Phantom Rat

Team: Darren Klaty - Chelsea Bledsoe - Charlie Rodenkirch - Alex Broderick - **Advisor:** Paul Thompson

Client: Surendra Prajapati, Graduate Student, and Thomas "Rock" Mackie, Director of Medical Devices, WID

Background

Figure 1. PET/CT Scanner at WIMR

Phantoms are used in the medical industry with the main purpose of testing imaging equipment such as CT scanners and MRI machines like the PET/CT scanner shown in Figure 1. They are also used educationally to teach interventional imaging guided procedures to students and doctors, and by maintenance crews for servicing equipment.

In the testing of an imaging device, a phantom must scan similarly to how the real specimen would. Thus, phantoms are constructed of materials that contain different densities to mimic various bodily tissues such as the muscle tissue, lungs, and organs. [1]

There are many different types of phantoms to simulate scanning of animals and humans. While these phantoms are designed to be anatomically equivalent to their corresponding specimens, they often do not look like the animal or human they simulate. In fact, many phantoms are just objects that contain places for testing inserts. Although they may not look like their designated specimen, they scan with extreme precision to mirror the animal or human they are portraying.[2]

Motivation

This open source rat phantom project is part of Thomas Mackie's larger venture of designing and producing a combined PET/RT/CT scanner for the imagining and treatment of small animals. Thomas Mackie is the chairman, co-founder, and co-inventor of TomoTherapy Inc. as well as a UW-Madison professor in medical physics. His focus is the construction of medical devices that can be used anywhere from research labs to clinical, with the goal of improving current technologies.[3] Consequently, the scanner requires a rat phantom that can test, calibrate, and service the system so that it can be as successful as possible.

Currently, one can purchase rat phantoms like one shown in Figure 2 for a significant amount of money. These types of phantoms, while durable and accurate, cannot be used in a scanner such as that being developed by Thomas Mackie because they do not contain slots for thermoluminescent dosimeters (TLD), organ, and tumor inserts. Other companies produce sphere-shaped and block phantoms that contain such inserts, but don't look like a rat. Thus, there is not presently another product on the market that both contains the necessary inserts and anatomically looks like a rat as this rat phantom will.

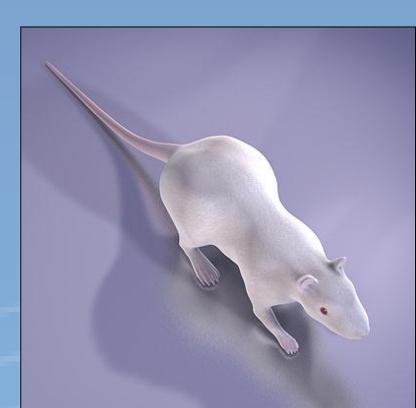

Figure 2. Rat Phantom for CT Scanner[4]

Budget

Item	Vendor	Price
Real Rat Skeleton	Sand Castle Science	$71.82
Balistics Gel	Copps	$9.37
LN-300 lung material	Gammex RMI	N/A
LV-1 liver material	Gammex RMI	N/A

Requirements

- Weigh less than 2kg
- 12 cm diameter maximum
- Anatomically accurate to a real rat
- Accurate tissue densities for lungs, muscle, bones, and liver
- Withstand repetitive use for testing purposes
- Withstand exposure to radiation without contamination
- Include spaces for three different 1mm x 1mm x 1mm TLD detector inserts
- Include slots for removable organ and tumor inserts

