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Drum breach: Operational temporalities, error politics and WIPP's kitty litter nuclear waste accident

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Abstract

In February 2014 at the WIPP transuranic waste repository in New Mexico, a drum erupted in fire. It exposed 22 people to radiation, shut down the underground facility for 35 months and cost the United States over a billion dollars. Heat and pressure had built up in the drum due to chemical reactions with an organic kitty litter, *Swheat Scoop*, which had been mistakenly added to it at Los Alamos National Laboratory, the birthplace of the atomic bomb. This article disrupts two prominent narratives: (a) that the accident was induced by a typographical error made after a waste packaging operations supervisor misheard 'inorganic kitty litter' as 'an organic kitty litter' during a meeting, and (b) that it was induced primarily by 'mismanagement' at WIPP, Los Alamos and the DOE's New Mexico field offices. It does so by exploring how a series of overambitious political initiatives, fraught labor relationships, financialized subcontracting arrangements and US Department of Energy (DOE) performance incentives set the stage for Los Alamos's notorious error by accelerating US waste packaging, shipping and repository emplacement rates beyond systemic capacity. Attention to *operational temporalities* shows how an often-overlooked nexus of schedule pressures, political-economic imperatives and regulatory breakdowns converged to modulate nuclear waste management workflows and, ultimately, trigger a radiological accident.

Keywords

nuclear waste, accidents, temporality, regulation, subcontracting

Just before midnight on Valentine's Day 2014, a nuclear waste drum burst open deep in the United States Department of Energy (DOE)'s Waste Isolation Pilot Plant (WIPP) geologic repository just outside of Carlsbad, New Mexico. Built in an underground salt

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deposit, WIPP is the final resting place for much of America's transuranic[1] defense nuclear waste: a hodgepodge of residues, soils, rags, gloves, tools, clothing, debris, cleaning supplies, and other items contaminated with radioactive elements during US nuclear weapons production and waste reprocessing operations. When the drum erupted, it spewed out radionuclides and fire for over two hours. Plastics and cardboards burned. The repository's underground Continuous Air Monitor alarms went off. Its ventilation system began automatically filtering underground air. Small quantities of radionuclides escaped to the surface through a defective damper on a vent. The next morning, one hundred forty people were onsite, standing outside. They were unaware of what had happened the night before. Radionuclides were detected aboveground. A shelter-in-place order was given. Twenty-two people received minor radiation doses. DOE accident investigators were on the scene, but for a different reason: Nine days earlier, a truck used for hauling salt had caught on fire underground. After nearly fifteen years of smooth operations, the WIPP repository had two major incidents, only days apart.

In 2015, a report from the DOE's Accident Investigation Board identified 'thermal runaway' as the scientific cause of WIPP's 'drum breach' accident (Department of Energy [DOE], 2015a: 215). The drum, #68660, had been shipped to WIPP from Los Alamos National Laboratory, the DOE laboratory famous for building the Manhattan Project's first atomic bombs. The drum saw a buildup of heat and pressure due to exothermic reactions between its nitrate salt waste contents and a wheat-based kitty litter named *Swheat Scoop.* The *Swheat Scoop* had been added to it at Los Alamos's Waste Characterization, Reduction and Repackaging Facility (WCRRF). WCRRF was supervised and staffed by the private subcontractor EnergySolutions, which – attempting to absorb liquids and prevent chemical reactions in the drums – mistakenly used organic *Swheat Scoop*, rather than the inorganic zeolite clay kitty litter recommended to them. They also added an organic acid neutralizer, *triethanolamine*, which reacted with the nitrate salts. As a Los Alamos manager joked, the lab accidentally 'made 700 dirty bombs, but only one worked'. After weeks of heating up, drum #68660 experienced an 'energetic event' – to use DOE terminology – and 'deflagrated' more than three hundred miles south of Los Alamos and more than two thousand feet below Carlsbad's surface. The DOE shut down the repository for decontamination and safety culture recovery for nearly 35 months. Waste shipments to WIPP from across the US nuclear weapons and national laboratories complex – from Oak Ridge National Laboratory, Idaho National Laboratory, Hanford, Savannah River and elsewhere – were backed up. The *Los Angeles Times* estimated that the accident's total cost would exceed two billion dollars (Vartabedian, 2016).

This ethnographic case study will unwind the complex tangle of personalities, political conditions, chance events, financial incentives, legal agreements, scientific considerations, chemical reactions, and institutional pressures that converged to destroy Los Alamos waste drum #68660 that February night. It has emerged from 68 unstructured interviews conducted in New Mexico, Idaho and Washington DC from 2017 through 2019. Interviewees include current and former personnel from WIPP, the DOE, Los Alamos National Laboratory, Idaho National Laboratory, the US Environmental Protection Agency (EPA), critical public interest groups, media outlets, the Carlsbad Environmental Monitoring & Research Center and various private waste cleanup

contractors. Interviews were recorded at informants' offices, homes or – more often – at local pubs, restaurants or cafés. I supplemented these interviews by observing and taking notes at public hearings, meetings and workshops on transuranic waste management.[2] My aim was to (a) understand my informants' perspectives on drum breach accident causation and then (b) compare and contrast their perspectives with the DOE's Accident Investigation Board's analysis of the root causes of WIPP's 2014 drum breach. My ethnographic inquiry revealed stark contrasts between my field informants' articulations and the DOE's official accounts.

I introduce the term *operational temporalities* to gesture to a nexus of political-economic forces, schedule pressures and regulatory gaps that – while largely ignored by DOE accident investigators – have modulated the pace of US transuranic waste management operations over the years. Drawing from STS literatures on accidents, safety culture and temporality, the article will describe how heightened operational temporalities converged to set the stage for WIPP's 2014 accident. It will then scrutinize the drum breach's ongoing politics of error – its post-accident contestations about causation and culpability – by deconstructing two prominent narratives: (a) that the drum breach was induced primarily by a typographical error made after a WCRRF waste repackaging supervisor misheard the phrase 'inorganic kitty litter' as 'an organic kitty litter' during a meeting and (b) that the drum breach was induced primarily by 'mismanagement' at WIPP, Los Alamos National Laboratory and the DOE's field offices in New Mexico. This will reveal how a reductive overemphasis on these two factors – in the DOE's Accident Investigation Board's 2015 report, in articles written by DOE insiders and in influential media outlets – overshadowed systemic shortcomings in the nuclear weapons complex's waste management process that went unaddressed in the accident's aftermath. These blind spots, the article concludes, are temporal in character: They implicate DOE's schedule-driven approach to transuranic waste cleanup subcontracting and performance incentives and how they too often stoke pressures to uphold rapid temporalities of waste cleanup, repackaging, shipping and disposal at the expense of regulatory compliance and worker safety.

Operational temporalities

Understanding WIPP's 2014 radiological accident requires attention to heterogeneous temporalities (Schrader, 2015: 684; Traweek, 1992) and timescapes (Adam, 1998): attention to how various scales and horizons of time – electoral cycles, productivity deadlines, communication speeds, transportation schedules, radioactive half-lives and more – can affect the pacing of waste management practices. These cleanup efforts are led by the DOE's Office of Environmental Management, responsible for 'legacy' wastes left behind from decades of nuclear weapons production. This waste has been stored at DOE sites and laboratories. Since WIPP opened in 1999, the drums have undergone pre-shipment repackaging procedures to comply with its Waste Acceptance Criteria rules. This involves removing 'parent' drums from storage and approximating their contents through radiographic imaging, 'Acceptable Knowledge' data about the waste's origins and visual inspections of the opened drums on glovebox trays. After that, the wastes are repackaged into 55-gallon containers called 'daughter drums' and shipped on America's highways to

Carlsbad, where they are emplaced underground at WIPP. This system is overseen by the DOE's National Transuranic Program and its Central Characterization Project, which are responsible for ensuring that the wastes are suitable for disposal. These organizations are based at the DOE's Carlsbad field office, which also oversees WIPP's private management contractor Nuclear Waste Partnership.

