The Plutonium Spill at NIST-Boulder, June 2008

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Learning Objectives

- Describe the plutonium spill that occurred in June 2009
- Analyze resulting internal doses
- Identify failures of the safety program and regulatory consequences

REAC/TS

- The Radiation Emergency Assistance Center/Training Site (REAC/TS) is a U.S. Department of Energy (DOE) facility in Oak Ridge, Tennessee.
- REAC/TS' mission is to provide medical management of radiation accident victims
- REAC/TS is a member of REMPAN
- REAC/TS staff includes physicians, nurses, and health physicists

Background

- The U.S. National Institute for Standards and Technology (NIST) is located in Gaithersburg, MD, outside Washington, D.C.
- NIST also operates a laboratory in Boulder, CO (NIST-B)
- Project involved developing new detector for homeland security applications
- Detector is an array of micro-calorimeters, much like an infrared camera, optimized for 100-keV photons

NIST-Boulder Background

- Areas of Interest:
  - Atomic clocks, nanotechnology, basic and applied physics, optoelectronics, chemical research, quantum sensors
- Facilities:
  - 84 Acres, shared with NOAA and NTIA
  - 350 tech staff, 300 guest researchers, ~$100 million

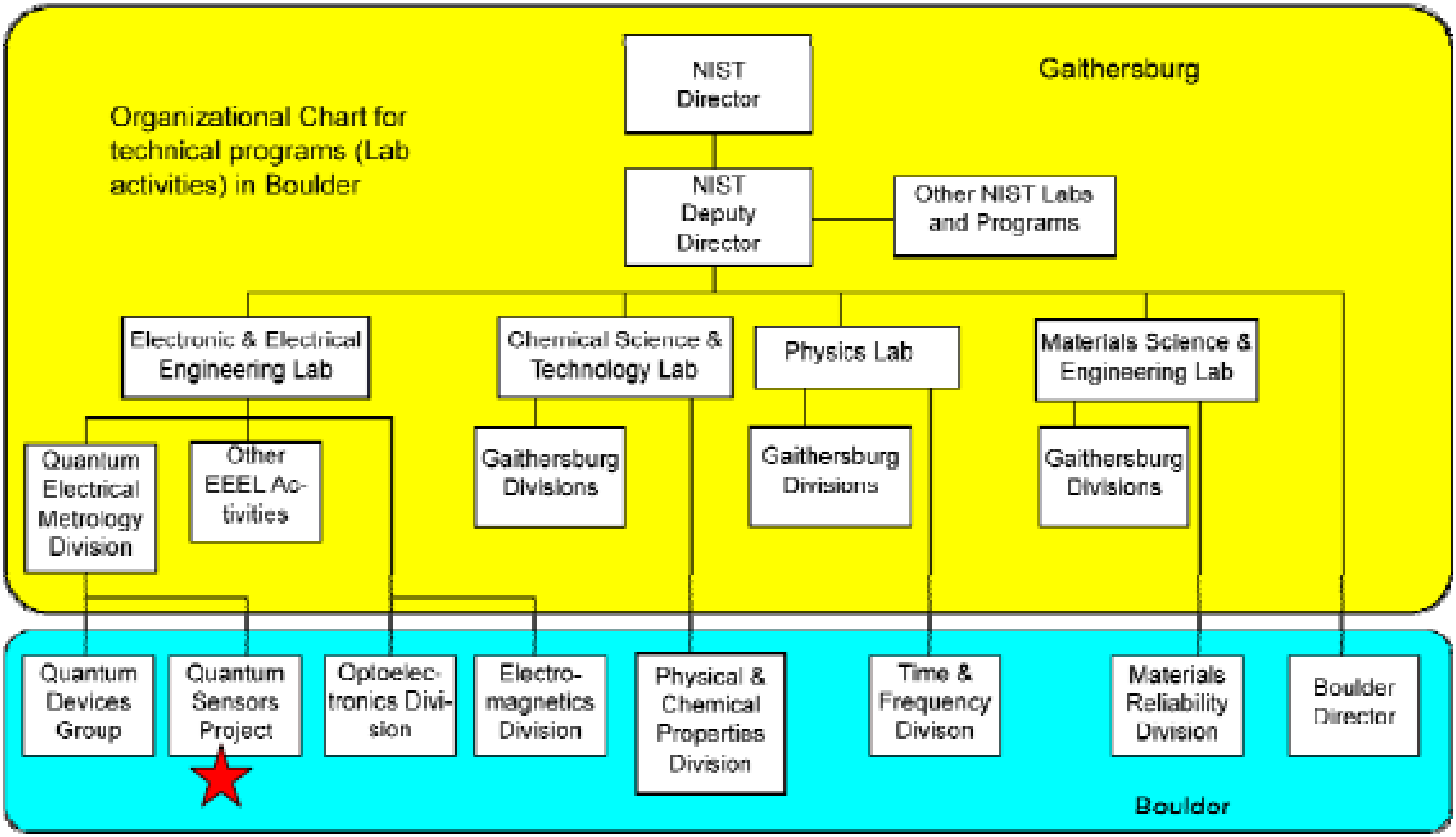


Figure 1. Organizational chart for research activities in Boulder. The organization directly involved in the incident is marked with a (★).

