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Atomic energy for Antarctica: the rise and fall of "Nukey Poo"

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Research Article

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Abstract

Antarctica is often cast as a last wilderness, untouched by humans and set aside for peace and science. Yet it also has a nuclear past that foreshadowed a shift in human interactions with the continent, away from development and towards protection. This paper examines the discourse around the installation and the dismantlement of PM-3A, the first and only large-scale nuclear reactor to have been used on the Antarctic continent. Affectionately known as "Nukey Poo," the reactor was greeted with optimism by the USA and was seen as a catalyst for a more comfortable and technologically advanced future for the humans at McMurdo Station. This techno-optimism spurred visions of a resource-rich Antarctic future. When it became apparent a decade on that the reactor was too costly and had been leaking, the narration shifted to centre on environmental protection, resulting in the removal of a mountainside of gravel in the name of ecological restoration. The reactor is gone, but not forgotten – the site is designated as a Historic Site and Monument under the Antarctic Treaty System. Spanning from the Cold War to the Madrid Protocol era, the story of Nukey Poo provides a useful lens through which to track the evolution of attitudes towards Antarctica and to reflect on imagined Antarctic futures.

On Ross Island, Antarctica, the US McMurdo Station sits nestled beneath Observation Hill. The peak looms skywards, marked with a cross that commemorates Heroic Era explorer Robert Falcon Scott and his four companions, all of whom perished in Antarctica in 1912. Their story of hardship, endurance, and sacrifice is well known and often repeated (Larson, 2011; Scott, 1913). What is less known is that the flanks of Observation Hill bear the marks of another kind of history: a nuclear one. Between 1961 and 1979, the site was home to the first and only nuclear reactor to be used in Antarctica. Today, an inconspicuous plaque marks the site of PM-3A, or "Nukey Poo," as the power plant was known. This plaque and the gap left by the 12,200 tonnes of contaminated hillside that were removed during the clean-up are the only physical reminders of the reactor. Yet the story continues to challenge dominant assumptions about the far south, offering a useful lens through which to examine two ways of valuing this region: as a place to develop or a place to protect.

Antarctica's young human history and unique governance and territorial status make it a particularly interesting location to examine the history of nuclear technology. Antarctica is governed by the Antarctic Treaty System (ATS), which has at its heart the Antarctic Treaty (Antarctic Treaty Secretariat, 2017). By the 1950s, seven nations had made claims to sectors of the continent (Argentina, Australia, Chile, France, Norway, New Zealand, United Kingdom), but these were not universally recognised (Gilbert, 2015). The USA and USSR were both interested in the region, but neither wanted the other to gain a territorial foothold. The Antarctic Treaty, which was signed by the 12 original signatories in Washington, DC, on 1 December 1959, designated Antarctica as a place for peace and science and provided a solution: most notably, Article IV put existing claims into abeyance and prevented any new claims being asserted while the Treaty was in force (although the USA and USSR both reserved the right to make a claim in future). Although the Antarctic Treaty designates Antarctica as a place for international scientific cooperation (Article III) and specifies that "any nuclear explosions in Antarctica and the disposal there of radioactive waste material shall be prohibited" (Art V), nuclear energy is permissible – and has been used in the far south.

Given the interests of the two superpowers in the far south, and their fears regarding the use of nuclear weapons in the region, the Antarctic Treaty can be seen as a remnant of the Cold War. Indeed, Musto (2019) claims that "the United States spearheaded the Antarctic Treaty negotiations in part because of a fear that Antarctica could become a dangerous theatre of the Cold War" (p. 330). Article I of the Treaty notes "Antarctica shall be used for peaceful purposes only," foregrounding security concerns and providing a vision for a shared, conflict-free future. Provisions such as freedom of inspection (Article VII), which today are used to ensure operators comply with environmental standards, were originally intended to ensure Antarctica would not be used to store nuclear weapons. In this regard, the Antarctic Treaty set a precedent for arms

control elsewhere, with *The Japan Times* observing how an inspection system in the Antarctic "could naturally serve as a pilot system for an effective disarmament plan in the future" (15 November 1959) (qtd in Musto, 2019, p. 331).

