Replacing Cesium-137 Irradiators at Mount Sinai

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National Academies of Sciences of

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Radioactive Sources:
Applications and Alternative Technologies

September 9, 2020

Topics Covered

- When and how did we start?
- Hazard and risk analysis
- Action plan with three phases
- The decision making process of transitioning to alternative technology
- Financial, regulatory, and other implications related to the transition
- The timeline of the transition and support from federal agencies
- Selecting a vendor and the preparation for the transition.
- Challenges faced during transition and how they were overcome.
- Training of personnel to operate the alternative technology.
- Equivalency testing and other operational considerations.
- Lessons learned from the transition.
- Suggested future work

2010

One year before the 10th year 9/11 anniversary

On 9/11 our own planes were used as missiles. Is there anything in my facility that could be used maliciously?

What are the risks?

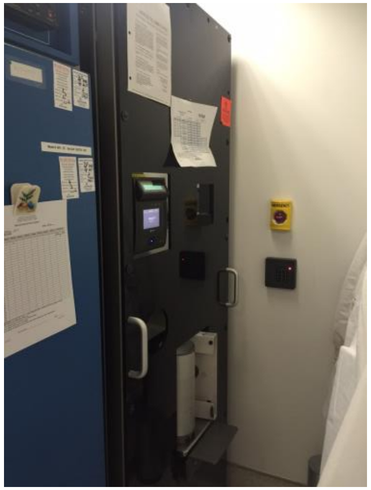
What to prepare for?

2010

Originally Mount Sinai had 4 Irradiators

Research Irradiators

Blood Bank Irradiators



All were considered as category 2 radioactive sources.

Weapons of Mass Disruption (WMD)

Goiânia- Brazil Accident – 1987

- An old radiotherapy source was stolen from an abandoned hospital.
- 112,000 surveyed- 249 had significant contamination and 4 died.
- Small capsule contained about 93 grams (3.3 oz) of highly radioactive cesium chloride (Cs-137 CsCl).
- The IAEA states that the source contained 50.9 TBq (1,380 Ci) when it was taken away.
- 80 grams of CsCl powder resulted in more than 40 tons of radioactive waste.

Reference: The Radiological accident in Goiânia Vienna: International Atomic Energy Agency. 1988. ISBN 92-0-129088-8

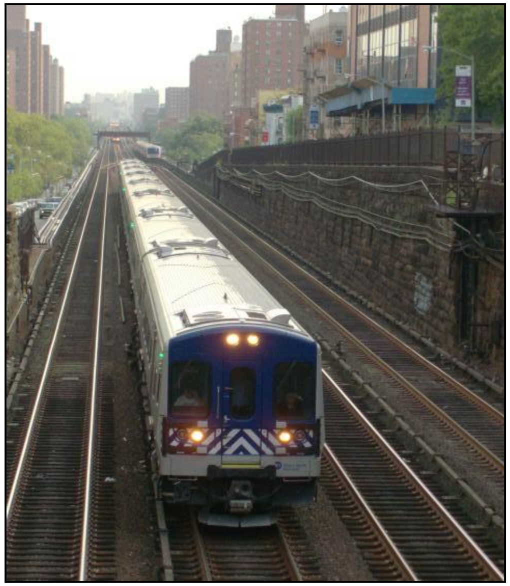
2010
Al-Qaeda and Jewish Targets

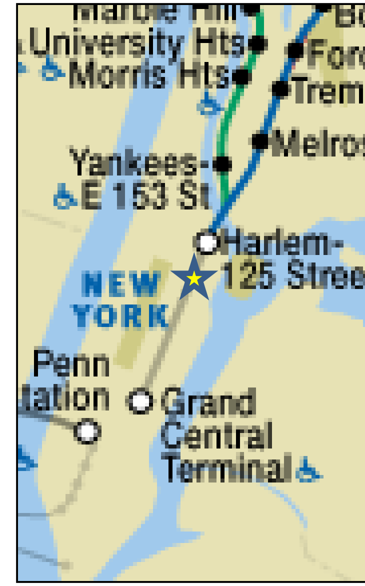
- **Apr 2002-** **Suicide bombing of synagogue in Tunisia killed 19.**
- **Nov 2002-** **Suicide bombing of a hotel in Kenya owned by Israelis killed 16.**
- **May 2003-** **Bomb attack in Morocco of Jewish Cultural Center killed 45.**
- **Nov 2003-** **Two synagogues in Turkey bombed killed 23.**
- **Oct 2005-** **Germany sentenced 4 Arab men for planning to attack Jewish targets.**
- **May 2009-** **FBI arrested 4 for planning to attack Riverdale Jewish Center.**
- **Oct 2010-** **Explosives were found on a cargo plane from Yemen to be used against Jewish synagogues in Chicago.**

2010
History of Terrorist Train Attacks

- **Tokyo, Japan (March 1995)** – Sarin, a biological agent was released in the subway.
- **Madrid, Spain (March 2004)** – During morning rush hour, 10 bombs in 4 different trains exploded.
- **London, U.K. (July 2005)** – Coordinated suicide bombing attacks during morning rush hour.
- **New York, U.S.A. (September 2009)** – An Al-Qaeda recruiter, recruited three U.S. citizens to detonate suicide bombs in the Manhattan subway system.

2010
Hazard Analysis & Location of Mount Sinai





2010-Key Locations

Mount Sinai at Madison Avenue and 100th Street

Transportation	Location	Distance from MSMC
Metro North Exiting the tunnel	99th Street and Park Avenue	0.24mile
4/5/6 Trains Express Stop	86th Street and Lexington Ave.	0.87 mile
6 Train Local Stop	96th Street and Lexington Ave.	0.35 mile
6 Train Local Stop	103rd Street and Lexington Ave.	0.36 mile
6 Train Local Stop	110th Street and Lexington Ave.	0.72 mile
2 Train Express Stop	110th Street and Lexington Ave.	0.71 mile

2010- SPECIFIC TO MOUNT SINAI

- **Location in New York City**

  Since 9/11 there have been 20 terrorist attempts towards NYC. Mount Sinai is located in New York City with many subway entrances located within less than a mile.

- **Mount Sinai has 4 Radioactive Sources**

  These radioactive material sources could be used as dirty bombs (WMD)

- **Hospital Entity**

  Terrorist groups would target hospitals to delay the response to mass casualties - Mount Sinai is a major hospital.

- **Jewish Entity**

  Argentina bombing was chosen only because of its Jewish identity. Mount Sinai is a Jewish entity.

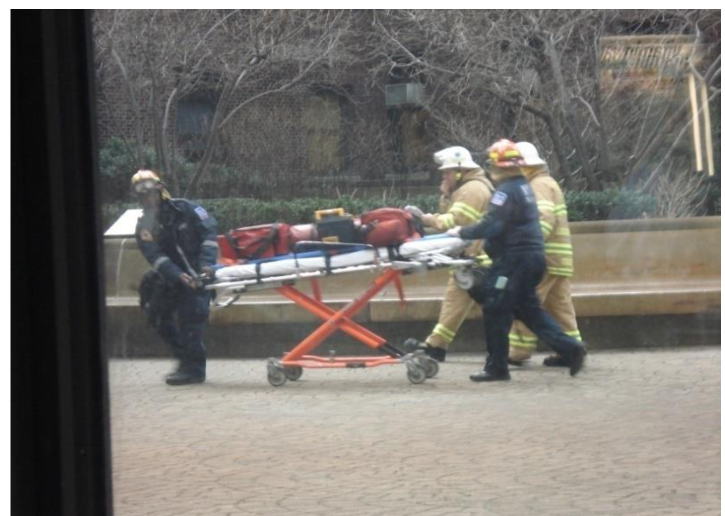
2010- ACTION PLAN

Phase 1- Get ready for the worst case scenario - Prepare to respond to Radiological Incidents.

Phase 2- Reduce the risk: Limit Access, Harden Security, FBI background check

Phase 3- Remove the risk: Use Alternative Technology and dispose all radioactive irradiators.

Drills with Other Agencies



Steps Taken to Reduce Risk

- Limit Access
  - One person has unescorted access instead of 144 people.
- Partnership with NNSA/GTRI
  - Hardening the irradiators (increased the time required to remove the source so that the police could arrive before it is stolen).
- Security Enhancement
  - Collaboration with government agency and installing security equipment. RMS unit, biometric access, intrusion detection, etc.
- RMS was connected to the police department
  - Police department was connected to RMS unit for remote monitoring. Mount Sinai was the first to be connected to LMSI.
- Background check
  - FBI background check on those staff having unescorted access to the irradiators (to be alone with the unit).