During my fieldwork, I tracked how a series of political, financial, ecological, regulatory, interpersonal, technological, and organizational forces mediated the US transuranic waste complex's repackaging, shipping and repository emplacement rates over time. Studying these *operational temporalities* revealed how entanglements of schedule pressures can accelerate or decelerate the workflows of waste cleanup staff, office employees, subcontractors, administrators, middle managers, regulatory compliance specialists, and other personnel. It showed how a constraint of temporal form (Riles, 2010) can shape nuclear risk governance (Beck, 1987) and how the structuring agencies of schedules can frame workplace behaviors (Luff et al., 2000) and expectations (Borup et al., 2006). It demonstrated how 'time-binding mechanisms like money and legal procedure' (Luhmann, 1976: 151) can endow organizations with 'social and structuring continuity' across time 'as each present moment transitions to the next' (Kinsella, 2020: 524). Research at this nexus can bring social scientific literatures on nuclear waste accidents into closer dialogue with Science and Technology Studies scholars' growing interests in temporality (e.g. Kowal et al., 2013; Schrader, 2015; Tousignant, 2013; Wajcman, 2019; Whitney, 2019).

Yet operational temporalities are not just about deadlines and timetables. Prior to WIPP's 2014 accident, pressures to stay on schedule – widespread among technicians, managers, politicians, subcontractors, and DOE officials – were reinforced by explicit institutional incentives to hasten the pace of waste disposal operations, as well as implicit pressures to deviate from regulatory protocols and safety standards expected of high-reliability organizations (Roe and Schulman, 2008). At issue, then, are the subtle ways that financial bonuses, regulatory oversight gaps, management strategies and political agendas can intersect to generate self-defeating fixations on performance milestones. Rapid operational temporalities do not, on their own, generate operational risks any more than slow operational temporalities prevent them. But studying how political-economic pressures interacted with workflow speeds can reveal an often-overlooked array of incentives that entice US nuclear waste organizations to accelerate productivity without commensurately expanding quality control, regulatory oversight, or operational safety mechanisms. Incentivizing the former while neglecting the latter can lead to accidents. Boeing's recent 737 Max crashes and fraught Dreamliner 787 rollout, for instance, emerged from contexts in which 'safety had been compromised in a rush to complete' and 'pressure for speed' resulted in operational 'sloppiness' (Barbaro and Toeniskoetter 2020). Indeed, '[l]arge technical organizations' tend to 'prioritize meeting deadlines and fulfilling production targets' – and establish 'internal reward structures' that reflect these priorities – when large 'revenue streams are at stake' (Gusterson, 2011b).

Fortunately, there are rich precedents for examining the temporalities of nuclear waste management organizations. Plutonium-239 has a half-life of 24,100 years; uranium-235, over seven hundred million years. These 'exceptional temporal schemes' (Saraç-Lesavre, 2016: 25) have sparked productive debates about the ethical, regulatory and epistemic

challenges of protecting distant future generations from radioactive inheritances (Ialenti, 2020a).[3] Nuclear waste repositories require many decades of organizational continuity throughout their R&D, construction, licensing, operations and decommissioning phases (Pescatore and Vári, 2006). These long-term institutional planning horizons have sparked productive debates about intergenerational equity (Shrader-Frechette, 2005), multi-decade budgeting strategies (Saraç-Lesavre, 2016), long-term repository 'megaproject' evaluation (Lehtonen, 2015) and the transmission of nuclear waste expertise to successors amidst intergenerational workforce turnover (Ialenti, 2020b).[4] Yet nuclear waste risks entangle with the shallower time horizons of contemporary sociopolitical processes too.[5] These include the short-term timescales of litigation and political cycles (Downey, 1985; Jacob, 1990), policymaking (Chilvers and Burgess, 2008; Macfarlane, 2003), public participation (Endres, 2009) and fluctuations in public trust in nuclear experts, technologies and institutions (Downey, 1988; Gusterson, 2000; Kinsella, 2016).

This nexus of time horizons – the multi-millennial, the intergenerational and the sociopolitical – animates US transuranic waste operations. Krupar's (2011) work on the Rocky Flats plutonium production plant's decommissioning, for example, examines the Colorado site's contamination with radically long-lived radioactive elements, its conversion into a recreation area for future generations and its transformation from an 'industrial territory' to a 'wild space' in the shorter-term horizons of public discourse. However, to uncover the causes of WIPP's drum breach accident, one must zoom in even further, directing analysis to a subtly different nexus of organizational contexts, temporal coordinates, and political-economic incentives. This means bringing these questions to bear on the day-to-day, hour-to-hour, and minute-to-minute tempos of the US transuranic waste management complex's most mundane operations: examining sociotechnical practices of removing decades-old waste drums from storage, opening them, inspecting them, repackaging them, filling out paperwork, shipping them to Carlsbad, filling out more paperwork and then, finally, emplacing them permanently in WIPP. These low-profile, everyday routines of cleanup, scheduling, documentation, subcontracting, accounting, performance bonus compensation and project management have plodded on quietly since WIPP began accepting waste in 1999. They are the contexts of ordinary (Lynch, 1993), situated (Suchman, 1987), and practical (Soler et al., 2014) action – mediated by subcontractor financing frameworks and varying degrees of regulatory oversight – in which drum breaches and other accidents take root.

Social studies of nuclear safety culture (Perin, 2005) and nuclear accidents (Perrow, 1984) have examined operational practices in nuclear power plants. Baker et al. (1994) have studied the temporal relationships between plant operator errors and lengthy, fatigue-inducing work shifts. However, matters of operational temporality remain largely unstudied in contexts of nuclear waste management. This is, in many ways, understandable. Transuranic waste operations proceed behind guarded fences, administrated by the DOE's often opaque culture of national security. The non-classified grey literatures about this work – DOE project evaluations, laboratory technical reports, policy documentation and press releases – often erase their own authorship, concealing the identities of the managers, contractors, experts, technicians, and operators that produce it. These reports are monitored by critical public interest groups like the Los Alamos Study Group, NukeWatch New Mexico and the Southwest Research & Information Center. However,

transuranic waste operating cultures mostly avoid academic scrutiny. This gap in analysis mirrors a temporal divide within the DOE. The complex's top experts have long focused more on WIPP's 'post-closure phase': analyzing repository designs, plotting out safety concepts and hyperconstructing (Gusterson, 2008: 559) models of how WIPP's engineered components could interact with geophysical conditions for ten thousand years following the facility's decommissioning. WIPP's near-future 'operational phase' – its everyday waste exhumation timelines, repackaging schedules, shipping rates and repository disposal tempos – has long been seen as comparatively straightforward: more the province of logistics-oriented private subcontractors ('implementers') than PhD-holding national laboratory scientists. During an interview, a former Sandia National Laboratories scientist contrasted this operations phase work with 'real science', half-jokingly describing it as 'tedium and boredom' spurred on by 'some nincompoop in the corner yelling "Hurry up! We have a goal on a chart!"'

WIPP's February 2014 drum breach brought greater attention to transuranic waste operations. Soon after WIPP shut down, a 'Technical Assessment Team' of experts from five DOE national laboratories conducted experiments and literature reviews to help discern the accident's causes. At DOE Headquarters in Washington DC, the Deputy Assistant Secretary for Safety, Security and Quality Programs commissioned two investigations. Phase 1 focused on how radiological materials escaped from WIPP and were released into New Mexico's ecosystems. Phase 2 examined the causes of the drum breach itself. The investigators conducted interviews and reviewed documents, videos and photographs – subsuming this evidence to DOE methodologies of 'causal factors analysis, barrier analysis, change analysis, root cause analysis, Integrated Safety Management (ISM) analysis and Human Performance Improvement analysis'. Their task was to 'identify relevant facts; analyze the facts to determine the direct, contributing and root causes of the event; develop conclusions; and identify Judgments of Need for actions that, when implemented, should prevent recurrence of the accident' (DOE, 2015a: 13). However, they were required to 'confine their analyses to the accidents themselves' by not factoring in 'larger, structural problems within the [DOE] and its contractors that created the environment in which these accidents could happen' (Klaus, 2019: 197). This restricted the investigation's scope from problematizing key political-economic drivers that ultimately proved central to accelerating WCRRF's and WIPP's operational temporalities. The result was a narrowly framed analysis that failed to address many of the accident's root causes.