Today, 57 nations are parties to the Antarctic Treaty (Antarctic Treaty Secretariat, 2023), and the ATS includes a complex web of annexes and agreements that reflect changing priorities over time. These provide protection to various parts of the region: most notably, the Convention on the Conservation of Antarctic Marine Living Resources (CAMLR Convention, 1972) deals with resources and ecosystems in the Southern Ocean, while the Protocol on Environmental Protection to the Antarctic Treaty (Madrid Protocol, 1991) affords protection to wildlife, landscapes, and historic sites on the continent. This protection was not inevitable. As Antonello (2019) notes, between the signing of the Antarctic Treaty and the CAMLR Convention, the concept of Antarctica was transformed "from a cold, abiotic, and sterile wilderness, a lifeless and inert stage for geopolitical competition, into a fragile environment and ecosystem demanding international protection and management" (p. 4). The story of Nukey Poo falls into the period when Antarctica was being considered in different ways by both policymakers and the wider public back home. This paper presents the life story of PM-3A, the first nuclear reactor in the Antarctic, as a particularly American narrative. It argues that the reactor's trajectory helped change environmental perceptions of the far south, prefiguring modern environmental protection standards and highlighting a shift in emphasis from instrumental to intrinsic valuation. Most importantly, the story of Nukey Poo shines a light on the imagined Antarctic futures of our past, paving the way for us to imagine our own tomorrows.

Nuclear power in the Antarctic

The use of nuclear power in Antarctica was first mooted in the 1950s, with prominent figures such as the American polar expert Admiral Dufek championing the proposition. Following his own visit to Antarctica in the summer of 1956, Sullivan, a *New York Times* journalist, was also impressed by the potential of icebreakers and nuclear power for the region, writing that "the atomic age is forcing us to reappraise our attitude towards Antarctica" (1957, p. 352). The US Naval Nuclear Power Unit (NNPU) was established on 6 July 1960, tasked with "responsibility for the design, procurement, construction, operation, and maintenance of nuclear shore systems and for the training of personnel to support them" (Shafer, 1967, p. 38). In August of the same year, the US Congress authorised the installation of a reactor at McMurdo Station. The reactor was intended to be the first of several for the far south, as nuclear power was seen as an ideal way of providing remote Antarctic stations and field camps with electricity and warmth (Spiller, 2015). PM-3A, or "Nukey Poo," as it was affectionately known around McMurdo Station, was built by the Martin Marietta Company of Baltimore, Maryland (Seabee Museum, 2011; Shafer, 1967). It arrived in Antarctica on 14 December 1961, "50 years to the day after Roald Amundsen became the first man to reach the South Pole" (Dufek, 1962, p. 728). Intended to be portable (the PM stands for portable, medium powered), PM-3A was the third reactor in a series, following PM-1 in Wyoming, and PM-2A at Camp Century in Greenland (Wilkes & Mann, 1978). As a uranium-fuelled pressurised-water reactor, with a capacity of 1.8 megawatts, the plant was designed to create steam, which was then used to drive a turbine and create electricity (Muldoon, 1980). Its installation and commission in early 1962 (Fig. 1) was met with great optimism by the USA, but this was not to last. Ten years later – and only halfway into its intended 20-year lifespan – the reactor stopped generating. By 1979, a full-blown clean-up of the site had been undertaken.

This paper uses the narrative of Nukey Poo to reflect on desired Antarctic futures. Building upon existing operationally and historically focussed works, including Wilkes and Mann's detailed 1978 article "The Story of Nukey Poo," it traces attitudes towards the PM-3A reactor as they move from the optimism of the early installation through to the rhetoric of protection apparent during the clean-up phase and the ongoing complexities related to the reactor's afterlives. I argue that this fascinating episode in Antarctic history is both entangled with the continent's commercial past and presents a useful example to consider how visions of Antarctic futures change over time. The episode of "Nukey Poo," the Antarctic nuclear reactor, sheds light on the parallel changes of relationships with nuclear energy and the human relationship with the Antarctic continent and illustrates a shift in emphasis from a frontier mentality to a mentality centred on wilderness preservation (Spiller, 2015). Examining the narratives that circulated around the station when Nukey Poo was erected and when it was dismantled reveals an ideological shift, as Antarctica starts to move from being seen as a place of resources, with instrumental value, to a place with intrinsic value that is worthy of protection. Although the latter framing of the far south was not enshrined within the Antarctic Treaty System until two decades after the reactor stopped producing energy (the Madrid Protocol, which explicitly names intrinsic value, was signed in 1991), elements of the environmental monitoring regime and the clean-up of the site foreshadow the pro-environmental attitudes that would come to dominate the management of human activity in the region over the next half century.

