PRECISION
X-RAY IRRADIATION

- Combined Global experience and installed base
- World's largest dedicated cabinet x-ray company
- 1000s of systems in use worldwide
- Dedicated to Radiation, Agriculture, and Cancer Research
- Combined service and technical expertise
- Advanced development with partnerships worldwide

faxitron®

PXi PRECISION X-RAY

Precision X-Ray Irradiation Team

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Capital Sales Product Manager

X-ray irradiation

Introduction to cabinet irradiators

- A cabinet x-ray system is a **lead-lined** cabinet that contains an **x-ray tube and high voltage generator.**
- Meets all radiation safety requirements specified in **Federal Regulation 21 CFR 1020.40 - < 0.5mR per hour at 5cm from any surface.**
- The fully-enclosed system requires **no** additional shielding or safety precautions
- X-ray irradiators are **safer, simpler, and less costly and much more versatile** than radioisotope alternatives (Cesium, Cobalt, etc.).

Precision X-Ray and Faxitron X-Ray Irradiators

Long Tradition of Supplying Alternatives to Gamma Sources for Pre-clinical Radiation Research Based Studies

- X-Ray Beam inside fully shielded lead cabinet
- Beam projects from X-Ray source at top of cabinet
- Easily controlled with collimation and shielding
- Control of kV, mA and time.
- Improved safety – energy turns on and off
- Cesium Replacement

Faxitron CP160: 1996

Precision X-Ray X-RAD 320: 2006

National Cancer Institute

Key Improvements Since 2008 Radiation Use and Replacement Report

How PRECISION has led the way to make X-ray Irradiators more powerful and more ~~foolproof~~

Track the Variables

- Touchscreen User Interface Control Software
- Integrated Dosimetry and Dose Control
- Automated Shelf Positioning
- Automated Adjustable Collimators
- Automated Filter Control
- Automated Dose QA
- Programmable Control and Database of All Above

Add Capabilities

- Higher power for higher throughput studies
- Improved Treatment Targeting with Imaging:
  - -2D and 3D X-Ray/CT and Bioluminescent Imaging
- Rotating and Planetary rotating shelf modules
- Full Treatment Planning Software (SmART System)
- Environmental Controls (02, CO2, Temperature)
- Dose Mapping Services
- Multiple Systems for Specific Applications and Budgets

Our Products

Innovative x-ray systems

CellRad System
(130 kV)

MultiRad Systems
(160, 225, 350 kV)

X-Rad Systems
(160, 225, 320 kV)