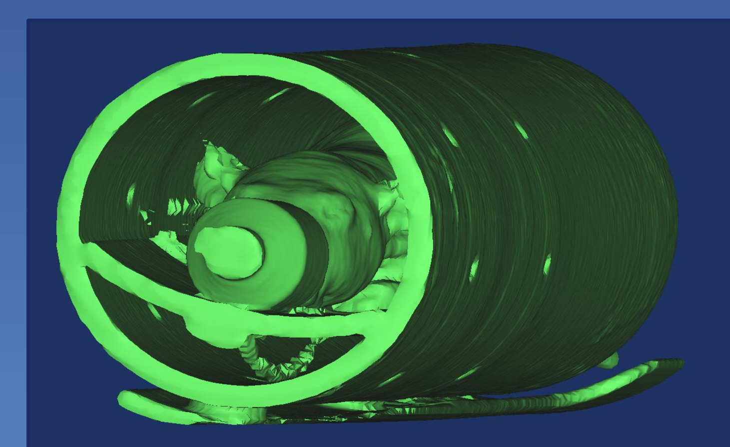

Figure 4. Scan of rat before editing

Figure 5. Negative mold of phantom

Fabrication

Mold

1. Obtain full body CT scan of rat skeleton at the Small Animal Imaging Center at the Wisconsin Institute for Medical Research
2. Obtain comparable sized real rat CT scan
3. Import 1200 scan slices into Mimics software program
4. Use density threshold to obtain the necessary tissues of the scan
   -Table and respirator for the rat were included in this threshold, as their densities were similar to the range of the threshold
5. Edit out everything in scan slices except the rat body (Figure 6)
6. Convert edited file into a STL 3D file to prep for printing
7. STL file used in Magics software to create a negative drop-cast of the rat phantom
8. Print mold using Wisconsin Institute of Discovery 3D printer

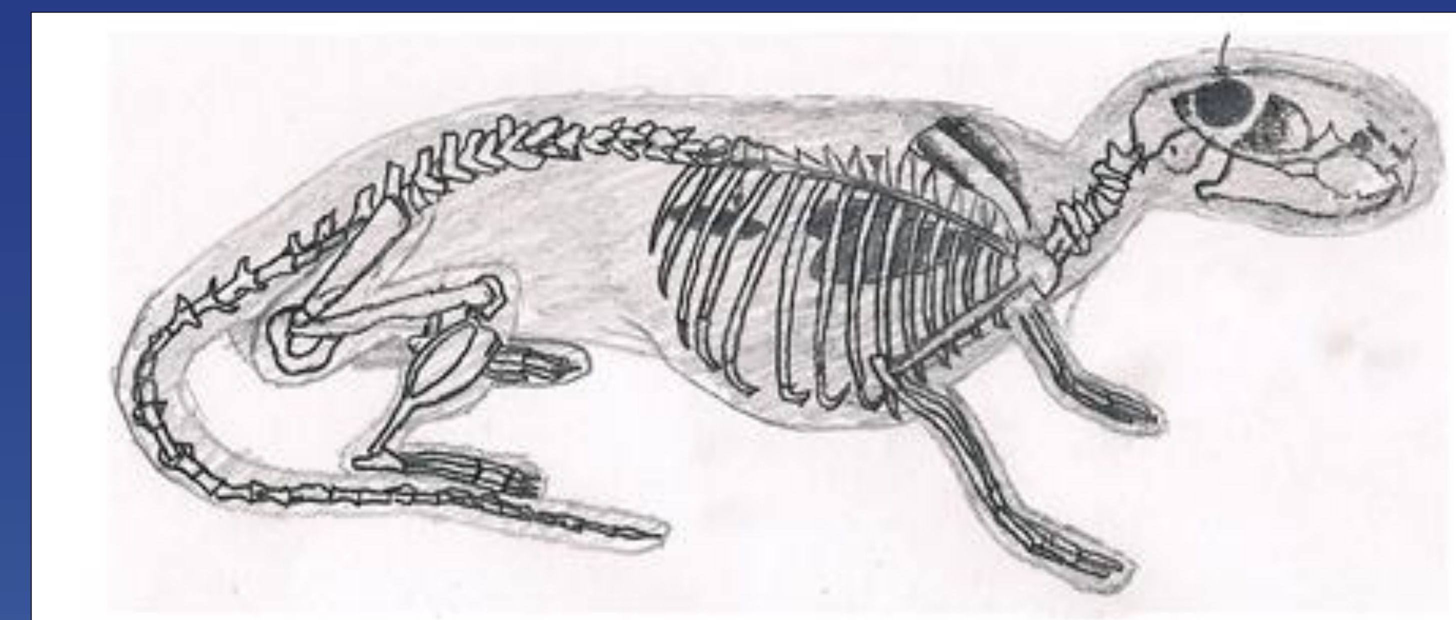

Figure 3: Solid design of rat phantom, including bones and specified organs

Final Design

- Solid phantom for optimal scanning accuracy
  - Different than previous designs with cuts in them
- Includes 4 different tissue types: bone, muscle, liver and lung
- Contains bones obtained from a pre-assembled real rat skeleton that was purchased online
- Bones must be taken apart and rearranged into the negative mold before pouring in ballistics gel
  - Ballistics gel will hold them in place once it has hardened
- Rat muscle tissue is mimicked by the ballistic gel
- Gel will encase the skeleton and organs to form the exterior structure of the body
- Organs machined from materials of the appropriate densities from Gammex RMI
- Slots for placement of the TLD into the ballistics gel
  - End location for TLD is 1mm x 1mm x 1mm