Pre-Arranged Plan between NYPD And Mount Sinai Medical Center

For Theft, Intrusion, Diversion of Radioactive Materials in Quantities of Concern

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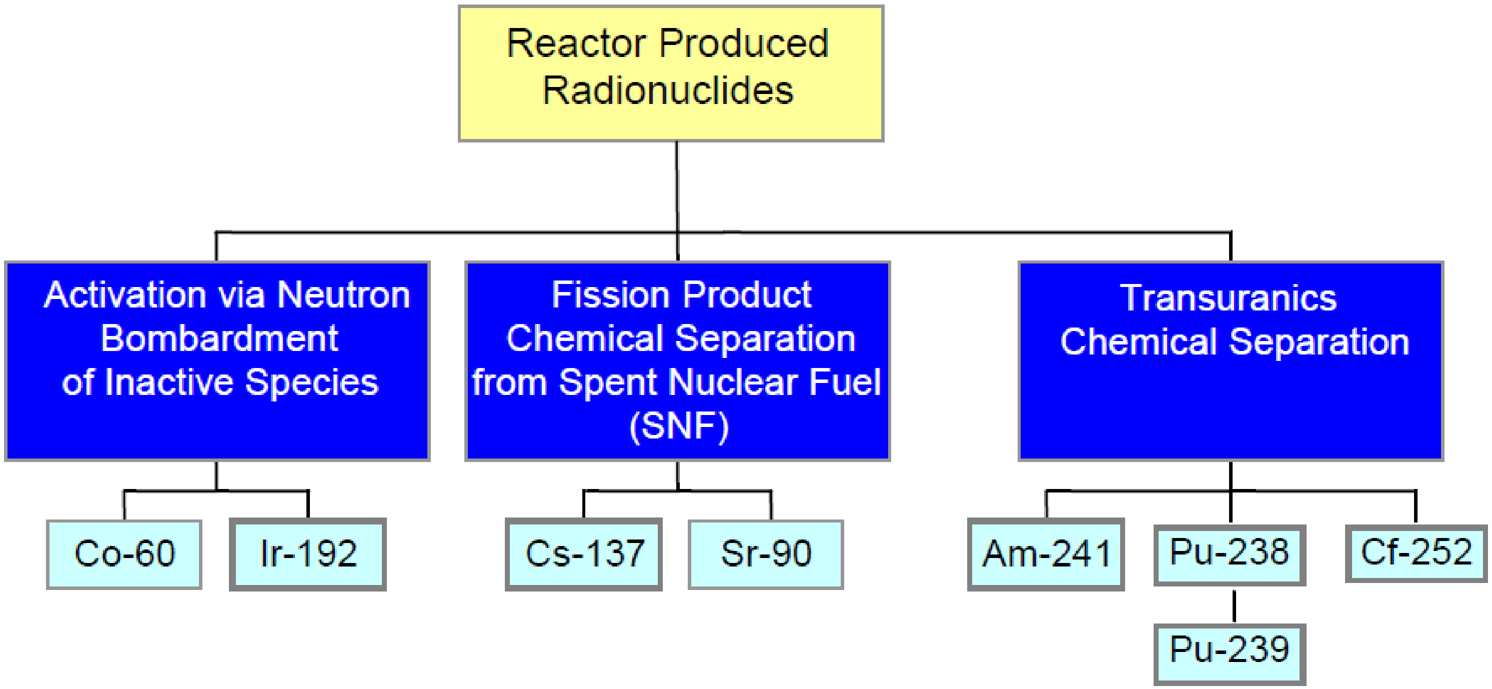
HOW Cs-137 SOURCES ARE PRODUCED?



Taken from Connell et all 2006

Gaps in Insurance Coverage

- ✓ Insurance policy usually excludes:
- ✓ Under our Property Damage Policy: loss or damage from nuclear radiation or radioactive contamination.
- ✓ Within the TRIPRA coverage, loss or damage from biological or chemical terrorism defined as the "dispersal, discharge or release of pathogenic toxic, poisonous or damaging biological or chemical agents in an act of terrorism."
- ✓ Exclusions Render Coverage for NBCR terrorism acts extremely limited with the exception of damage from fire.
- ✓ In order to add radioactive decontamination converge, it would cost about $1.5 Million

Irradiator Comparisons*

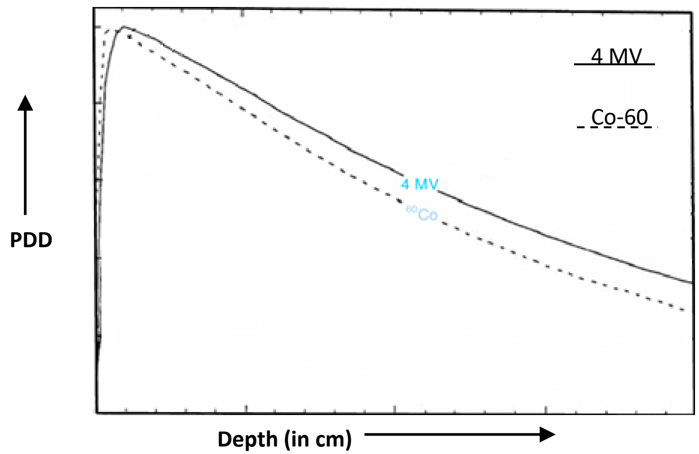
	Cs-137 Irradiator	X-ray Irradiator
Purchase Price	$160.000-$325,000 Est. $242,500	$110,000-$240,000 Est. $175,000
Site Preparation	$7,500	$0 -3,600
Licensing Costs	**$15,400**	**$2,500**
FBI Background check	$3,800	None
Transportation+ Disposal	**$200,000**	**$2,500**
Life	the source needs to be replaced about every 30 years ($150,000)	The tube needs to be replaced about every 12 years ($20,000); The life span of x-ray machine is ~12 years
	After 10 year, the cost to keep is about the same (Cs blood irradiator and x-ray blood irradiator	
PM Cost per year	~$10,000 (RMS, PM, dose map)	$4,750 (warranty)
Regulatory Inspection	Yes, annually (NYPD + NYCDOH)	None
Insurance coverage for Decontamination	**$1.5 Million**	**None**

*Cost-Benefit Analysis of Switching from Cs to X-ray Irradiators – Erik Bakken, University of Wisconsin-Madison

Co-60 & LINAC

LINAC

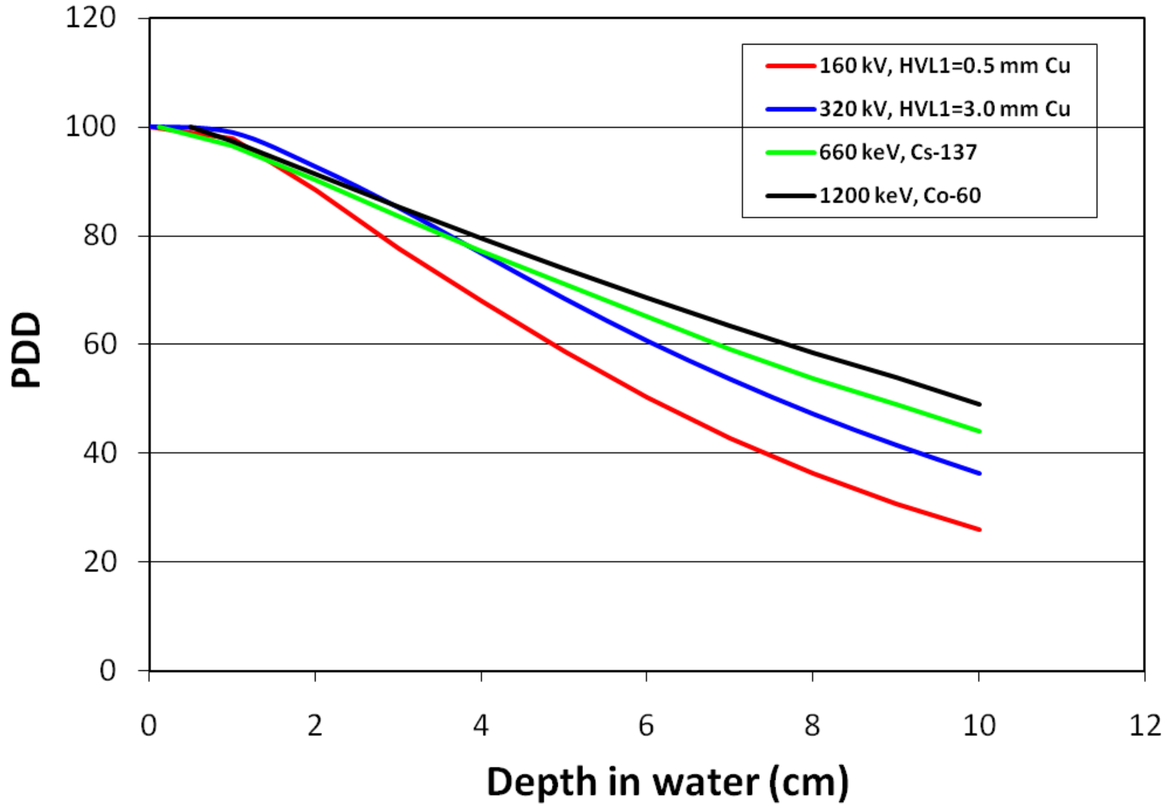
Co-60



Percentage depth dose curves in water for a 10 × 10 cm2 field at 100 cm SSD for photon beams from cobalt-60 gamma rays and 4 MV X-rays.