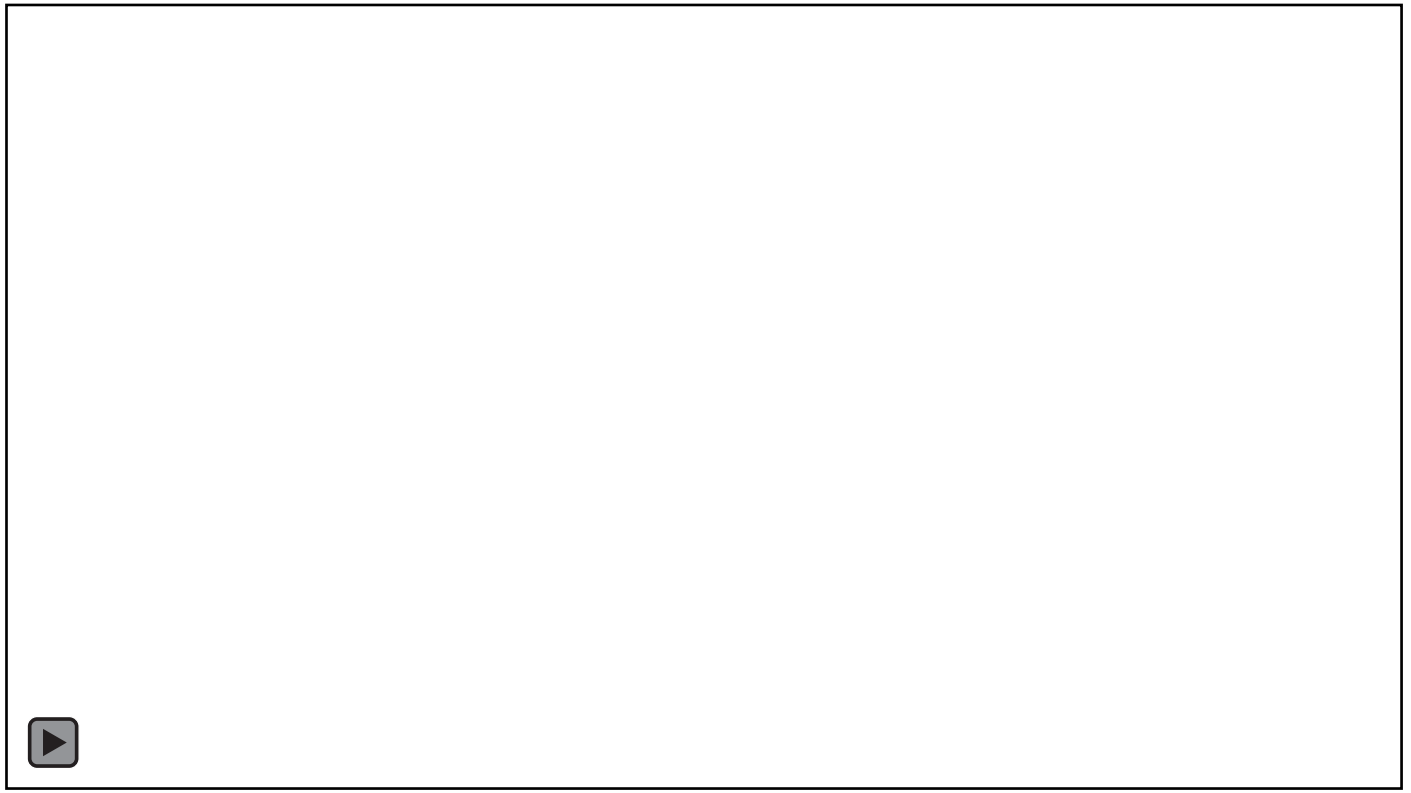
SmART+ System
(225 kV)

CellRad

Only benchtop cell irradiator

Why did we create this system?

- Designed for cell culture room placement
- Plugs directly into a traditional outlet
- Integrated dose measurement and quality assurance



