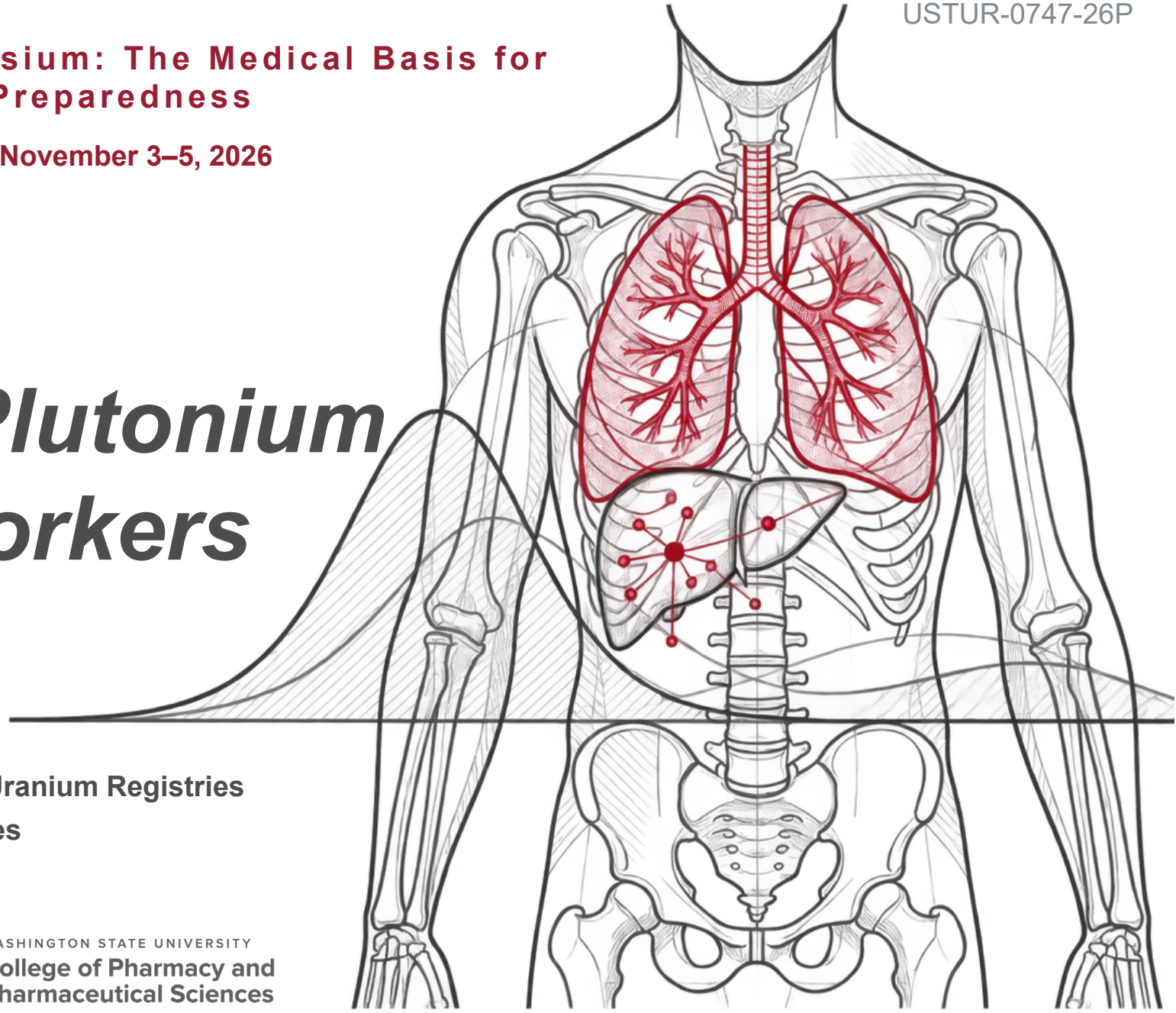
Sixth REAC/TS International Symposium: The Medical Basis for Radiation-Accident Preparedness

Oak Ridge, Tennessee, USA, November 3–5, 2026

# USTUR at 60: *Learning from Plutonium and Uranium Workers*



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Washington State University · Richland, WA

WASHINGTON STATE UNIVERSITY
College of Pharmacy and Pharmaceutical Sciences

## WITH GRATITUDE

To our **Registrants** – whose foresight and generosity built the scientific foundation of the USTUR and continue to inform radiation protection today.

HISTORY

# United States Transuranium and Uranium Registries (USTUR)


Rocky Flats, July 25-26, 1966



**1966** Registry conceived (U.S. Atomic Energy Commission 'Plutonium in Man' meeting, Rocky Flats)

**1967** Registry proposed (7th Annual Hanford Biology Symposium, Richland)

**1968**

Plutonium Registry **established**

Hanford Environmental Health Foundation ***contract***

**1970**

**Renamed** U.S. Transuranium Registry (USTR)

Scope broadened ***beyond plutonium***

**1978**

U.S. Uranium Registry (USUR) **established**

Administratively ***separate*** entity

**1992**

USTR + USUR = USTUR **consolidated** into a single entity

Moved to Washington State University under a ***research grant***

**Analytical and management support:** HEHF, Los Alamos Scientific Laboratory, Pacific Northwest Laboratory, Rocky Flats Plant

HISTORY

# Mission

## THEN

"*To protect the interests of workers, employees, and the public by … the acquisition and provision of the latest and most precise information about the* ***effects of the transuranic elements on man***." (Bruner 1967)

By the end of the 1970s, the mission had shifted away from epidemiology.

## NOW

To advance understanding of **actinide biokinetics and tissue dosimetry** in occupationally exposed workers, refining dose-assessment methods that support epidemiology, risk assessment, and regulatory standards.

FOUNDATIONS

# Why human data matter

Biokinetic models can be built on four types of evidence. The USTUR provides **the strongest:** **H1** – data from humans exposed to the element of interest.

> *"Greater confidence can be placed in a biokinetic model based on H1 data than on H2, A1, and/or A2."*

Leggett, R. W., Bouville, A., Eckerman, K. F. (**1998**) *Reliability of the ICRP's systemic biokinetic models*. Radiation Protection Dosimetry **79**(1–4): 335–342.

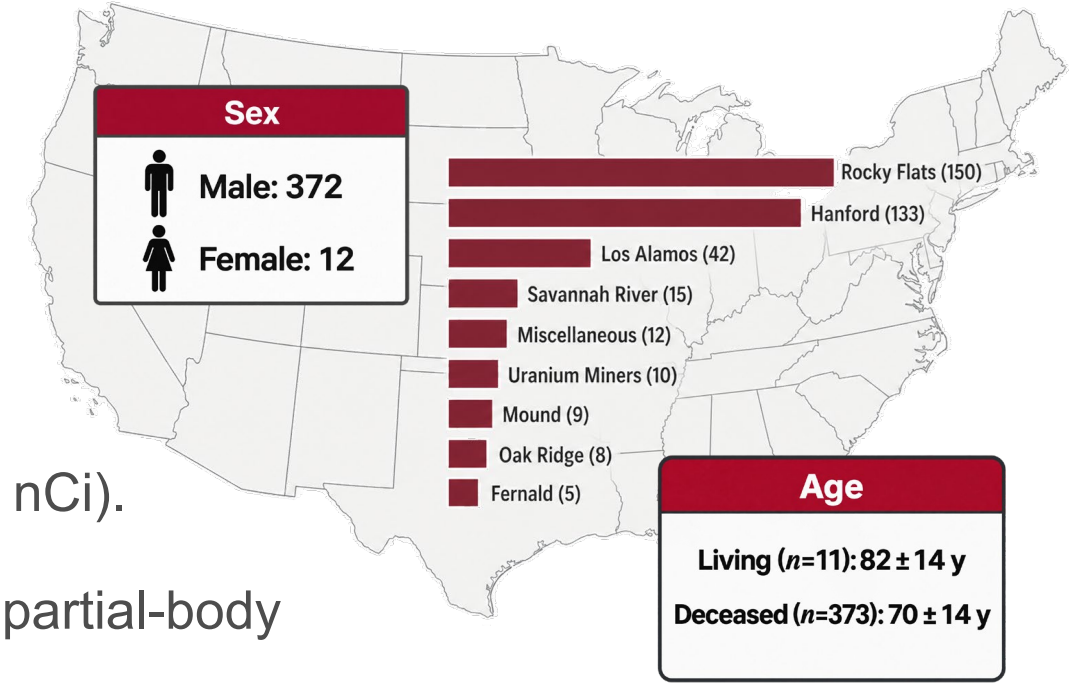


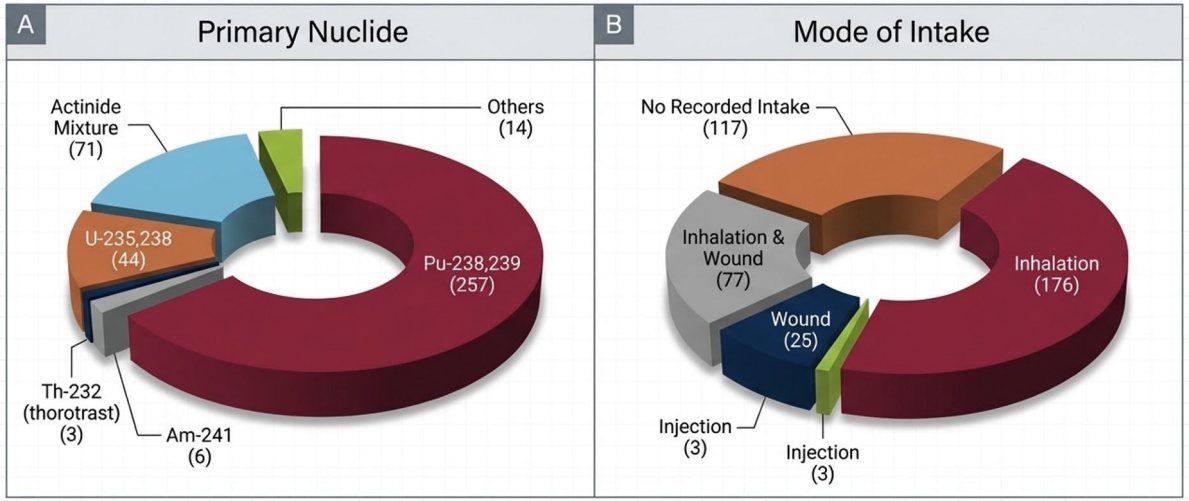
RESOURCE

# The Registrants

Primarily DOE-site nuclear workers with **documented actinide exposure** and internal deposition of ≥74 Bq (2 nCi).