10,000 Ci → @1ft → ~38R/sec

Penetration as a Function of Energy



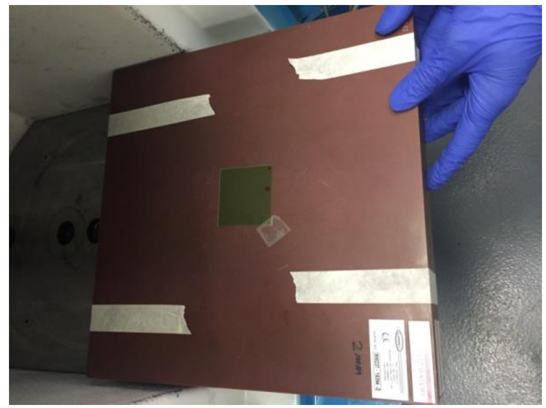
PDD plotted from data in BJR Supplement 25, for Three X-ray Qualities and for Cs-137 and Co-60. For all the following parameters apply: W=10 cm, SSD=50 cm[11]

2013 - New Research Building

- Decided on RadSource RS2000 X-ray Irradiator (160 kVp)
- Purchased on April 2013.
- The Initial cost was $110,000 including a 2-year warranty.
- Encouraged researchers to start using X-ray for cells and mice.
- It is used daily ~ 3-4 times/day, everyday of the year.
- NO system failure has been reported since purchased.
- NO complaints from researchers since purchased.

Experimental Setup For Depth Dose Measurement

X-Ray Irradiator

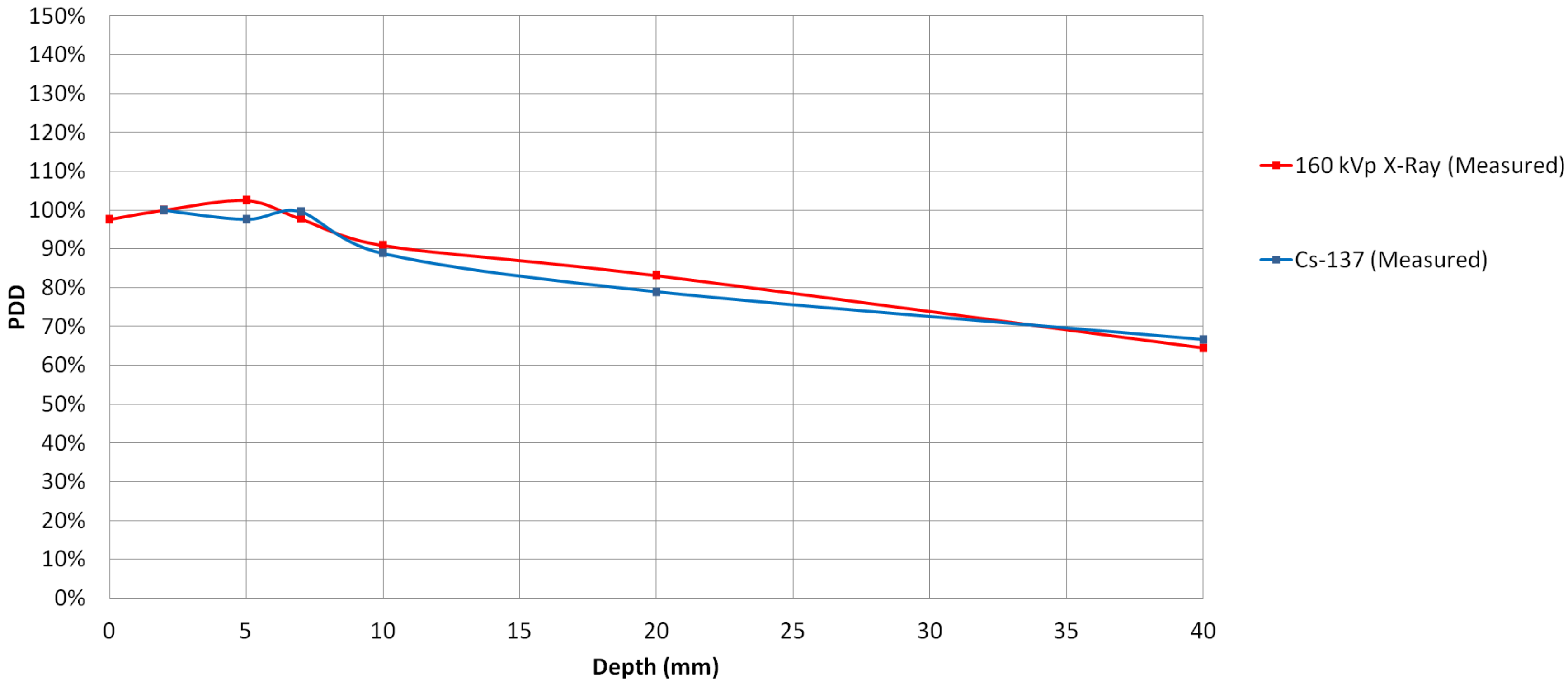


Cs-137 Irradiator

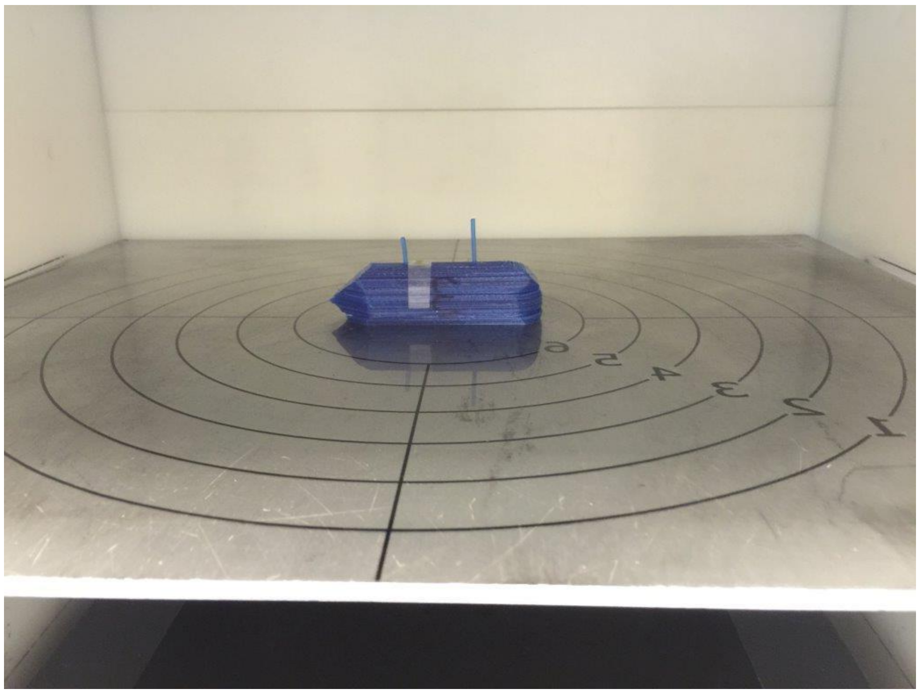
• EBT2 film measurement in JL Shepherd Mark 1 Cs-137 irradiator, no lead attenuator was used, location 3, no turntable rotation, irradiated to the dose of 6 Gy; EBT2 film measurement in RS 2000 x-ray irradiator, 160 kVp, 25 mA, level 3.

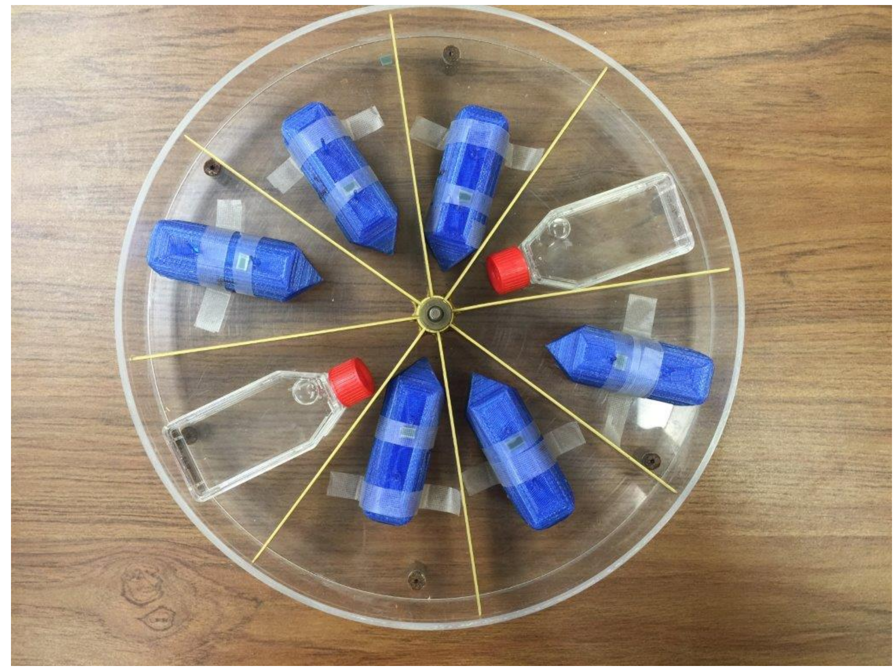
•Solid water phantom was used. Films were sandwiched in different thicknesses of solid water phantoms.

