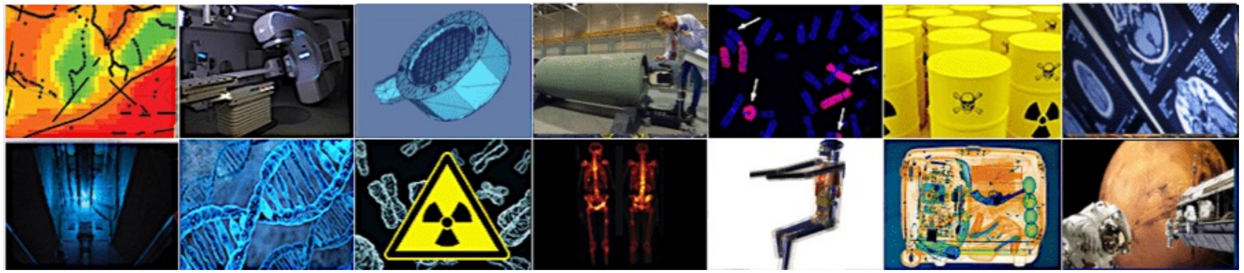
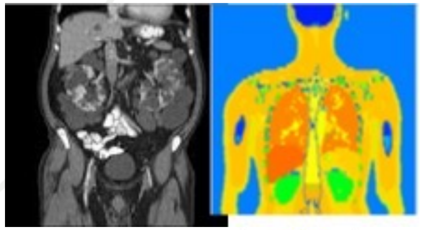
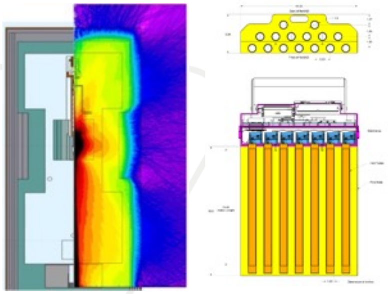
RED²

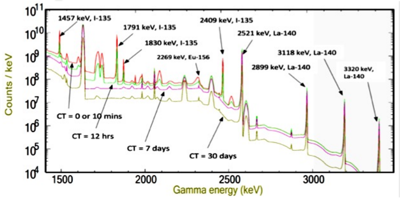
Radiological Engineering, Detection, and Dosimetry



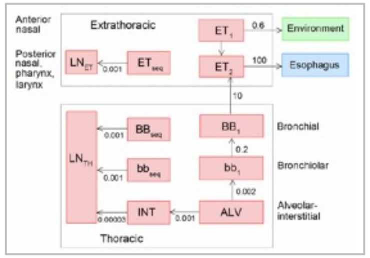
Mission: The **Radiological Engineering, Detection, and Dosimetry (RED²) Laboratory**, led by **Dr. Shaheen Dewji**, conducts innovative, interdisciplinary research focusing on harnessing both computational capabilities in Monte Carlo radiation transport modeling and experimental measurements for applications in radiation detection, radiation protection and shielding, dosimetry, health physics, and nuclear materials accounting.

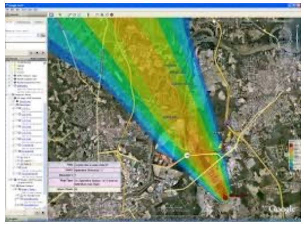






- **Computational Dosimetry and Shielding** → Development of dose coefficients and shielding design using Monte Carlo radiation transport codes → Age/sex-specific anthropomorphic computational phantoms → Radionuclide biokinetic models for emergency response and nuclear medicine
- **Radiation Detection** → Employment of validation and verification of gamma-ray spectroscopic detector responses → Contaminated environmental media for environmental assessment and decommissioning → Field triage of uptake during nuclear, radiological, and fission product release events
- **Nuclear Nonproliferation and 3S (Safety, Security & Safeguards)** → Nuclear materials control, accounting, and safeguards of SNM → Gamma-ray spectroscopic analysis for safeguards by design of of advanced non-LWR reactors → Neutron multiplicity counting for field search/detection and criticality safety





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RED² Laboratory Status and Outlook

- **Fall 2023 Research Group**
- 10 Ph.D. students
- 3 M.S. students
- 5 undergraduate students
- 1 Post-doctoral Fellow and 1 Research Engineer