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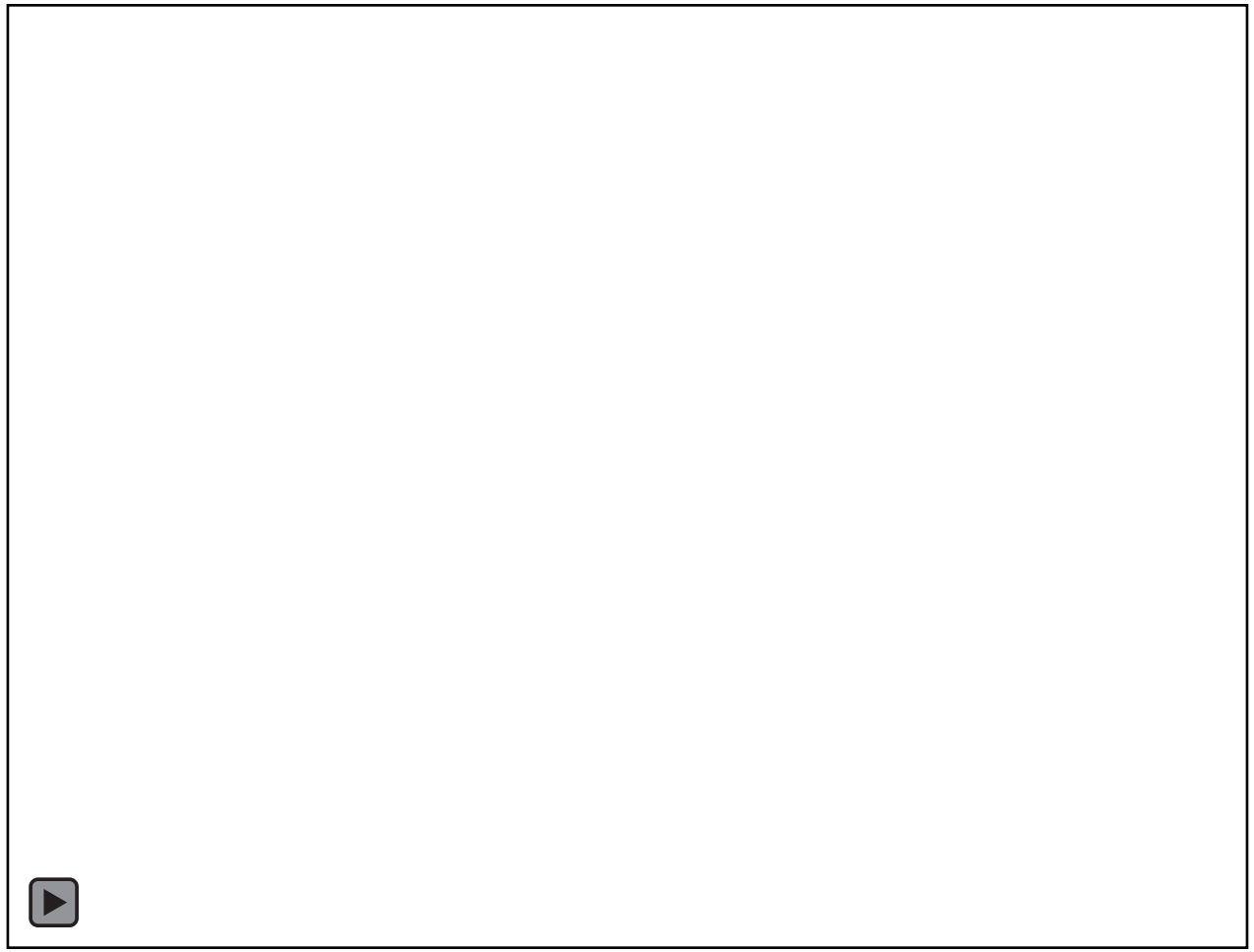
MultiRad Systems

Cabinet irradiators built to be fully integrated

Why did we create this system?

- Fully integrated system with closed-loop cooling system included in footprint
