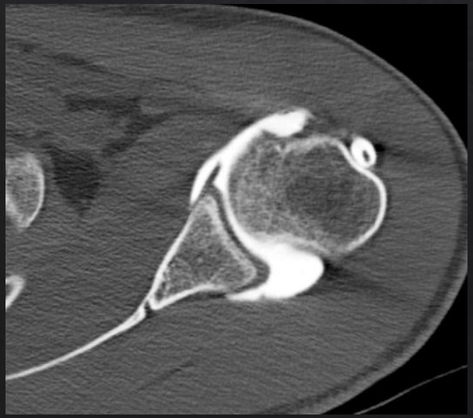
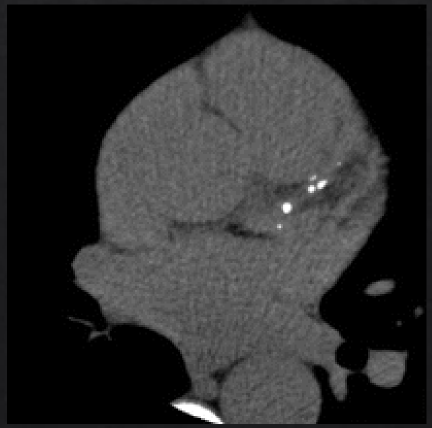
Focused Tomography

Reducing Radiation in CT

Introduction

- Focused Tomography is a technology that permits a dose reduction of up to 90% for CT imaging of an anatomic region of interest (ROI)
- Current CT technology requires that the entire axial plane of the body be exposed to a relatively uniform dose of radiation
  - But why expose the entire body to the full dose if a smaller section would suffice?



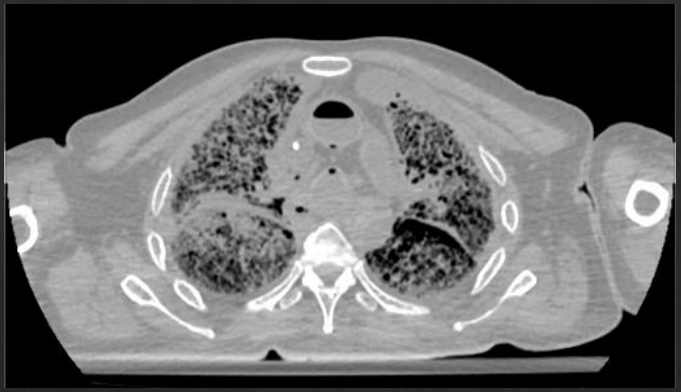


Figure 1: A CT image taken at 17 mGy

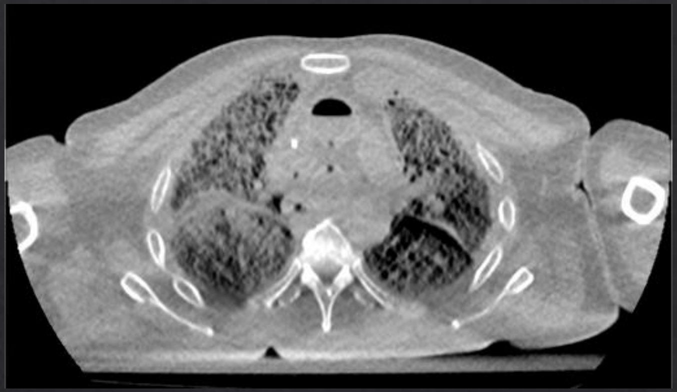


Figure 2: The same image taken at 1.7 mGy

Figure 3: The data from the images in Figs. 1 and 2 were combined using the Focused Tomography method, with an ROI over the spine at 17 mGy, and 1.7 elsewhere.

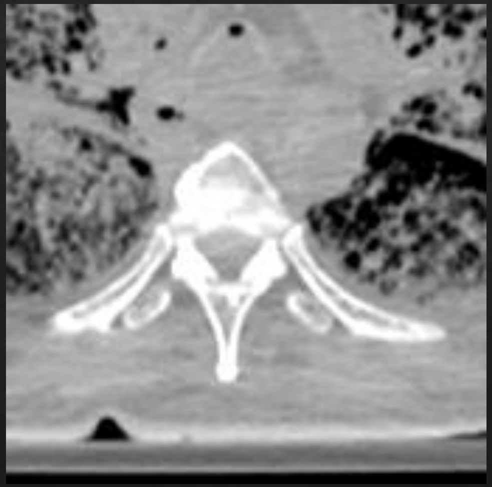


Figure 4: Magnified view of the spine from Fig. 1

Figure 5: Magnified view of the spine from Fig. 2. Note there is much less definition on the spine.