Nuclear power in the USA

Nationalism and power have long been intertwined; in many countries, "nuclear prowess became intensely associated with national identity" (Stirling, 2014, p. 86). Different dominant imaginaries about nuclear power exist in different nations – as Jasanoff and Kim (2009) outline, "sociotechnical imaginaries" play an important role in shaping national perceptions of both technologies and desired futures. These imaginaries consist of "collectively imagined forms of social life and social order reflected in the design and fulfillment of nation-specific scientific and/or technological projects" (Jasanoff & Kim, 2009, p. 120). Throughout the 1950s, "civilian nuclear power was the centerpiece of a political effort" in the USA to frame the atom as a positive force (Hamblin, 2006, p.731). US President Eisenhower's 1953 speech to the UN Assembly, entitled "Atoms for Peace," sought to differentiate the atoms used for power generation from the atoms used in war – this was particularly important in the aftermath of WW2 when the USA dropped atomic bombs on Japan. This framing cast nuclear energy as something contained, controlled, and benign and the key to a more prosperous future.

Although nuclear energy continues to provide 18.5% of the US's electricity needs today (International Atomic Energy Agency, 2024), the technology has been viewed differently by the public at various points in time. As Stirling (2014) outlines, "the history of nuclear power presents a starkly disruptive picture, moving from early success as a synonym of Modernity, to later failure as a potentially destabilising antonym" (p. 86). Nukey Poo follows a similar trajectory but on a much shorter timescale. The widespread

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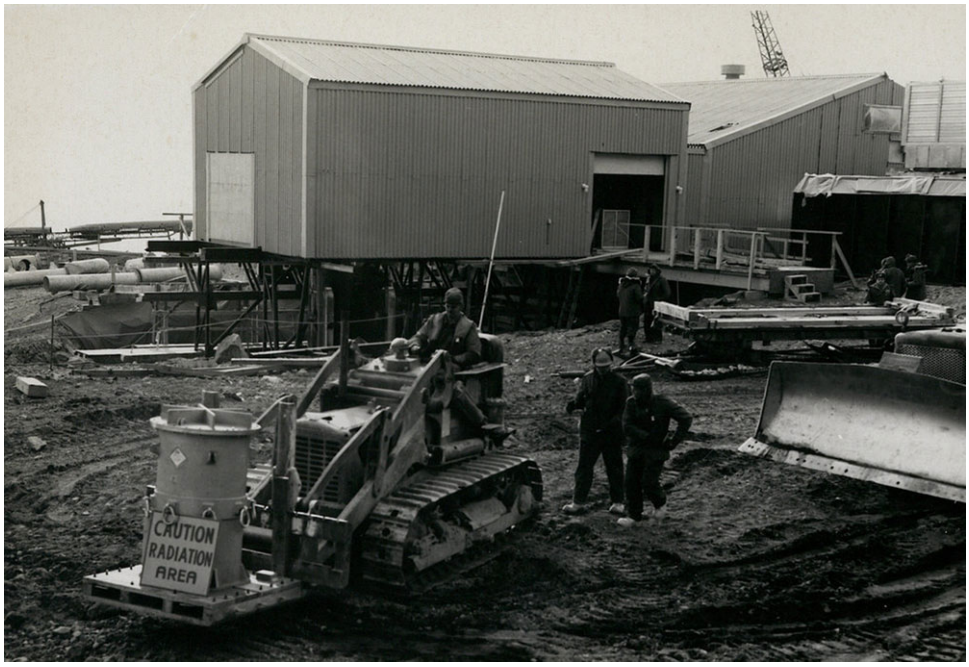