Calibration Laboratory

- Detector being calibrated occupied one corner of a multi-use laboratory routinely occupied or occasionally used by about 20+ individuals, most of whom were not radiation workers
- Sources stored in a locked 2-drawer file cabinet near entrance, some distance from detector

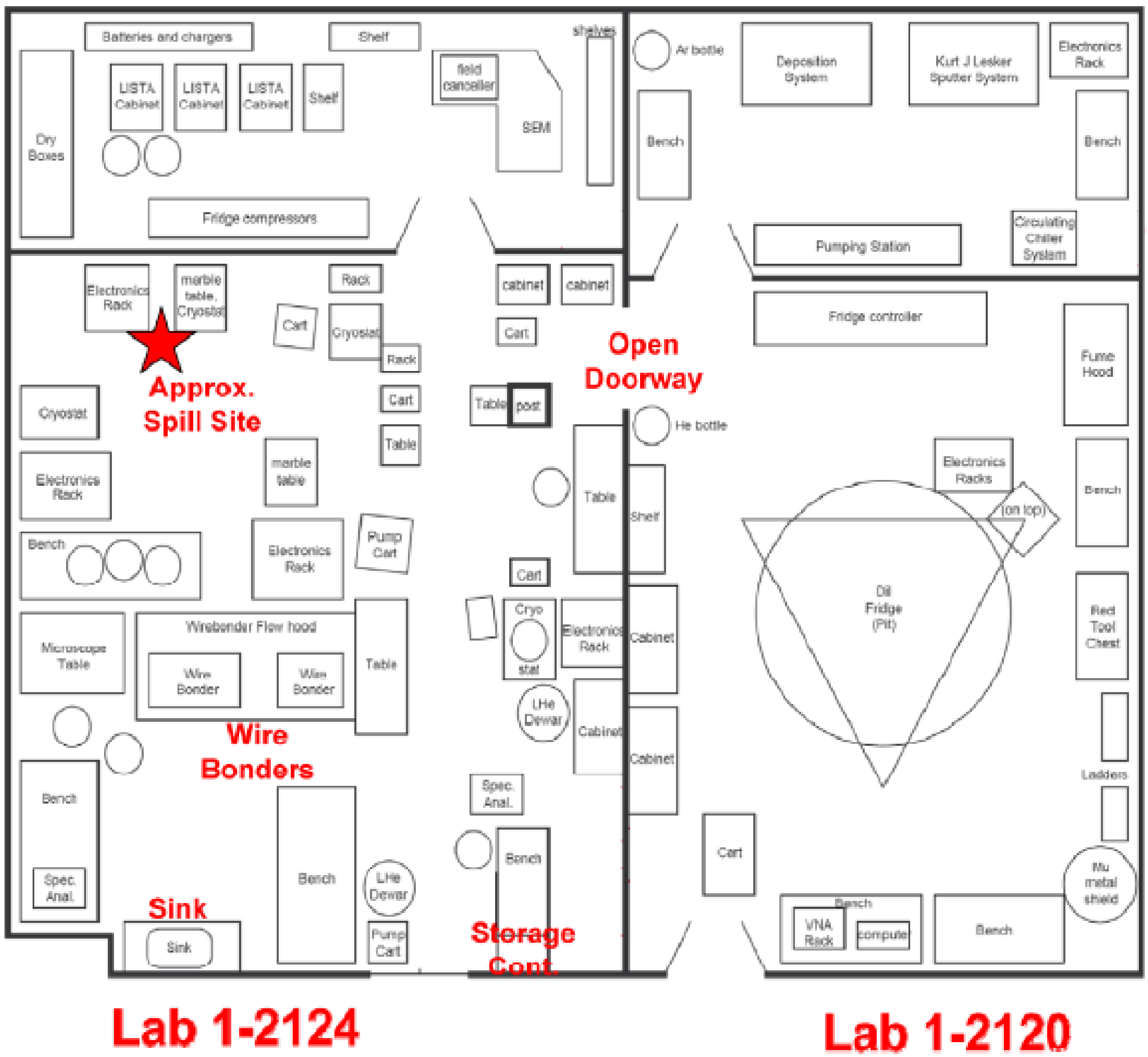
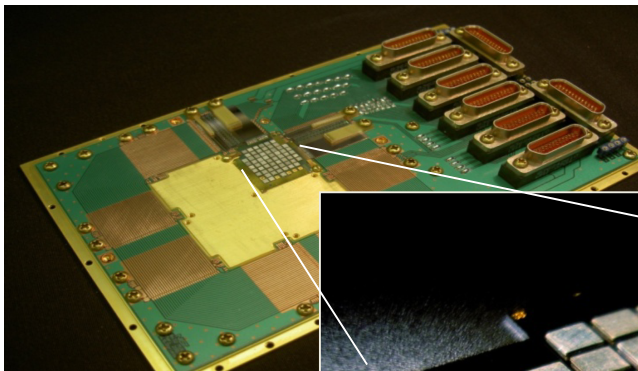
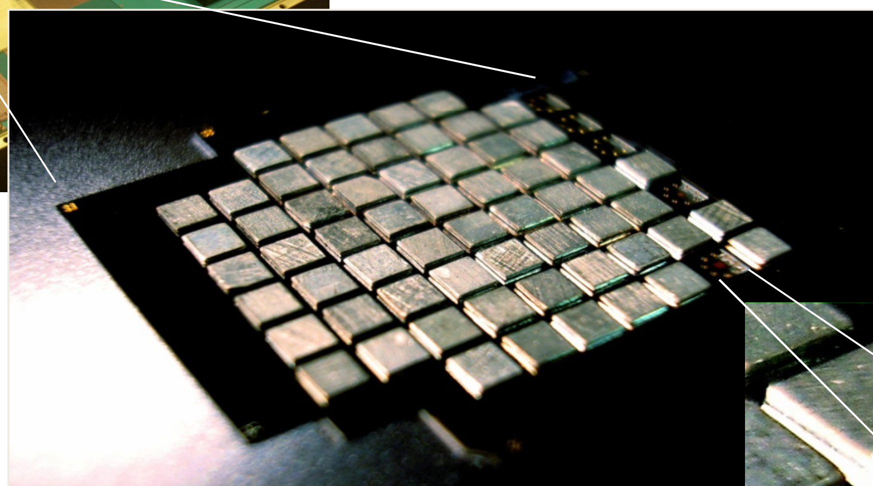
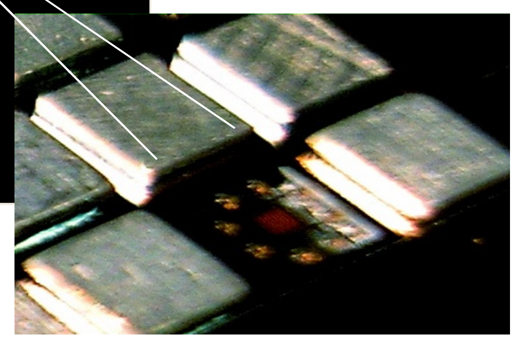