The sections to follow reinsert systemic questions about the US transuranic waste cleanup complex's operational temporalities back into the DOE's official representations of WIPP's 2014 drum breach. This is a response the DOE's bureaucratically circumscribed genre of accident reportage, which, as a retired scientist who worked with WIPP put it, '*always* avoids fingering the root cause and the people responsible' by 'never criticizing the broader system' or 'blacklisting' those who break protocol. By conducting its inquiry internally, the DOE was, as New Mexico's former Environment Department Secretary Ryan Flynn saw it, 'investigating itself' (Oswald, 2014). This was enabled by the DOE's lack of external oversight. The US Nuclear Regulatory Commission (NRC) – which oversees the commercial nuclear energy sector, but, for the most part, not the

nuclear weapons complex – has never conducted inspections of the DOE's transuranic waste operations. It has little authority over them, aside from its power to license waste shipping packages. The US Defense Nuclear Facilities Safety Board can make safety recommendations to the DOE but has no formal authority to enforce them. Radiological materials, governed by the US Atomic Energy Act of 1954, are exempt from all major national environmental laws. Under the 1992 Land Withdrawal Act, the US Environmental Protection Agency (EPA) was empowered to regulate aspects of WIPP's operations – setting WIPP's radiological dose limits and making facility permit decisions for hazardous waste operations at Los Alamos, Carlsbad and elsewhere. However, when enforcing the US Resource Conservation and Recovery Act (RCRA), the EPA's jurisdiction is restricted to the waste's non-radiological components. The EPA's RCRA enforcement functions are often delegated to state government bodies, such as the New Mexico Environment Department: an agency that failed to audit WCRRF's operational practices for two years prior to the accident.

By default, then, US transuranic waste operations and accident investigations are implemented, funded and overseen almost entirely by the DOE: a multiplex entity which includes its federal headquarters, its regional field offices, its national laboratories and its many private subcontractors.[6] Since its inception as the US Atomic Energy Commission in 1946, the DOE's nuclear weapons and waste complex has been managed and operated by prominent defense-industrial corporations. Sandia National Laboratories in Albuquerque – which develops non-nuclear components for nuclear weapons – was managed by a subsidiary of AT&T in 1949, a subsidiary of Martin Marietta (later Lockheed Martin) in 1993 and a subsidiary of Honeywell since 2017. Los Alamos National Laboratory was managed by the University of California from 1943 until 2006, when the DOE reissued its contract to the Bechtel-led company Los Alamos National Security, LLC (LANS).[7] The University of California managed Lawrence Livermore National Laboratory – a DOE nuclear weapons design lab in the San Francisco Bay Area – from 1952 until 2007, when it was replaced by Lawrence Livermore National Security, LLC (LLNS): a cooperation between Bechtel, the University of California, BWX Technologies and Amentum. Under LANS and LLNS, employees at Los Alamos and Livermore have reported feeling 'discouraged' from raising 'issues' about new policies 'lest any criticism endanger the managers' bonuses', as it is 'frowned upon' to broach 'any issue that would put the performance bonus at risk' (Gusterson, 2011a: 15).

The DOE's histories of military-industrial subcontracting are inextricable from its histories of environmental contamination. When DuPont ran the Hanford plutonium plant in 1945, managers accelerated operations by removing uranium fuel rods from cooling ponds after just five weeks rather than the recommended three months, causing it to release four times as many radioactive isotypes into the air, soil and river (Brown, 2013: 69). When the Dow Chemical Company managed the Rocky Flats plant from 1952 until 1975, nuclear waste drums were placed in outdoor fields, where they leaked into the soil and groundwater – or breached due to unvented gases (Krupar, 2011: 270). In 1957, Los Alamos personnel buried contaminated lab equipment, including significant quantities of uranium-238 and plutonium-239, in outdoor dirt pits and underground shafts – leaving no record of the waste's characteristics from 1957 to 1971 and poor records from

1971 to 1988 (Masco, 2004: 535). From 1954 to 1984, Idaho National Laboratory's nuclear waste injection wells pumped strontium-90, iodine-129, tritium, and other radioactive elements directly into the Snake River Plain Aquifer – a drinking water source for over three hundred thousand Idahoans (Idaho Department of Environmental Quality [Idaho DEQ], 2005). Chemical wastes and radioactive isotopes, including cobalt-60 and cesium-137, were dumped into the Idaho lab's unlined pits and left to percolate into the dirt (Environmental Protection Agency [EPA], 1991). During fieldwork, I asked a chemist who had worked for the Central Characterization Project about the DOE complex's mostly unwritten history of drum breach accidents. She told me this:

> There's been a number of events. Back in the 1970s, there was drum that lifted its lid at Argonne National Laboratory in Chicago. It was sitting in the back of a van. Suddenly the lid punched through the roof. Another time, there was a drum at Paducah [uranium enrichment facility in Kentucky] in the early 1980s. The drum tipped over, then exploded. It seems it was the uranium fines [fine particles or shavings] that did it.[8]

When I mentioned this to a chemist who worked for a nuclear waste analysis group in Carlsbad, he told me the following:

> The [DOE] complex has long failed to recognize that chemical reactions continue after you dispose of radioactive waste. This has led some pretty incompatible materials to be put together in drums. They had an incident in [Nevada] where they had waste sitting in a disposal cell for thirty years. Then they had a flood. Some water intruded into the disposal cell, which suddenly blew the waste drums out of the ground. This was due to improper disposal of sodium metal. The drum crossed the site boundary when it blew!

WIPP's 2014 radiological accident was not the DOE complex's first drum breach. Nor would it be its last. In April 2018, the DOE's 'Accelerated Retrieval Project' – a waste repackaging program at Idaho National Laboratory run by a subsidiary of the Fluor Corporation – had four drum breach accidents. They were triggered, in part, by accelerated operational temporalities incentivized by a similar set of political-economic imperatives. Fluor's internal investigation determined that 'lessons learned from the 2014 WIPP event' were not 'effective in strengthening processes': workers felt uncomfortable voicing concerns that could 'delay mission-related objectives' or 'impact cost or schedule' as 'schedule pressure was reinforced by multiple occasions of accommodations/agreements to waive or delay meeting requirements to not impact schedule' (Idaho Cleanup Projec Core, 2018: 1659). It found the Accelerated Retrieval Project to be lacking in 'documentation and procedures for key safety requirements' and 'focused on processing waste to meet milestone requirements rather than compliance with requirements' (vii). With the DOE's reward structures and histories of transuranic waste (mis)management in view, the next sections will explore how entanglements of national- and state-level political-economic agendas – interacting with workplace schedule pressures, local sociopolitical dynamics, regulatory gaps and political-economic imperatives – fostered an acceleration of Los Alamos' waste repackagers' operational temporalities from 2012 to 2014. These factors laid ground for avoidable errors and set the stage for WIPP's February 2014 breach accident.

The spirit of 3706

In 2011, Northern New Mexico's Los Conchas wildfires came within three-and-a-half miles of Area G, where Los Alamos National Laboratory stored transuranic waste in outdoor bubble tents. The state's governor, Susana Martinez, addressed the issue in television news conferences. Memories lingered of how, in 2000, the Cerro Grande forest fires took the homes of hundreds of local families and damaged laboratory buildings. Fears of future wildfires reconfigured Los Alamos's organizational frames (Eden, 2004: 50): it reoriented how the lab's managers identified, represented and approached operational practices. After the Cerro Grande fires, the lab developed Quick to WIPP, a program for accelerating transuranic waste shipments. After the Los Conchas fires, Governor Martinez sought further action from the DOE. In January 2012, the DOE and the New Mexico Environment Department proposed a joint solution: an 'action-oriented' Framework Agreement to accelerate the shipment of 3706 cubic meters of waste from Los Alamos to WIPP. If these deadlines were met, the DOE would issue the lab's management company, Los Alamos National Security, hefty performance bonuses (DOE, 2012a). During interviews, two managers recalled Bechtel sweetening the deal by offering handsome personal bonuses to senior directors. Motivating productivity through performance bonuses is common among federally-funded US military, security and intelligence contractors (Reno, 2020: 20–48). With these reward structures in place, incentives to rapidly repackage and ship Area G's transuranic waste were set. These efforts became known as the 3706 Campaign (Ialenti, 2018; Johns-Hughes et al., 2013).

Officials from the State of New Mexico and the DOE framed the 3706 Campaign's objectives in 'project-time', bounding it with scheduled milestones (Tousignant, 2013: 241). Los Alamos and its subcontractors were tasked with implementing it. New managers were hired to oversee the lab's environmental programs. Some were known for successfully accelerating shipments from Idaho National Laboratory to WIPP. The managers recruited a larger labor force and new operations supervisors from EnergySolutions, a Utah-based nuclear waste services company, owned by a private equity firm from New Jersey. EnergySolutions, alongside a small local environmental services company, helped recruit workers to execute the campaign. Collaborating with the lab's transuranic waste program, they sought to make the WCRRF waste repackaging facility operate around the clock, turning it into a 24/7 'production operation' (Romero et al., 2014).