- **Student Awards**
  - 2021-2022 2 Health Physics Society Graduate Fellowships
  - 2022-2023 4 Health Physics Society Graduate Fellowships
  - 2022-2023 American Nuclear Society Everitt P. Blizard Memorial Graduate Scholarship
  - 1 DOE NEUP Scholarship + 1 HPS Scholarship
  - 1 Best Paper Award (2022 Annual Meeting of HPS)
  - 2023-2024 2 Health Physics Society Graduate Fellowships
  - 2023-2024 1 American Nuclear Society Graduate Fellowship

- **Laboratory (Boggs 3-30)**
  - 6 Mirion NAIS 2x2 NaI detectors with digital base
  - Male CIRS Atom Phantom
  - Landauer microSTAR® ii Medical Dosimetry System
  - Mirion SPIR-ACE $LaBr_3$
  - Sources (check, point, area)
  - *On Deck: ADVACAM AdvaPIX Timepix3 hybrid pixelated detector*
  - PACE High Performance Computing
- **Teaching**
  - Fall 2021: MP6402 Radiation Dosimetry
  - AY2023-2024 – New course – Internal Dose Assessment
- **Professional**
  - National Academies of Science, Engineering, and Medicine (NRSB, LDR study)
  - General Chair – 14th International Conference on Radiation Shielding/2022 American Nuclear Society Radiation Protection and Shielding Division (Sept. 2022)
  - Board of Directors, American Nuclear Society
  - Board of Directors, Health Physics Society
  - 1 Podcast (NPR Outside/In)

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RED² Laboratory – Active Research Collaborations

Thrust Area 1: Computational Dosimetry

- Evaluation of Exposure Pathway, Internalized Uptakes, and Dosimetry for Military Personnel from Radiological and Toxic Metal Sources
- Uncertainty Analysis of Dose Coefficients for Nuclear Incident Response
- Low Dose Exposure Evaluation on Human Population Health
- Enhancement of Biokinetics using Physiologically-Based Models for Internalized Radionuclides

Thrust Area 2: Radiation Detection

- Evaluation of Exposure Pathway, Internalized Uptakes, and Dosimetry for Military Personnel from Radiological and Toxic Metal Sources
- A Hybrid Radiation Transport Detector Response Function Methodology for Modeling Contaminated Sites
- Neutron dosimetry and Assay with a Portable Neutron Multiplicity Detector

Thrust Area 3: Radiation Shielding

- Shielding Design And Optimization Of Novel MV Photon Preclinical FLASH Radiotherapy System
- Activation Studies in Petawatt Laser Facilities

Thrust Area 4: Nuclear Safety, Security & Nonproliferation Policy, and Nuclear Knowledge Management

- Risk-informed Consequence-Driven Physical Protection System Optimization for Microreactor Sites
- Nuclear Material Accountancy During Disposal and Reprocessing of Molten Salt Reactor Fuel Salts

National Nuclear Security Administration
U.S.NRC United States Nuclear Regulatory Commission Protecting People and the Environment
NIH National Institute of Allergy and Infectious Diseases
Sandia National Laboratories
Los Alamos National Laboratory EST. 1943
National Cancer Institute
Oak Ridge National Laboratory
SLAC National Accelerator Laboratory
Pacific Northwest National Laboratory
Lawrence Livermore National Laboratory
ORAU
IAEA
NEA Nuclear Energy Agency
Northwestern University
Técnico Lisboa
Berkeley University of California
Emory University
UF University of Florida
Texas A&M University