Comparing Measured Percent Depth Dose



Mouse Phantom Measurement

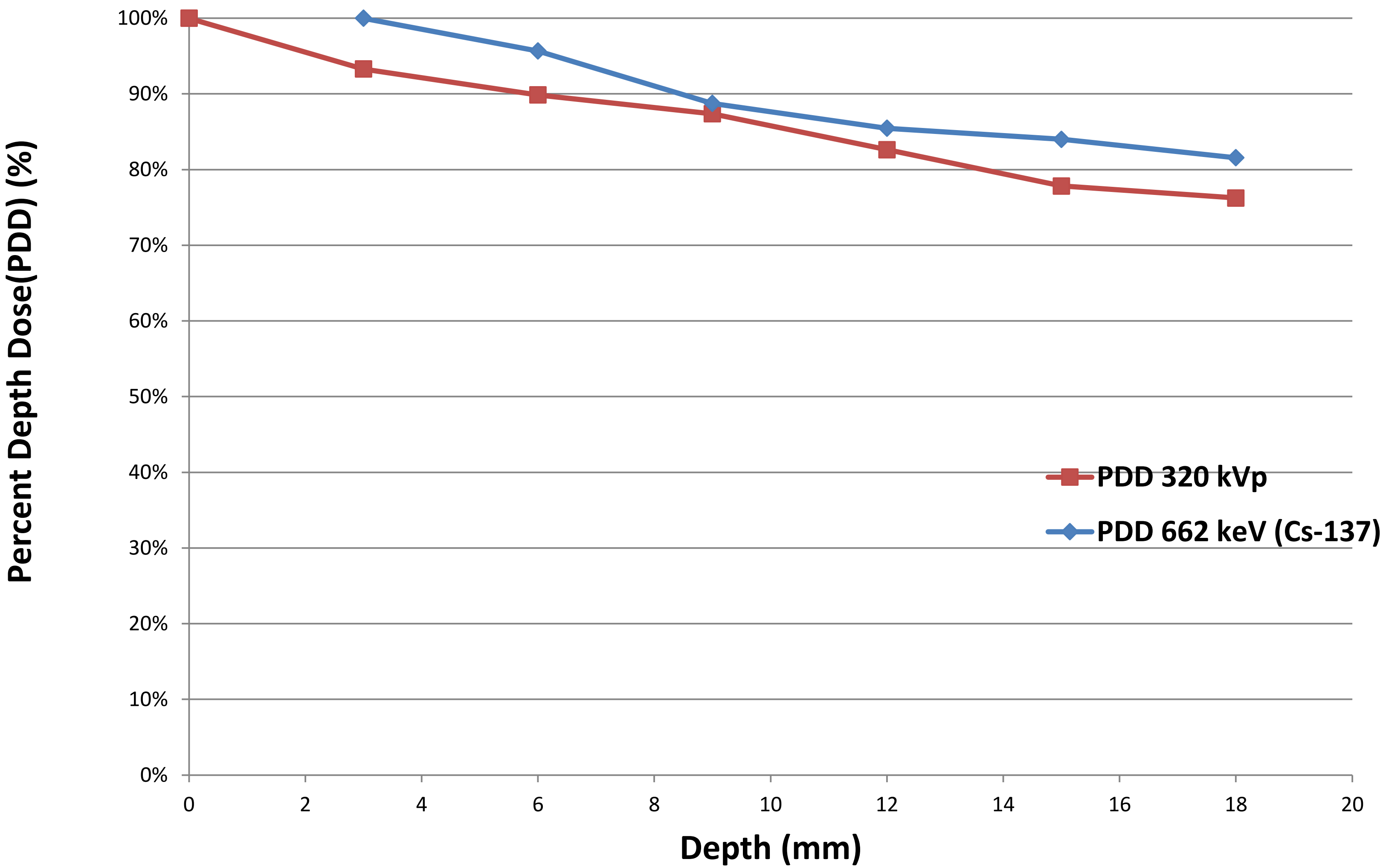




Mouse holder rotation and error

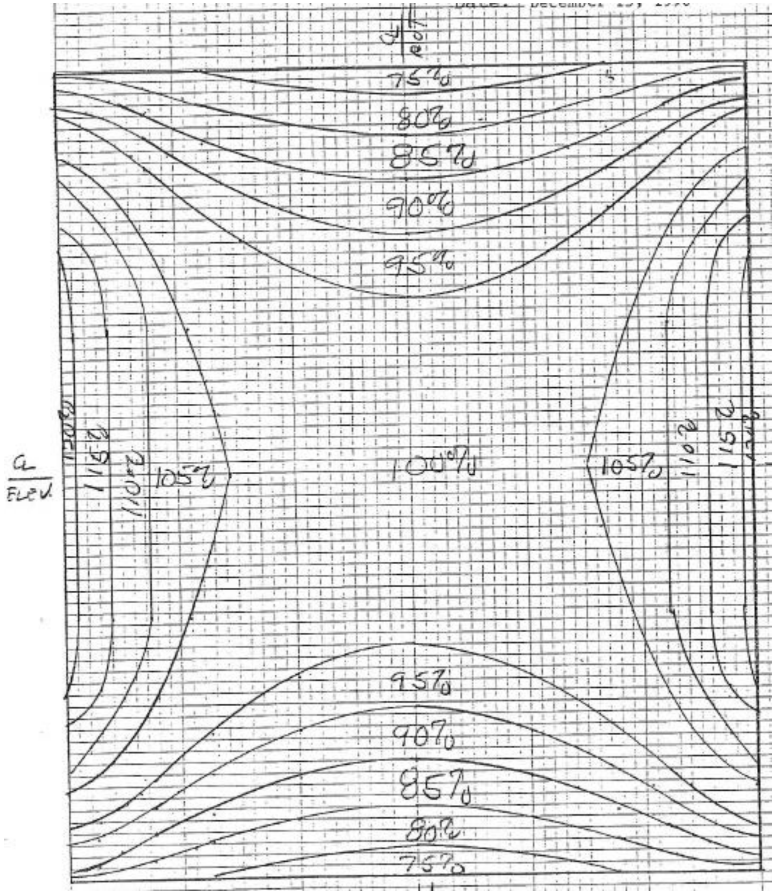
MEASURMENT

Percent Depth Dose (PDD) Curve of 320 kVp (Precision X-ray XRad 320) VS 662 keV (JL Shephard Mk-I-68) in Small Rodent Phantoms



Dose Delivery Deviation

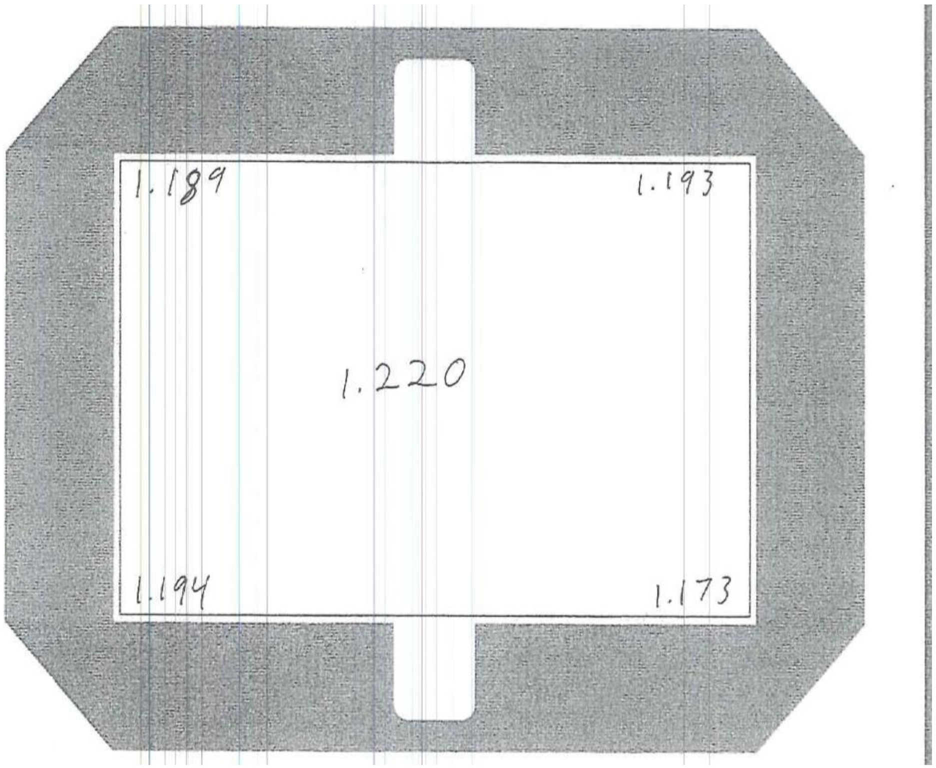
Cs-137



Isodose map of Cs-137 Irradiator at position 3

±20 % dose deviation while irradiating mice

X-ray



Dose rate measurement at RS2000 x-ray irradiator at level 1 with RAD+

±3.8 % dose deviation while irradiating mice

Dose Rate and Repair Mechanism

- The 4 R's of Radiobiology:
  - Repopulation
  - Redistribution
  - Re-oxygenation
  - **Repair:** Extending the period of time over which a dose is delivered allows for cells to repair sub lethal damage