One Los Alamos interviewee recalled how a Bechtel manager worried that rehiring the lab's existing employees would slow down progress. The manager saw longtime Los Alamos personnel as having 'cultural issues' left over from when the lab was run, supposedly less efficiently, by the University of California until 2006. He wanted schedule-driven EnergySolutions supervisors with business acumen running WCRRF. He sought workers who 'won't stop work every day' with nitpicking concerns. New workers, who often had little or no experience with radioactive waste, were hired from economically vulnerable regions of northern New Mexico and trained rapidly. The 3706 Campaign proceeded, to use Los Alamos interviewees' words, at a 'blistering' pace by following an 'aggressive schedule'. One lab employee recalled how, prior to the campaign, they were shipping three or so drums per week. By March 2012, however, they planned to make about 358 shipments in three years, at a rate of five or six per week (Johns-Hughes et al.,

2012). By the end of fiscal year 2012, they had already made two hundred thirty shipments. This far surpassed their initial target of 184 shipments. In March 2013, the head of Los Alamos's transuranic waste program described their plans to make a total of six hundred fifty shipments by June 2014 (Schecker, 2013). This approached, in just three years, the total number of shipments made during Los Alamos's entire previous twelve-years of shipping to WIPP.

Los Alamos's reputation for shipping out waste at a snail's pace was changing. Waste work had long been seen as lower in status at the lab than its higher-profile national security and scientific missions. But the lab's own *Los Alamos Science and Technology Magazine* now called the 3706 campaigners a 'world-class team of overachievers' who 'found ways to process the waste more efficiently' with 'remarkable results' (Schecker, 2013). However, the stage was also being set for errors. Safety culture is, in part, a story an organization tells itself about how to approach risky task environments (Rochlin, 1999: 125). At WCRRF, these safety stories were increasingly drowned out by stories of performance metrics, planning sheets and visual graphs charting the 3706 Campaign's great productivity. As one Los Alamos scientist put it, a 'little island' was being erected at WCRRF that 'isolated a high-performing group to meet a deadline'. The island was suddenly well-funded. A manager recalled how the lab's environmental budget had previously allocated about two-thirds toward environmental remediation and one-third toward waste. The 3706 Campaign reversed this ratio. Yet by funneling this money toward accelerating shipments rather than improving operational standards, the richer program did not necessarily become a safer program (Wildavsky, 1981).

Throughout my interviews, Los Alamos managers, lab scientists, workers, and technicians noted organizational deficiencies that, in their eyes, set the stage for WIPP's accident. Two managers lamented how it had been unwise to 'spin off' WCRRF to EnergySolutions, letting the subcontractor run, supervise and staff it with its own personnel, while leaving the directorate with only one quality control specialist (See also DOE, 2015a: D3, D14–D17). Others noted how WCRRF's waste repackagers were not in touch, day-to-day, with the lab's Area G waste storage personnel and how, as the number of laborers there grew rapidly, the number of supervisors overseeing them did not. Some explained how DOE's Central Characterization Project specialists rarely, if ever, bothered to visit WCRRF in person to evaluate operating procedure changes (DOE, 2015b: 7). Los Alamos and EnergySolutions personnel, interviewees noted, were reluctant to let them into the facility. Waste characterization specialists instead reviewed packaging procedure changes remotely through digital paperwork (DOE, 2015a: ES9, ES11, ES12, ES15). Others criticized, in hindsight, how WCRRF's EnergySolutions supervisors' hasty operational temporalities had been enabled by the now-fired lab managers' hasty rubber-stamping of new work procedures (DOE, 2015b: 8, 9). As Sagan (1993: 37) once noted, when 'pressure to maintain high production rates' takes precedence over safety or oversight, 'hasty-decision-making, violation of safety rules and jerry-rigged procedures' can lead to accidents.

The 3706 Campaign's myriad pressures infused a sense of urgency into WCRRF's operators' everyday 'knowledge-laden routines' (Eden, 2004: 3). Incentives to meet 3706 campaign deadlines began to overshadow everyday rituals of safety (Rochlin, 1999: 136). EnergySolutions supervisors did not halt work when waste repackagers

reported orange or yellow smoke and foaming chemical reactions (DOE, 2015a: ES8). Interviewees told of how a 'territorial' EnergySolutions supervisor would respond to concerned WCRRF operators with 'You're not a chemist, get back to work!' They told of a worker not being allowed to call medical help when he felt chest pain. They told of another who, when voicing safety concerns, was told something like: 'If you have a problem, there are plenty of people out there who would love to take your job!' One Los Alamos interviewee criticized the 'disgusting and demeaning' ways a 'gruff' EnergySolutions supervisor treated workers. Shaking his head, he said: 'You don't have to beat people into submission.'

Back when the 3706 campaign was in motion, however, few resisted the supervisor's strong personality. As a Los Alamos health and safety specialist put it: WCRRF was so successful in meeting 3706 Campaign milestones that nobody 'wanted to look' at its operations. This established an organizational gulf between Los Alamos lab scientists' deep understanding of chemical reaction risks and WCRRF's EnergySolutions supervisors' ignorance of them. Scientific ignorance became compartmentalized (Gross, 2010) such that once the WIPP drum breach's causes were discovered, WCRRF personnel reacted with surprise to an outcome that any chemist would have seen as obvious.

There were, however, several times at which Los Alamos's waste repackaging mistakes could have been fixed. WCRRF's operations were halted in March 2012 because scientists at Los Alamos's Carlsbad office discovered that EnergySolutions personnel were using an incompatible material called *Wastelock 770* to absorb liquids in the drums. The absorbent material contained sodium polyacrylate, an organic material. The scientists were concerned about fuel-oxidizer reactions between the organic *Wastelock* and the nitrate salt wastes: the same chemical process that would make Los Alamos drum #68660 erupt at WIPP two years later. They suggested that the WCRRF operators should instead use inorganic zeolite clay. In response, EnergySolutions supervisors began developing a new repackaging procedure. Yet, in the heat of the 3706 Campaign, they did so hurriedly. Their instruction sheet ended up requiring WCRRF operators to use 'an organic absorbent (*Kitty Litter/Zeolite*® absorbent)'. This was nonsensical: zeolite is inorganic not organic. As a scientific name for a mineral, it requires no '®' symbol. However, no Los Alamos scientists or managers flagged the procedure as flawed. Anxious to keep up with the 3706 Campaign's schedule, they simply rubber-stamped it. This lapse occurred in state of 'practical drift': a steady 'uncoupling of local practice from written procedures' (Snook, 2000).

A summary of WCRRF's revised repackaging procedure was then emailed to a waste characterization specialist in Carlsbad, though his formal approval was never required. A Carlsbad-based subcontractor soon noticed the organic/zeolite contradiction. When he raised the issue with his superiors, they directed his inquiry to the DOE's Carlsbad field office. The response was 'Oh that's just a typo', which led him to wrongly believe that 'organic' was a typo and that WCRRF personnel did, in fact, understand the need to use inorganic zeolite. As his colleague emphasized during an interview: at the time, the specialist had over one hundred fifty procedure revision requests from across the site on his desk, each marked with terms like 'major', 'minor', 'editorial', and 'non-technical'. Los Alamos's flawed procedure was not marked as important. Facing pressure to 'keep containers moving' into WIPP, he was unable to give the issue much time. As a consequence,

in September 2012, Los Alamos's WCRRF waste repackaging operators – following the uncorrected procedure instruction sheet – began using yet another organic absorbent: the infamous wheat-based *Swheat Scoop*.

Several interviewees speculated about why WCRRF personnel might have preferred *Swheat Scoop*. Some said zeolite was dusty and annoyed the workers. Others said previous absorbents' dust was clogging WCRRF's high-efficiency particle air (HEPA) system – slowing down productivity with frequent filter changing. Many confided that, with the 3706 Campaign's pressures high, it was simply quicker to drive down to Los Alamos's Smith's Grocery store when WCRRF ran out of formally procured absorbent, purchase the *Swheat Scoop* kitty litter sold there and haul it back to the lab in a worker's pickup truck. Organic newspaper-based kitty litter was also sometimes used. When I contacted the former WCRRF supervisor, I received no response. However, a former EnergySolutions insider who worked alongside her assured me that the supervisor simply misunderstood verbal instructions during a meeting and was never given the scientists' technical document recommending zeolite. After that meeting, the supervisor drafted the WCRRF procedure revision purely based on her memory and notes. When Los Alamos lab managers approved her procedure revision, she just assumed the instruction was correct and then got back to her job: meeting the 3706 Campaign's deadlines.