Figure 6: Magnified view of the spine from Fig. 3.

Business Potential

- There are approximately 3500 CT machines deployed in Florida alone
- Probably more than 100000 of them worldwide.
- They are supposed to be calibrated and updated every 6 months
- We can produce this altered collimator and associated software for $50-70 K, with a profit of $20 K. It can be easily installed. New CT machines cost $2M, and don't have this benefit.

- We have a worldwide patent. If we sell to 5% of the market, that's $100M in profit yearly from the used machine market
- In addition, we will be reducing cancer occurrences via the reduced radiation
- Siemens, GE, and Canon have indicated that they will incorporate Focused Tomography on their new machines, in due time… perhaps a year

Focused Tomography Team

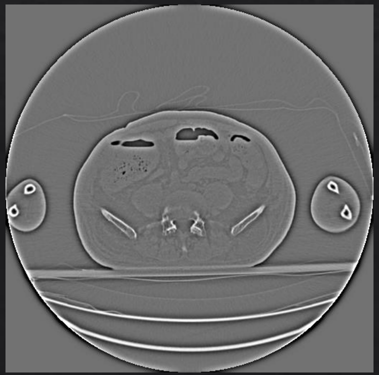
- Dr. Timothy Olson, Patent Co-Author, President, Swamp View Technologies, Formerly Associate Professor, The University of Florida
- Dr. Stephanie Leon, Patent Co-Author, Chief of Diagnostic Medical Physics, Dartmouth Health, Formerly Associate Professor of Radiology, Shands Hospital, The University of Florida
- Dr. Philip Templeton, formerly Professor of Radiology: Massachusetts General, John Hopkins, Department Head, Radiology, University of Maryland
- Dr. Chris Lightcap, Founding Owner and Operator, KCL Robotics
- Mr. David Hickman, MBA, Software and Hardware Expert

Scientific Backgrounds

- Dr. Timothy Olson (Mathematician)
  - Began work in CT in 1988 and developed the mathematical basis of focused tomography in the early 90’s
  - After his publication in 1993, 100+ related papers followed citing his work
    - However, they all relied upon 0-1 sampling, i.e. sample or don’t sample
    - Not possible in CT, since you cannot turn the x-ray tube on and off so quickly
  - Discovered the current approach while at Johns Hopkins, and subsequently developed it at The University of Florida
- Dr. Stephanie Leon (Medical Physicist)
  - Chief of Diagnostic Medical Imaging, Dartmouth Health, Formerly Associate Professor, Shands Hospital, University of Florida
  - Suggested a collimator design that could satisfy the mathematical assumptions of the method in a feasible way, permitting the revival of the project
  - Dose reduction is now a major concern in Radiology, so the time is right
- Dr. Philip Templeton (Radiologist and Advisor)
  - Former Mass General and Hopkins Professor, Former Professor and Chairman of Radiology, University of Maryland, and teleradiology entrepreneur, now founder of DocPanel

The Algorithm

- All images are composed of both high-frequency and low-frequency data
  - High-frequency data provides fine detail in the image
  - Low-frequency data provides the overall structure of the image
- Radiation dose primarily affects the amount of noise in an image, with lower doses resulting in more noise
- Dr. Olson's insight was that:
  - The high-frequency data must be acquired with low noise (higher dose), but only within the ROI
  - The low-frequency data must be acquired over the entire image to permit accurate reconstruction, but higher noise (lower dose) is acceptable



Significant New Points

- We can accomplish the reconstructions directly from images altered by the adaptive collimator
  - This makes retrofitting existing machines much easier
  - This is included under a Continuation in Part (CIP) of the original Focused Tomography patent
  - Retrofit can be done with a plug and play collimator and minor software alterations
- We alter the received data, and have proved and demonstrated that images can be obtained at two different dosages with accurate reconstructions and 90 % dosage reduction
  - We utilized the simplest of algorithms to demonstrate this, Filtered Backprojection
  - Advanced algorithms such as Iterative Refinement and AI algorithms will just augment these savings
- We have theoretically calculated not only the transmitted dosages, but the point by point received dosages, and have experimentally verified these results

The Algorithm

- The algorithm:
  - Permits substantial reduction of total patient radiation dose
  - Fully preserves standard clinical image quality where the radiologist needs it
  - Can permit adequate visualization of structures outside the clinical area of interest, which may be important for anatomic localization and the detection of incidental findings

- Dr. Olson has developed solutions that work with and without access to the raw (sinogram) data, which is reflected in our Continuation in Part (extension) patent.