**Volunteers** who consent to postmortem whole-body or partial-body **tissue donation**.




**384**
Enrolled

**52**
Whole-body

**332**
Partial-body

BEST-KNOWN REGISTRANT

# “The Atomic Man”

The **largest recorded americium intake** occurred during the 1976 Hanford ion-exchange column explosion, which released **~100 g of $^{241}$Am**.

ESTIMATED UPTAKE

## >40 MBq†

→ Extensive Ca/Zn-DTPA chelation therapy

→ Systemic deposition after treatment **≈0.5 MBq**

† First-year absorbed dose (Gy): lungs 11.3; liver 10.7; endosteal bone surface 8.8.



Besemd November 1985–

**A smile that's radiant**

By CRAIG TROIANELLO
Of the Herald-Republic

PROSSER — It's been nearly a decade since an explosion at Hanford turned Harold McCluskey into the world's most radioactive man.

He still gently shakes his head when describing the events leading to that Aug. 30, 1976, accident that changed his life and opened a new frontier in the treatment of radiation victims.

At the time of the accident, McCluskey worked at a Hanford waste-recovery facility producing americium 241. Among its uses, the substance is utilized in smoke detectors.

A five-month strike was ending when McCluskey arrived at his work station that August night. During the strike, an americium-soaked resin had sat in the vessel in which the extraction process took place.

McCluskey's job included adding nitric acid to the solution. But this time he objected. Operating rules clearly stated resin should not be allowed to sit more than 90 days, he said.

McCluskey says he warned his supervisor.

"I got out the rule book and I showed them," he said.

But word came back to override the rules, he said.

Moments after adding the nitric acid, the mixture exploded. Violently.

Shielding materials designed to withstand pressures of 1,150 pounds per inch shattered into shrapnel.

The effect was not, McCluskey says, unlike a hand grenade. Hundreds of shards of leaded glass, metal, Lucite, and resin — all contaminated with radioactive americium — ripped through his face respirator and became embedded in his face.

When transported to a special hospital room in Richland, McCluskey was considered so hot that he was handled by remote control. At first, his only contact was with doctors and nurses wearing rubber suits and respirators.

Not only was his face impregnated with radioactive debris, but McCluskey also had inhaled lungfuls of contaminated air while lying on the floor after the explosion. Every time he exhaled, he expelled americium.

Recovery was slow and unpredictable. No one had ever been exposed

(See RADIATION, Page 2A)

(Color separation by Byron Jensen)

(Staff photo by R

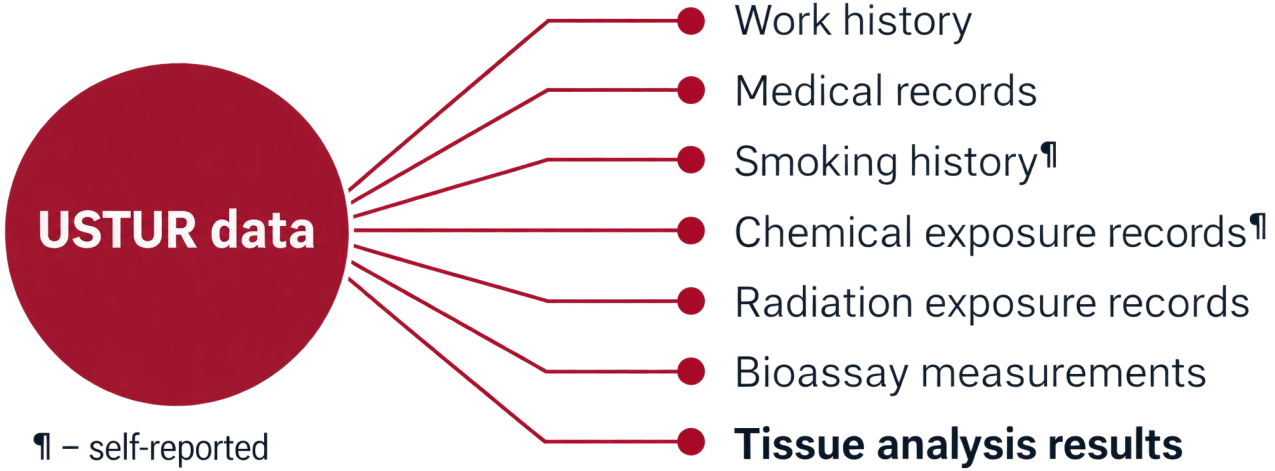
Harold McCluskey, peppered with radioactive shrapnel in an accident almost a decade ago, survived but is still is 'hot' enough to make a Geig crackle.