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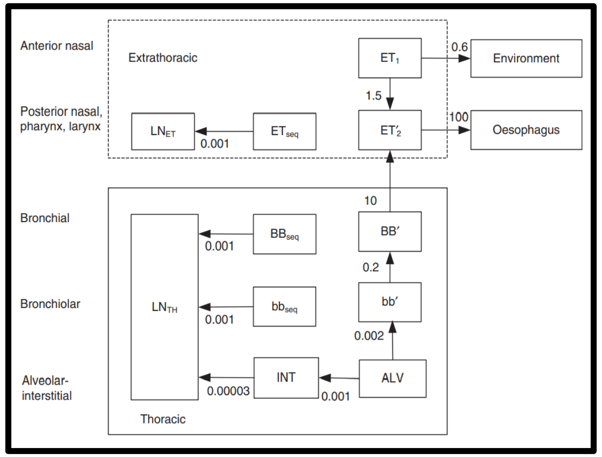
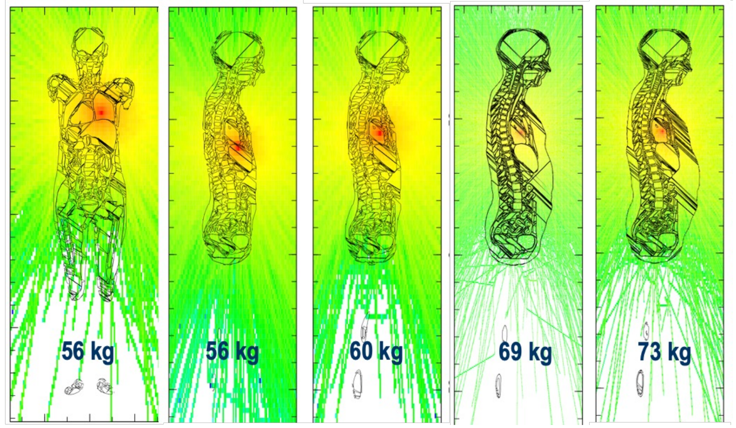
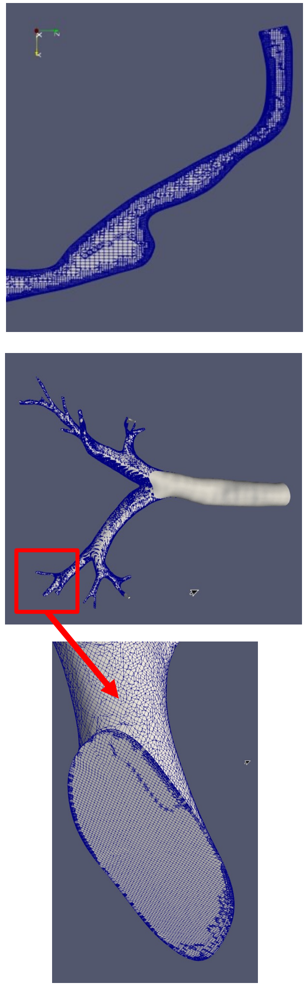
RED² Research Highlight 1: Enhancement of Biokinetics using Physiologically-Based Models for Internalized Radionuclides

- **Challenge:** Following mass population exposures from radiological or nuclear (RN) events, radionuclide biokinetic models can be used to determine the time-dependent activity concentrations of internalized radionuclides in tissues/organs

- **Goal:** Construct realistic biokinetic models representative of an exposed non-reference population or Warfighter
  - lack of consideration of basic physiological processes, from defining realistic source terms from RN events
  - translation to mechanistic parameters that define inhalation intake kinetics, uptake into blood, and excretion
  - Employ CFPD to correlate realistic source-lung deposition behavior for public
- **Impact:** Proposed expansion in biokinetic modeling will for the first time allow in-vivo assay and prediction of the efficacy of novel decorporation agents in humans following an acute RN uptake for a representative population.
- **First use of machine learning in this field (Bayesian neural networks, convolutional neural networks, Random forest, Hidden Markov Chain)**
- **Extended application:** PBPK for radiopharmaceutical therapies