First Steps

- Before building the collimator, first steps involved testing the algorithm on realistic clinical images
- Using a clinical CT scanner, we acquired CT scans of a cadaver at 17 mGy and 1.7 mGy
- Scans were combined to simulate imaging at full dose inside an ROI and low dose outside the ROI
- Sinograms were created from the combined images, then re-reconstructed with the focused tomography methodology

Accuracy of the Reconstruction

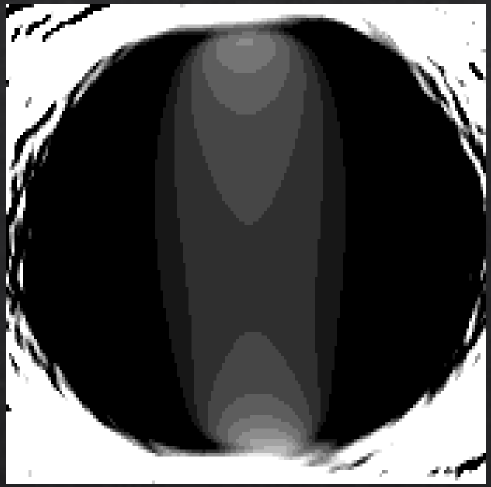
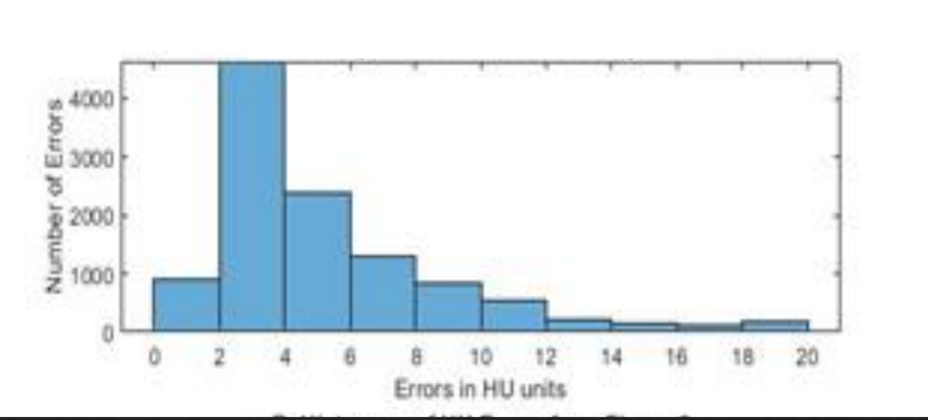


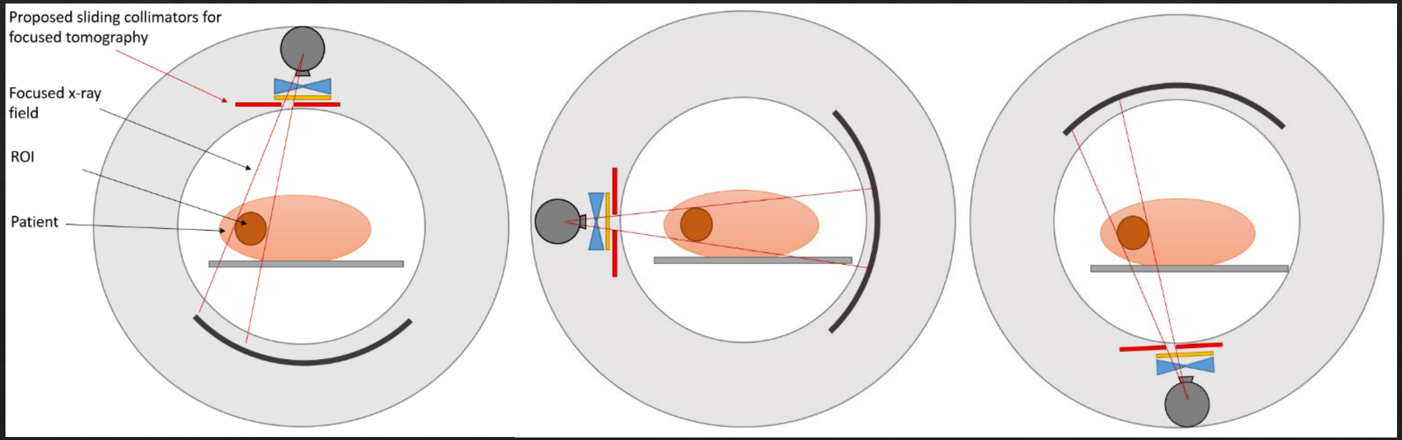
Image showing the difference between the full-dose image and the Focused Tomography image within the ROI, displayed at a window width of 10 HU and level of 0.