Most agreed that Los Alamos National Security, as the management contractor responsible for the project, was ultimately to blame for WCRRF's shortcomings. Fearing future wildfires and eager to collect the DOE's and Bechtel's bonuses, it failed to adequately train and oversee its subcontractors. This allowed gaps to open up between transuranic waste knowledge, policies and practices (Hoffman and Barrios, 2019). Feeling stretched too thin, workers, supervisors and managers became so accustomed to shirking regulations to meet highly valued deadlines that their illicit activities appeared, to them, unremarkable. A normalization of deviance (Vaughan, 1996: 5) took root, marked by an incremental acceptance of warning signs, which otherwise should have signaled that operational standards were declining. Breaching safety culture norms – such as failing to halt operations when operators express discomfort with them – became ordinary amidst Los Alamos's routinization of oversight gaps, enthusiasm for meeting DOE performance bonus deadlines, managerial pressures to speedily ship waste, empowering of scientifically inexperienced WCRRF supervisors and lack of appetite for workers questioning their bosses' orders. Yet the entanglements of schedule pressures driving the 3706 Campaign's accelerated operational temporalities extended outside of Los Alamos and Carlsbad as well.

Waste makes haste

Los Alamos lab managers' oversight gaps and EnergySolutions' knowledge gaps were exacerbated by DOE Headquarters' schedule pressures and the State of New Mexico's regulatory enforcement gaps. The DOE's Office of Environmental Management had not established a field office in Los Alamos. It only had a field office for the US National Nuclear Security Administration: the DOE division responsible for defense nuclear science. Personnel there attended more to nuclear weapons and national security than to environmental cleanup and waste. This helped the 3706 Campaign proceed unhindered.

In summer 2015, a post-accident internal review at Los Alamos discovered several hundred RCRA regulatory violations. A WIPP interviewee criticized how Governor Martinez had 'wiped out' and replaced certain New Mexico Environment Department personnel who had rich knowledge of WIPP. Steve Zappe, who had a background in geophysics and RCRA compliance, had been known for his strict enforcement of WIPP's Hazardous Waste Facility Permit. When Governor Martinez took office in 2011, Zappe was reassigned to the New Mexico Environment Department's Food Safety program. A new technopolitical regime (Hecht, 1998: 55) was installed to facilitate the 3706 Campaign's momentum.

When a new manager arrived at Los Alamos from Idaho to help restore the lab's transuranic waste program's operating culture after the accident, he was startled by its 'abysmal' understanding of RCRA. He sent one hundred people to the nearby Buffalo Thunder resort for an intensive, three-day RCRA training course. Prior to the accident, however, the 3706 Campaign was portrayed to outsiders as 'highly successful' (Johns-Hughes et al., 2014). A WIPP interviewee recalled how Governor Martinez had been 'very vocal' about the 'great things' she was accomplishing. In June 2012, Los Alamos's transuranic waste program threw a 1000th Shipment Celebration party featuring the governor (DOE, 2012b). The lab made a promotional video about the 3706 Campaign featuring EnergySolutions supervisors. At a 2013 Waste Management Conference in Arizona, the secretary of the New Mexico Environment Department called the campaign a 'regulatory partnership' and heralded 'collaboration' as the key to its success (Martin, 2013). A Mission Accomplished party for the 3706 Campaign's on-time completion was prematurely planned. The DOE's '15 Years of Safety Operations at WIPP' medals were prematurely minted. Enthusiasm for these celebratory rituals came to overshadow the everyday safety rituals of a strong organizational culture (Rochlin, 1999: 136).

Los Alamos's and WIPP's transuranic waste teams' hasty operational temporalities entangled with New Mexican state politics too. Many interviewees suggested Governor Martinez was expedient in scheduling the 3706 Campaign's June 2014 deadline to coincide with her re-election campaign. By 2011, Los Alamos had become irrecoverably behind on several commitments outlined in the DOE's and State of New Mexico's 2005 Consent Order for environmental cleanup (New Mexico Environment Department [NMED], 2012). These delays had been due, in part, to yearly Congressional funding constraints (Department of Energy and New Mexico Environment Department [DOE, NMED], 2012). The 3706 Campaign doubled as a way for Los Alamos and the DOE to make up for some of their past slowness. As a former New Mexico State Representative recalled in an interview: the 3706 Campaign allowed the DOE to publicly demonstrate that it could at least accomplish *some* major environmental goals by mid-2014. With these 'negotiations between temporal and social orders' (Kowal et al., 2013: 471) as a backdrop, making good on the 3706 Campaign's deadlines could, it was thought, give the DOE leverage when seeking leeway from the State of New Mexico in 2015, when the Consent Order for cleanup would be re-negotiated (NMED, 2016).

Pressures to hasten WCRRF's operational temporalities did not, however, trickle down only from New Mexico's political leadership. A WIPP manager who worked with the DOE's National Transuranic Program recalled how, in the mid-2000s, his colleagues assumed that the vast majority of transuranic waste could be removed from all major

DOE sites, with the exception of Hanford, by 2018. WIPP's operational life was initially projected to last only twenty-five years (Waste Isolation Pilot Plant [WIPP], 1984: 1). Had WIPP been intended to operate longer, he suggested, more funds would have been put toward facility upkeep – but a 'run to failure' mentality took hold instead. When 2009 Recovery Act federal stimulus funding became available, it had to be used for 'shovel-ready' local economic revitalization projects. Inés Triay, the DOE's Assistant Secretary for Environmental Management, created jobs by accelerating waste shipments from Hanford, Savannah River, Idaho and elsewhere to WIPP (Triay and Anderson, 2009). Reflecting on these initiatives, a WIPP manager told me how the repository had initially been designed to accept seventeen contact-handled waste emplacements per week, plus two remote handled emplacements.[9] Yet, in the weeks leading up to the accidents, it was accepting about thirty and five, respectively. By 2014, WIPP had 'exceeded the designed shipping rate' by accepting about twenty-five per week, reaching maximums of up to thirty-six per week (DOE, 2019: 8, 9).

Several interviewees recalled how, as waste emplacement rates rose, Carlsbad's Skeen-Whitlock building – home to the DOE's regional field office, WIPP's management contractor Nuclear Waste Partnership and the DOE's National Transuranic Program – was overwhelmed by paperwork, shipment volumes and pressures from DOE Headquarters to help uphold economic stimulus imperatives. The Carlsbad field office's technical assistance functions began to overshadow its oversight duties (DOE, 2015a: ES11, 59). After drum #68660 erupted on February 14, 2014, the building was abuzz with hypothesizing, debates about accident scenarios and scientific disagreement. Amidst this confusion, Los Alamos personnel drafted a plan, with the help of the Carlsbad field office, to continue the 3706 Campaign. Under pressure to, in an EnergySolutions insider's words, meet the 'governor's goal', the DOE, as a specialist at WIPP put it, wanted to 'make a deadline'. Key WIPP managers advocated for the campaign's continuation, as did officials at DOE Headquarters, such as Frank Marcinowski: a top policy and regulatory affairs director. JR Stroble, the Director of the DOE's National Transuranic Program, lauded the plan, as did the New Mexico Environment Department Secretary Ryan Flynn and Senator Tom Udall (Fletcher, 2014). In early April 2014, the 3706 Campaign waste shipments resumed, re-routed to a private nuclear waste repository in West Texas run by Waste Control Specialists, LLC, where they were to sit until WIPP reopened (EPA, 2014).