- Integrated internal dose measurement and quality assurance
- Automated shelf, collimator and filter wheel options
- Minimal training required for use



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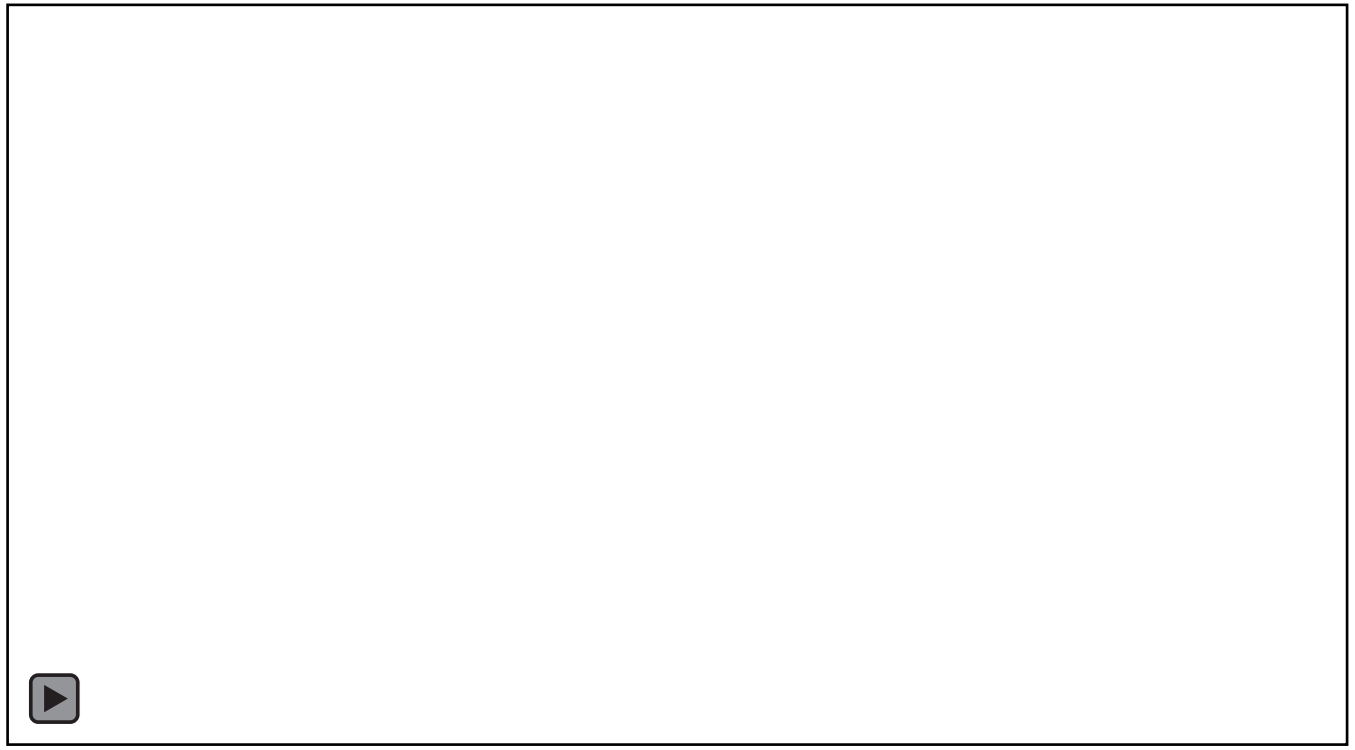
X-Rad Systems