Histogram of HU errors between the full-dose and Focused Tomography images. The clinical impact of such small shifts is negligible.

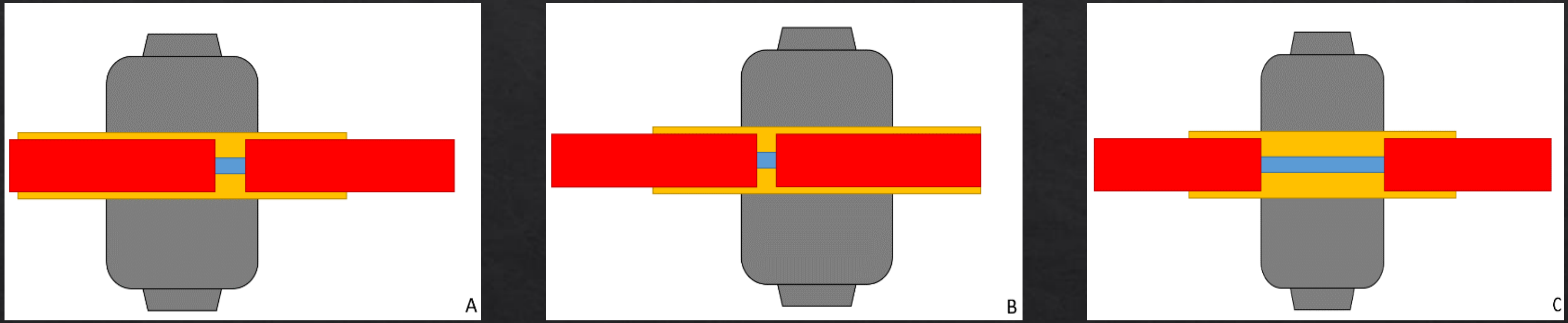
Collimator Design and Construction

- Having shown that the algorithm works, the next step was to design and build the collimator
  - Semi-radiolucent sliding blades that transmit ~10% of x-rays
  - Size and position of opening is adjustable in real-time during gantry rotation
  - Collimator is installed in addition to existing filters and collimators



“Snapshots” of the x-ray tube and associated components at three different positions during each rotation. The sliding collimators (red) adjust position during the rotation to keep the ROI in focus.

