

Statistical Detective Work to Understand the Radioactive Release at WIPP

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On Valentines Day 2014 an “incident” at the Waste Isolation Plant (WIPP) in Carlsbad, New Mexico resulted in a radioactive release

Headlines Followed:

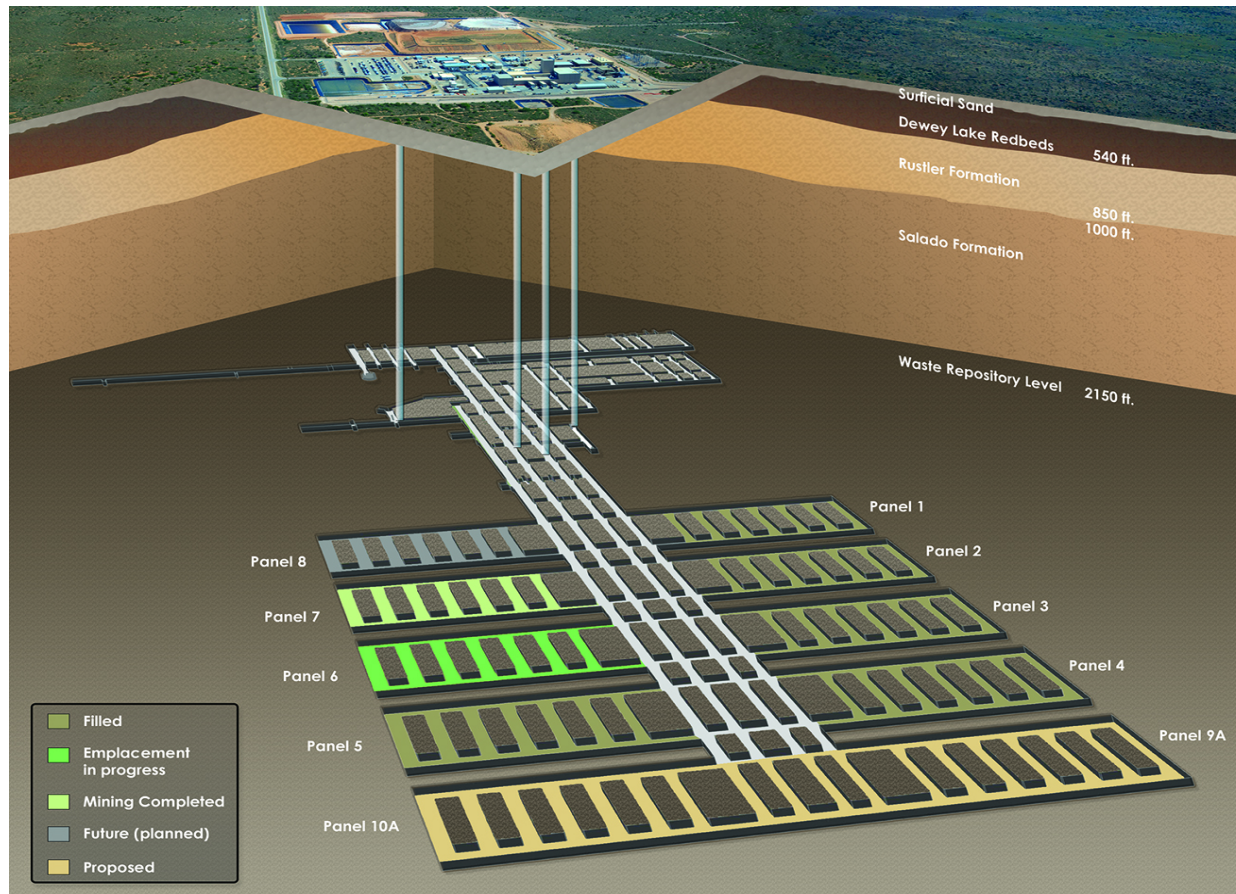
- **US Nuclear Waste Dirty-Bombs New Mexico With Plutonium**
- **Serious "radiation incident" at NM waste facility has public concerned**
- **DOE Issues Citations for 2014 WIPP Incidents**
- **WIPP's future uncertain**
- **Nuclear accident in New Mexico ranks among the costliest in U.S. history - “will top \$2 billion”**