Figure 3. Plan view of the lab where the spill occurred and the connected labs that were isolated due to the incident.

Gamma spectrometer delivered to LANL

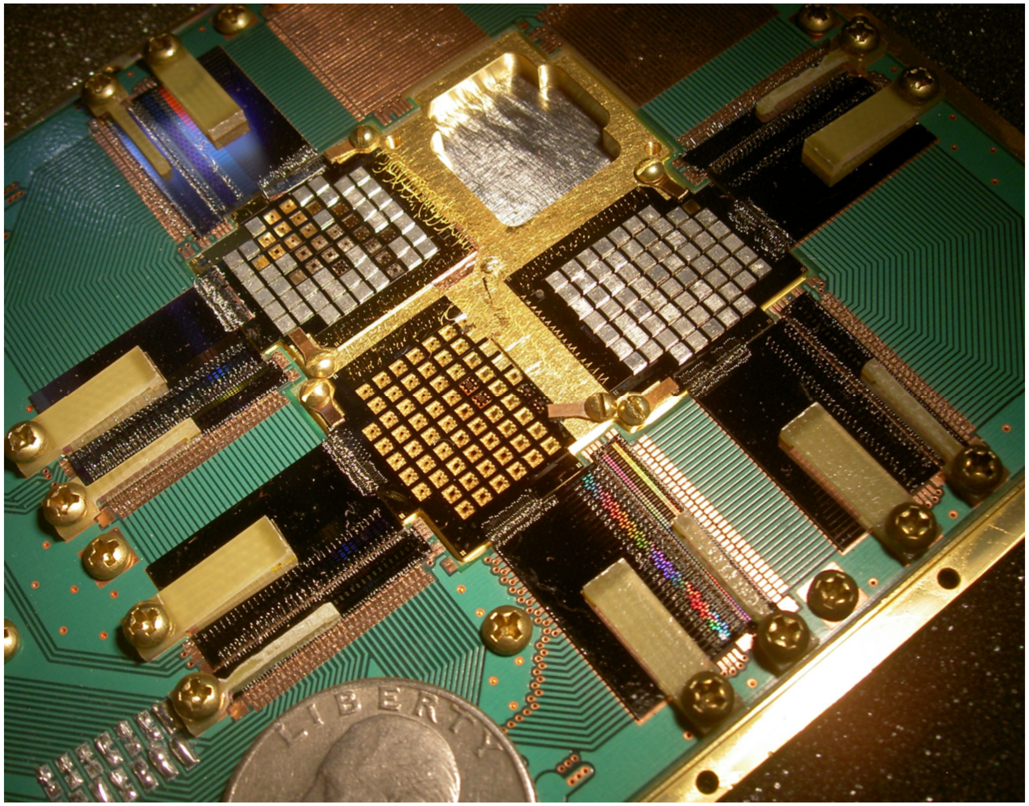


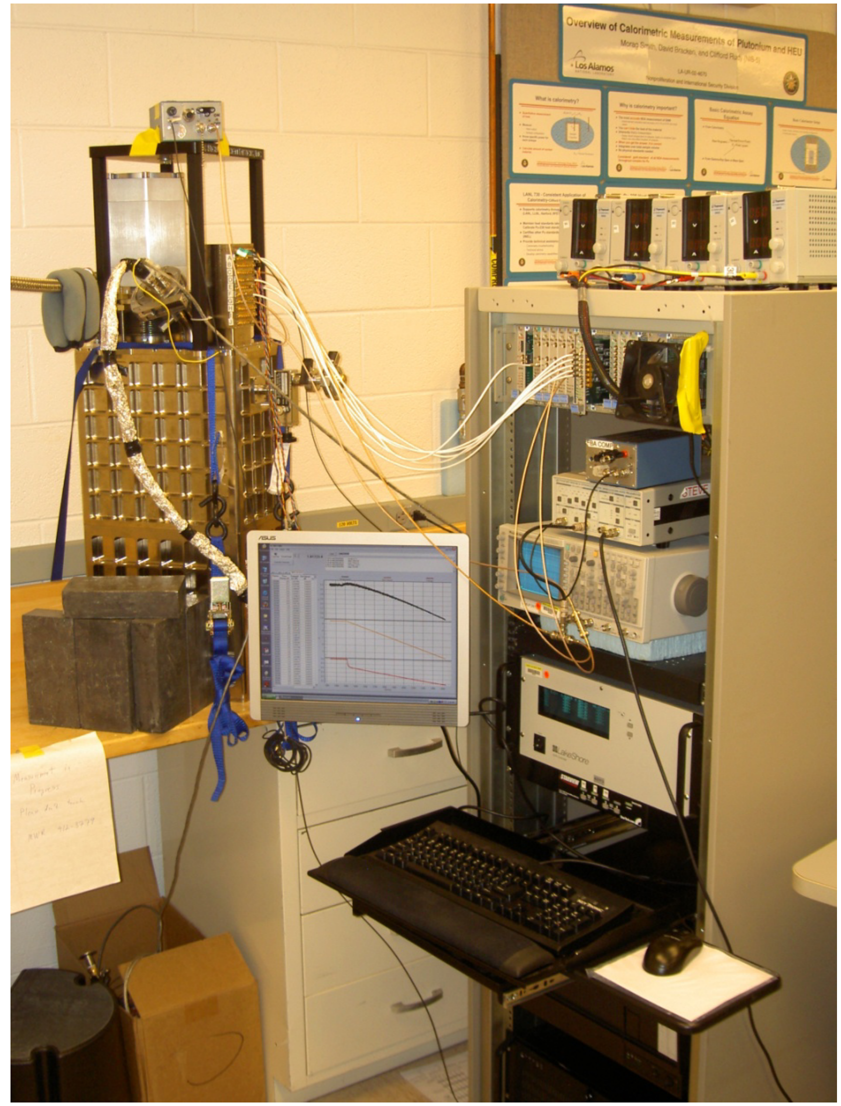