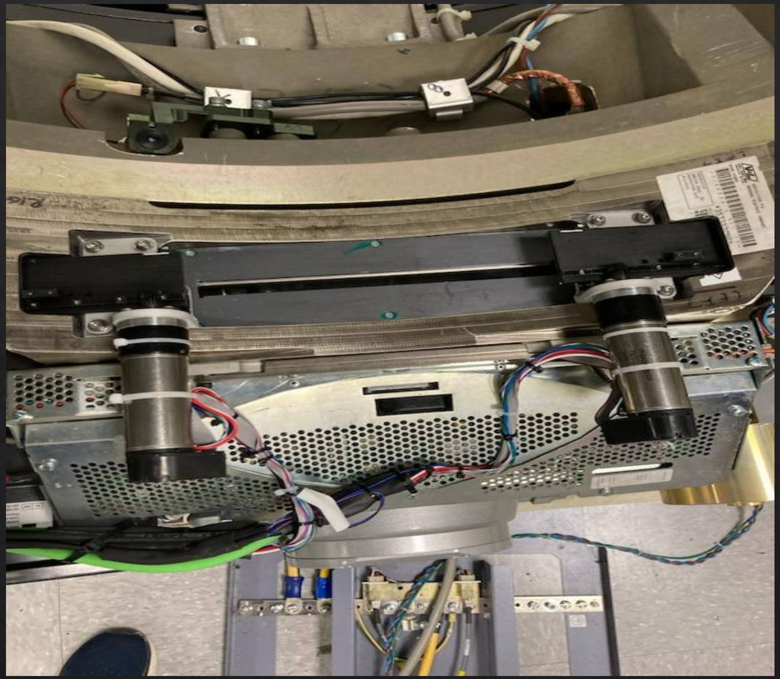
Collimator Design and Construction



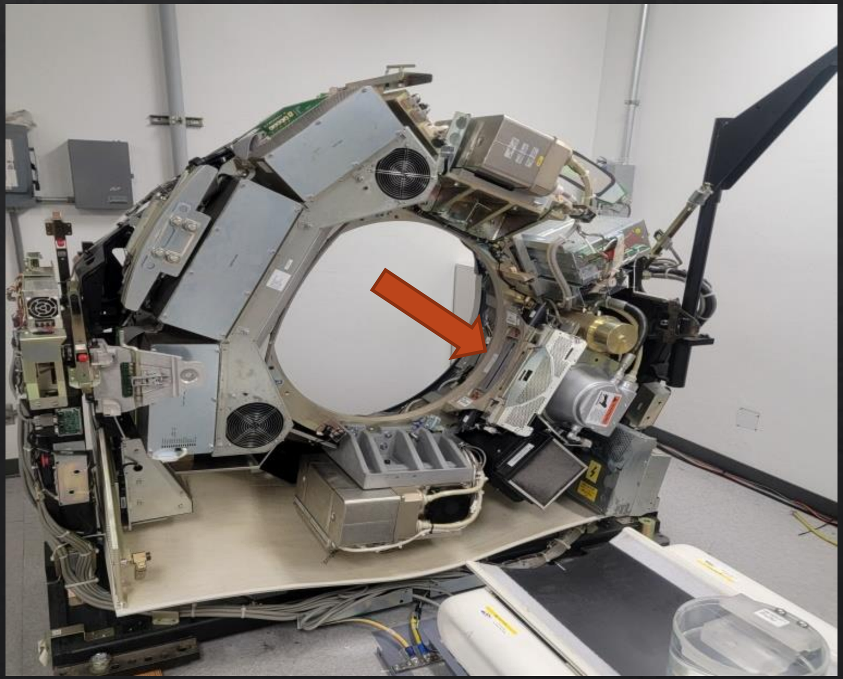
A bottom-up view of the sliding collimator (red), pre-patient collimator (yellow), filters (blue), and x-ray tube (gray). A) and B) show two different positions allowing ROIs of different sizes and locations. C) shows the sliding collimators fully open, permitting a standard CT exam.