- **Threshold for repair is 1 Gy/min**
- A lower dose rate means longer irradiation time, which means more time for sub lethal damage repair
- **X-rays do not have this issue**

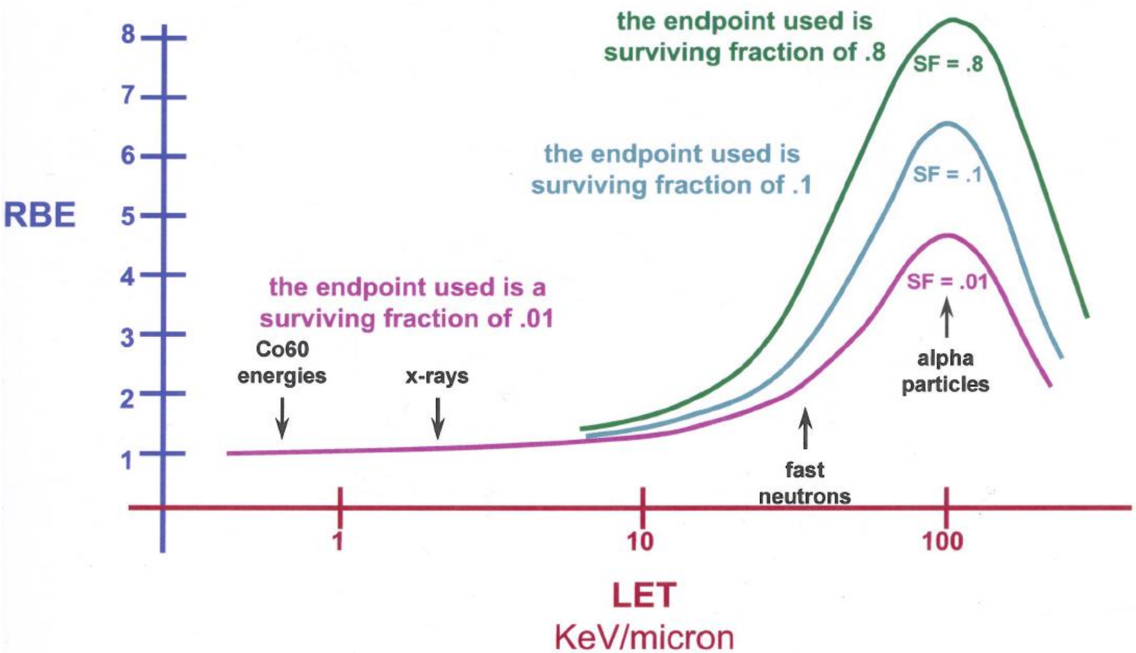
Cs-137 Irradiator	X-Ray Irradiator
0.5 Gy/min	1.25 Gy/min
~12 min irradiation time for 6 Gy	**~5 min** irradiation time for 6 Gy

Cs-137 Decay Correction

- Cs-137 decays ~1% in 5 months or ~2.3% in a year. Need to correct every a few months and recalibrate field once a year.
- After 10 years, the difference in calculated activities between a 30.17 year and 30.0 year half-life source is 0.13%
- **X-rays do not have this issue**

Reference	Half-life (yr)
NIST	30.17
IAEA	30.05
MIRD	30.0

Relative Biologic Effectiveness (RBE) & LET

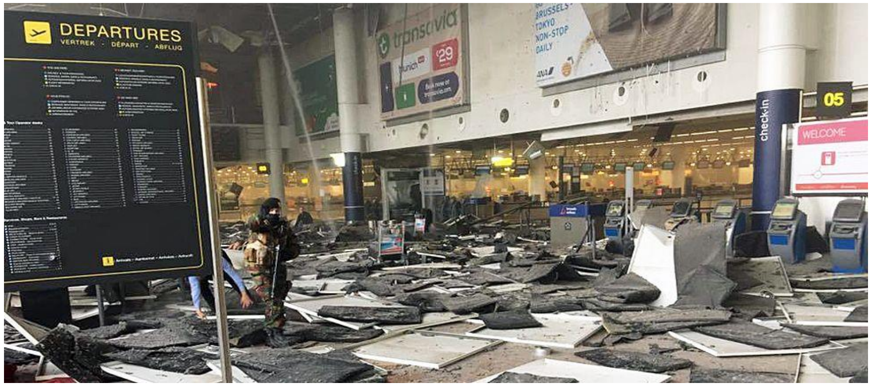


Radiation	LET (keV/µm)	RBE
Co-60 γ-rays	0.2	**0.9**
250 kV x-rays	2.0	**1.0**

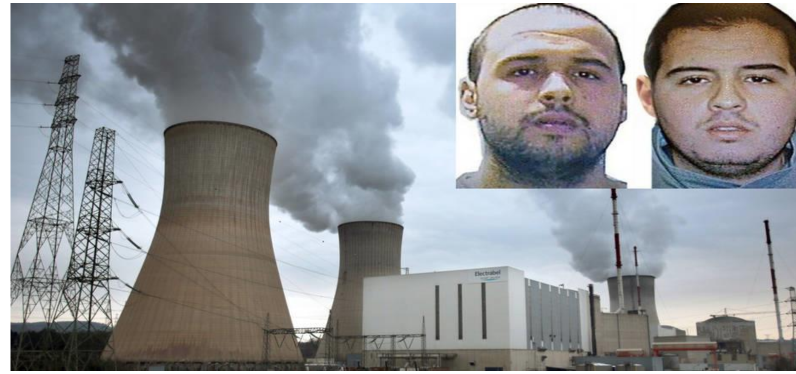
Variation of RBE with LET for survival of mammalian cells of human origin

(*from Radiobiology for the Radiologist, 6th Ed, Eric J. Hall; JB Lippincott Co., Philadelphia, 2005*)

2016 - Brussels Terrorist Attack



The aftermath in the departures hall at Brussels Zaventem airport following the explosions



El Bakraoui brothers initial target ; nuclear power plant

- **Exact time of explosion at Metro was 9:11 am**
- **32 Killed- 340 Injured in both attacks.**
- **Islamic state took responsibility.**
- **The brothers who died in suicide bombings at the Brussels airport and subway had been involved in secret video surveillance of director of SCK-CEN at the Nuclear Power Station. This recording of about ten hours was seized in December 2015 at one of the suspects of the attacks in Paris, Mohamed Bakkali**.

CCTV footage captured the three attackers shortly before two of them detonated explosives

*https://www.dhnet.be/actu/belgique/exclusif-les-freres-el-bakraoui-visaient-nos-centrales-nucleaires-56f3778d35702a22d5ad606b

Decision making on the Irradiators

Considerations

- FDA Approved (Blood)
- Energy
- Irradiator chamber size
- Irradiator size (considering our space is limited)
- Self-cooling system
- The add-ons (collimators, adjustable shelves…etc.)
- Price of the machine and the warranty cost
- Renovation Cost
- Shorter downtime
- The review of other users

Process

Step 1. collect information online to see what irradiators are available

↓

Step 2. Narrow down to 2-3 desirable units

↓

Step 3. Ask the vendors to introduce their units to the users (researchers, blood bank)

↓

Step 4. Collect the opinions from the users and make a decision

Biomedical Irradiator: Mount Sinai Decision Making

We found information on Kimtron HiRad System, Xstrahi, Faxitron MultiRad System, RadSource RS2000, and Precision X-ray Xrad 320.

We narrowed down to Faxitron MultiRad 350 and Precision Xrad 320 because of more desirable energy, total cost, the internal dose measurement too, imaging accessories, collimator add-on, and the ease of maintenance.

We invited Faxitron and Precision X-ray to introduce their units.

We eventually picked Precision X-ray Xrad 320 based on the above mentioned advantages, Mount Sinai researchers' opinions and other user's experiences.

New X-ray Irradiators in Mount Sinai

Blood Irradiator

RS 3400, 150 kVp

Research Irradiator

X-RAD 320, 320 kVp

How to approach researchers?

Boiling a Cup of Water

30-45 minutes

60 years ago

1.2 minutes

2017

Successful X-ray Irradiation Experiments - 1*

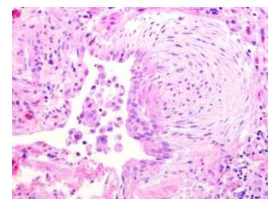
- **First experiment**:
  - Used 35 mice for bone marrow transplantation
  - Irradiation: 6 Gy each time (12 Gy total) (12-24 hrs interval)
  - Survival: 50 days. Only one mouse died out of 35 transplanted mice
  - Chimerism: All recipients were around 90% of donor origin. Similar result to using Cesium source.

