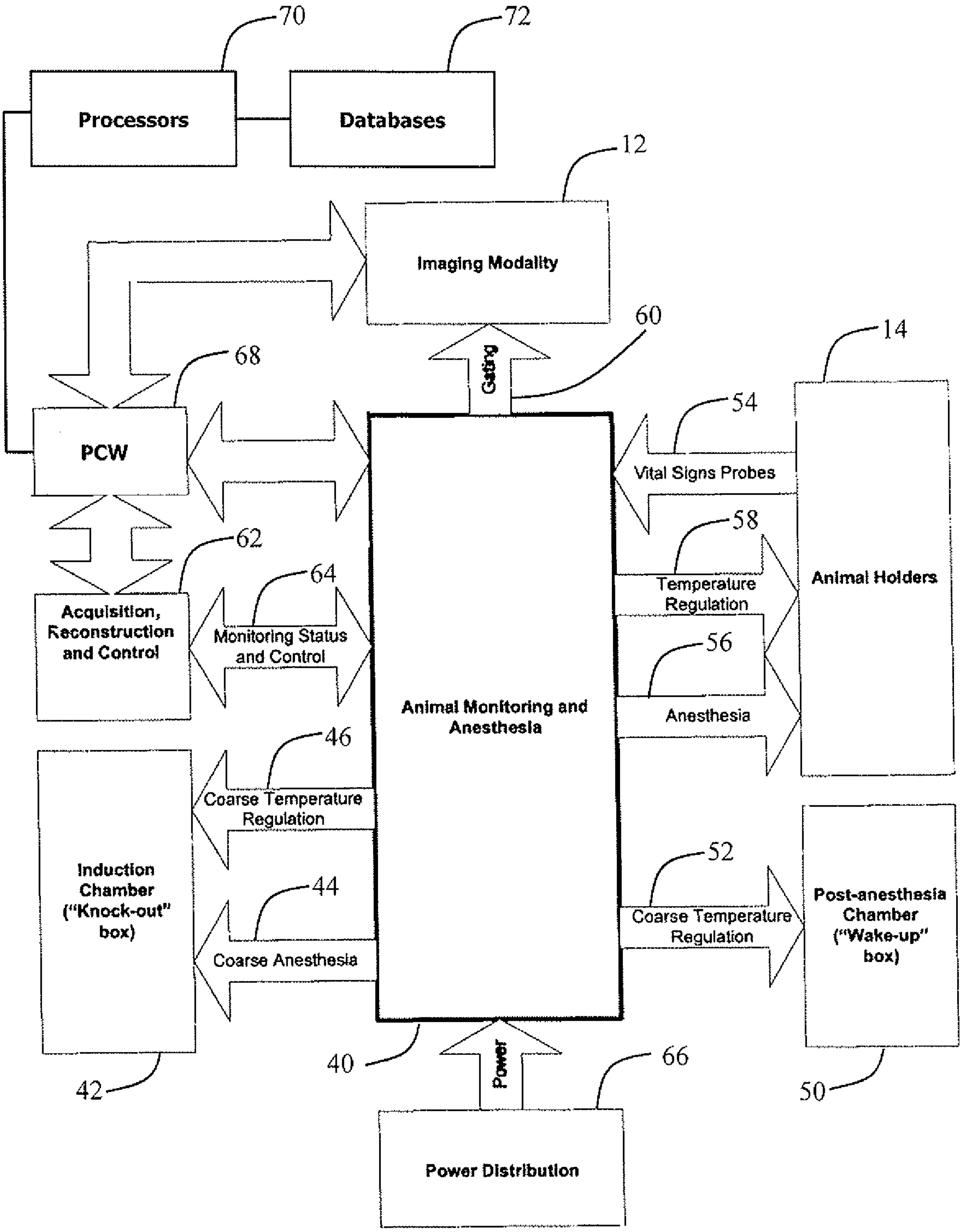
70
72
Processors
Databases
12
Imaging Modality
60
Gating
68
PCW
14
54
Vital Signs Probes
58
Temperature Regulation
62
Acquisition, Reconstruction and Control
64
Monitoring Status and Control
56
Anesthesia
Animal Holders
Animal Monitoring and Anesthesia
46
Coarse Temperature Regulation
44
Coarse Anesthesia
Induction Chamber ("Knock-out" box)
52
Coarse Temperature Regulation
Post-anesthesia Chamber ("Wake-up" box)
40
42
Power
66
50
Power Distribution