Collimator Design and Construction

- We have installed and tested our collimator on a GE BrightSpeed CT scanner



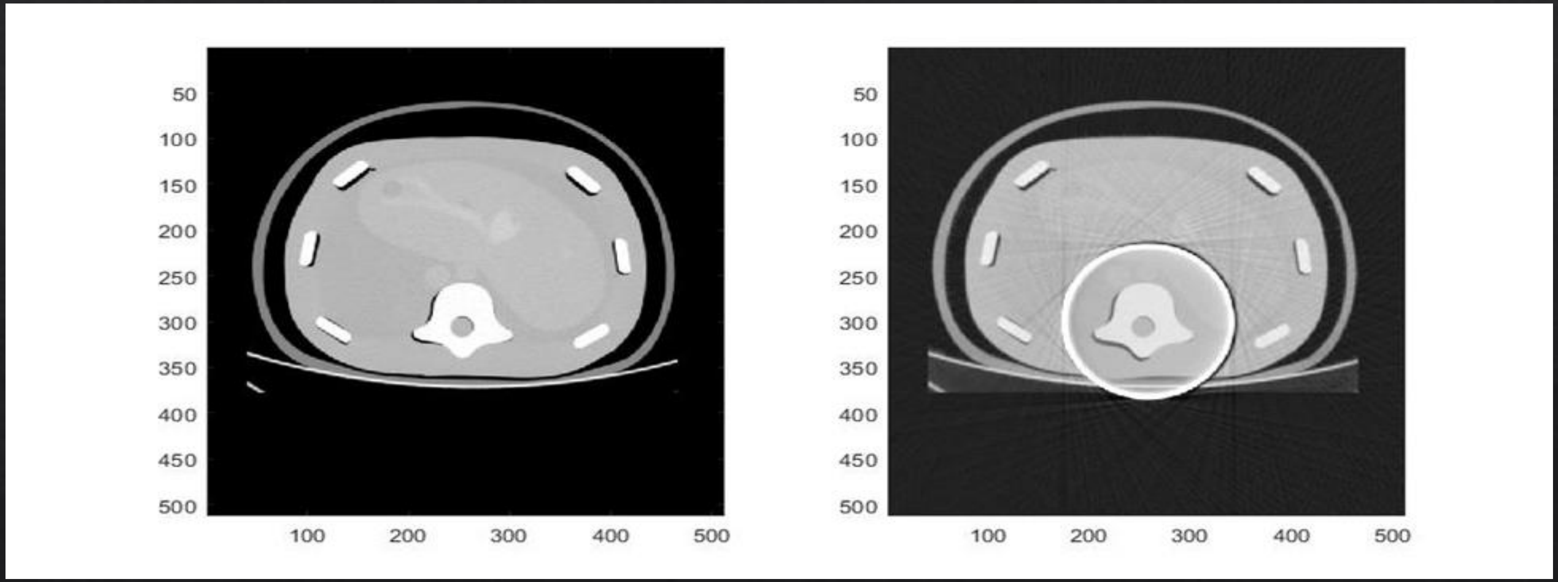
The Focused Tomography collimator



Position of the Focused Tomography collimator within the CT gantry

Preliminary Experimental Images

- Axial images were acquired of a phantom at 120 kV and 120 mAs, with collimator in place, and reconstructed successfully with the Focused Tomography algorithm.
- Note the presence of the Gibb's ringing surrounding the ROI. The Gibb's ringing is a results of the sharp edge on the collimator blades and can be eliminated by beveling the blades' edges



Left: full-dose image of the phantom, Right: image of the same slice of the phantom with the collimator focused on the spine

Completing the Equation

- Focused Tomography can result in sizeable dose reduction with traditional detector technologies and reconstruction algorithms, providing a relatively inexpensive upgrade to traditional CT systems
- However, Focused Tomography could also work synergistically to "complete the equation" in dose reduction by being paired with AI reconstruction and processing algorithms, as well as with photon-counting CT (PCT)
  - AI and PCT can permit excellent image quality with global dose reduction, but don't change the fact that many organs and tissues do not really need to be irradiated at all
  - Only Focused Tomography provides "internal shielding" to protect organs that don't need to be exposed in the first place
  - Together, these technologies create a **comprehensive dose reduction solution** to allow optimal patient imaging with the lowest possible risk

Patent and Exclusive Rights

- University of Florida Research Foundation filed a U. S. Utility Patent Application Serial No.16/986,014, filed August 5, 2020 entitled FOCUSED TOMOGRAPHY.

- University of Florida Research Foundation has been granted a United States Patent for FOCUSED TOMOGRAPHY, Patent No. 11,801,017. The patent was issued on October 31, 2023.

- University of Florida Research Foundation has filed a Continuation in Part extension for the United States Patent for FOCUSED TOMOGRAPHY, Patent No. 11,801,017. This covers the algorithm to reconstruct directly from images rather than raw sinogram data. This has been conditionally approved, and a NOA (Notice of Allowance) is expected.

- Swamp View Technologies has the exclusive, worldwide license to United States Patent No. 11,801,017 from the University of Florida Research Foundation. We are Swamp View Technologies!

United States Letters Patent No. **11,801,017** for **"FOCUSED TOMOGRAPHY."** This patent was issued on October 31, 2023, and will expire on August 5, 2040,United States Patent United States Letters Patent No. **11,801,017** for **"FOCUSED TOMOGRAPHY."** This patent was issued on October 31, 2023, and will expire on August 5, 2040.

Summary

- For CT scans focused on an anatomical region of interest, the combination of the Focused Tomography collimator and algorithm permits:
  - A radiation dose reduction of up to 90%
  - Preservation of clinical image quality and HU accuracy within the ROI
  - Visualization of structures outside the ROI
- The algorithm has been successfully employed on cadaver images on a hospital CT scanner, as well as on phantom images employing our collimator
- The first prototype version of the collimator has been successfully installed and tested on a GE BrightSpeed CT scanner, requiring only minor tweaks
- University of Florida Research Foundation has been issued a U.S. Patent for Focused Tomography, Patent No. 11,801,017.
- Swamp View Technologies, LLC has fully executed license for the exclusive worldwide rights to U.S. Patent for FOCUSED TOMOGRAPHY, Patent No. 11,801,107.