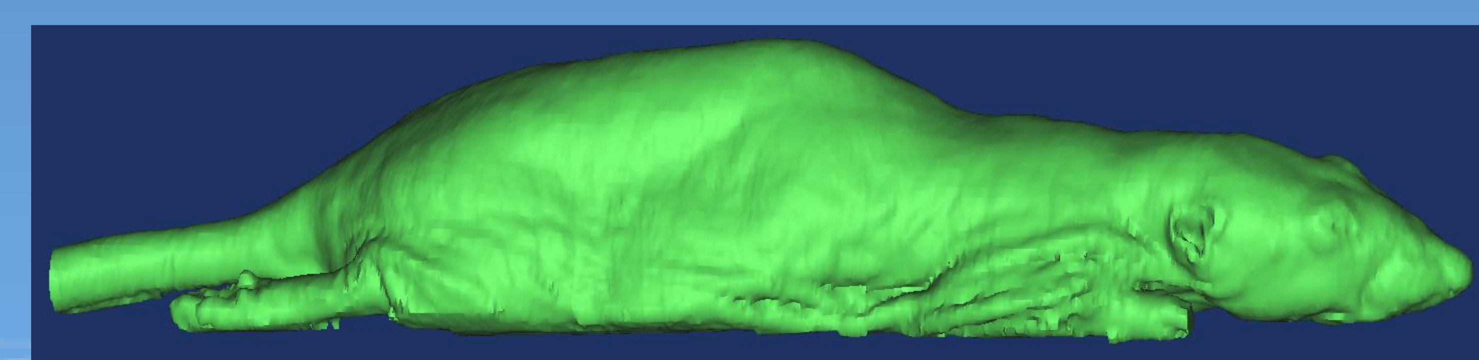

Figure 6. Edited 3D model of rat scan

Phantom

1. Obtain tissue materials from Gammex RMI
2. Machine tissue materials into correct shape and size of rat organs
3. Place tissue materials and rat skeleton into negative drop cast mold of the phantom
4. Lock two halves of the mold together using clamps
5. Prepare ballistics gel and pour into mold
6. Wait 36 hours to cure gel
7. Take mold apart and cut the flashing off of phantom

Testing

- Preliminary scans in the PET/CT scanner at WIMR
- Phantom will be used to calibrate PET/CT/RT scanner that is currently in the design process
- Future scans in the combined scanner will be compared to scan of a real rat shown in figure 7

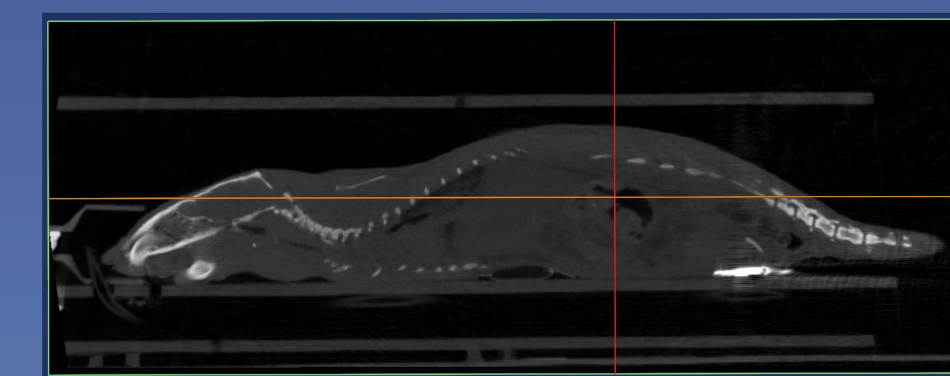

Figure 7: PET/CT scan of real rat

Future Work

- Add organ components to the device as the organs we were to use ended up being too expensive and the time delay was too long
- Incorporate a vascular model to show flow and distribution of blood as it carries radiation
- Use multiple rat skeleton models in order to have a variety to test
- Scan the model and compare to that of an actual rat from WIMR's scans

Acknowledgements

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- Surendra Prajapati, Graduate Student, Client
- Thomas "Rock" Mackie, Director of Medical Devices, WID
- Benjamin Cox
- Mohammed Farhoud, WIMR

References

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3. Morgridge Institute for Research, Wisconsin Institutes for Discovery. 2011. http://discovery. wisc.edu/home/morgridge/about-morgridge/ leadership/thomas-mackie/

4: "Rat Phantoms" runelocus.com