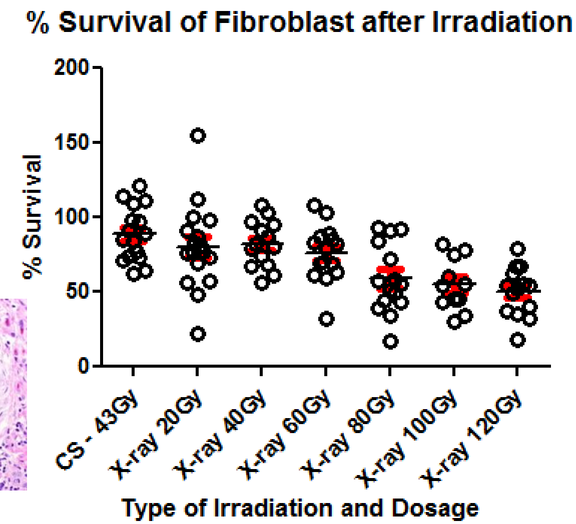
- **Second experiment:**
  - Irradiation: 6 Gy each time (12 Gy total) (12-24 hrs interval)
  - Survival: 30-50 days. This is a model disease and development of LCH is expected after transplantation
  - Chimerism: All recipients were around 100% of donor origin. Similar result to using Cesium source.

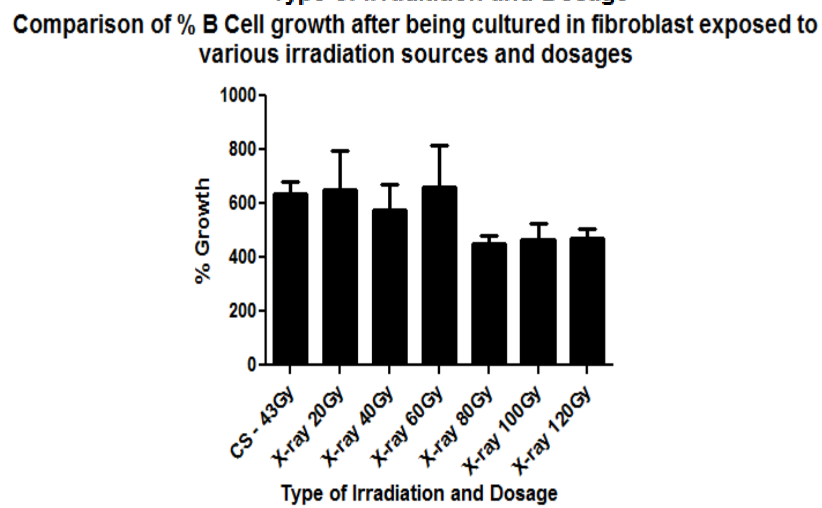
** Dr. Miriam Merad laboratory – Icahn School of Medicine at Mount Sinai*

Successful X-ray Irradiation Experiments -2*

- To grow human B cells on irradiated human fibroblasts
- To compare standard irradiation (43Gy) to various doses of x-ray (20-120Gy)
- Measured
  - fibroblast survival over 3 days
  - growth of B cells when plated on the fibroblasts
- Our data indicate that 20-60Gy x-ray has equivalent effects to standard 43 Gy cesium irradiation, and that Xray doses above 80Gy impair fibroblast and B cell growth compared to the standard 43 Gy cesium irradiation



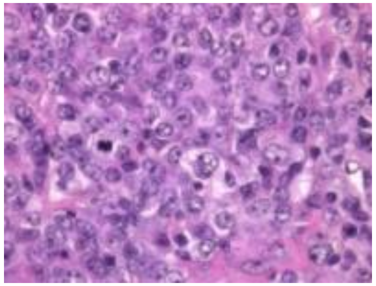




** Dr. Peter Heeger laboratory – Icahn School of Medicine at Mount Sinai*

Successful X-ray Irradiation Experiments -3

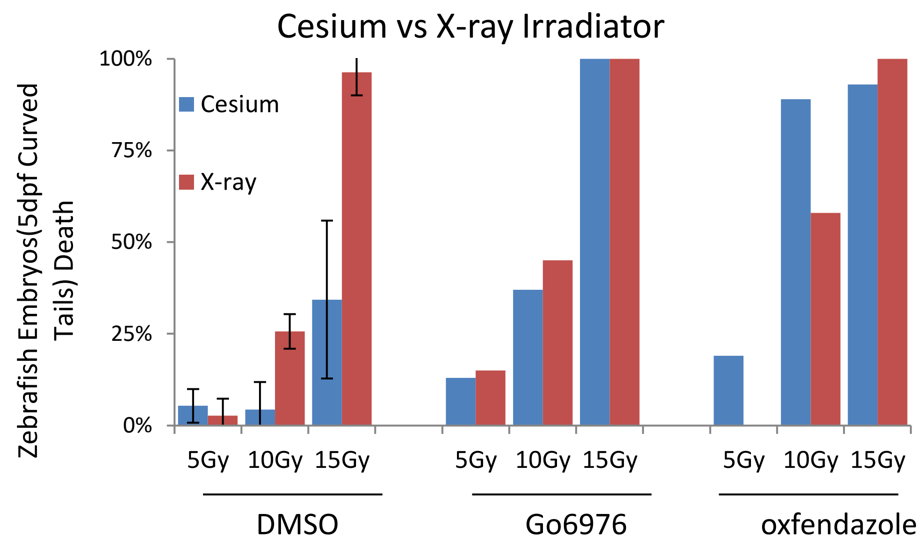
- Assess the effect of irradiation on survival of A20 lymphoma cell line
- Irradiation: various doses (9Gy-100Gy)
- Readout: Annexin V staining for apoptosis of A20 cells after 48h
- Apoptosis is induced in a dose dependent manner, increasing from 25% at 9Gy to 60% at 75Gy, doses over 75Gy did not show a further increase in apoptosis induction

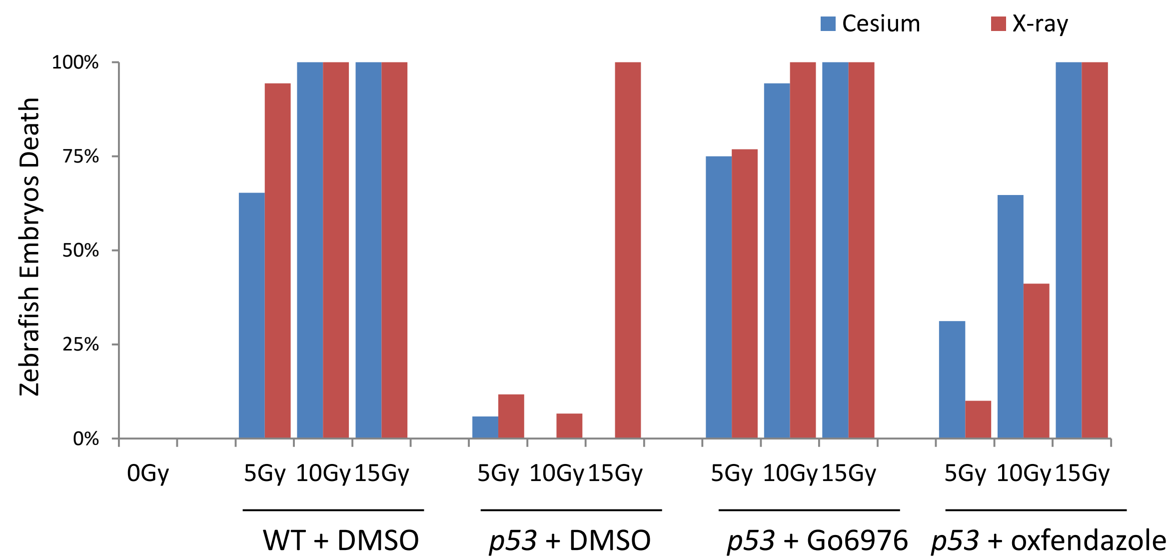


** Dr. Joshua Brody laboratory – Icahn School of Medicine at Mount Sinai*

Successful X-ray Irradiation Experiments - 4

- X-ray is toxic at 10 and 15 Gy in embryos (5dpf curved tails) that normally tolerate these doses when delivered by Cesium with DMSO; otherwise, x-ray and cesium irradiation give very similar death rates under the condition that the same dose given to the zebrafish embryos.
- X-ray is toxic to the embryos of zebrafish when the embryos are irradiated to 15 Gy with p53+DMSO.