Expandable x-ray irradiation and imaging platform

Why did we create this system?

- Extra large internal chamber and high dose rate for increased throughput
- Modular design presents opportunity to upgrade system upon purchase or later
- Most widely published x-ray irradiator in the world



Planetary Pie Turntable in X-Rad 225XL

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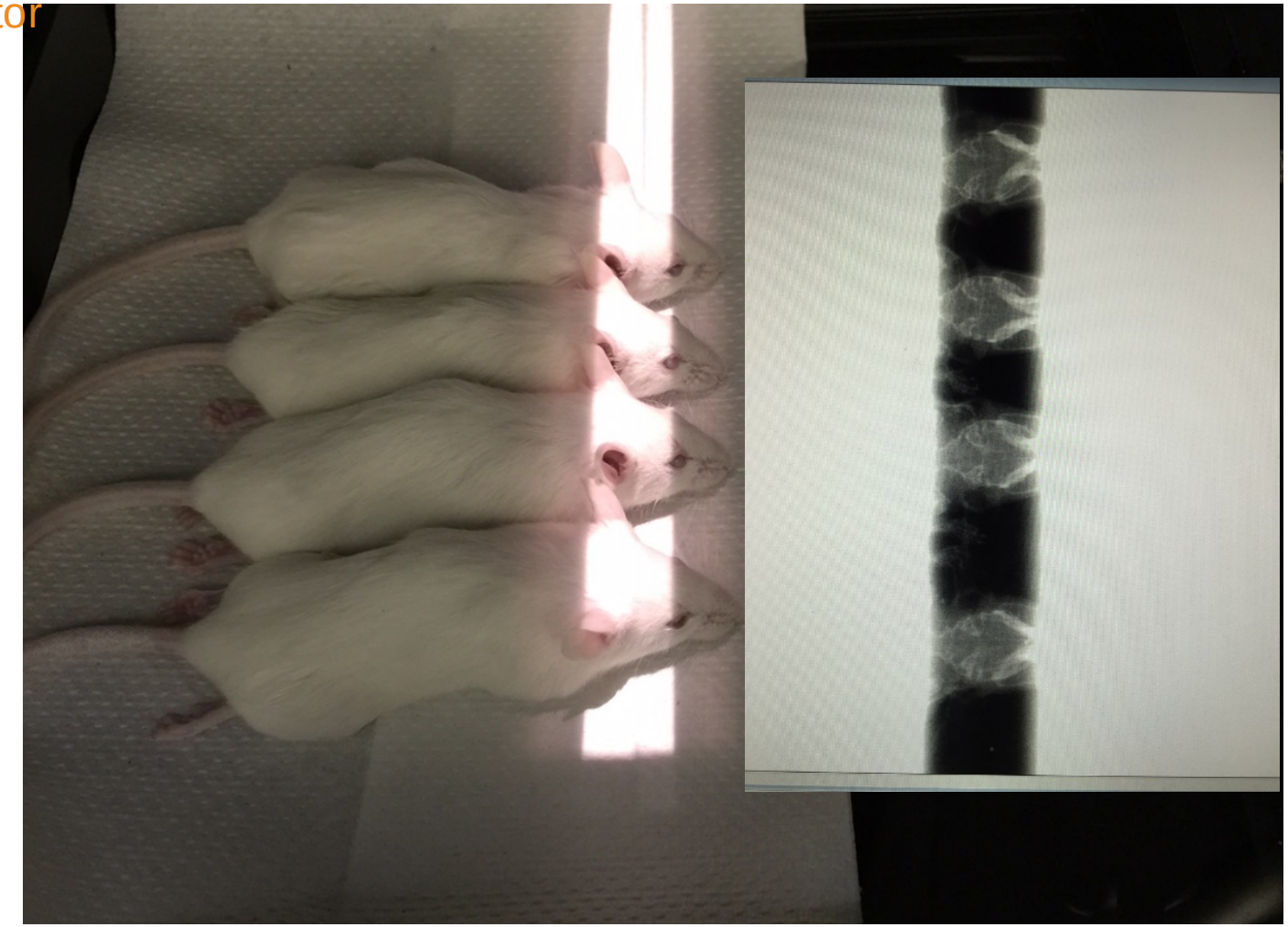
X-Rad Collimation and OptiMAX Targeting