The rationale for continuing the 3706 Campaign was straightforward. The most likely accident scenario – DOE, Los Alamos and WIPP officials assumed – was that salt, rock, or a roof bolt had fallen from the repository ceiling and punctured the drum from the outside. If that were to be the case, the accident would not have been caused by a chemically reactive cocktail of materials inside the drums and shipments could continue. There was, however, little evidence to support that assumption. A WIPP subcontractor recalled 'vigorous discussion' – among Los Alamos and WIPP leadership plus DOE officials from Washington DC and Carlsbad in the weeks following the accident – about whether it was wise to re-route shipments to West Texas simply to meet campaign deadlines. Another interviewee – a chemist – recalled exclaiming 'of course!' when the DOE's Los Alamos field office asked him in April 2014 whether organic kitty litter could react dangerously with nitrate salt wastes. He told me how his boss, a now-fired Bechtel lab

manager, became furious when he learned that he had communicated with the DOE's Los Alamos field office without his permission. Meanwhile, in Carlsbad, scientists asserted that it was impossible for rocks or roof bolts to travel at speeds fast enough to break open a drum and disperse significant amounts of radiological materials throughout the facility and several miles downwind. As a chemist argued in March 2014:

> I knew right away … I'm going: 'You turned your waste into cigarette smoke.' That only happens when you have a really violent explosion. This is not 'Oh, some rock salt fell on a drum.' … But everyone else was in denial: 'Oh no you can't say it's the waste's fault.' I had people in the WIPP building screaming at me so much that spittle was coming out of their mouth. Pounding on my desk, saying 'You quit this! It was not the waste.' They were really bent out of shape. … The 3706 Campaign had everything to do with it. Schedule pressure always causes them to take shortcuts.

When 3706 Campaign waste shipments were ordered to proceed, a WIPP contractor felt shocked: 'Some people couldn't believe our ears: They just said, 'Yeah, we're just going to ship it?' … I would have said, "Stop everything and figure it out." I think [WIPP's management] was getting lots of pressure from [DOE] HQ.' Within a few weeks, it became clear that the chemists were correct: A drum with chemically reactive contents had, in fact, erupted with fire from the inside. The DOE suspended the shipments on May 2nd. Managers at the West Texas repository then realized that the 113 drums they had just received from Los Alamos contained *Swheat Scoop* and that storing them was illegal under their facility's RCRA permit from Texas's Commission on Environmental Quality. The drums, potentially ignitable during transportation, could not, legally, be shipped to WIPP either. In 2017, the DOE began paying Waste Control Specialists over $19-million over a two-year period for storing the drums at their West Texas facility (DOE, 2017). A retired DOE scientist recalled how a 'lax individual' at the DOE's Carlsbad field office, once overly 'motivated to get 3706 done', quietly left his position after it was derailed. The decision to continue the 3706 Campaign was a breach of 'chronological accountability' (Whitney, 2019: 281): a failure to reflexively reconsider past decisions and the deadlines attached to them, in light of new information and changing circumstances.

Error politics

The DOE's official accident report, released in April 2015, revealed the recklessness of activities once white-boxed (Wynne, 1988) in artificially tidy reports.[10] Los Alamos National Security, the report explained, had failed to implement many of the DOE's Carlsbad field office's work process controls, as well as those in its Hazardous Waste Facility Permit from the New Mexico Environment Department. The DOE's Los Alamos field office and its Carlsbad-based National Transuranic Program had failed to ensure the adequacy of WCRRF's waste repackaging procedures. The DOE's Central Characterization Project in Carlsbad had failed to compile adequate 'Acceptable Knowledge' information about its mixed inorganic nitrate salt drums. EnergySolutions, Los Alamos National Security and the DOE's Los Alamos field office had lacked healthy safety cultures (DOE,

2015b). WIPP's accident was self-revelatory: It exposed the previously hidden histories that set the stage for it (Garcia-Acosta, 2002). It divulged 'uncertainties that are so easy to ignore when things work well' and created opportunities for institutional learning (Stilgoe, 2017: 27). Seeing the error in his ways, a specialist from Los Alamos's Area G waste storage area explained that he now regrets succumbing what he calls the 'puppydog effect': During the 3706 Campaign, he had reveled so much in the pats on the back he was receiving for meeting deadlines that he began to over-focus on schedule over safety. Los Alamos's and Carlsbad's transuranic waste programs spent months implementing the report's dozens of 'corrective actions' and 'judgments of need'.

Yet the DOE's accident report had blind spots. While it noted in passing how the 3706 Campaign's operations hinged on 'high workload and time stress' and focused on 'budget, financial and schedule performance versus operational oversight' (DOE, 2015a: 180, 202), it mostly downplayed the 3706 Campaign. The number 3706 appeared only ten times in the 394-page pdf document. The 3706 Campaign was never explicitly mentioned in its eighteen-page executive summary, in its description of the accident's root causes, or in its 'Conclusions and Judgments of Need' table. The campaign was first broached in a short paragraph under the heading 'Relevant LANL and WIPP History' on Page 19 – the pdf document's 55th page. Casting the 3706 Campaign as an infrequently mentioned sideline item, the DOE failed to identify it as a 'local root', a 'systemic root', or a 'contributing' cause of the accident. As a retired DOE Headquarters official told me: it would be 'out of [the Accident Investigation Board's] lanes' to suggest that the DOE 'shouldn't be doing major campaigns' like 3706. It would not be 'okay', he continued, 'for *any* DOE accident report to criticize the "campaigns" concept itself'. These omissions, as well as the bureaucratically circumscribed genre of DOE accident reportage that enabled them, can be read as subtle plays in the civic theater or ritual politics of culpability (Jasanoff, 2005) – the drama of assigning 'blame for failures and credit for successes' (Sagan, 1993: 23) – that often follows accidents.

Projecting auras of bureaucratic objectivity (Weichselbraun, 2020), the DOE's accident report emphasized demarcations between DOE officials (presenting them as outside observers watching cleanup efforts unfold) and the complex's operations (presenting them as an external field over which the DOE could serve as a neutral judge). In practice, however, these entities were inextricable. Seemingly autonomous organizations like Los Alamos, its subcontractor EnergySolutions, the DOE's field offices in New Mexico and WIPP's management contractor Nuclear Waste Partnership were interdependent nodes in a wider socio-technical system (Hughes, 1983). Still, when the DOE translated a 'seamless flow of action' into a 'discursive justification' for wrongdoing (Law and Mol, 2002: 97, 98), it separated itself from the accident. The report criticized DOE Headquarters' failure to establish proper 'line management' over regional operations in New Mexico (DOE, 2015a: ES-8). However, it mostly ignored how its own cleanup complex's operational temporalities were accelerated by its own policies of (over)compensating for decades of cleanup inaction and of waste production with insufficient concern for its implications: It expedited waste emplacement at WIPP. The report thus failed to fully portray how the 3706 Campaign – with its sped-up waste shipment tempos, hands-off managerial oversight, routine regulatory violations and schedule-driven subcontractors – established conditions that enabled WIPP's 2014 accident.

In July 2019, David Klaus, the DOE's former Deputy Under Secretary for Management and Performance who oversaw the accident investigations before his 2017 retirement, published an article rejecting the 3706 Campaign's role in the accident. Klaus's article (2019: 200) briefly acknowledged how the 'pressure of deadlines' and the 'potential for financial bonuses' can 'bring out problems in an organization'. It shrewdly criticized how the 2000 NNSA Act established an 'operational fence' between the National Nuclear Security Administration and the rest of the DOE, including its Office of Environmental Management. Yet it ultimately presented these structural shortcomings as factors which merely 'compounded' the more 'fundamental' cause of WIPP's 2014 accident: 'management failure' at Los Alamos National Laboratory, combined with a general erosion of WIPP's operating culture. Like the DOE's accident report, Klaus's article barely addressed the US transuranic waste cleanup complex's incentive structure, lack of regulatory oversight, or temporalities of operation. It therefore lacked an explanation of why multiple oversight breakdowns – from Los Alamos managers rubber-stamping WCRRF procedures, to the DOE's overemphasis on productivity, to the New Mexico Environment Department's failure to audit WCRRF, to the DOE's frenzied waste cleanup tempos in Idaho – were occurring at multiple organizations throughout the US transuranic waste complex all at once. Questioning why Klaus reported 'no conflict of interest' when he submitted his article for publication, a Los Alamos scientist described it as a 'program push' for his former employer. He then criticized how Klaus completely ignored the 3706 Campaign's ill-fated, post-accident continuation to West Texas.