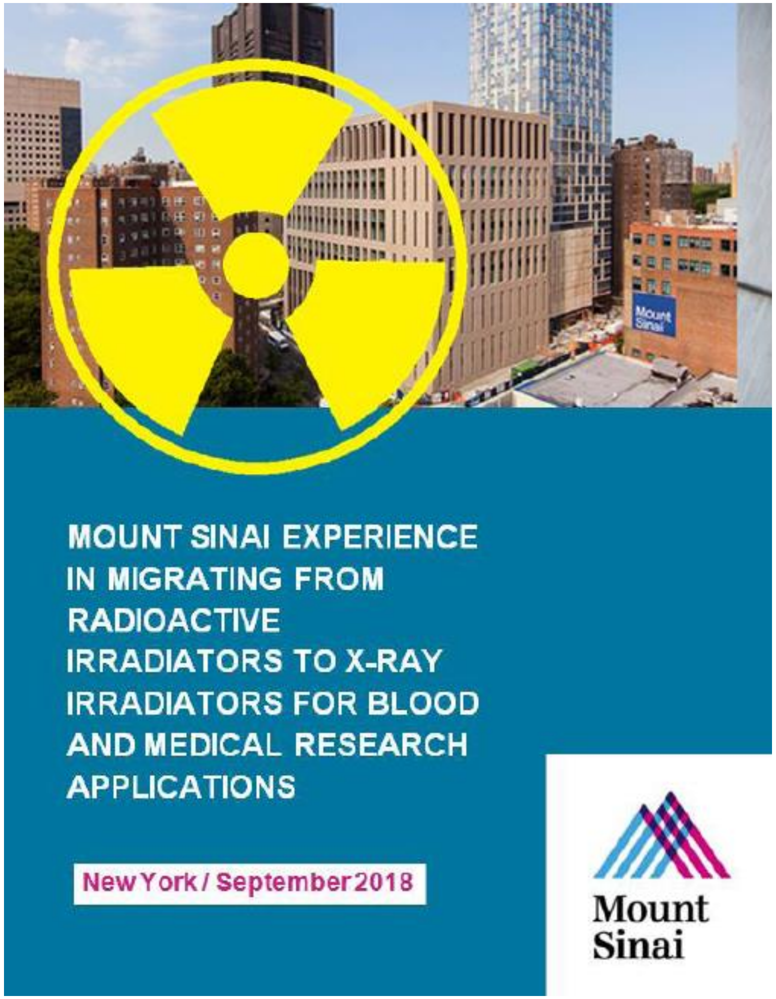
** Dr. Samuel Sidi laboratory – Icahn School of Medicine at Mount Sinai*

Successful X-ray Irradiation Experiment - 5

- Experiment:
  - **Used 12 mice for whole brain irradiation**
  - **Irradiation: 5 Gy x 2 (48 hour interval) [total: 10 Gy]**
  - **Survival: 30 days. No deaths.**
  - **X-Ray irradiator gives similar results to Cs-137 irradiator**

** Dr. Costas Hadjipanayis laboratory – Icahn School of Medicine at Mount Sinai*

Where to find the report?

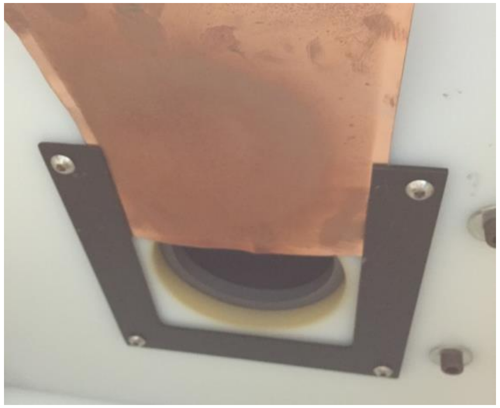


- https://www.nti.org/media/documents/Mt._Sinai_Final_Report.pdf

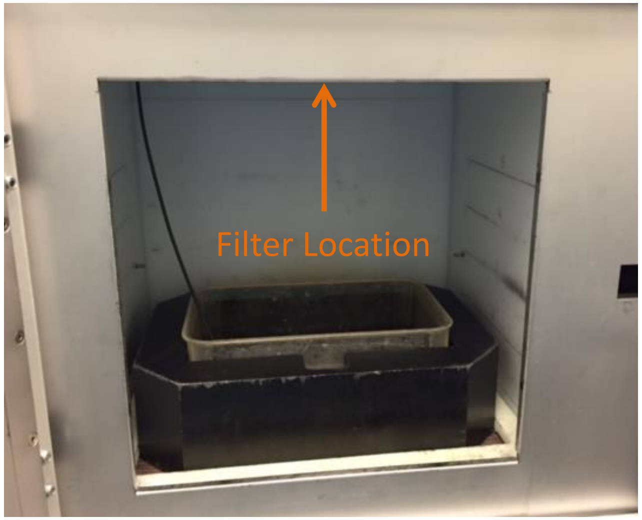
42 mice died- Copper Filter Issue

- The copper filter on the irradiator ceiling can be displaced inadvertently while moving cages or irradiator equipment
- If the copper filter gets dislodged it can result in a dose rate that is 10x higher
- Make sure the filter is completely covering the aperture before irradiation

Correct



Incorrect



Exposure Time Input Error

- The dose chart on the irradiator lists the time in **minutes and seconds**
- The irradiator accepts the time **only in seconds**
- If the time is inputted incorrectly it could result in an overdose
- Care must be taken to make sure the time is properly converted into seconds before starting the irradiation
- A new time table shown in seconds is created to avoid the time input error.

Intended Exposure Time	Actual Inputted Exposure Time
4 min 48 seconds (4 x 60 + 48 = 288 sec)	448 seconds
6 Gy dose delivered	9.33 Gy dose delivered
Correct dose delivered	Incorrect dose delivered (156% of intended)

RS 2000 Irradiation Time Tables

Machine Settings 160 kV 25 mA

LEVEL 1 (inside RAD+)
Dose rate: **1.25 Gy/min**

Dose rad (cGy)	Dose Gy	Time (sec)
200	2	96
250	2.5	120
300	3	144
350	3.5	168
400	4	192
450	4.5	216
500	5	240
550	5.5	264
600	6	288
650	6.5	312
700	7	336
750	7.5	360
800	8	384
850	8.5	408
900	9	432
950	9.5	456
1000	10	480
1050	10.5	504
1100	11	528
1150	11.5	552
1200	12	576

LEVEL 3
Dose rate: **2.06 Gy/min**

Dose rad (cGy)	Dose Gy	Time (sec)
200	2	58
250	2.5	73
300	3	87
350	3.5	102
400	4	117
450	4.5	131
500	5	146
550	5.5	160
600	6	175
700	7	204
800	8	233
900	9	262
1000	10	291
2000	20	583
2500	25	728
3000	30	874
3500	35	1019
4000	40	1165
4500	45	1311
5000	50	1456
6000	60	1748
7000	70	2039
8000	80	2330
9000	90	2621
10000	100	2913

LEVEL 5
Dose rate: **4.51 Gy/min**

Dose rad (cGy)	Dose Gy	Time (sec)
2000	20	266
2500	25	333
3000	30	399
3500	35	466
4000	40	532
4500	45	599
5000	50	665
5500	55	732
6000	60	798
6500	65	865
7000	70	931
7500	75	998
8000	80	1064
8500	85	1131
9000	90	1197
9500	95	1264
10000	100	1330

Model: RS 2000
S/N: 3228
Mount Sinai Medical Center

Formula to calculate time based on Gy
Example: Target dose 45 Gy and sample placed on level 3 (2.06 Gy/min)

$$Time\ (sec) = \frac{45\ Gy}{2.06\frac{Gy}{min}} \times 60\frac{sec}{min} = 1311\ sec$$

January 2018 - Final Irradiator Disposal

Reliability Issue with X-ray Irradiators – Mount Sinai's Experience

- **RS 2000 Research Irradiator**
  - **Purchased in April 2013.**
  - **Annual maintenance $8000**
  - **It is used on both mice and cells, including whole mouse irradiation, tumor targeting, and plates of cells irradiation.**
  - **129 members of the Tisch Cancer Institute & 123 other labs have requested to use it. It is used daily ~ 4-5 times/day, everyday of the year.**
  - **Tube died in September 2019- replaced as part of annual maintenance**

- **RS 3400 Blood Irradiator**
  - **Installed in January 2017. It is FDA approved.**
  - **Processes six 1-liter canisters in one cycle (25 Gy in less than 5 minutes).**
  - **Dose uniformity.**
  - **Annual maintenance $17,500**
  - **It was used to irradiate about 900 units of blood product in the first month. We stress tested to use it to irradiate more than 100 units of blood product in one day .**
  - **December 2019 a part was damaged and had to be replaced.**

Pros of X-ray Blood Irradiators

- FDA approved units
- No FBI finger printing and background check
- No security issues and quarterly testing of RMS
- No regulatory agencies inspection
- Low initial transportation and disposal costs ($2,000*2 vs $200,000*2 for CsCl)
- Low insurance premium for possible sabotage and malicious use
- No Decay correction
- Constant irradiation time throughout the lifetime
- Higher throughput (6 bags at once in x-ray irradiators vs 2 bags in CsCl irradiators)
- No annual reconciliation with NSTS website
- Self-shielded and self-cooled
- Discount on the annual warranty if the institution sends staff for training on trouble shooting.

Blood Irradiator Experience

-From January 2017 to May 2019, the unit was running perfectly
-PM expired on January 2019
-Annual maintenance was ignored when there was change in management.
-September 2019: Rotator issue, needed new contract, new PO, ISODOSE curve, etc.
-Since the annual contract is signed, we have not had any problem.
-Since then, the company provides service on the same day.

Lessons Learned

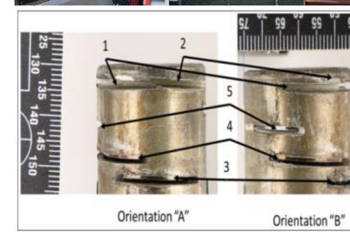
- Separate applications

  Blood - FDA approved - is it reliable?