Aug 23 2014 L.A. Times headline –

Cause of New Mexico nuclear waste accident remains a mystery

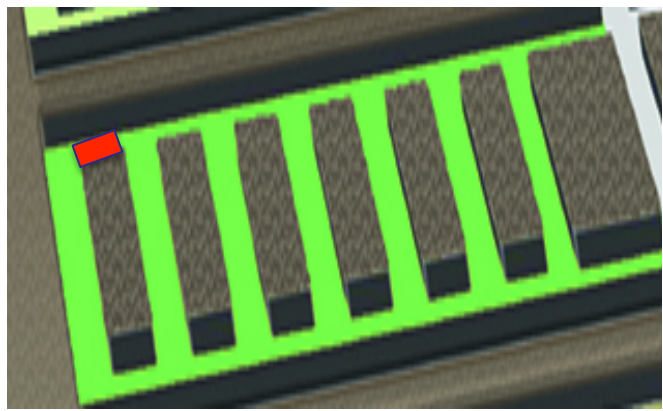
“Experts still haven't unraveled how an accident contaminated the nation's only **dump for nuclear weapons waste”**

Some “Dump” (\$3 billion)

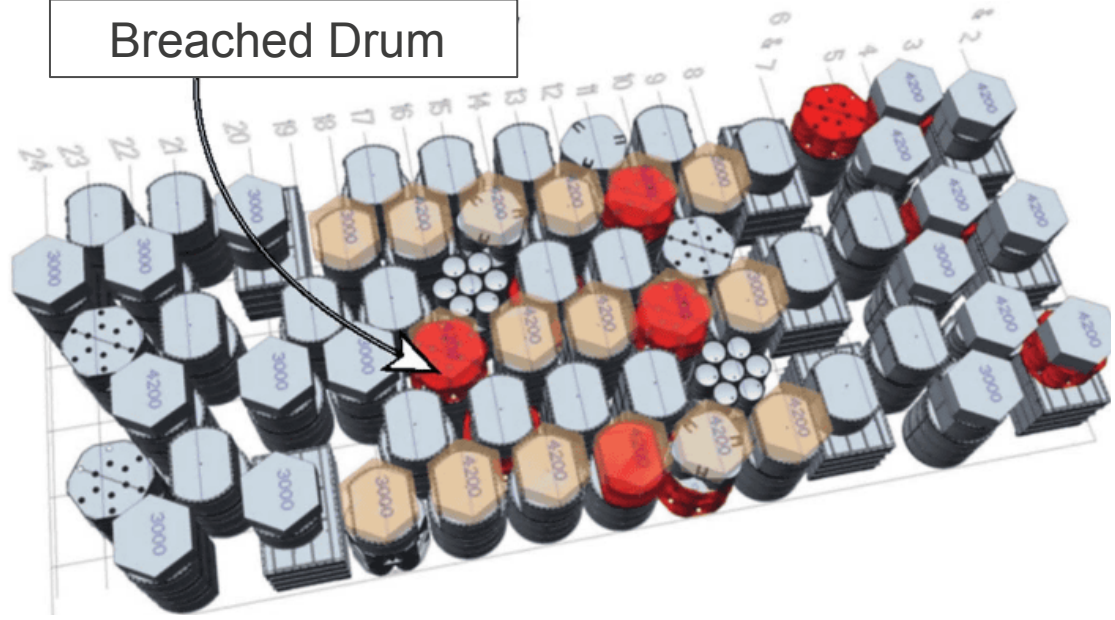


- Underground disposal area - 8 panels with seven rooms in each panel (rooms are the length of a **football field**, 1/4 the width and 13 feet high)
- 2150 feet below the surface in Salado (salt) formation
- Approximately \$200 million per year to operate the “dump”

Incident in Room 7 Panel 7



Breached Drum



From the August LA Times article:

- **55-gallon drum of nuclear waste, buried in a salt shaft 2,150 feet under the New Mexico desert, **violently erupted** late on Feb. 14 and spewed mounds of radioactive white foam.**
- **The flowing mass, looking like whipped cream but laced with plutonium, went airborne, traveled up a ventilation duct to the surface and delivered low-level radiation doses **to 21 workers.****
- **The accident contaminated the nation's only dump for nuclear weapons waste and gave the nation's elite ranks of nuclear chemists **a mystery they still cannot unravel.****



Unraveling the Mystery

- What they knew in August 2014:

- At least one 55 gallon drum breached
- It was a Los Alamos drum in room 7 of panel 7 (Drum 68660)
- It was one of two daughter drums from a parent drum that had 14 bags of nitrate salts, each with a different mix of Pu239, Pu240 and Am241 (isotopics)
- 68660 contained some combination of the 14 bags mixed with a neutralizing agent, and **organic** “kitty litter”
- There were air sampling isotopic ratio measurements from fixed samplers near the explosion
- The isotopic ratios did not match measurements on 68660 made just before shipping

Unraveling the Mystery

- **What they did not know in August 2014**
 - **One drum or more than one drum?**
 - Discrepancy between air sample isotopics and reported drum isotopics
 - **What caused the drum to explode (internal, external, both)?**
 - Could not get a reaction with mixture of materials comparable to the 14 bags (plus kitty litter and neutralizer)
 - There had been a truck fire a week before – a factor?
 - Could something have fallen on the drum?
 - **What about the sister drum?**
 - Sister drum was under observation at Los Alamos, no energetic reactions

The Plot Thickens- August 7, 2014 one of the *elite* actinide experts (Kirk Veirs) contacted us

- Believed shipping isotopic ratios could be wrong
 - $^{240}\text{Pu}/^{239}\text{Pu}$ and $^{241}\text{Am}/^{239}\text{Pu}$
- Had isotopic data for each of 14 bags at packaging of parent drum (1985)
- When he looked at isotopic ratios resulting from all 14 bags, they were closer to sampled, but not close enough
- Could we figure out if isotopic ratios from a subset of the bags would match the sampled values?
- **Needed results ASAP!!!**

Radiological Forensic Analysis

- **Identified all possible combinations of 2 to 7 bags from the 14 (9,843 combinations)**
- **Determined the isotopic ratios for each combination at the time of the explosion**
- **Found those combinations that within measurement uncertainties matched the air sample measurements –“the suspect combinations”**

Some Analysis Details

- Knew ^{241}Pu , ^{239}Pu , ^{241}Am values for each bag in 10/1985
- Needed to calculate values at time of explosion (2/2014). Complicated calculations done by Veirs
- To determine suspects formed “uncertainty ellipses”
 1. Calculated ratios for each combination
 2. For each combination i , the normalized differences are:

$$x_i = (\text{Air Monitoring (Pu240/Pu239)} - \text{Calculated(Pu240/Pu239)}) / 0.07997$$

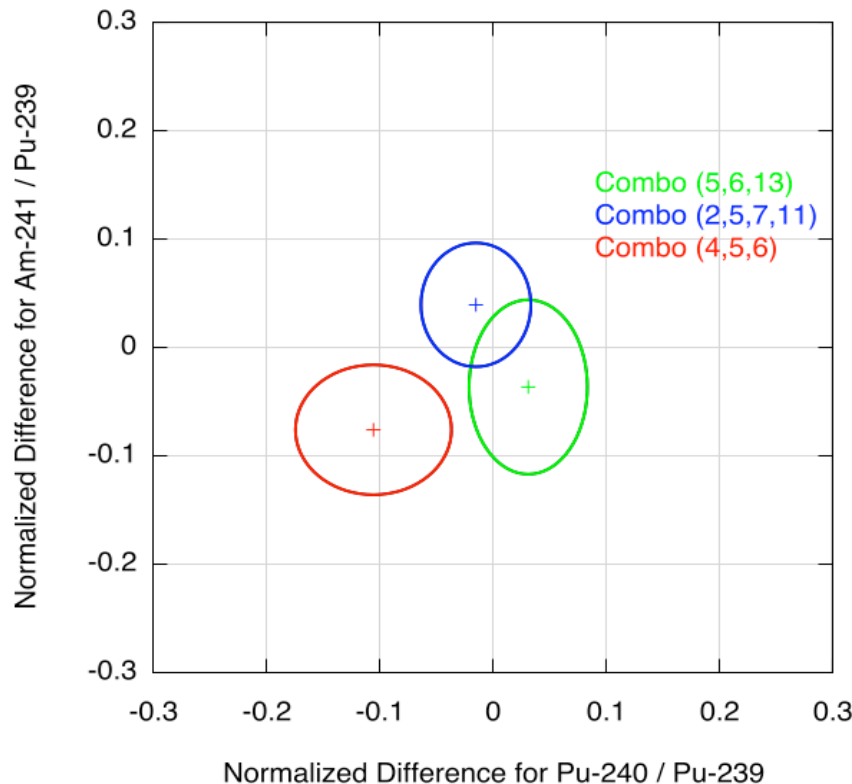
$$y_i = (\text{AirMonitoring(Am241/Pu239)} - \text{Calculated (Am241/Pu239)}) / 0.308$$