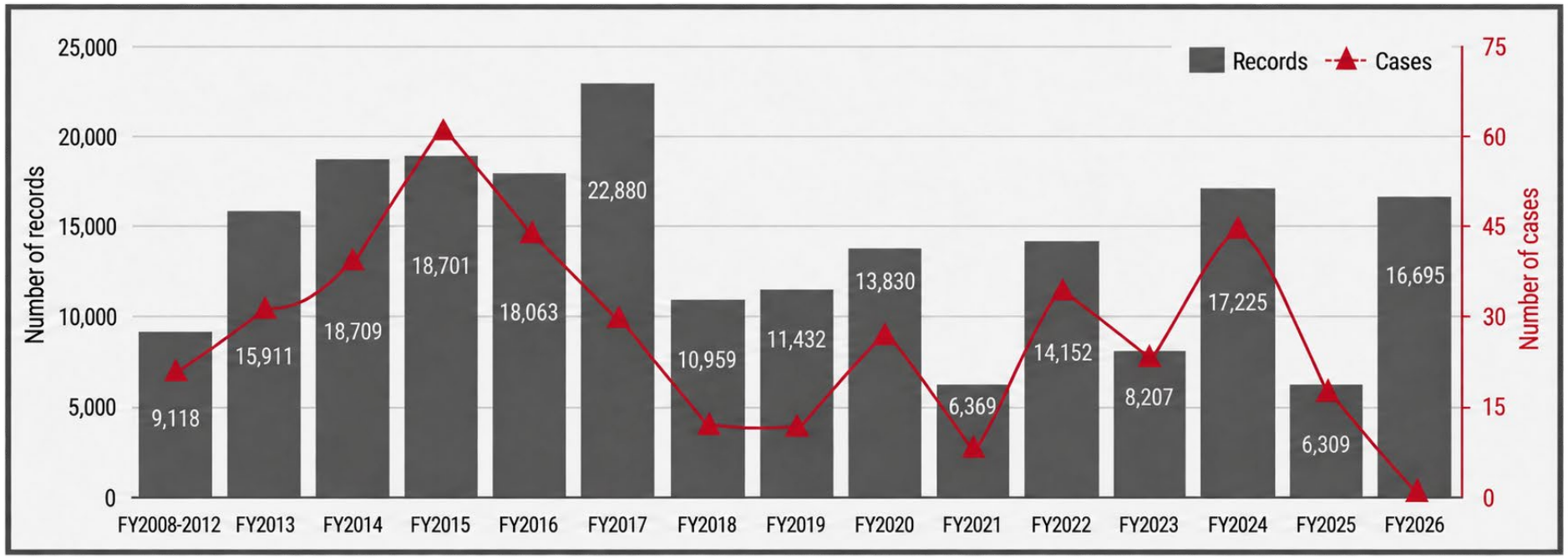
RESOURCE

# Health physics database

**395 total cases**
52 whole-body, 332 partial-body, and 11 special-study cases

**208,836 total records**



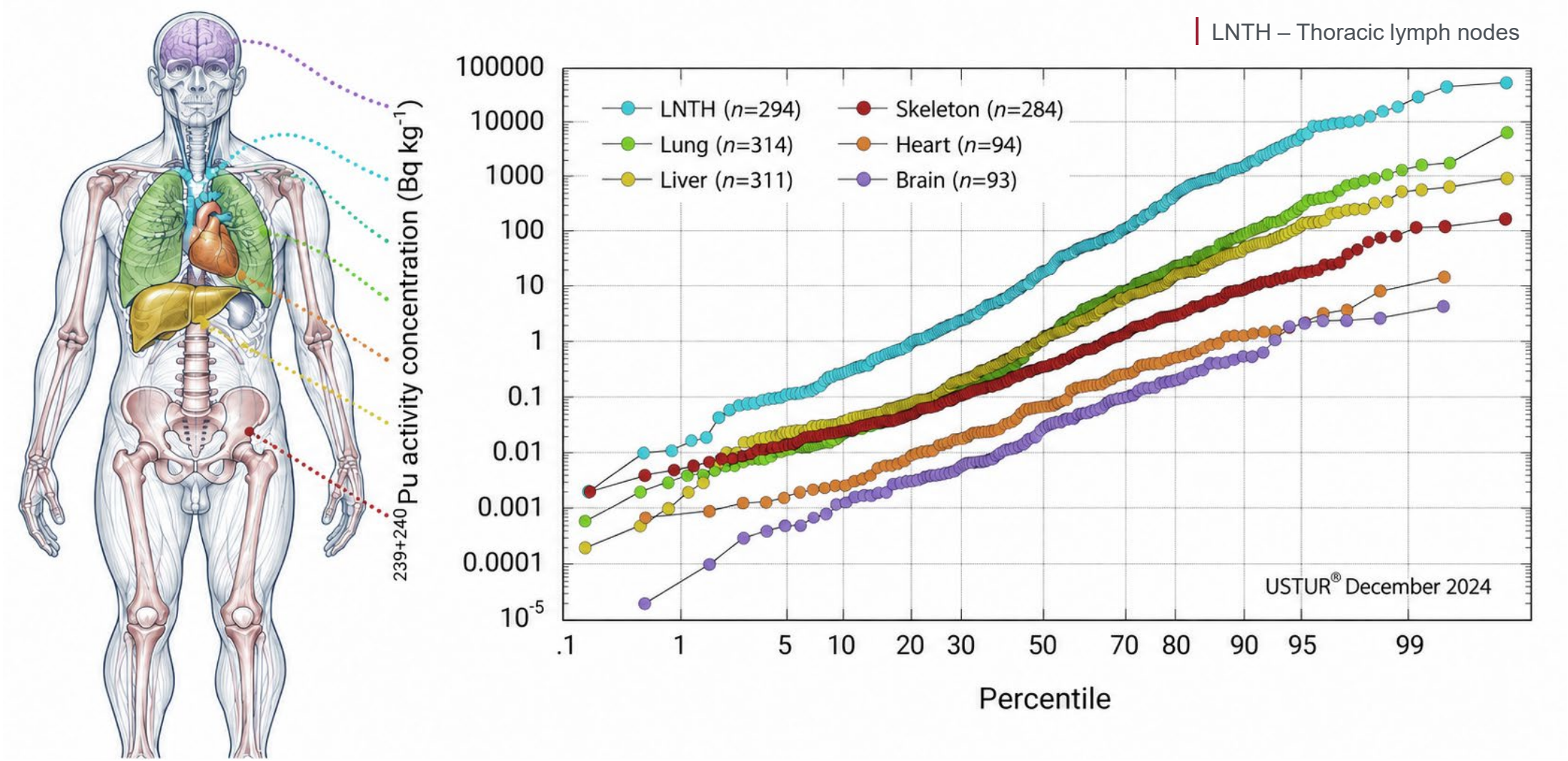




## Status

- Systematic database population initiated
- All existing data entry completed
- Missing data obtained; entry in progress

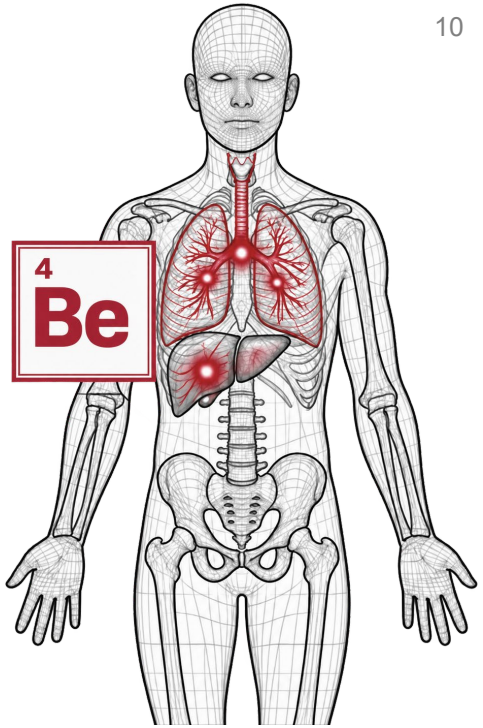
RESOURCE

# Tissue analysis results



RESOURCE

# Beryllium at USTUR




**106 cases**
Self-reported occupational exposure to Be

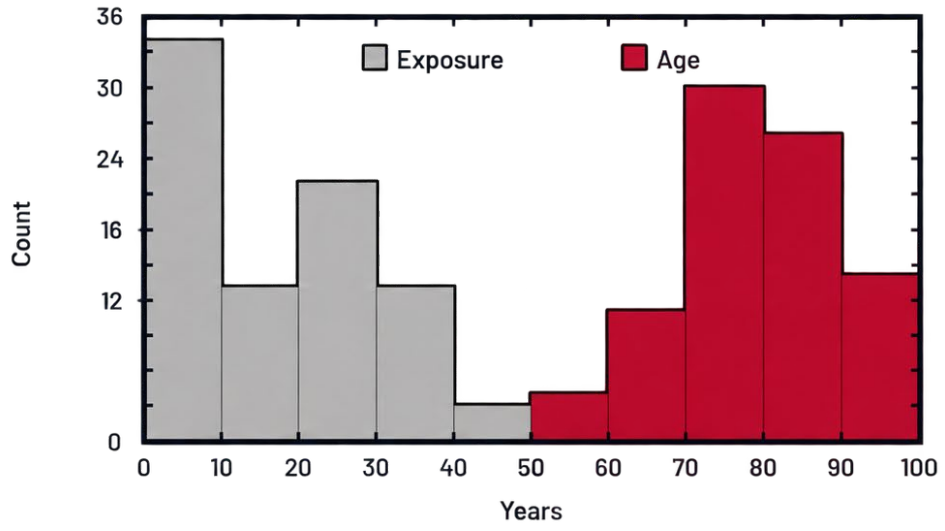
**85 cases**
Confirmed exposure durations

**The autopsy cohort**
16 whole-body,
69 partial-body

## Cohort demographics

Age: **79 ± 10 years** (range: 55-99)

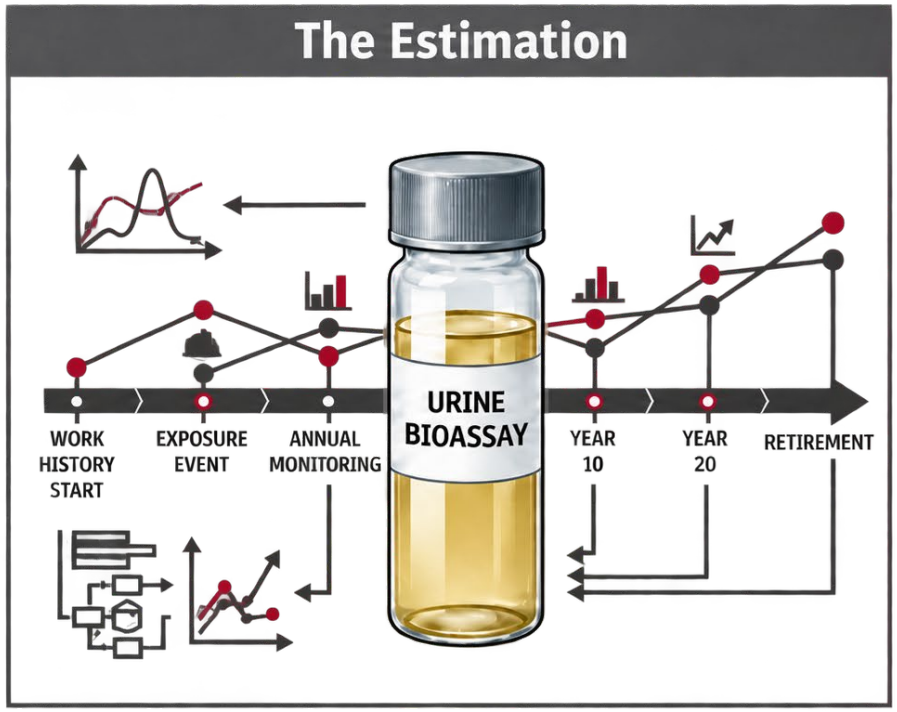
Primary co-exposures:
**Pu (78), U (6), Am (1)**

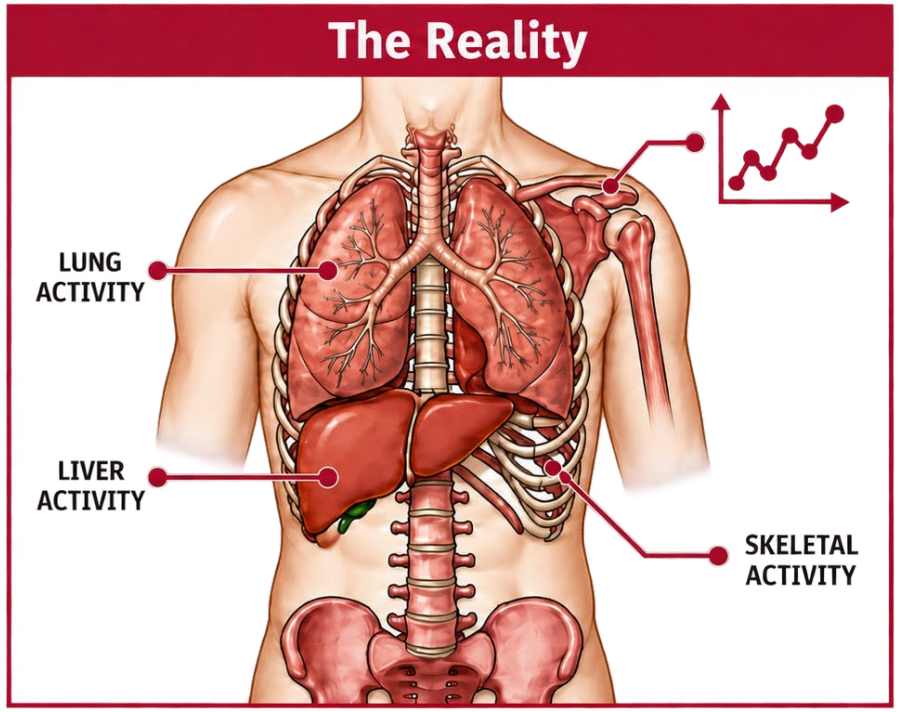


UNIQUE SCIENTIFIC ASSET

# United States Transuranium and Uranium Registries

The USTUR allows exposure records, bioassay data, work histories, medical records, and postmortem tissue measurement results to be linked for the same individual.