Targeted Head irradiation with Variable Collimator

- Variable collimator set to expose brain only
- Light field demonstrates beam delivery
- Multiple mice can be targeted at once
- X-ray imaging verifies brain as targeted tissue



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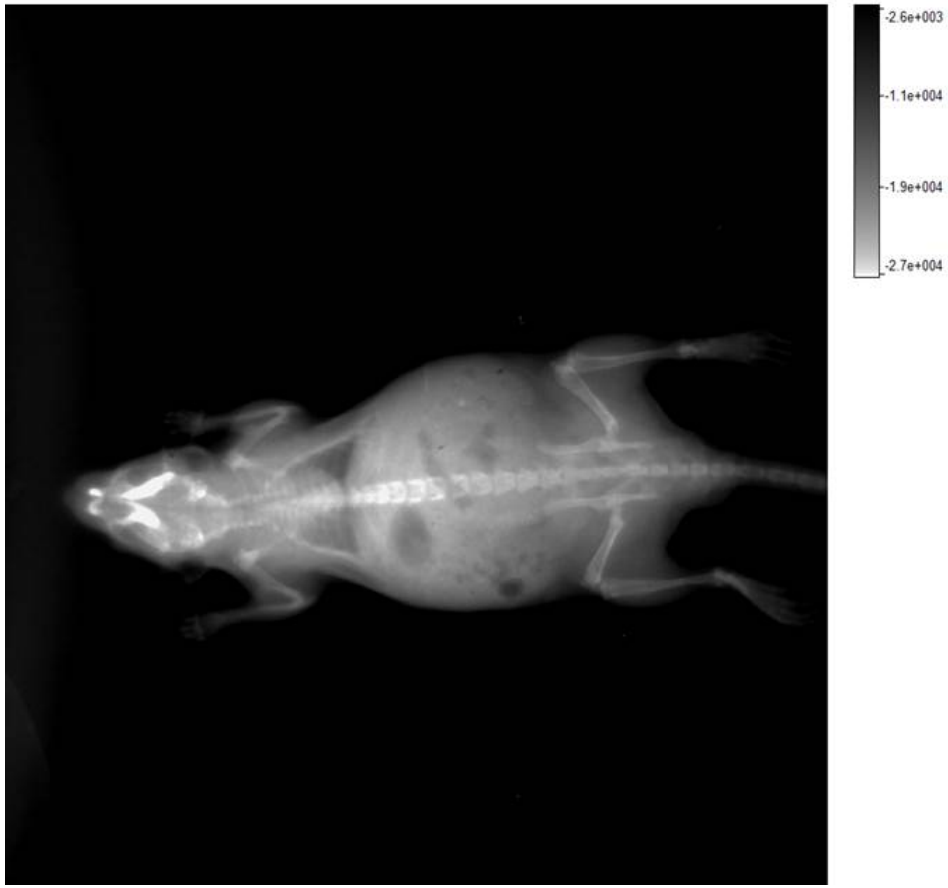
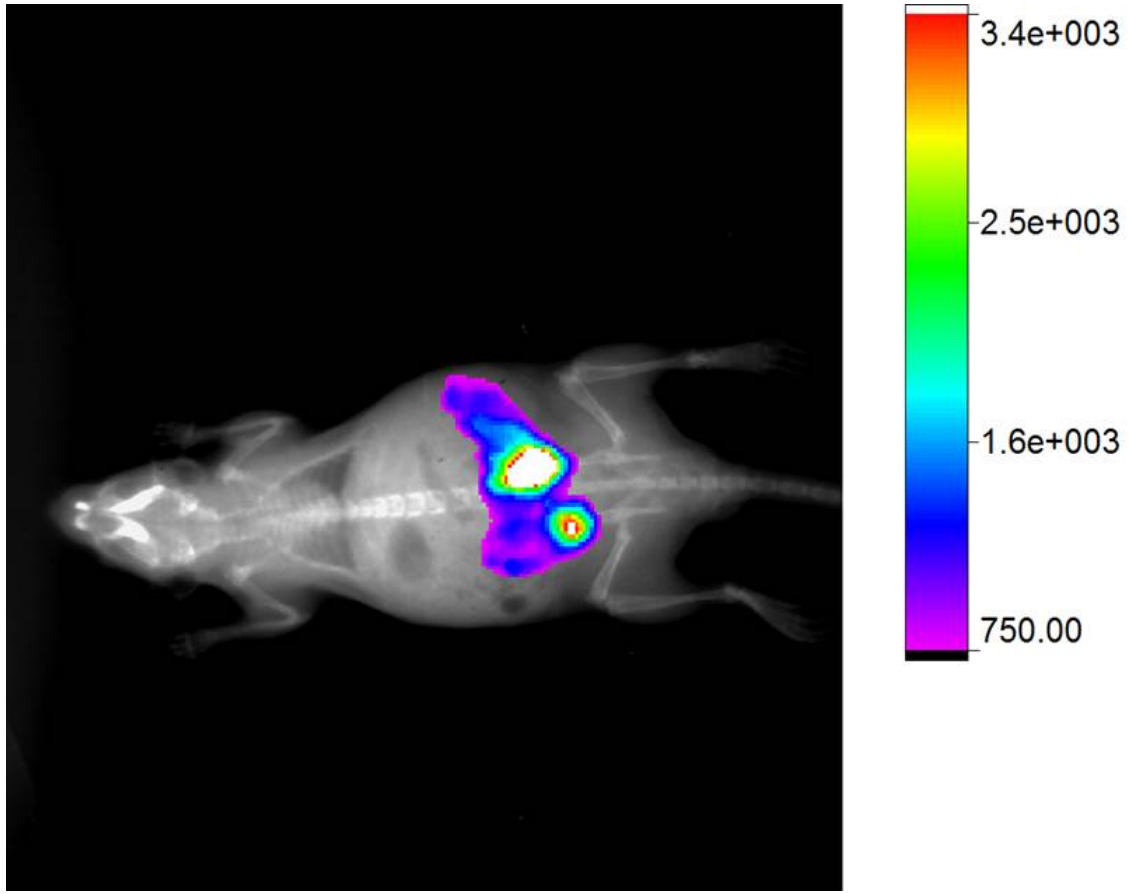
OptiMAX X-ray and luminescence imaging