Klaus's and the DOE self-investigators' analyses disproportionately attributed blame to mismanagement and oversight breakdowns in New Mexico. They failed to fully unpack how cleanup workflows were hastened by (a) DOE Headquarters' political-economic incentives to meet 3706 Campaign waste shipment deadlines and (b) DOE officials using federal stimulus funds to draw WIPP toward accepting waste shipments at rates exceeding its intended design basis (DOE, 2019: 8, 9) without supplying adequate funding for repository maintenance. Both analyses, in Reason's (1990: xi) terms, correctly diagnosed key active errors (i.e. individual operator errors, manager errors and notetaking errors) while neglecting to diagnose key latent errors (i.e. harried systemwide temporalities, political decision-making patterns and state-driven NIMBY pressures). They did so by emphasizing operator errors and management failures lower in the US transuranic waste management complex's chain-of-command (which did indeed contribute to the accident) while deemphasizing the DOE's incentive structures and political pressures to uphold rapid operational temporalities (which also contributed to the accident). Delimiting the bulk of responsibility to New Mexico, the DOE 'blame[d] one bad apple or one broken switch for the failures of a risky system' (Knowles, 2014: 243).

Identifying the 3706 Campaign as a root cause of the accident, then, would not provide a 'convenient excuse' (Klaus, 2019: 200) absolving Los Alamos or EnergySolutions of blame. It would simply extend this blame up the chain-of-command to include the umbrella organization that oversaw, funded and authorized their hasty operational temporalities in the first place: DOE Headquarters. Several interviewees suggested that it was in the DOE's interest to deemphasize links between WIPP's 2014 drum breach and its own 2012 Framework Agreement with the State of New Mexico, the deal that set the 3706 Campaign into motion. The DOE's support for Los Alamos's and WIPP's rapid

operational accelerations was, indeed, documented in its own yearly performance assessments. In 2012 – the year WCRRF made its infamous kitty litter error – the DOE called Los Alamos's success in 'exceed[ing] FY12 above ground Transuranic shipments' a 'positive' item of 'significant note' and rewarded it with bonuses (DOE, 2012a: 29). When a June 2013 DOE assessment flagged how 'in relation to the 3706 campaign the team's observation of work at times appeared harried', the DOE did not intervene. Interviewees speculated that the DOE sought to disconnect narratives about WIPP's 2014 accident from narratives about WIPP's vastly accelerated pace of waste emplacement – a trend its National Transuranic Program and Carlsbad field office promoted and oversaw for years prior to the drum breach.

However, DOE officials were not the only ones deflecting attention from the US transuranic waste complex's harried operational temporalities. This blind spot was also reinforced, perhaps unintentionally, by a series of widely circulating, yet misleading, media stories about the accident's backstory. One narrative overemphasized WCRRF's EnergySolutions supervisor's flawed 'organic absorbent (*Kitty Litter/Zeolite*® absorbent)' procedure instruction – oversimplifying the mistake as a typographical error. This story began with a *Santa Fe New Mexican* investigation that detailed the comedy of errors that led to the drum breach. Written just nine months after the accident, the exposé remains impressively accurate. However, it also disseminated a key inaccuracy: that 'something as simple as a typographical error in a revision of LANL's procedural manual for processing waste containing nitrate salts may have precipitated a switch from inorganic clay kitty litter to the organic variety' (Malone, 2014). This proved incorrect. A flawed procedure instruction did lead WCRRF to change absorbents. However, the switch was not from 'from clay to organic' (Brumfiel, 2015), but from one chemically incompatible organic absorbent, *Wastelock 770*, to yet another chemically incompatible organic absorbent, *Swheat Scoop*. WCRRF made the same error twice, even after intervention from scientists. The use of organic absorbent, therefore, predated the flawed procedure instruction. Nevertheless, spinoff articles with titles like 'A Typo & A Bag of Kitty Litter Might Cost US Taxpayers Billions in Nuclear Waste Cleanup' (Mosher, 2016) suggested that the accident 'all started with a dumb typo' (Zhang, 2014).

Yet it would be inaccurate to call 'organic absorbent (*Kitty Litter/Zeolite*® absorbent)' a 'typo'. This nonsensical instruction was not the result of, say, a scatterbrained laboratory scientist attempting to write 'inorganic' but accidentally typing 'an organic' instead. Nor was it the result of a clerical error made by a secretarial staffer or 'note-taker' (Oswald, 2015). Rather, it was written by a top EnergySolutions supervisor who, lacking the scientific training to understand why inorganic absorbent was required, was still empowered by Los Alamos to run a nuclear weapons waste facility with limited oversight. The supervisor was hired not for her scientific expertise, but for her expertise in accelerating WCRRF's operational temporalities. Attributing her mistake to a typo would ignore (a) how the 3706 Campaign's hasty operational temporalities hinged on a compartmentalization of scientific ignorance at WCRRF and (b) how WCRRF's decision to use *Swheat Scoop* was just one of several hundred RCRA regulatory violations occurring in Los Alamos's transuranic waste program at the time. As journalists' 'typo' narrative overemphasized the agency of WCRRF's textual errors, it also deemphasized the complex sociopolitical, financial, regulatory and organizational relationships that converged to make that error and the dozens that occurred alongside it, possible in the first place.

Post-accident media reports also implied that, if WCRRF personnel had just used the inorganic zeolite clay that scientists had recommended to them, their repackaging procedures would have been sound. From a regulatory perspective, this was incorrect. WCRRF's permit under RCRA did not authorize the 'treatment' of waste. Yet by using the kitty litter not only to absorb free liquids in the drums, but also to prevent the waste from igniting once it was repackaged into a new container, WCRRF was treating waste. EnergySolutions' goal in mixing the nitrate salts with organic kitty litter and organic acid neutralizer was to lessen – to treat – its chemical reactivity. Therefore, even if WCRRF's procedure manual had correctly instructed waste repackagers to use inorganic zeolite, Los Alamos still would have needed to formally request an operating permit modification from the New Mexico Environment Department to do so. It did not. Therefore, WCRRF's use of any kind of absorbent – organic or inorganic – was in violation of RCRA rules under WCRRF's permit. Both zeolite and *Swheat Scoop* broke federal rules.

Investigative journalists and DOE officials alike acknowledged how small errors can cascade across organizations to trigger larger accidents (Perrow, 1984). Oversimplifying this as a 'typo' performed a double function. On the one hand, it helped sensitize publics to how small failures can have large consequences. On the other hand, it obscured the near-term temporal dimensions of how the DOE's National Transuranic Program's policies, expedited waste repackaging and emplacement initiatives and regulatory oversight gaps entangled to trigger drum #68660's eruption. Yet these narratives have, wittingly or unwittingly, helped minimize the DOE's responsibility by localizing blame to 'management failure' in New Mexico and 'typographical error' at WCRRF. This was not an 'epistemic accident' (Downer, 2010): It did not occur because widely accepted scientific knowledge turned out to be erroneous or absent. Nor was it an 'executive failure' (Perrow, 2007: 167): It was not a simple case of lab directors harming their organization by committing it to illegal activities for their own financial gain. Rather, incentivized by the DOE's yearly performance rewards, Bechtel's bonus packages, the 3706 Campaign's sociopolitical pressures and Recovery Act stimulus funding, a wide range of lab managers, subcontractors, workers and DOE officials failed to call foul on organizational failures occurring all around them: at the DOE's field offices in Carlsbad and Los Alamos, at WIPP's and Los Alamos's management companies, at DOE Headquarters in Washington DC and elsewhere.

Conclusion

This article presented an ethnographic account of the forces that propelled the US transuranic waste management complex's accelerated repackaging, shipment and repository emplacement temporalities beyond organizational capacity. It demonstrated how these workflow accelerations were driven by DOE officials' overambitious cleanup plans, WIPP's rising rates of waste emplacement, Congressional funding politics, allocations of federal stimulus money, DOE contracts and incentive structures and state-level political pressures (e.g. Cary, 2019; Idaho Cleanup Projec Core, 2018: vii). To meet the 3706 Campaign's tight schedules, Los Alamos National Security managers and EnergySolutions cut corners (DOE, 2015a: ES7–ES8). They allowed DOE and Bechtel performance bonuses, the Town of Los Alamos's wildfire concerns, New Mexico's gubernatorial politics, WCRRF's scientific knowledge gaps and WCRRF's schedule-driven supervisors to

override regulatory and safety imperatives. This intensified pressures on operators to hastily repackage waste. WCRRF's operating culture became increasingly 'bunkered' off (Koehler, 2002) from the world outside, swamped by its own rapid productivity, limited oversight, precarious labor relationships and sociopolitical commitments. This resulted in WIPP's 2014 radiological accident, its 35 months of shutdown and 113 transuranic waste drums getting stranded in West Texas.