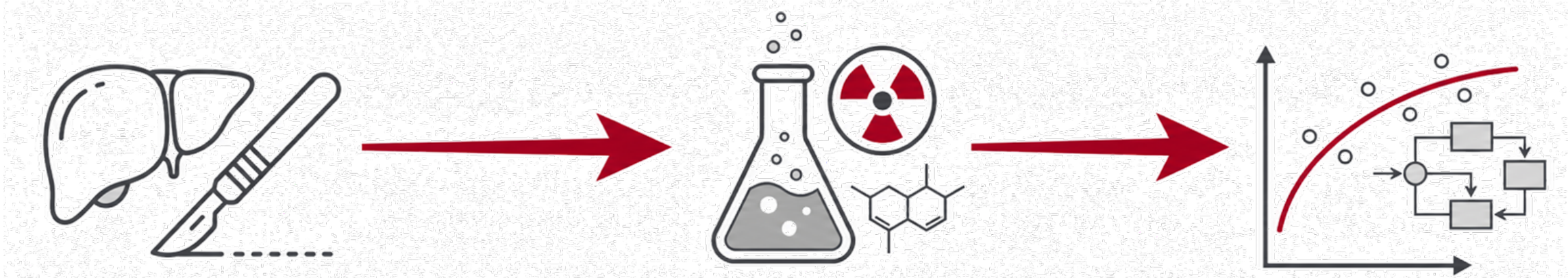



*The Registries fills a major gap in dosimetry by providing human data for model validation and development at a scale unavailable elsewhere.*