Uncertainty ellipses

- Uncertainty ellipses defined as

$$[(x-x_i)/3\sigma(x_i)]^2 + [(y-y_i)/3\sigma(y_i)]^2 \leq 1$$

- Where $\sigma(x_i)$ is the standard deviation of x_i and $\sigma(y_i)$ is the standard deviation of y_i

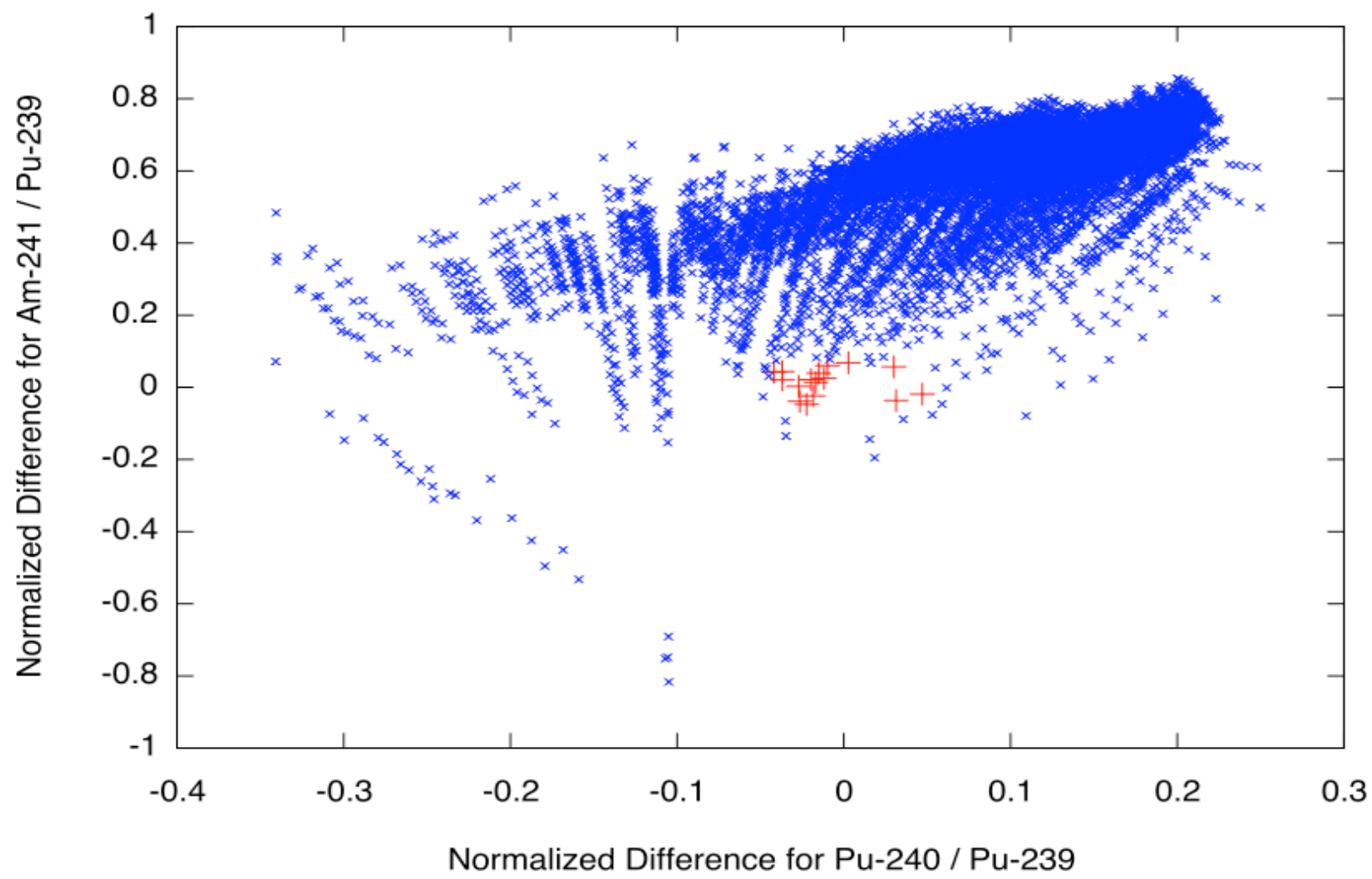


The **suspects** are those combinations whose uncertainty ellipses contain (0,0) (calculated value = sampled value)