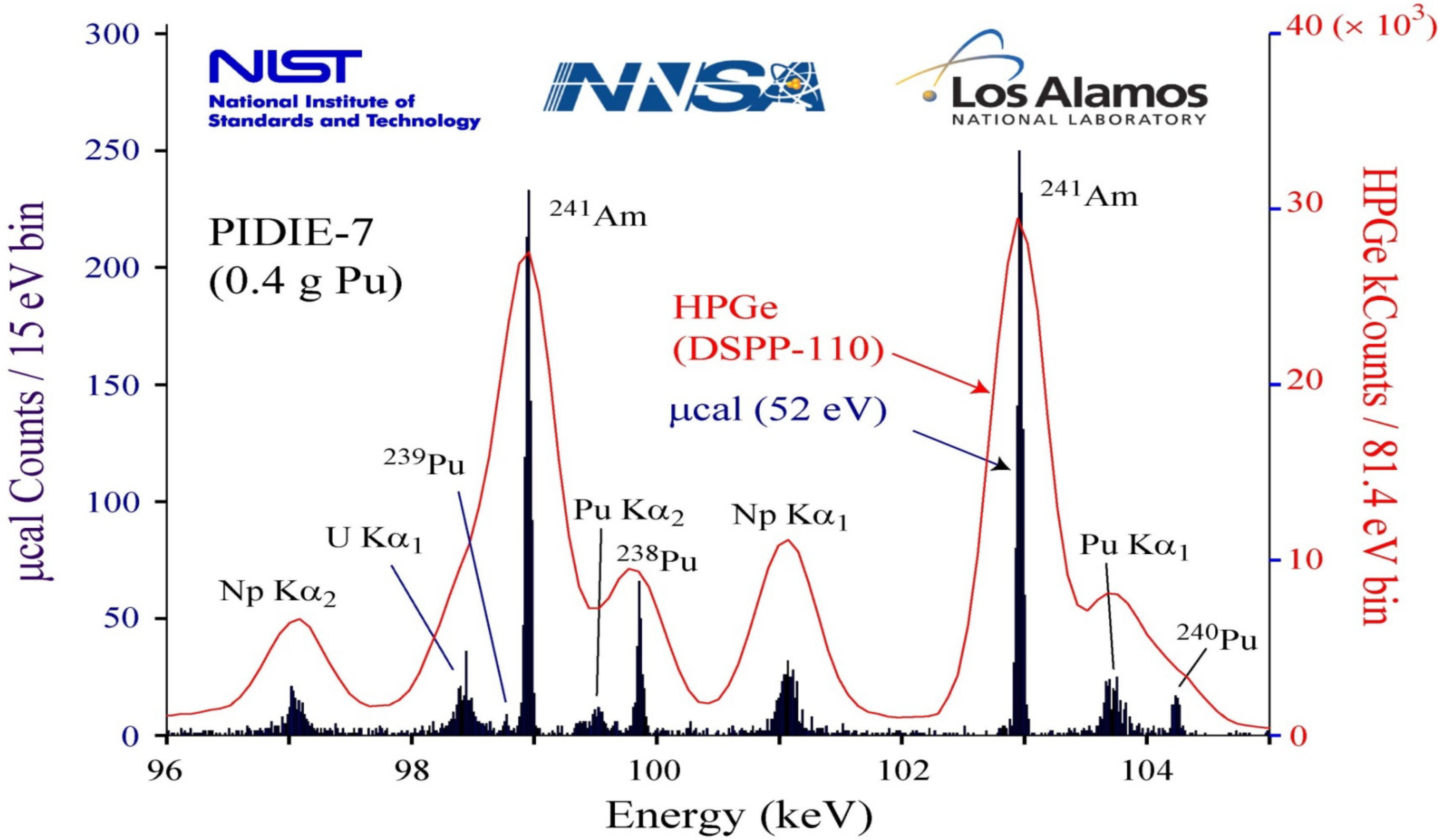
subarray with 61 complete pixels

Detector Array





LANL-NIST Pu spectrum: isotopes clearly resolved

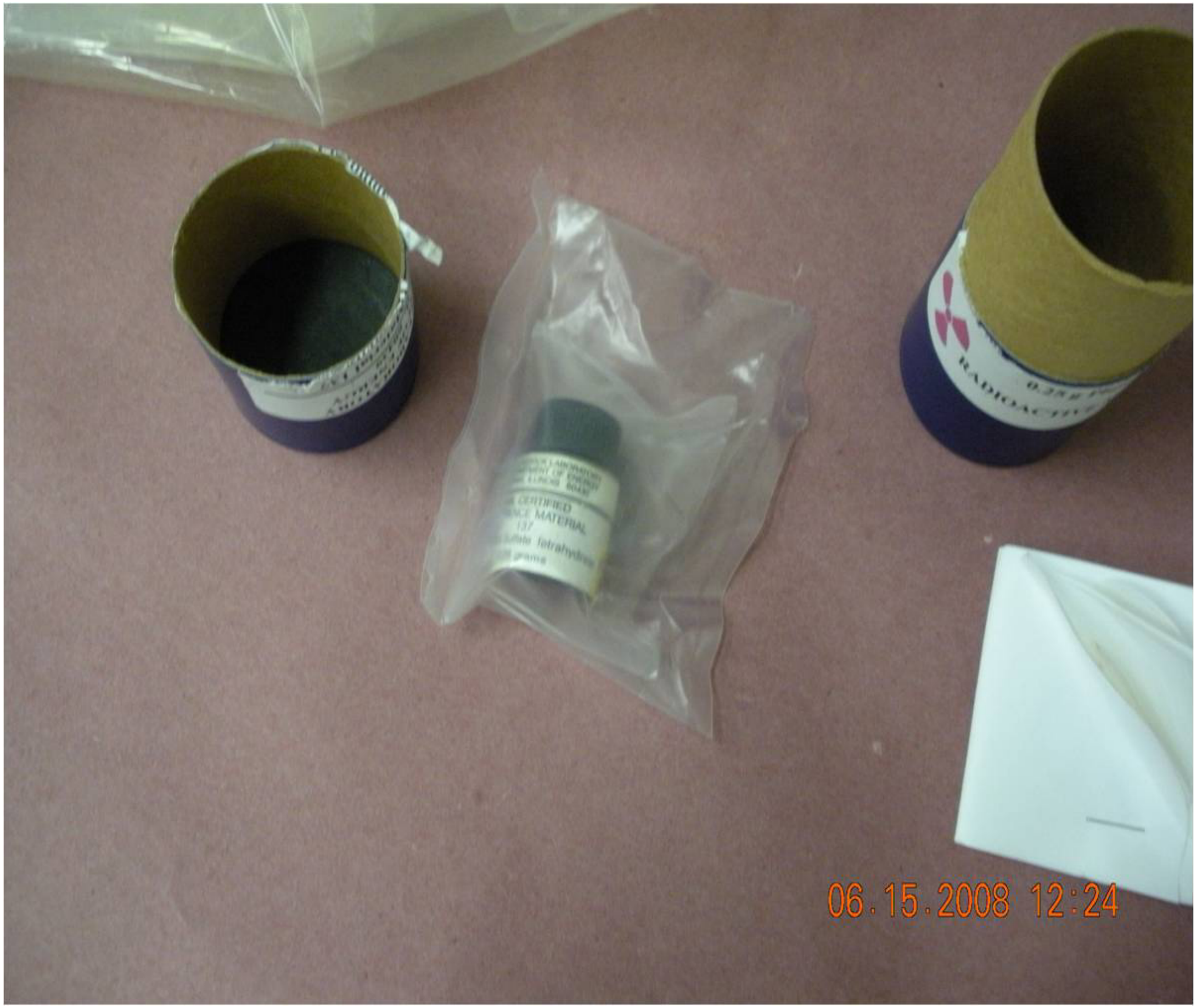


Detector Location

Plutonium Source

- The source was 250 mg of $^{239,240}Pu$ sulfate tetrahydrate in a glass vial, about the size of a liquid scintillation vial, with a rubber O-ring seal under the screw-on cap; activity ~ 0.6 GBq
- Sample was prepared as Standard Reference Material about 20 years ago by the DOE New Brunswick Laboratory at Argonne East