OPERATIONS

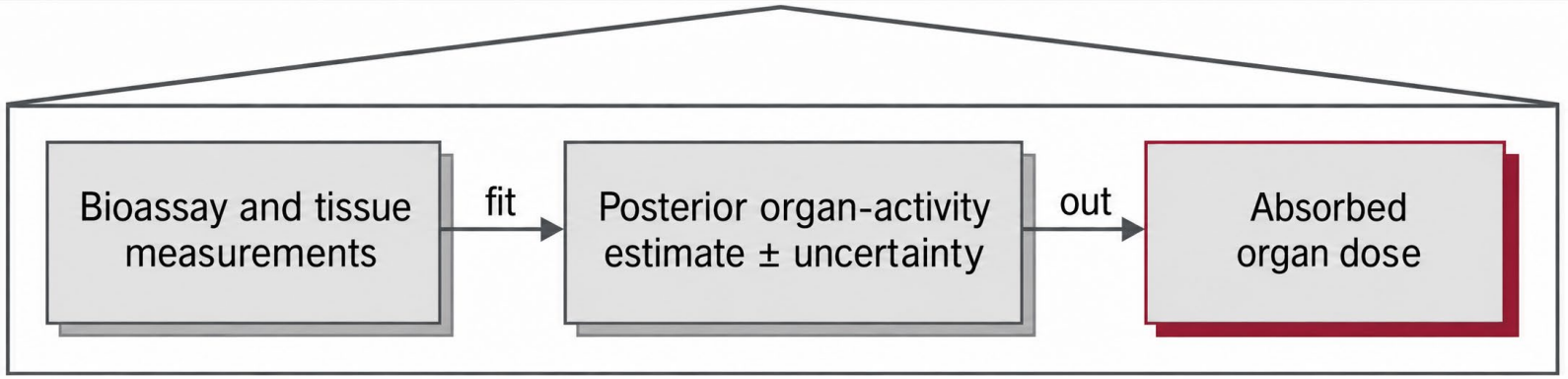
# From autopsy to dose estimation



**Autopsy and tissue collection**
Organ preservation

**Radiochemical analysis**
Tissue activity measurement

**Biokinetic modeling**
Intake and dose estimation

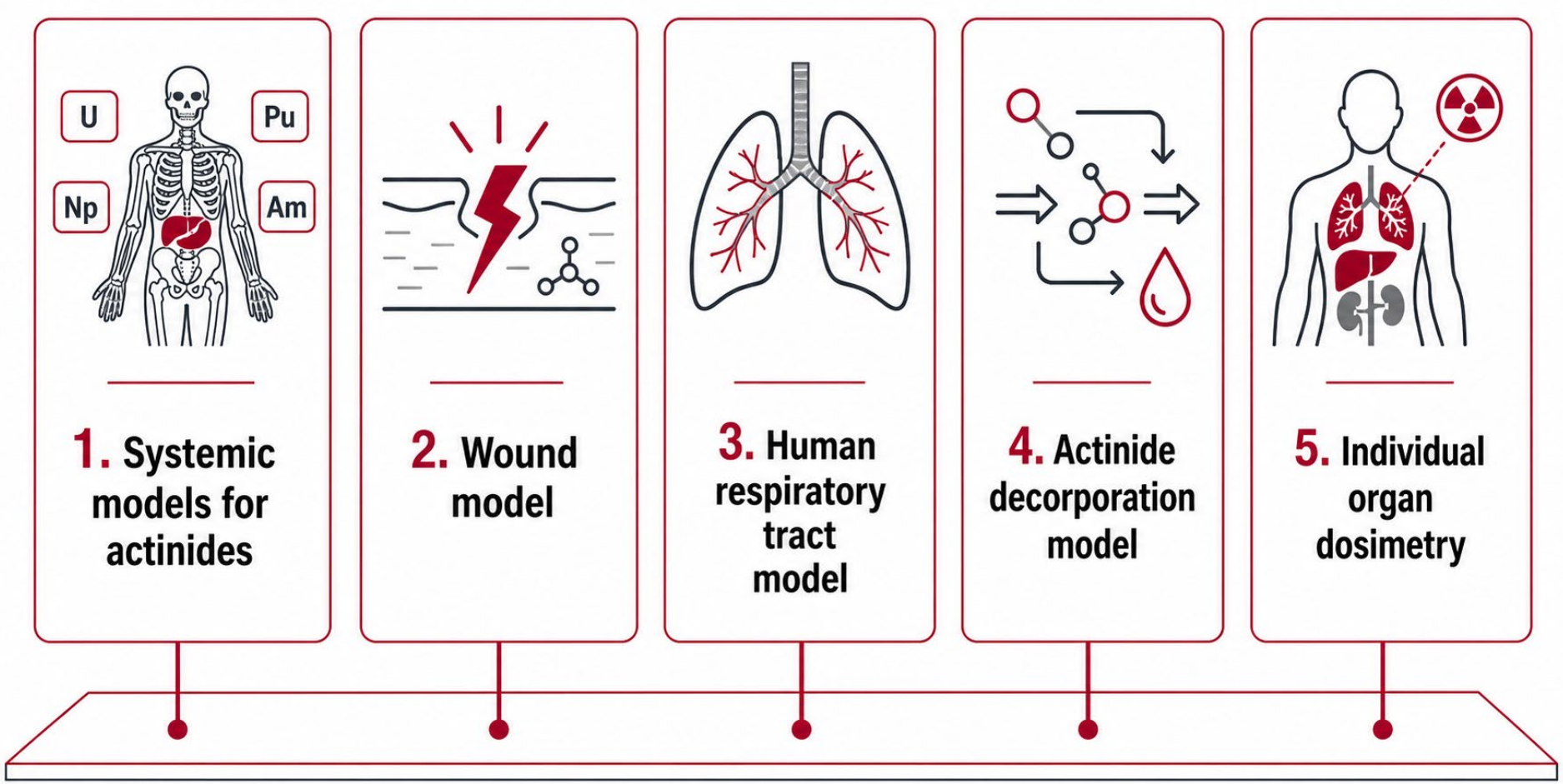



*Every step carries uncertainty that must be quantified, not hidden.*

SCIENCE

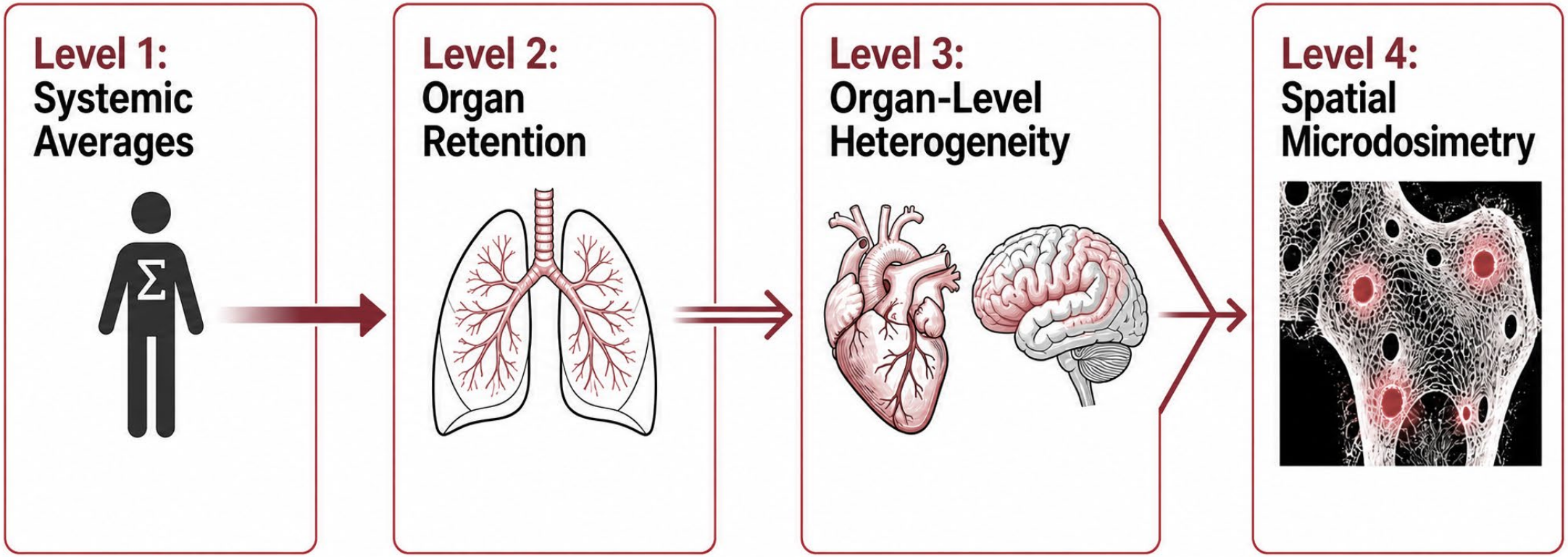
# Primary research: actinide dosimetry

Developing, testing, improving, and parameterizing actinide biokinetic models



BIOKINETICS AND DOSIMETRY

# Actinide dosimetry at every scale




*The closer we look, the less adequate historical averages become.*
*Accurate radiation protection requires models that reflect biological reality at every scale.*

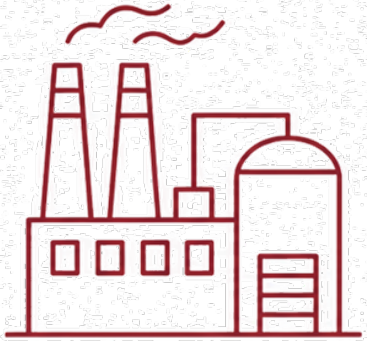
BIOKINETICS AND DOSIMETRY

# Site-specific uncertainty: material type

Different manufacturing processes produced plutonium in different physical forms, resulting in different absorption behavior in the human body.

## Hanford

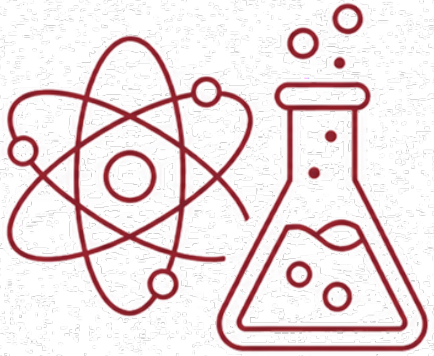
1943–1989



Large-scale plutonium **production** for nuclear weapons, beginning with the Manhattan Project

## Los Alamos

1943–present



Plutonium **research** and **processing** supporting nuclear weapons and scientific applications

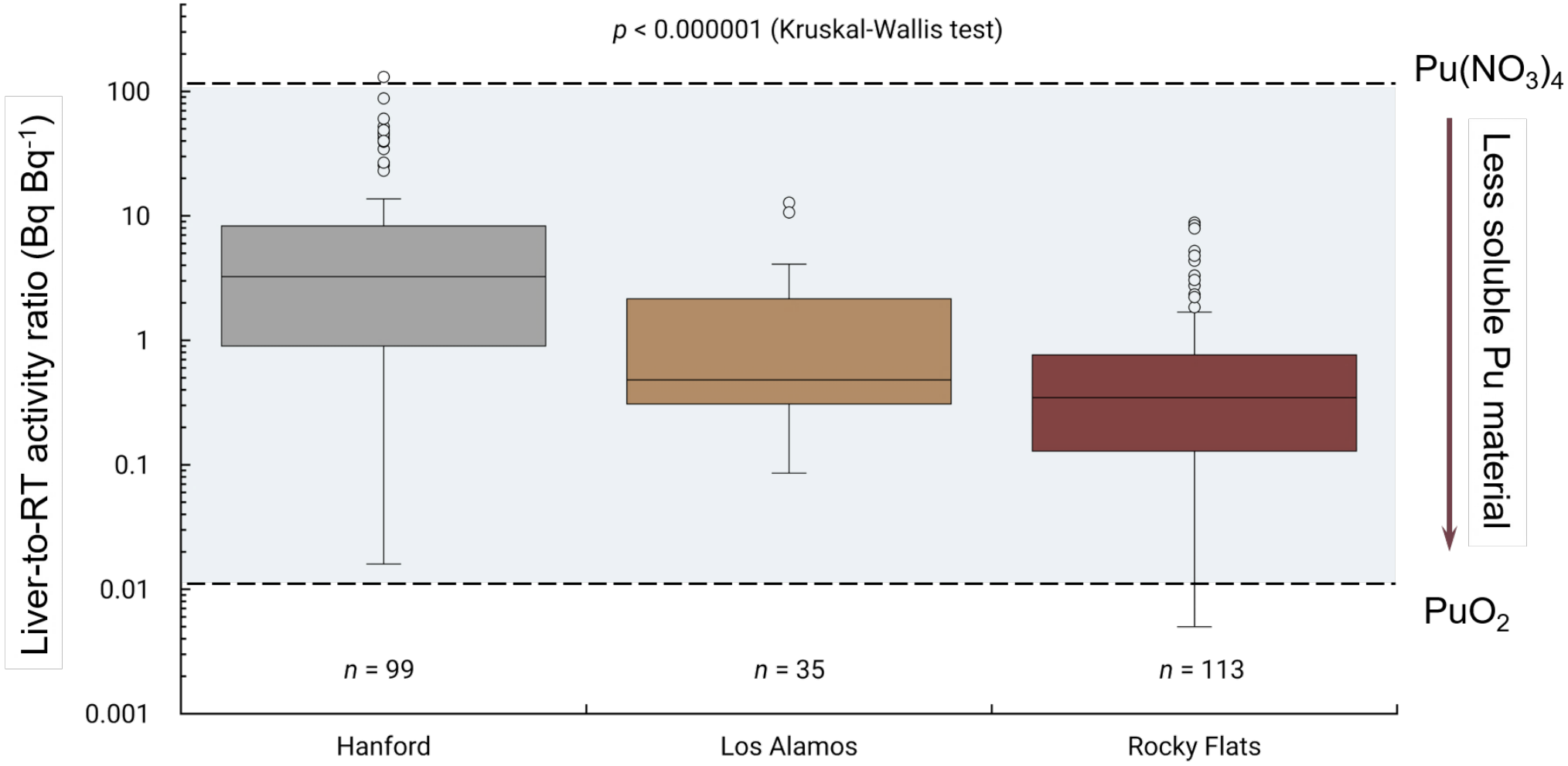
## Rocky Flats

1952–1992



Pit (trigger) **production** and plutonium **recovery** with distinctive material chemistry

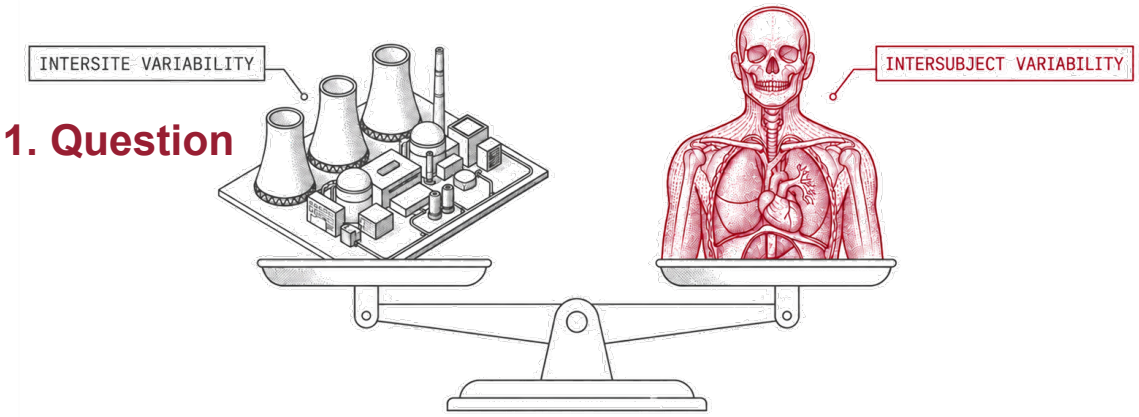
# Defining site-specific plutonium solubility