Had the DOE commissioned a more independent investigation – one that included social scientists sensitive to matters of operational temporality – WCRRF's schedule pressures may have been treated not as noise in the system, but as central to its analysis. This could have provided valuable lessons about how the US transuranic waste cleanup complex must, as a Los Alamos scientist put it, proceed at a more 'deliberate' speed, remembering that 'a stitch in time saves nine' and that 'slow is smooth, smooth is fast'. Instead, however, influential post-accident narratives – from DOE officials and critical journalists alike – failed to appreciate how fixations on local, state and national political-economic goals entangled not only with WCRRF's expectations to shirk protocols, but also with lab managers' and DOE field offices' failures to oversee them. The DOE, in turn, faced little pressure to reconsider its transuranic waste complex's systemic operations, political-economic priorities and performance incentives. Organizational shortcomings like these are best illuminated not by self-investigation within the DOE complex, but by independent analysis – informed by STS scholarship on accidents, temporality and safety culture – born of interactions between social scientists, natural scientists, and nuclear policy experts. This interdisciplinarity can not only provide a more comprehensive understanding of drum breach accident causation, but also an opportunity for the DOE to learn the lessons it overlooked in WIPP's 2014 accident's aftermath.

For this more holistic form of accident analysis to improve US transuranic waste management operations, however, the DOE complex's incentive structures and lack of regulatory oversight would need to be rethought and reformed. As this article highlights, the US Nuclear Regulatory Commission, the US Defense Nuclear Facilities Safety Board and the US Environmental Protection Agency lack meaningful regulatory enforcement authority over transuranic waste. These loopholes have left the DOE complex to regulate itself. Many informants described the DOE as 'self-regulating'. However, a retired activist from the Snake River Alliance in Idaho saw it differently: 'There's no such thing as self-regulation; the DOE is unregulated.'

Given the DOE's decentralized control over its subcontractors, military-industrial corporations are often free to cut corners, to employ personnel without proper training and to repeatedly make similar mistakes without systemic correction. As a retired scientist who worked on both the WIPP and Yucca Mountain repository projects put it:

> After any accident, [the DOE complex] just sort of says, 'Well, we're gonna get rid of someone, ship 'em off, give 'em a new desk.' That's code for 'Well, we punished them.' That's not the way it's supposed to end. It's supposed to end in disgrace. If this were a commercial industry, they'd be blacklisted.

Under such conditions, it is difficult to imagine even the most meticulous accident analysis generating meaningful reform without formal structural authority behind its

recommendations. This is precisely where an independent, federally-funded regulatory or watchdog organization – staffed by scientists, social scientists and policy experts not be beholden to the DOE or its contractors – could add value. Unfortunately, however, no such organization exists.[11]

So far, the DOE's drum breach accidents have – in health, environmental and safety terms – been relatively minor events. But they could have been much worse. Drum #68660 could have erupted in the daytime, during normal operations, with workers nearby. More drums could have breached. Could another mispackaged drum – from Los Alamos, Idaho, or elsewhere in the DOE complex – travel along America's highways and erupt underground at WIPP once more? If so, would the repository need to be shut down and decontaminated again? What if workers were to be nearby? What if a drum were to breach in transit? The challenge of preventing further accidents calls for closer scrutiny of the US transuranic waste management complex's operational temporalities. But until the DOE complex acknowledges the risks latent in its susceptibility to respond to political-economic pressures by accelerating its operational temporalities beyond its operational capacities, its history of drum breach accidents may repeat itself once again.

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Notes

1. A regulatory term used exclusively in the United States, 'transuranic' refers to wastes with more than 3700 becquerels per gram of radioactive elements that are heavier than uranium. These elements have atomic numbers greater than 92 and tend to be long-lived.
2. As examples: In January 2018, I attended a meeting at the Carlsbad Environmental Monitoring and Research Center, where a proposed modification to WIPP's operating permit from the New Mexico Environment Department was discussed. In June 2019, I attended a hearing hosted by the US Defense Nuclear Facilities Safety Board in Washington DC, which considered potential federal policy responses to recent drum breach accidents in New Mexico and Idaho. In September 2019, I attended a seminar at DOE Headquarters in Washington, DC about the 'History of the DOE and the Weapons Complex', which was framed as a training session for new Department recruits.

3. Social scientists exploring these multi-millennial time horizons have scrutinized how the framers of the US geological repository project at Yucca Mountain's licensing procedure temporally extended modernist regulatory conventions (Kinsella, 2016) and ancient legal adjudicatory rubrics (Ialenti, 2014) 1 million years into the future. They have reflected on how repository projects can stretch engineers' epistemological, spatial and temporal boundary work to extremes (Bloomfield and Vurdubakis, 2005) and how subjective value judgments can influence radically long-term, quantitative repository facility performance assessments (Macfarlane, 2006; Shrader-Frechette, 1993). Engaging with nuclear waste's challenge of 'imagining society 10,000 years from now' (Galison and Moss, 2015), they have revealed numerous ways that socio-technical imaginaries of containment (Jasanoff and Kim, 2009) have been drawn into far future timescales. This has meant rethinking proposals to design monuments and semiotic systems to warn distant future societies to not dig near a repository (Hecht, 2018: 132; Masco, 2006: 197–202).
4. Social scientists exploring these intergenerational time horizons have questioned how and whether economistic discount rate calculations can determine how much present generations should invest to protect their descendants from radioactive risks (Goodin, 1978). They have examined proposals for establishing long-term nuclear waste documentation archives to facilitate institutional continuity across human generations (Pescatore and Mays, 2008). They have also questioned whether a repository's aim should be to bury radioactive waste irreversibly for perpetuity, or whether it should be made retrievable for future generations (Barthe, 2009; Lehtonen, 2010).
5. Social scientists exploring these near-term horizons have scrutinized how nuclear waste governance intersects with sociopolitical temporalities. Downey (1985) has tracked shifts in the US high-level waste repository siting strategy's balance between federal- and state-level decision-making. He has shown how perceptions of experts' credibilities realigned throughout public disputes over the WIPP repository's siting in Carlsbad (Downey, 1988). Macfarlane (2003) has examined the co-production of scientific knowledge, politics and policy as the DOE transitioned from a more geology-centered to a more engineering-centered rationale for siting a repository at Yucca Mountain. Jenkins-Smith et al. (2011) have investigated changes in public support for the WIPP repository across New Mexico's demographic, ideological and regional divides. Gusterson (2000: 332) has noted the 'fluidity' of public perceptions in his ethnographic work on the DOE's and activists' competing positions regarding a nuclear waste incinerator proposed for Livermore, California. Impacting the fates of nuclear wastes with radically long-term consequences, sociopolitical circumstances like these have been shown to shift over mere days, weeks, and months.
6. Nevertheless, insiders articulate the DOE complex as a 'coherent set of social, spatial, and scientific relations with a common history' (Tousignant, 2013: 731).
7. Los Alamos National Security, LLC was a jointly-run limited liability corporation that also included the URS Corporation, BWX Technologies and the University of California. In November 2018, LANS lost its contract. It was replaced by Triad National Security, LLC: a cooperation between Battelle, the University of California and Texas A&M.
8. Uranium fines can be 'pyrophoric' – or liable to ignite spontaneously – if exposed to air (University of Nebraska, 2014: 2).
9. Contact-handled waste emits less gamma radiation and can be handled directly by workers. It was defined as waste containing 'more than 100 nanocuries of alpha emitting transuranic isotopes per gram of waste with half-lives greater than 20 years and a payload surface dose rate not greater than 200 millirem per hour'. Remote-handled waste emits more and requires the use of special container shields and waste handling machinery. It was defined as waste containing 'more than 100 nanocuries of alpha emitting transuranic isotopes per gram of waste

with half-lives greater than 20 years and a payload surface dose rate of 200 millirem per hour or greater' (DOE, 2011: 3). For data on WIPP's waste emplacement rates from its opening in 1999 to its post-financial crisis influx, (see Pecos Management Services 2010).

10. White-boxing can be defined as the distillation of 'complex, open-ended and incompletely rule-determined technical-social constitution' of technological operations into 'standardized, tidy rule-following models' that appear more 'externally accountable' to policymakers and publics (Wynne, 1988: 160).
11. From 1978 through 2004, the DOE-funded Environmental Evaluation Group (EEG) conducted technical evaluations of WIPP. The EEG was offered significant critical independence. It appointed its own staff. Its reports did not require DOE preapproval. However, the DOE ultimately controlled the EEG through the power of purse: The DOE defunded and disbanded the EEG in 2004 (see Butler, 2014).

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