  Research – cells, mice, zebra fish, etc.
- Self-cooled X-ray irradiator is the preferred choice
- Water filter should be used
- X-ray irradiator should be kept in an air conditioned room
- Get your staff trained by the manufacturer if possible
- Take advantage of remote assistance if provided by the manufacturers
- Encourage radiation physicists, Radiobiologist and researchers to work together

2019- Confirmation of My Fear

- 2019- University of Washington Research Facility Irradiator Leakage
- An irradiator with 2,900 Ci Cs-137 was being decommissioned on May 2, 2019 by INIS, a DOE subcontractor. Capsule with Cs-137 had to be removed from the irradiator before transport. Capsule had to be cut free from the tungsten sleeve, where the capsule was cut by accident along with the sleeve.
- May 30, 2019 JIT formed to investigate- Took 9 months to investigate. No formal DOE leadership mechanism - defining roles and responsibilities
- An small amount of Cs-137 spread into the irradiator, loading dock and a 100 ft radius around the loading dock. Ventilation to building was not isolated for days so the first three floors of the building were contaminated
- 13 people were exposed and the licensee indicated highest whole-body exposure was 55 mrem.
- US DOE spent $8.6 million on decontamination of the leakage. Total cost estimated to be about $30 Million

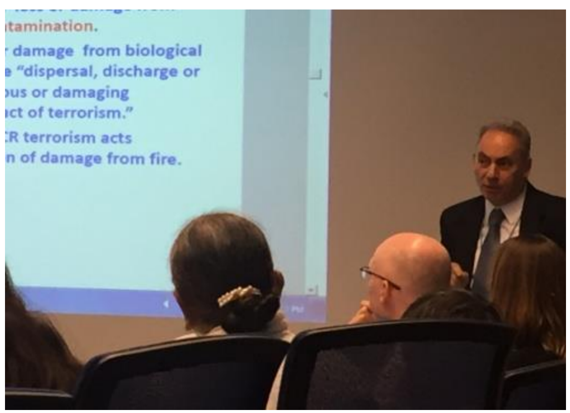


Snapshot of Mount Sinai Efforts

Organized a meeting with all irradiator users in NYC to answer their questions

Held a press conference

Hosted a meeting with 20 VPs from all NYC area hospitals



Presented in National and International meetings

Published in CAP Today Journal

Status of NYC Cs-137 Irradiators

- 2015- There were 34 irradiators
  - Blood Irradiators 18
  - Research Irradiators 16

- 2020 less than 10 Irradiators left
  - Research 8 ?

Financial Resources Available

- **Off-site Source Recovery Program (OSRP)**
  - https://osrp.lanl.gov/
- **Office of Radiological Security (ORS) - Cesium Irradiator Replacement Project (CIRP) Program**
  - https://www.energy.gov/nnsa/office-radiological-security-ors

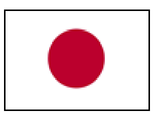
GLOBAL EFFORT

France

Started in 2006 a 10 year plan- They had 30 Irradiators. Replaced them with x-rays. Completed successfully.

Norway

They had 13 irradiators. They replaced them gradually with X-rays . Completed in 2015 successfully.



Japan

Started replacing about 20 years ago. 80% of blood irradiators have been replaced by X-ray

Insurance Coverage
Need to Review Regulatory Requirements

Automobile

Irradiator

- Licensed by state
- Registration with DMV
- Proof of Insurance
  - Financial Assurance -Liability
  - Personal Injury
  - Damage to property

- Licensed by state or NRC
- Registration with SSDS
- Proof of Insurance
  - Financial Assurance for Source Disposal
  - Financial Assurance to decontaminate after dirty bomb?

Policy of the U.S NRC - 2011

Protection of Cesium-137 Chloride Sources

- The NRC is working to make radiation sources more secure and less vulnerable to terrorists.
- The NRC has the responsibility to ensure the safe and secure use and control of radioactive sources, including Cesium Chloride (CsCl) sources.
- NRC recognizes that near term replacement of these devices is not practical or necessary due…
- NRC continues to believe that the security of these facilities should be maintained.
- The NRC supports efforts to develop alternate forms of Cs-137
- NRC will develop further rule or guidance on regulatory actions.
- In the event of a threat, NRC will be ready to issue additional security requirements.

Current Policy of NRC-
Briefed to NAS (M. Cervera) 2020

Non-isotopic Technologies

Remember:

- NRC mission is to **license and regulate the Nation's civilian use of radioactive and nuclear materials to ensure adequate protection of the public health and safety, promote the common defense and security, and to protect the environment**
- NRC authority is limited to radioactive and nuclear materials – no authority over machine generators of radiation
- NRC does not regulate the sectors (medical, research, energy, construction, …)
- NRC, to maintain objectivity and independence, **does not promote any technology** or influence business decisions

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

Transitioning from High-Activity to Non-Radioactive Sources (Alternative) Technologies: GARS-2016

The interagency Working Group on Alternatives to High-Activity Radioactive Sources (GARS) developed this guide to provide information and recommendations for transitioning to Alternative technologies.

- GARS has identified recommendations for Federal actions in four categories:

  - Federal Procurement or Grant-Making; - Agency Priorities; - Education and Outreach; Research and Development.

- In addition, the working group drew the following five conclusions from this effort:
  - Federal agencies should promote adoption of alternative technologies in federally funded programs and facilities by encouraging voluntary incentives, dedicated funding, and facilitated conversion.
  - Federal agencies should involve all key stakeholders in adoption of alternative technologies in the transition and should recognize the role of manufacturers, distributors.
  - Federal agencies should consider the full lifecycle costs of high-activity sources, including costs of security, disposition, and potential liability.
  - Federal agencies pursuing alternative technology replacements must balance the respective operational and technical needs of the user.
  - Users in medical applications are likely to continue using these sources for a considerable time, especially if alternatives are not suitable for their purposes

U.S. Department of Homeland Security - 2019

Alternative Technologies

- This report describes the status of the development and voluntary adoption of alternative technologies to industrial, medical, and research applications.
- These include (Co-60), (Cs-137), (Ir-192), (Am-241) sources in devices used in medical, industrial, and research applications
- For each application the report seeks to:
  - Examine alternative technology that are commercially available, exist or are under development (including technologies not approved in the United States market).
  - Outline the efficacy, lifecycle costs, and applications of these alternative technologies and potential barriers to adoption.
- This report focuses on the current use of the most common NRC Category 1 and 2 sealed sources used in in the United States.

Comparison of 2008 NAS Report and Current Status

2008	2020
These sources should be replaced in the US and, to the extent possible, elsewhere.	In the US, the radioactive irradiators are being phased out gradually. Globally, Norway, France, and Japan…etc. have already eliminated or are moving forward with plans to eliminate them.
Government action is required to implement replacement of radioactive cesium chloride sources because the alternatives cost more and the liabilities or social costs of the sources currently are not borne by the end users.	Government supported projects: OSRP and CIRP are helping the institutions to replace the radioactive irradiators with alternative technologies.
Non-radionuclide replacements exist for nearly all applications of Category 1 and 2 radionuclide sources (not just radioactive cesium chloride). At this time, these replacements may not all be practical or economically attractive, but most of them are improving.	The x-ray blood irradiators which are FDA approved and reliable are commercially available. More and more models of research use biomedical irradiators are commercially available and have proved to be equivalent with the radioactive irradiators.
In most (and perhaps all) applications, radioactive cesium chloride can be replaced by (1) less hazardous forms of radioactive cesium, (2) radioactive cobalt, or (3) non-radionuclide alternatives. However, not all of these alternatives are available now, and all are currently more expensive than radioactive cesium chloride for the users.	As for the x-ray irradiators, the cost of maintenance and operation is higher than the radioactive irradiator; however, the disposal cost and the licensing cost are lower than the radioactive irradiators.

Suggested Future Work -1

Federal Actions

- NRC's role is central - their active participation and support is key!
- Government agencies (i.e. GARS Report) should require alternative technologies in their applications

Operator Actions

- Licensees should be given a specific time period by the NRC to migrate to alternative technologies
- Licensees should update their regulatory insurance liabilities or purchase liability insurance for the continued use of large radioactive sources that could be maliciously used in an RDD (not just the cost of disposing the source)

Industry Actions

- Compile all working recipes from all institutions to create a look up table (X-ray model, energy, filter, distance to target, reflector, etc.
- Develop a user friendly manual with "recipes" (similar to how to defrost frozen meat in a microwave) for each X-ray Irradiator.
- Develop and provide affordable purchase/lease options (leasing, financing, similar to car industries)
- Develop and provide an incentive package to reduce the annual PM cost (similar to car insurance companies)
- Offer "remote access" to solve user technical difficulties
- Compile all practical lessons learned and provide them to the new users (keep X-ray in AC room, need water Filter, etc.)

Suggested Future Work -2

- Currently there are four X-ray based blood irradiators approved for use in the U.S. and Seven X-ray based blood irradiators, from six different countries, approved for use around the world.
- The NRC should adopt a policy to stop the purchase of radioactive irradiators.
- Applicants for radioactive irradiator should justify the requirements and justify why objectives cannot be achieved with an alternative technology.
- Radiation biologists, physicists and researchers must work together to solve remaining issues.

THANK YOU