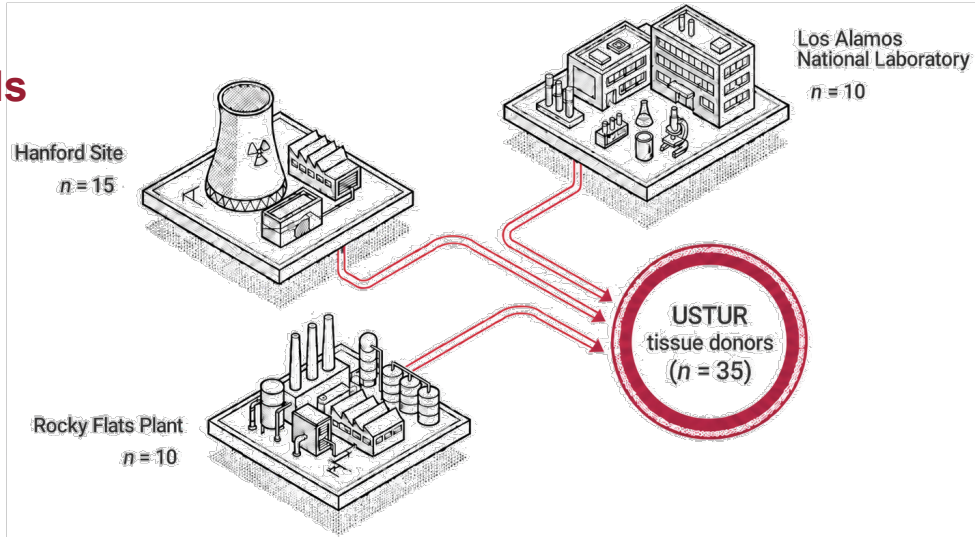
WORK IN PROGRESS

# Quantifying the limits of site-specific modeling

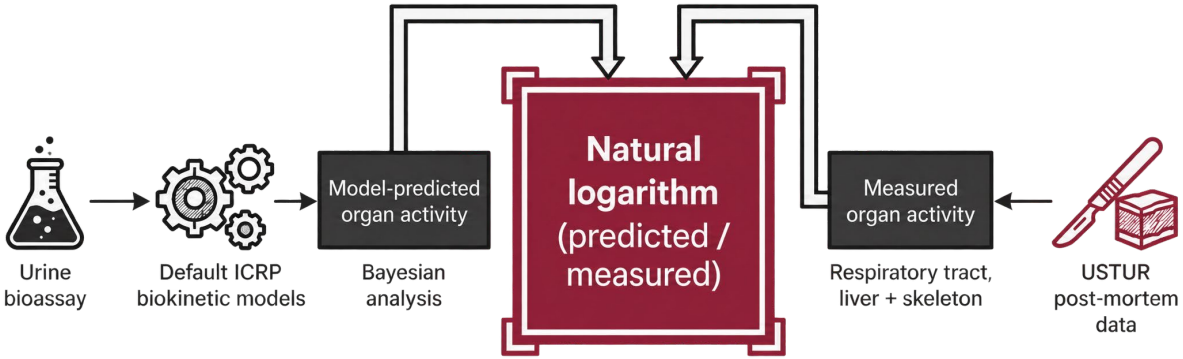
## 1. Question



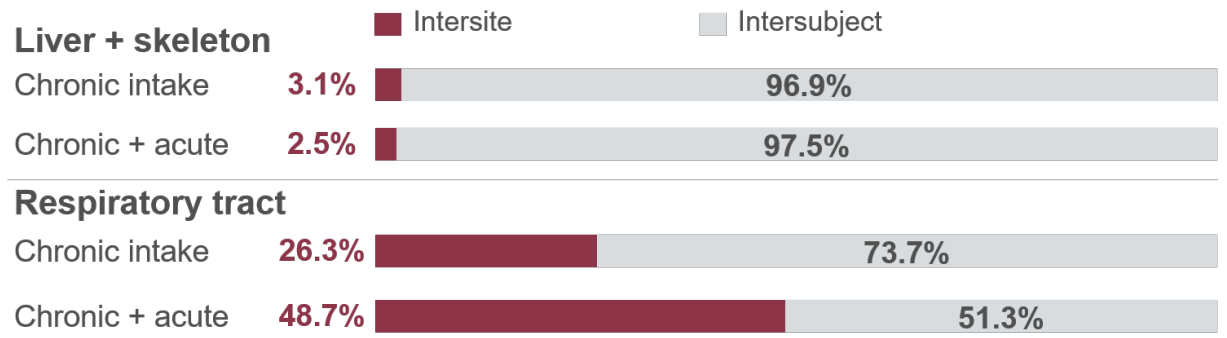

## 2. Materials




## 3. Method




## 4. Results




**Chronic intake**
Typical assumption in epidemiological dose reconstruction.

**Chronic + acute intake**
Better reflects intakes for selected USTUR cases.

Withers et al. (**2026**) *Descriptive partition using one-way ANOVA*. 3rd Meeting of the International Society of Radiation Epidemiology and Dosimetry (**abstract**).

RADIATION EPIDEMIOLOGY

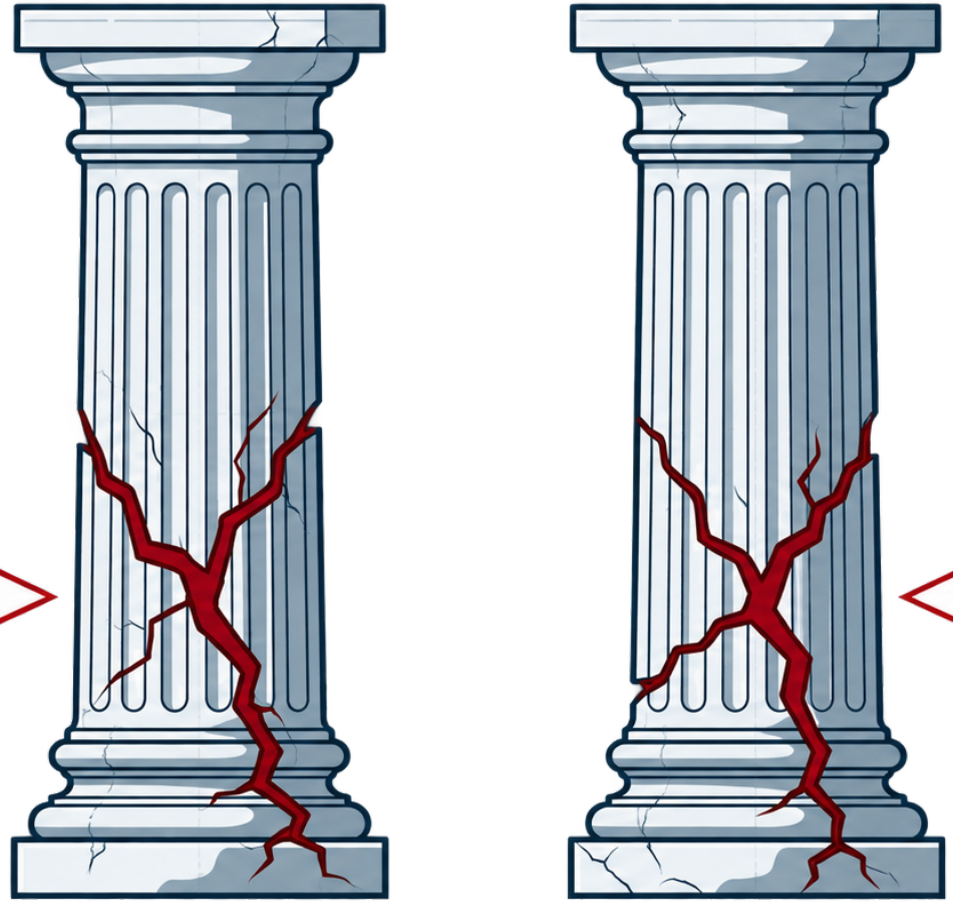
# USTUR contributions to radiation epidemiology

Radiation epidemiology often relies on indirect measures of exposure and health outcomes

**Dose Assessment**

**Standard Approach:** Bioassay data and biokinetic models (intake)

**The Vulnerability:** Theoretical model predictions often serve as **unverified proxies** for actual radiation dose absorbed by organs.



**Health Outcomes**

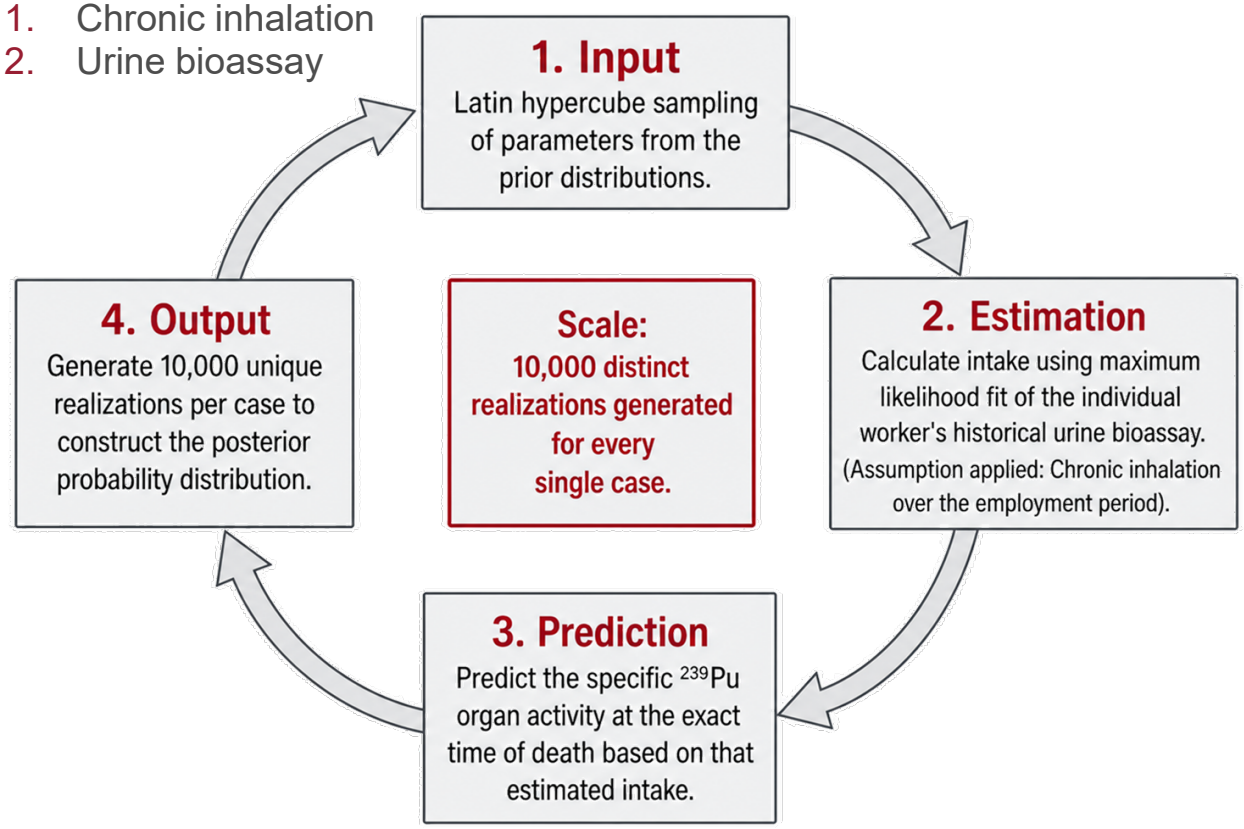
**Standard Approach:** Death certificate and ICD coding system (causes of death)