Figure 1. Core of uranium fuel designed to power the PM-3A nuclear electrical plant at McMurdo Station, W M Quinn, via Antarctica NZ Digital Asset Manager, CC-BY.

nuclear optimism of the 1950s, when the term "Atomic Age" was in wide circulation, was tarnished by the threat of nuclear weapons during the following decade. From the late 1970s onwards, there was a "virtual moratorium on building new power plants" in the USA (Jasanoff & Kim, 2009, p. 140), while public wariness of nuclear technology grew in the wake of the well-known accidents at Three Mile Island (1979) and Chernobyl (1986). Hecht (2010) notes that while claims of nuclear exceptionalism came mainly from atomic energy institutes during the early years of civilian nuclear power, anti-nuclear activists later used the rhetoric of exceptionalism to highlight the "dangers posed by exposure to radioactive substances" (p. 4). Nuclear power continues to be a contested topic, with some viewing it as the solution to the contemporary climate crisis (as of 2023, at least six new reactors are planned in the USA as part of the Carbon Free Power Project) and others concerned about the long-term impacts of nuclear waste products (Kinsella, 2015) – Beck (2003) cites as an example of overlapping discourses of risk "nuclear power vs the hole in the ozone layer," highlighting how human decisions back home have differing impacts on far off environments (p. 111) – and on different timescales. In the Antarctic context, the discourse of nuclear exceptionalism and Antarctic exceptionalism came together to create, in the US context, an initial narrative of optimism around the establishment of PM-3A.

Optimistic beginnings

During the early 1960s, nuclear power was viewed with optimism and seen as an exciting new solution to both the world's energy and societal problems (Högselius, 2011). In the USA, where nuclear power was pioneered, "pre-eminence in all things nuclear was a source of national pride and self-confidence" (Nuttall, 2005, p. 2), and technological advances carried great symbolic weight. A General Motors display at the 1964 New York World's Fair featuring a "miniature display of atomic powered bases at the South Pole and on the moon" (Spiller, 2015, p. 1) epitomised this optimism, with the inclusion of stars and stripes flags putting unambiguously US "polar conquest on display" (Spiller, 2015, p. 17). Developments such as the establishment of a nuclear reactor at the US's military base at Camp Century in Greenland, 161 km east of Thule (Doel, 2003) were seen as revolutionary harbingers of a nuclear future – as the admiring Admiral Dufek put it in 1962, "Camp Century represents both a daring concept and an amazing feat of engineering" (p. 721). As geographically remote as Antarctica was, it was not immune to this sentiment; as Wilkes and Mann (1978) write, "some of the euphoria rubbed off on Nukey Poo" (p. 34). The reactor was viewed as a positive development that would improve human lives, evidenced by Brewer's 1963 assertion that "Nuclear power in the Antarctic can, and does at McMurdo, provide a means of significantly improving the living conditions on that austere continent" (p. 48). PM-3A was seen as a trailblazer, enabling further development of the Antarctic frontier and reinforcing the USA as a technological leader (Fig. 2).

Nukey Poo represented both a national technological triumph on the global stage and a commitment to an ongoing US presence in Antarctica. Science and technology were cast as the modern frontiers (Spiller, 2015), while the uninhabited and remote continent of Antarctica provided the ideal backdrop against which such conquest could play out. The naval aviator and Antarctic expert Admiral Dufek was a strong proponent of nuclear power in the polar regions and championed the promise of the technology. His 1962 assertion that "PM-3A opens a dramatic new era in man's conquest of the remotest continent" (p. 712) evoked imagery and attitudes familiar from the "Heroic Era" of exploration (1891–1922), when men set out on gruelling inland treks to conquer the continent. The choice of the term "conquest," with all its militaristic overtones, was not accidental. While the early explorers set out with flags, pitting their bodies against the elements as they claimed new territory, the new technology in the nuclear plant represented a modern way for man to triumph over the hostile environment and reinforce human domination over the icy surroundings. By this time, the polar regions were recognised as

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Figure 2. Photo of PM-3A Nuclear Power Plant, 1965. United States Antarctic Program, Antarctic Photo Library, Photo taken by US Army Engineer Research and Development Labs, NSF. Public Domain.