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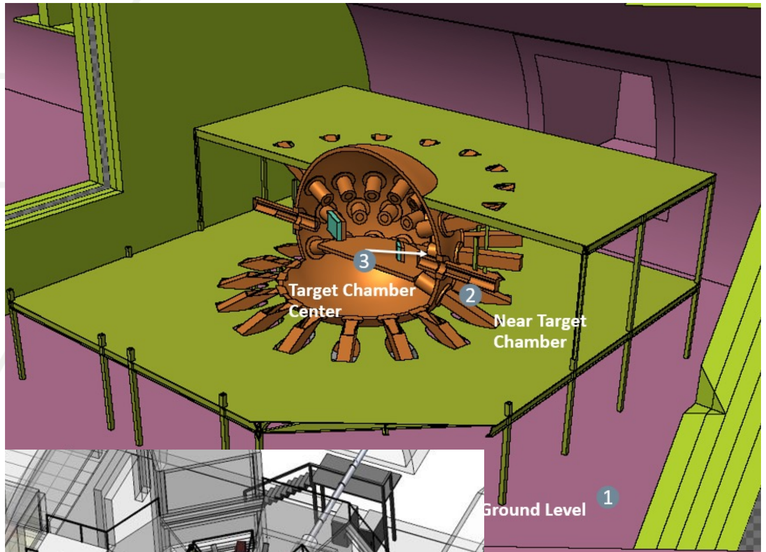
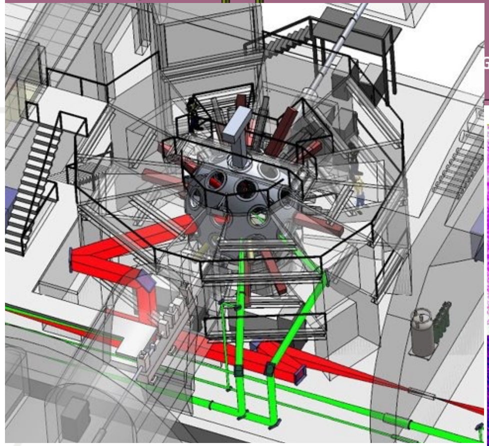
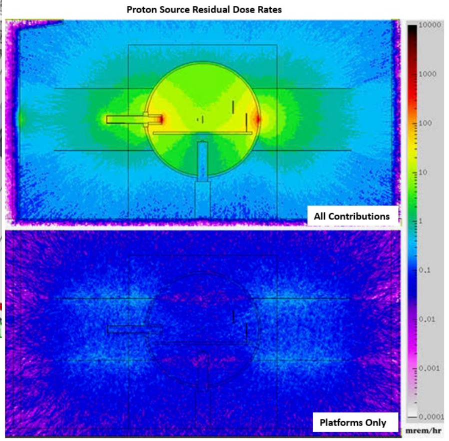
RED² Research Highlight 2: High Energy Physics Radiation Protection and Shielding Design

- MEC-U facility at SLAC





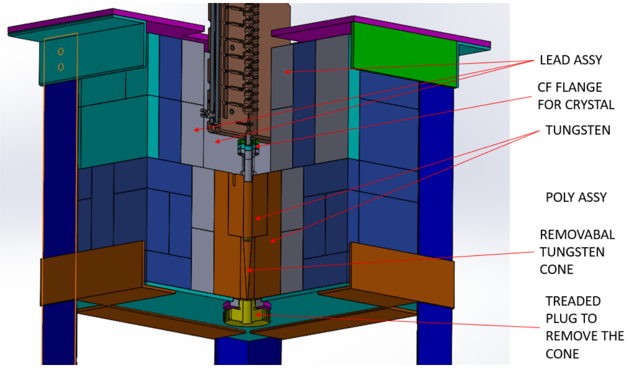


- FLASH Radiotherapy at SLAC

Use of metaheuristic genetic algorithms for shielding optimization (Nelder Mead Simplex)

Run	ObjF	Unc	RI	R2	R3	TT	T2	BSRL	BSTT	Tar_T	DR [GY/s]	Difference from FWHM [cm]	Penumbra [cm]	%electron Fluence	Final Temperature [K]
NMSS Final	12179	205	0.2	0.09	0.11	10.03	5.4	0.17	10.85	0.11	56	0.009	0.214	0.67%	2281
1	12241	129	0.2	0.09	0.11	10.03	5.4	0.17	10.85	0.11	54.2	0.011	0.218	0.67%	2336
2	10012272	130	0.19	0.09	0.11	10.03	5.4	0.17	10.85	0.11	54.3	0.015	0.217	0.64%	2368
3	11012189	120	0.2	0.08	0.11	10.03	5.4	0.17	10.85	0.11	47.6	0.000	0.218	0.64%	2496
4	11012154	129	0.2	0.09	0.1	10.03	5.4	0.17	10.85	0.11	50.0	0.004	0.211	0.64%	2423
5	12464	136	0.2	0.09	0.11	9.52	5.4	0.17	10.85	0.11	60.3	0.025	0.227	0.70%	2238
6	10012144	119	0.2	0.09	0.11	10.03	5.13	0.17	10.85	0.11	52.4	0.000	0.219	0.63%	2391
7	12214	124	0.2	0.09	0.11	10.03	5.4	0.16	10.85	0.11	53.9	0.008	0.218	0.66%	2253
8	10012129	132	0.2	0.09	0.11	10.03	5.4	0.17	10.3	0.11	57.8	0.001	0.217	0.68%	2469
9	20012184	133	0.2	0.09	0.11	10.03	5.4	0.17	10.85	0.1	59.3	0.005	0.219	0.75%	2374
10	10012200	118	0.21	0.09	0.11	10.03	5.4	0.17	10.85	0.11	53.4	0.009	0.216	0.64%	2360
11	12241	129	0.2	0.09	0.11	10.03	5.4	0.17	10.85	0.11	54.2	0.011	0.218	0.67%	2336
12	12241	129	0.2	0.09	0.11	10.03	5.4	0.17	10.85	0.11	54.2	0.011	0.218	0.67%	2336
13	11012142	120	0.2	0.09	0.11	10.53	5.4	0.17	10.85	0.11	48.6	0.001	0.213	0.65%	2457
14	12173	127	0.2	0.09	0.11	10.03	5.67	0.17	10.85	0.11	55.5	0.001	0.221	0.67%	2322
15	12241	129	0.2	0.09	0.11	10.03	5.4	0.17	10.85	0.11	54.2	0.011	0.218	0.67%	2336
16	12133	121	0.2	0.09	0.11	10.03	5.4	0.17	11.39	0.11	52.1	0.000	0.218	0.66%	2231
17	12241	129	0.2	0.09	0.11	10.03	5.4	0.17	10.85	0.11	54.2	0.011	0.218	0.67%	2336