Source Configuration



Source Acquisition

- NIST-B submitted a license amendment to USNRC to acquire “encapsulated” source
- Only source handling experience had been with “button” sources used for detector calibration
- Source acquisition form not reviewed nor approved by management as required by procedure, but was approved by RSC in Gaithersburg, MD

HP Controls

- NIST-B recently hired a full-time HP/RSO, who is also laser safety officer
- Training and source handling requirements (gloves, tongs, etc.) were established.
- Principal Investigator (P.I.) assigned as source custodian
- Worker #1 (a foreign post-doc) started ~ 1 May 2008

Training Program

- P.I. informed RSO new workers needed training
- RSO trained six new workers in April and assumed training was complete
- New post-doc did not receive training, but was permitted to work with Pu source to calibrate detector

Source Storage

Source Drawer

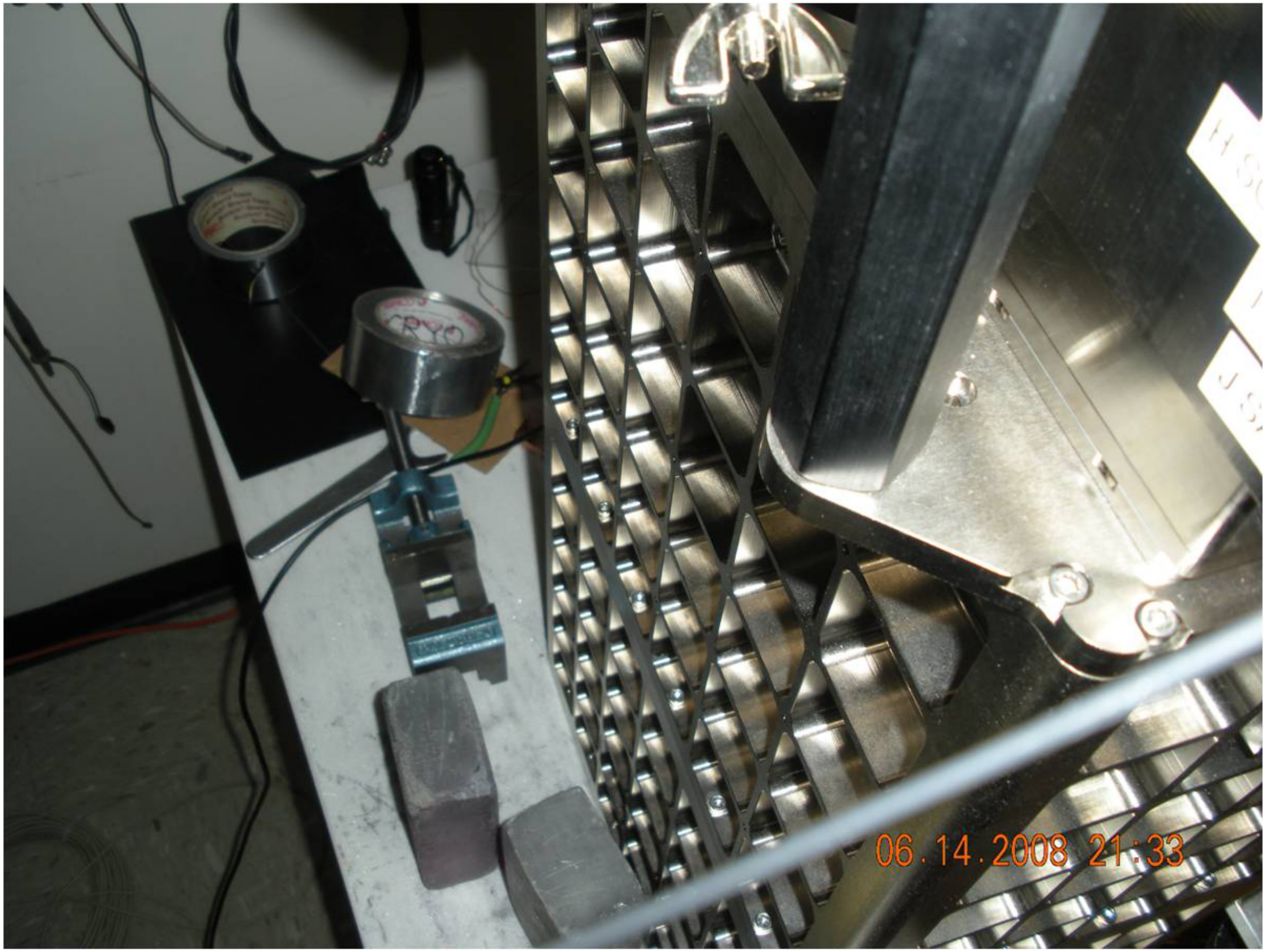
Source Handling

- Source vial shipped in double, heat-sealed plastic bags
- RSO added third “zip-lock” plastic bag
- Worker #1 removed source from outer bag and taped it to front of detector array
- Tape removal caused tears in heat-sealed plastic bags
- By first week in June, heat-sealed plastic bags were thoroughly torn, and worker #1 was handling source vial directly

Incident prologue

- On Friday 6 June Worker #1 and #2 (who had been trained) set up a long weekend run; they noticed varying count rate with source position, so tapped vial on marble bench top to settle powder in one corner
- Worker #1 also set up Pb bricks to shield computer from source to prevent failure from dropped bits he thought were caused by radiation.