Capability to overlay luminescence and x-ray imaging



X-ray at 50kV



Luminol Luminescence Overlaid on X-ray

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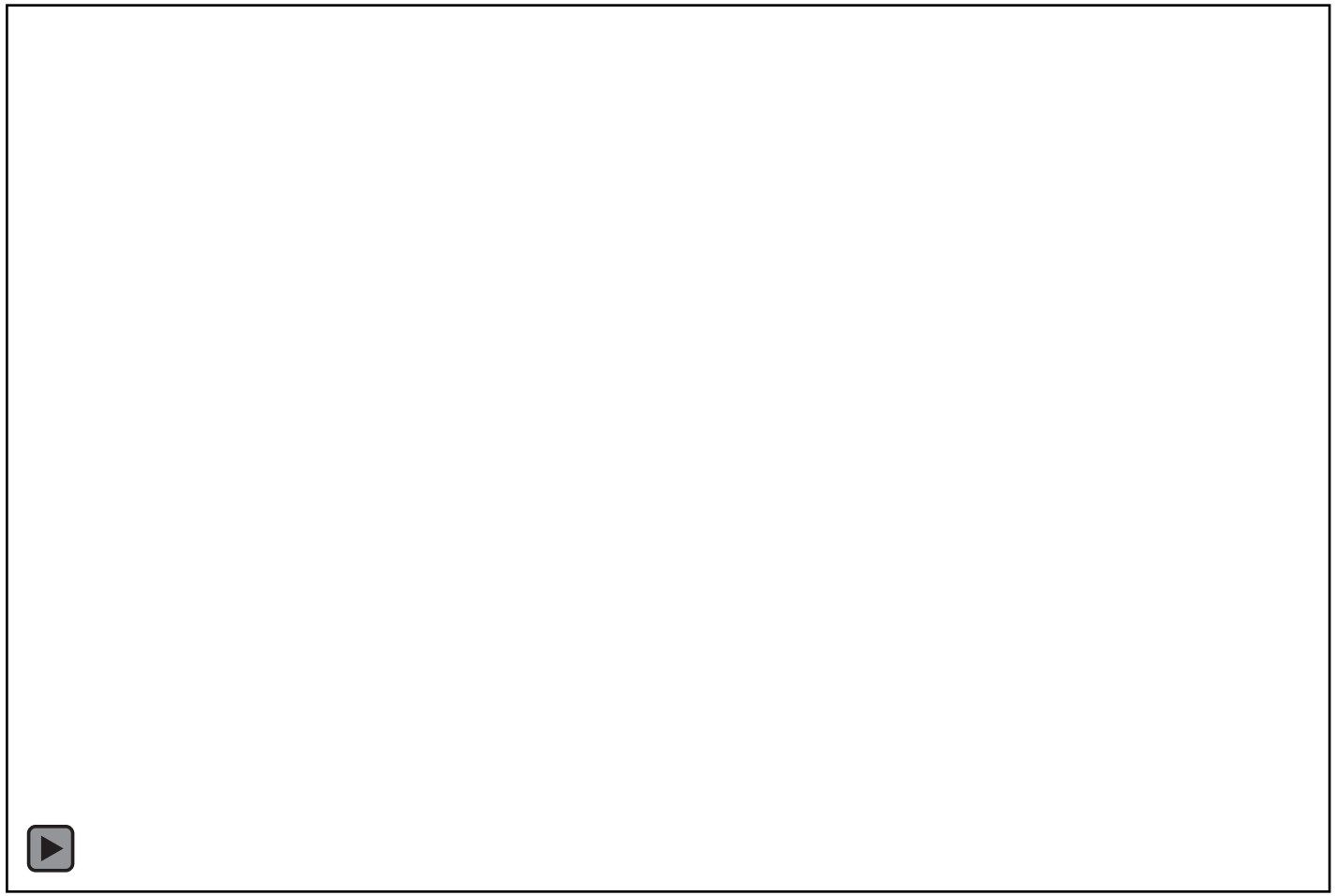
SmART+ System

Small animal image guided radiation therapy system

Why did we create this system?