FIG. 8

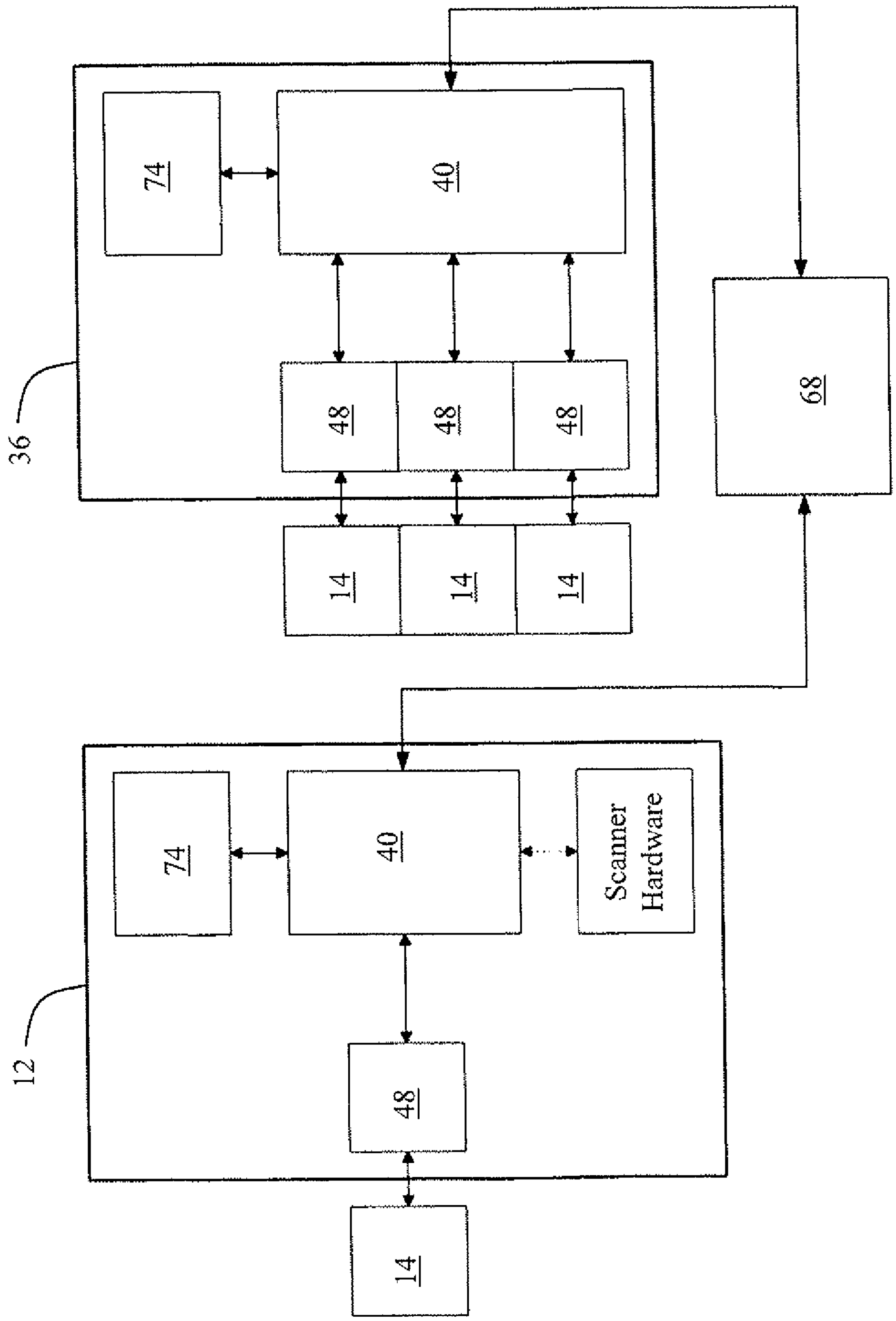


FIG. 9

| | | | |
|---|---|---|---|
| 专利名称(译) | 小动物成像胶囊和床系统 | | |
| 公开(公告)号 | [EP2155059A2](EP2155059A2) | 公开(公告)日 | 2010-02-24 |
| 申请号 | EP2008738085 | 申请日 | 2008-05-06 |
| [标]申请(专利权)人(译) | 皇家飞利浦电子股份有限公司 | | |
| 申请(专利权)人(译) | 皇家飞利浦电子N.V. | | |
| 当前申请(专利权)人(译) | 皇家飞利浦N.V. | | |
| [标]发明人 | ZAGORCHEV LYUBOMIR<br>BUCKLER ANDREW<br>JEAN ERIC<br>LATTO ANTONIO T | | |
| 发明人 | ZAGORCHEV, LYUBOMIR<br>BUCKLER, ANDREW<br>JEAN, ERIC<br>LATTO, ANTONIO, T. | | |
| IPC分类号 | A61B5/055 A61B6/04 A61B7/04 A61B5/00 A61B6/00 A61D7/04 | | |
| CPC分类号 | A61B6/04 A61B5/4821 A61B6/0421 A61B6/045 A61B6/508 A61B6/5235 A61B6/541 A61B2503/40 A61D7/04 | | |
| 优先权 | 60/939866 2007-05-24 US | | |
| 其他公开文献 | EP2155059B1 | | |
| 外部链接 | Espacenet | | |


摘要(译)

在小动物成像系统（10）中，提供至少一种模态（12）和对接站（36）。对接站（36）提供工作空间（47）和对接端口（48），用于准备和保持等待成像的麻醉动物。对于位置的复制，提供了对象模具（26），其将对象保持在对象床（16）上的可再现位置。还为等待扫描的受试者提供生命体征监测。床（16）包括基准点（28），以帮助登记相似的模态图像和不同的模态图像。胶囊（14）可以封装单个床（16），或者为了串联成像，胶囊可以封装多床配置，例如两个，三个或四个床（16）。为了更好地定位和便于用户接近，定位器（34）将胶囊（14）从模态（12）的后部定位。