Detector Face



Incident

- On Monday June 9, worker #1 was setting up another run and moving source by hand in front of detector while observing count rate on computer and stated he may have tapped the source bottle against one of the Pb bricks.
- Worker #1 stated he then noticed what appeared to be a crack in the bottle, so replaced it in outer plastic bag and source safe, washed his hands, took his notebook to his office, then notified P.I. about 1 hr later

P.I. Response

- P.I. was not made aware of potential seriousness of incident, so went to lab ~30 minutes later
- P.I. looked in source storage drawer and saw a second source that was obviously intact
- Worker # 1 then showed him the “cracked” source bottle

Ruptured Source

Immediate Actions

- P.I. observed “brown powder” inside source bag and also on bench top, and ordered the lab to be evacuated, but workers were told to wait in the hallway for further instructions.
- P.I. notified Group Leader, who came to lab, and advised workers to remove their shoes to avoid spread of contamination

Initial Survey

- P.I. used a newly-purchased alpha probe to survey bench top and discovered high levels of contamination
- RSO was on leave, but reached by phone and arrived at lab some 30 minutes later
- RSO took over incident management, and he and G.L. entered lab wearing anti-C coveralls and respirators to assess incident and shut down air and power systems
- Trained radiation workers began surveys outside lab

Area Surveys

- Contamination found in hallways, men's room, Worker #1 office, P.I. office, and on shoes and bare feet of workers in hallway outside lab.
- Workers decontaminated and sent home
- Surveys and decon of areas outside the lab continued for several days.

Call for Assistance

- On 12 June, NIST-B requested assistance from DOE for additional survey and decon work; Radiological Assistance Program (RAP) Teams from Los Alamos and Livermore arrived on site the next day
- High level of contamination found in lab sink, which discharged directly to municipal sewer line

Rap Team

Off-site Release

- The maximum release to the city sewer line was ~0.2 GBq
- Given a daily discharge of 450,000 gallons from the site, and a 30-day average, release was within regulatory limits
- However, extensive negative publicity and citizen concern resulted

Cleanup (before)

Cleanup (after)

Removal of inside drain piping

Removal of outside drain system

~50,000 lbs of waste

LLW shipment

Initial Bioassay

- Urine samples collected from 21 workers 13-16 June; all results negative except Workers #1 and #2
- Unfortunately, samples were 100-250 mL and analyzed by gross alpha-beta, DL = 0.4 mBq/L
- 1-liter samples collected week of 23 June for alpha-spec and TIMS

Worker #1 Initial Results

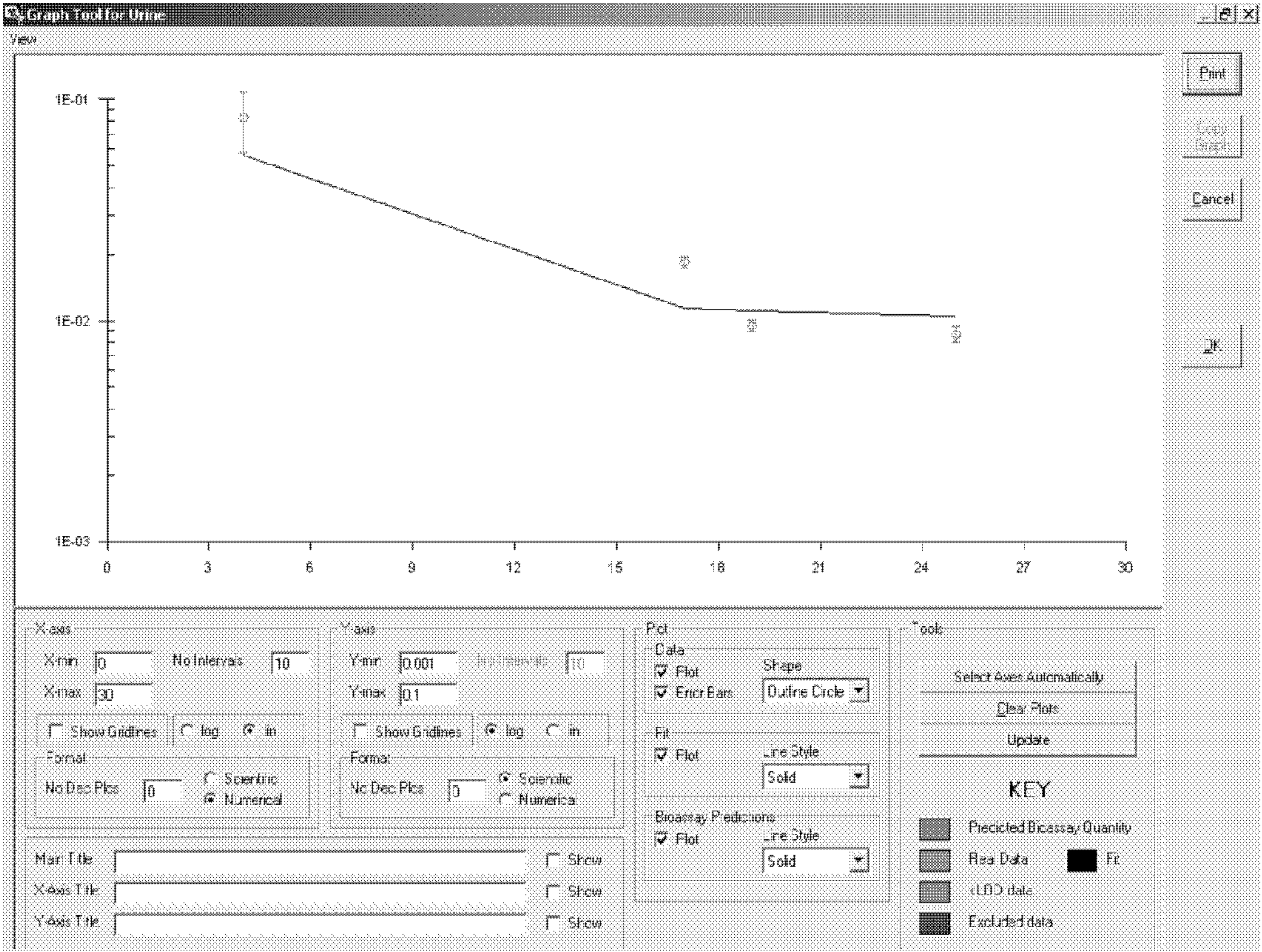
- Urine: 2 mBq/L; intake = 58 Bq;