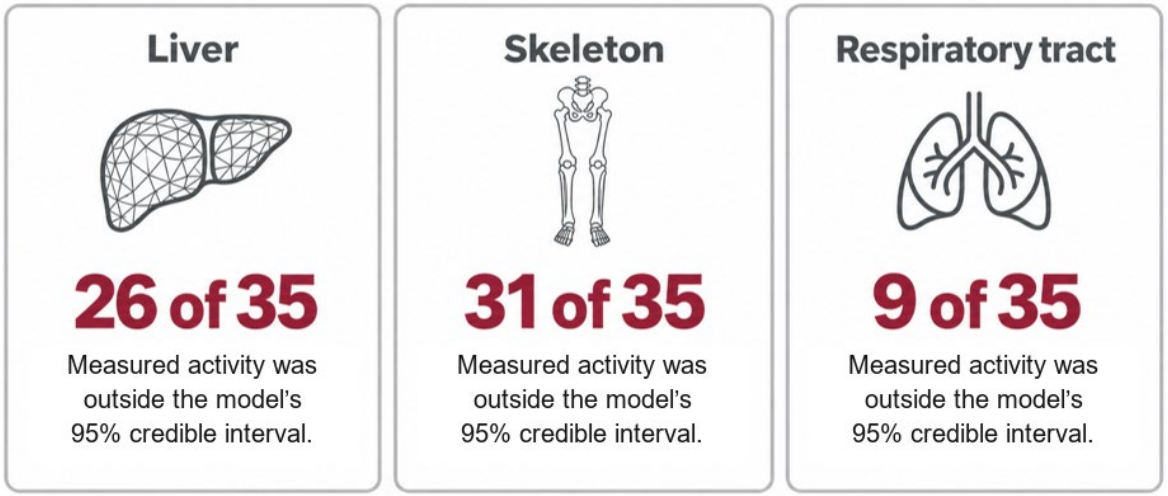
**The Vulnerability:** Administrative records are treated as clinical endpoints, creating substantial potential for epidemiologic misclassification.

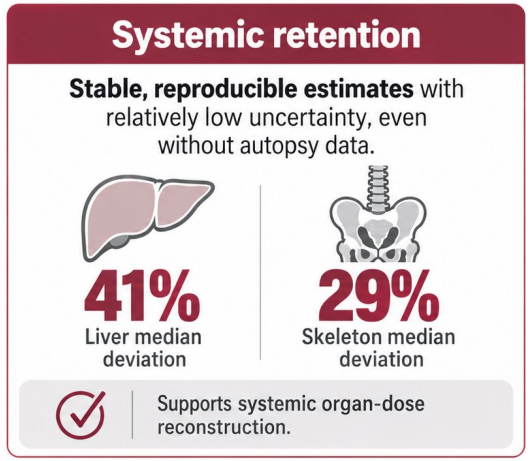
Avtandilashvili *et al.* (**2025**) *Validation of Bayesian modeling approach of uncertainty in organ doses using post-mortem measurements*. Sci Rep **15**: 20476

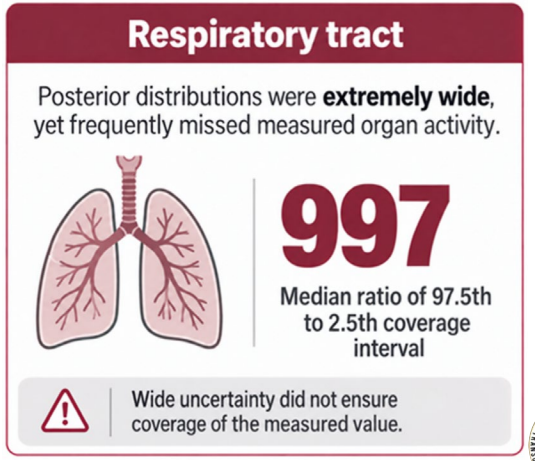
# Biokinetic model uncertainties: organ activity as a proxy for radiation dose