The devil's in the details –

Finding $\sigma(x_i)$ and $\sigma(y_i)$ is not trivial.
Details provided in QQ /QE paper

The 15 Suspects



Evidence

- **Drum 68660 could have acted alone, but**
- **how did 68660 do it when experiments with surrogate materials from all 14 bags did not show a sufficient energetic reaction?**

Clues for Designing Experiments

Combination Size (# Bags)	# of possible combinations	# of suspects	percentage of total number of combinations that are suspects
2	91	0	0.00%
3	364	2	0.02%
4	1001	8	0.08%
5	2002	4	0.04%
6	3003	1	0.01%
7	3432	0	0.00%
Total	9893	15	0.15%

More Clues

		Bag #													
Suspect Combina- tion	# of Bags (s)	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	3	0	0	0	0	1	1	0	0	0	0	0	0	1	0
2	3	0	0	0	0	0	1	1	0	0	0	0	0	1	0
3	4	0	1	0	0	1	1	0	0	0	0	1	0	0	0
4	4	0	1	0	0	1	1	0	0	0	0	0	0	1	0
5	4	0	1	0	0	1	0	1	0	0	0	1	0	0	0
6	4	0	1	0	0	0	1	1	0	0	0	1	0	0	0
7	4	0	1	0	0	0	1	1	0	0	0	0	0	1	0
8	4	0	0	1	0	1	1	0	0	0	0	0	1	0	0
9	4	0	0	1	0	1	0	1	0	0	0	0	1	0	0
10	4	0	0	1	0	0	1	1	0	0	0	0	1	0	0
11	5	0	0	1	0	1	1	1	0	0	0	0	1	0	0
12	5	0	0	0	1	1	1	1	0	0	0	1	0	0	0
13	5	0	0	0	1	1	1	1	0	0	0	0	1	0	0
14	5	0	0	0	1	1	1	1	0	0	0	0	0	1	0
15	6	0	1	0	1	1	1	1	0	0	0	0	1	0	0
TOTAL %		0 0%	6 40%	4 27%	4 27%	11 73%	13 87%	11 73%	0 0%	0 0%	0 0%	4 27%	6 40%	5 33%	0 0%

The Summation (August 21st 2014)

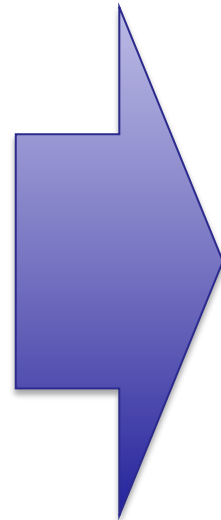
(two weeks after the call)

- **Isotopic ratios observed at WIPP at time of explosion could come solely from drum 68660**
- **Start experiments with four or five bags**
- **Most probable bags are 5, 6, and 7 in combination with one or two from {2, 3, 4, 11, 12 and 13}**

The Verdict – November 9, 2015

- **Surrogate material representing a probable subset of bags resulted in a reaction sufficient to cause the explosion of drum 68660 !!!**
 - “It turns out that a mixture made from four bags (6, 7, plus 4 and 13) is reactive at room temperature on the drum scale. This represents a very improbable event. So all of your work is paying off.”
- **Scientists concluded that “an unusual combination of potentially reactive bags went into 68660, whereas the less reactive bags went into the sister drum.”**
- **Perfect Storm**
 - Improbable combination
 - Organic kitty litter
 - Packaging environment

68660 was made in December 2014
remained outside in extreme cold
sent to WIPP in late January (still very cold)
warmed up in WIPP



Drums with Nitrate Salts, Pu, Am, organic kitty litter and neutralizer remain – 60 at Los Alamos

An image of the remediated nitrate salt waste that is being processed to eliminate the hazardous characteristic of ignitability that it bears.

40 remediated, 20 to go



113 Drums at a Texas Commercial Waste Site – Andrews, Texas

- DOE Studying Pathway for Combustible Waste Stored in Texas
 - The study is intended to “determine the path forward”
 - “Nothing has been determined at this point”



Questions?



QQ/QE paper available at
<http://www.tandfonline.com/eprint/BdEtkCVYPi984VaMdNzJ/full> or
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