  CED (BS) = 60 mSv

  eff. dose = 3 mSv
- Fecal: 9 Bq/d; intake = 56 Bq

- Initial report to REAC/TS was 20 (!) mBq/L, resulting in recommendation for DTPA Tx

Worker #1 Bioassay



Final Bioassay results

- Worker #1 intake = 40 Bq
  Eff. Dose = 2 mSv
  CED (BS) = 40 mSv
- DTPA TX averted 6 mSv CED (BS)
- Worker #1 had 2 Tx, wanted third
- 2 of 21 urine + via gross alpha/beta
- 2 of 10 urine + via alpha spec
- 16 of 29 urine + via TIMS

Causes of Incident

- Untrained worker allowed to use source without supervision
- P.I. did not ensure training conducted
- No emergency procedures developed or posted
- Inadequate equipment and trained response personnel on site

Contributing Issues

- Inadequate oversight by RSC and line management
- Post-doc under pressure to complete experiment for presentation at upcoming conference
- Sample “sealed” when prepared at 200 m elevation, but was being used at 2000 m.
- Poor safety culture (3 incidents in 2 years)

Initial Consequences

- Suspension of NRC license
  - ordered to develop decontamination plan using NRC-licensed commercial contractor
  - Contract for formal root cause analysis
  - Re-evaluate NISTs org structure and culture from a safety perspective
- Lab shuttered (plywood bolted over windows, doors sealed)
- Six independent investigations
  - NIST Safety, Health, and Environment Division
  - NIST Ionizing Radiation Safety Committee
  - City of Boulder
  - DOC Inspector General
  - NRC
  - “Blue Ribbon” panel convened by DOC Deputy Secretary
- House Committee on Science and Technology testimony by NIST Director

Root Cause Analysis

- Root cause: lack of management accountability and commitment at the highest levels at NIST to an effective operational safety culture at the NIST-Boulder facility

- Key Contributing Causes:
  1. Inadequate management oversight
  2. Inadequate operational safety management system
  3. Poor organizational safety culture
  4. Inadequate hazard analysis
  5. Poor safety training
  6. Inadequate emergency response

Key Contributing Causes

1. There was a lack of management involvement and accountability in all phases of the work cycle, including:

- **Project hazard analysis**
- **Risk evaluation**
- **Emergency preparedness**
- **Material procurement**
- **Design of experiments**
- **Resource planning and allocation**
- **Training**
- **Lab set-up and management**
- **Conduct of work**
- **Chain of custody**
- **Mentoring**
- **Oversight**
- **Performance measurement and evaluation**
- **Handling hazardous materials**

Key Contributing Causes

2. Inadequate operational safety management system

- No formal operational safety management system in place
- SHED and RSO not sufficiently integrated into lab operations
- Safety data not sufficiently evaluated and trended

Key Contributing Causes

3.Poor organizational safety culture

- No formal operational safety management system in place

- SHED and RSO not sufficiently integrated into lab operations

- Safety data not sufficiently evaluated and trended

Key Contributing Causes

4. Inadequate Hazard Analysis

- No Hazard Review Committee review/approval of use of Pu

- No formal hazard analysis performed on lab activities

Key Contributing Causes

5. Poor Safety Training

- No Pu handling training courses
- Poor enforcement of safety course attendance prior to use of Pu
- Lack of training on the behavior and dispersal of powders

Key Contributing Causes

6. Inadequate Emergency Response

- Slow and insufficient emergency reporting

- Lab not secured immediately

Final (?) Consequences

- March 2, 2010, NIST & NRC reach agreement under alternate dispute resolution program:
  - NIST to be fined $10,000
  - RSO (former NIST employee) banned from working under NRC license for 1 year
  - NIST to complete a number of corrective actions

Safety Culture

Level 1: Safety is external issue

Level 2: Safety is safety staff issue

Level 3: Safety is management issue

Level 4: Safety is individual issue

Level 5: Safety is everyone's issue

Risk decreases with each level