- Clinically relevant system for greater **translatability**
- CT image-guidance enables treatment planning with increased delivery precision
- Onboard imaging modalities enable novel therapeutic response evaluation and tracking



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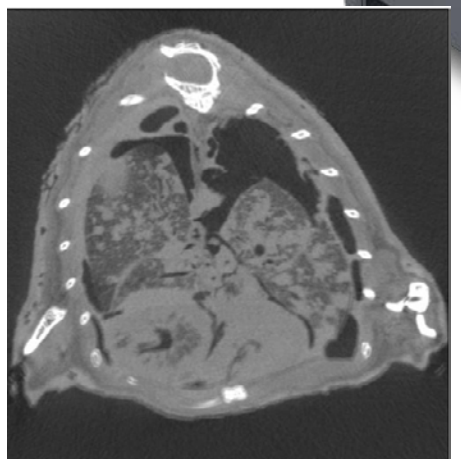
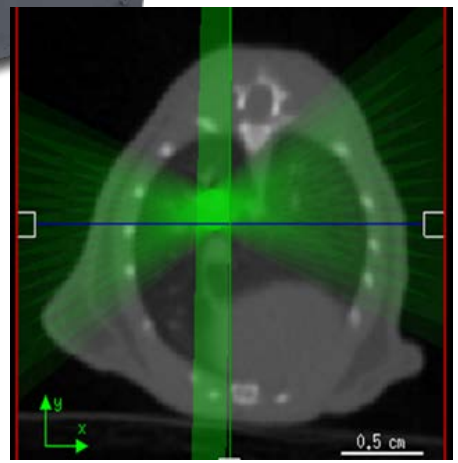
SmART+ System

Small Animal image guided Radiation Therapy system

- Accurate , Repeatable Targeting
- Minimal impact on surrounding tissue
- True MicroCT imaging
- Bioluminescence Imaging
- Full Treatment Planning with 3D commissioning
- Large Chamber for Cells, Mice, Rats, Rabbits
- NEW – SmART+ IB System for Proton and other heavy ion beamlines





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Cesium Irradiator Replacement Project (CIRP)

How does it work?

- The Department of Energy is working with users of cesium-137 based irradiators to convert to non-radioisotopic alternatives

- The government covers the following:
  - Proper disposal of cesium-137 irradiator
  - Up to 50% of the purchase price of a new X-Ray rradiator

- The site is responsible for the following:
  - The remaining 50% of new irradiator
  - Training, warranty/maintenance costs, and spare parts

Cesium irradiation vs X-ray irradiation

An overview of published comparison studies

- Dose depth curve Cesium-137 matched up to 4 cm depth (320 kV x-ray irradiator with F2 Filter) or <2 cm (160 kV x-ray irradiator) [1]
- X-ray irradiation is better for collimation (partial body irradiation)[1]
- Equivalent dose rate, field size, and uniformity compared to cesium-137

- Important Studies:

1. Smith, B. et *al.* University of California Systemwide Radioactive Source Replacement Workgroup Recommendations.
2. Potter, C. et *al.* Radiobiological Studies Using Gamma and X Rays. Sandia Report. 2013.
3. Kamen, J. et *al.* Successful Migration from Radioactive Irradiators to X-ray Irradiators in One of the Largest Medical Centers in the US. Health Physics. 2019.
4. Belley, M. et *al.* Microdosimetric and Biologic Effects of Photon Irradiation at Different Energies in Bone Marrow. Radiation Research. 2015.
5. Andersen, AHF.et. *al.* Comparable human reconstitution following Cesium-137 versus X-ray irradiation preconditioning in immunodeficient NOG mice. PLOSOne October 2020
6. Afrough B. et. *Al.* X-ray Inactivation of RNA viruses without loss of biological characteristics. Nature/Scientific Reports October 2020

How we communicate with researchers

We want to understand what is important to them!

- What are the most important features you require?
- What are your applications?
- How long have you been using Cesium sources?
- What are your potential hesitations in switching to X-ray?
- What questions do you have for our team?

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Challenges moving forward?

- Gaining consensus to change from broad group of researchers
- Control and reporting of remaining variables

  - Samples, sample holders, lead shields and collimators
- Support of additional comparative studies
- Improved training
- Improved reporting in publications
- Increased throughput for expanded applications

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