- Exceed Constraint
- Changed Dimension
- Better Design – Worse Performance
- Better Design – Same Performance
- Better Design – Better Performance



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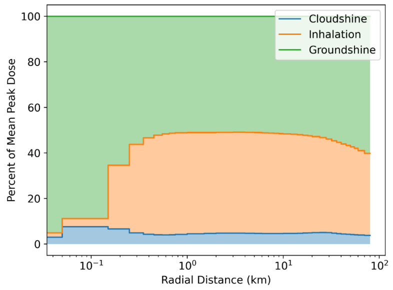
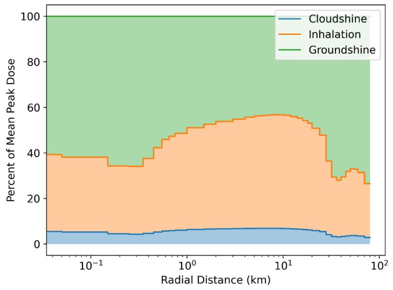
RED² Research Highlight 3: Advanced Reactor Safeguards and Security

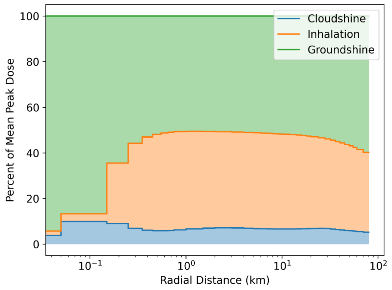
- (A) Risk-informed consequence-driven advanced reactor licensing from new regulatory language in 10CFR Part 53
- Lagrangian vs. Gaussian atmospheric dispersion for microreactor model using physical-security-informed source term
- Establishes areas outside EPZ cannot exceed 1 rem (0.01 Sv) threshold



SOARCA GPM



SOARCA PIC



INL HPR GPM

- (B) Nuclear material accountancy and hold-up for molten salt reactor systems

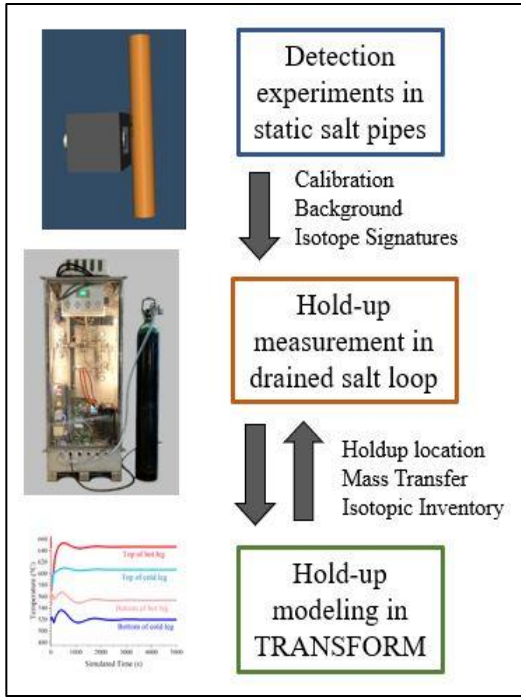


Figure 3. Combined experimental and modeling approach for holdup MC&A in MSR components. [4,5]

Questions!

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