Study assumptions:
1. Chronic inhalation
2. Urine bioassay



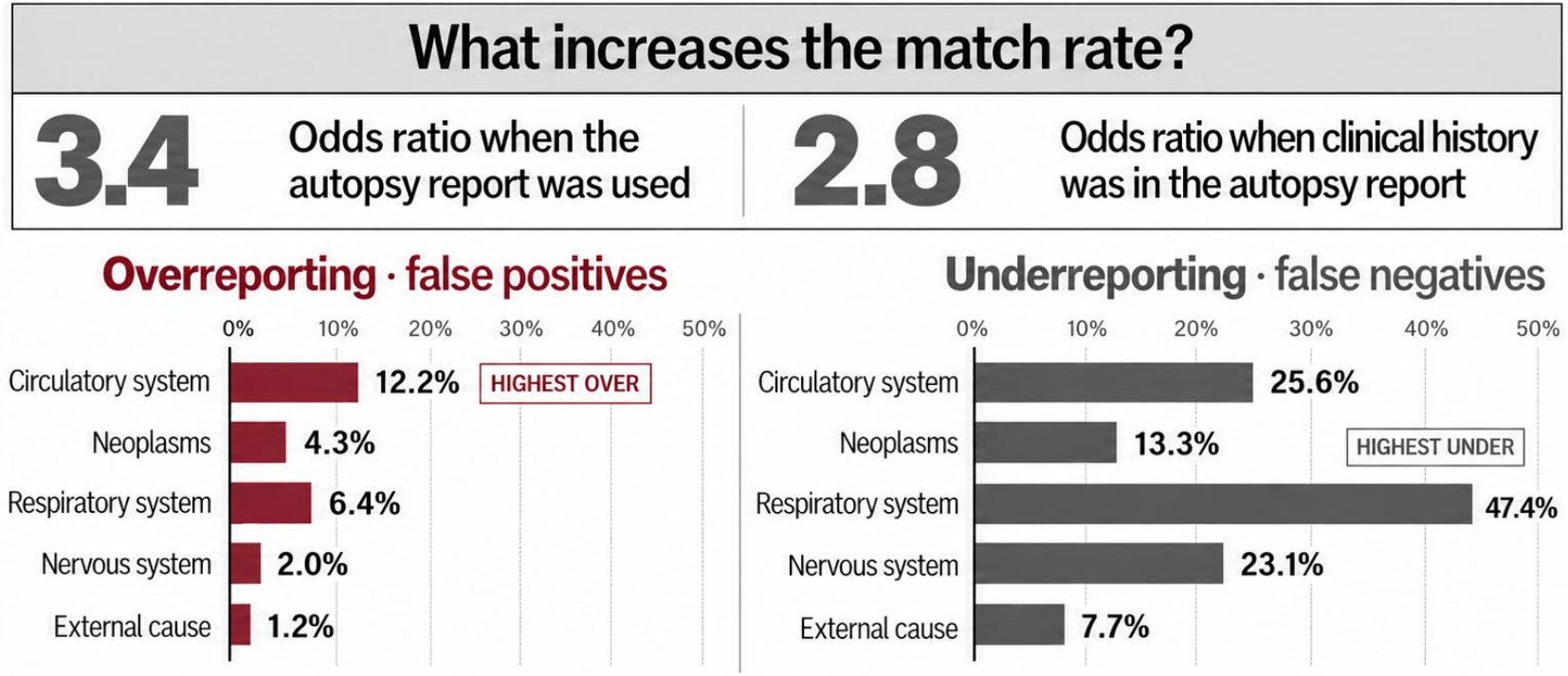



RADIATION EPIDEMIOLOGY

# Cause-of-death misclassification: death certificates versus autopsy reports

**25.4%**

**of death certificates misclassified the underlying cause of death at the ICD-10 chapter level.**



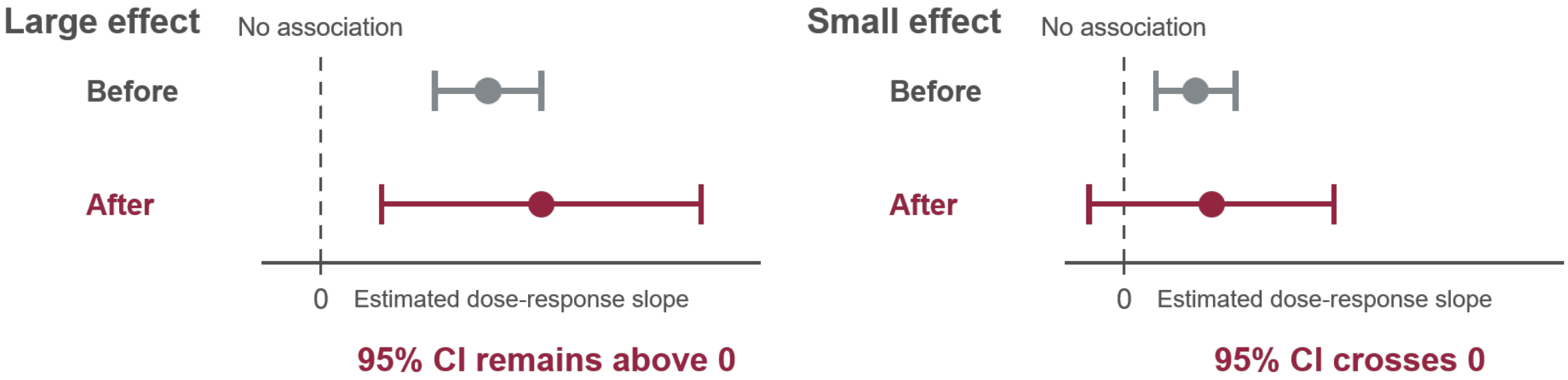

McComish et al. (**2024**) *Misclassification of causes of death among a small all-autopsied group of former nuclear workers: Death certificates vs. autopsy reports*. PLOS ONE **19**(5): e0302069.

Liu *et al*. (**2026**) *Inference under outcome misclassification in health risk models using a simulation study with a validation dataset*. Sci Rep **16**: 11981.

# How outcome correction changes the results

***Common heuristic**: correcting outcome misclassification strengthens the estimated association.*

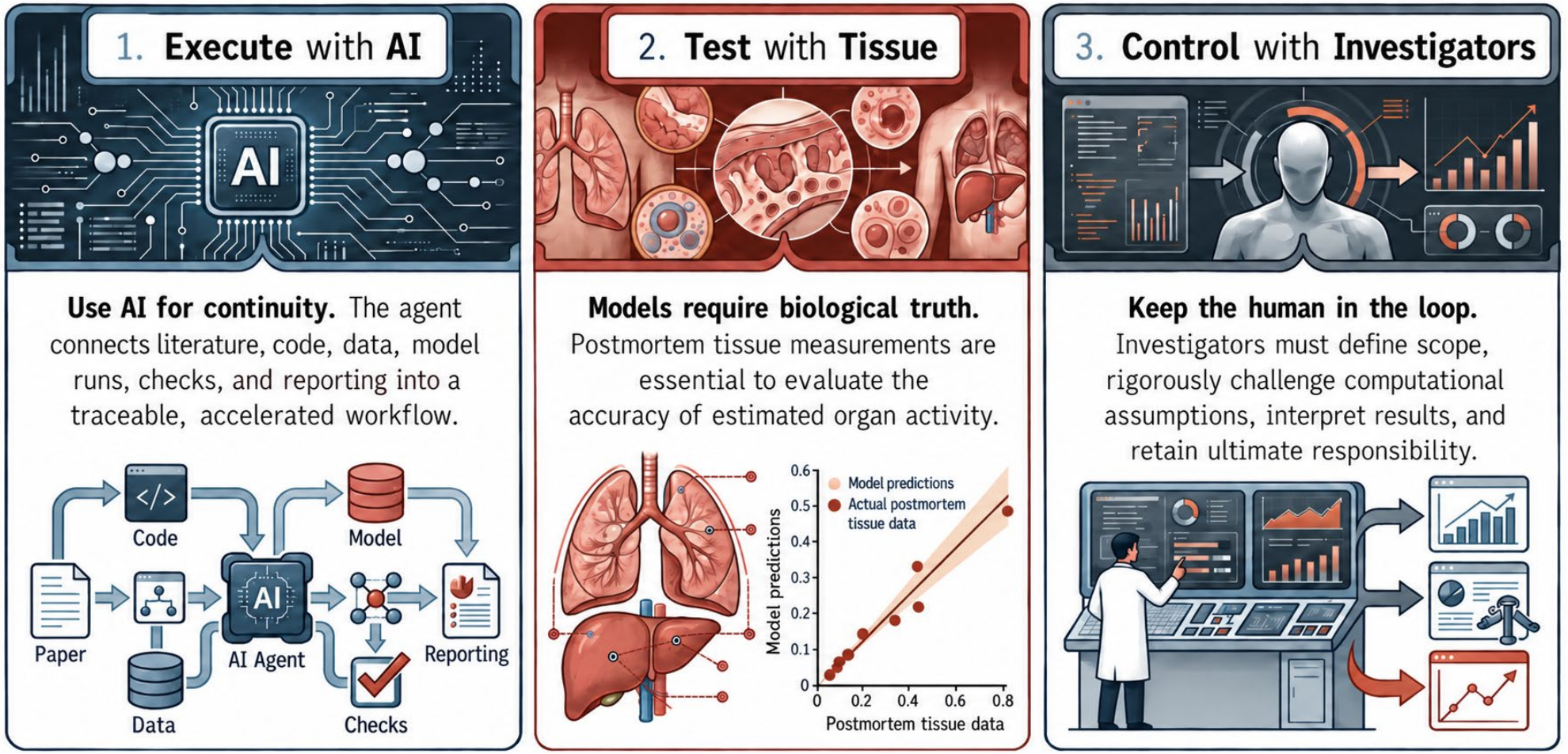
***Why this matters**: in low-dose radiation epidemiology, health effects are often small and conclusions are inherently marginal.*




***Findings**: correction increased point estimates on average and widened the 95% confidence intervals in our analyses, potentially altering statistical conclusions. **A larger corrected effect estimate does not necessarily mean a more statistically convincing association**.*

NEW HORIZONS

# Use of AI: Changing the way research is conducted



IN CLOSING

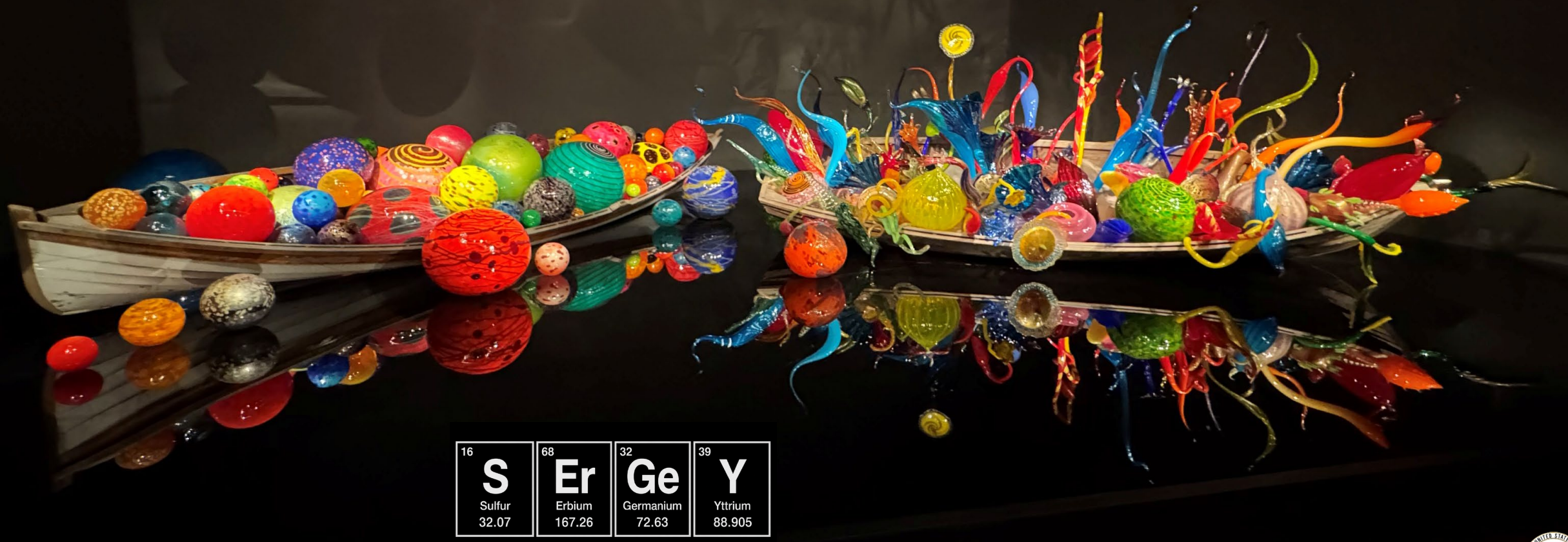
# Key takeaways

The *USTUR* is a **unique worldwide resource** for the comprehensive study of **actinide elements** in the human body.

The *USTUR* provides the **scientific evidence** required to ensure that **safety standards remain adequate** for these radioactive elements.

The *USTUR* supports **radiation epidemiology** by providing data needed **to quantify uncertainty in dose estimates and health-outcome classification**.

# Thank you for your attention!



| 16 | 68 | 32 | 39 |
|---|---|---|---|
| S | Er | Ge | Y |
| Sulfur | Erbium | Germanium | Yttrium |
| 32.07 | 167.26 | 72.63 | 88.905 |

Chihuly Garden and Glass, Seattle, Washington, USA