"attractive places for superpowers to test and prove themselves, both to their own populations and to the rest of the world" (Luedtke & Howkins, 2012, p. 147). Dufek's predecessor Admiral Byrd had been vocal in his (unsuccessful) attempts to secure a US territorial claim in Antarctica (Rose, 2008), but the nation continued to maintain the largest Antarctic station (McMurdo Station, Ross Island). This presence was well advertised; a PM-3A rubber stamp featured on navy mail (Fig. 3), and *TIME* magazine reported in December 1961 that "Because the U.S. has worked longer and harder on Antarctica, it is far ahead of all comers in taming and probing the continent" (TIME, 1961), citing PM-3A as an example.

Making use of Antarctica

During the 1960s, the instrumental value of science and technology in developing the Antarctic continent was foregrounded – they were tools that allowed humans "to make nature do their bidding" (Spiller, 2015, p. 13). The optimism associated with nuclear power in the polar regions is encapsulated in the final chapter of Dufek's 1960 book *Through the Frozen Frontier*, in which he imagined "Antarctica in the Year 2000." Dufek presented a future Antarctica where a permanent human settlement has been established, made possible in large part due to developments in nuclear technology. Not only is nuclear energy used for power, meaning "it is no longer necessary to haul in the old fuels like petrol and oil over large distances" (1960, p. 173) – it has additional applications for clothing, greenhouse crop production, and winter access. Logistically, Dufek foresaw winter flights becoming a possibility, as "unlimited nuclear energy lights up the airfield and the area for miles around" (1960, p. 177). He also raised the question of geoengineering, suggesting that nuclear energy could be used to create heat and influence air currents, thereby controlling rainfall by ensuring "rain clouds are made to pass over the desert areas of the earth" (1960, p. 184). This process would be controlled from Antarctica, making the continent an integral part of global climate systems. Such discourse linking nuclear activity and weather was widespread in the USA at the time – as Masco notes, "the US nuclear project was linked very early on to concerns about weather and climate" (2010, p. 9), with concerns related to both local impacts around test sites and the broader existential threat of a "nuclear winter." Discussions around geoengineering, or artificially controlling the climate (for instance, through cloud seeding, adding iron to the Southern Ocean, or supporting ice shelves (Moore et al., 2018)) continue today – both the ethical and legal implications of geoengineering have contemporary relevance given the current climate crisis (McGee et al., 2019).

Antarctica's value as a mineral resource depository also played a role in Dufek's vision of Antarctica's future; the admiral suggested that nuclear energy would enable future resource extraction. Writing for *The New York Times* audience in 1960, Sullivan amplified this view, asserting, "Antarctica is bound to have mineral resources comparable to those of other great continents" (1960, p. 20). Such predictions about future mining were shared by other prominent figures who were active in the Antarctic arena; in 1964, the director of the Australian National Antarctic Research Expeditions, Philip Law, predicted that by 1984 Antarctic mining would be well underway, supported by nuclear powered townships that were home to families (Jabour & Haward, 2011). While this kind of resource extraction has so far not occurred in Antarctica, negotiations throughout the 1980s towards a Convention for the Regulation of Antarctic Mineral Resources (CRAMRA) demonstrate that an attitude towards Antarctica as a place to use and develop lingered. (CRAMRA, which offered a framework for future mining that foregrounded environmental protection, never came into force but strongly influenced the development of the Madrid Protocol.)

For Dufek, the development of mines was a positive prospect that could in turn be used to broker global peace, as nuclear-powered ships transported ore to "foreign lands that are hungry for the new material to provide them power for peaceful purposes, to give them food, shelter, warmth, and the comforts of a good life" (1960, p. 178). The mention of peace is particularly salient given that the Antarctic Treaty, which required that "Antarctica shall be

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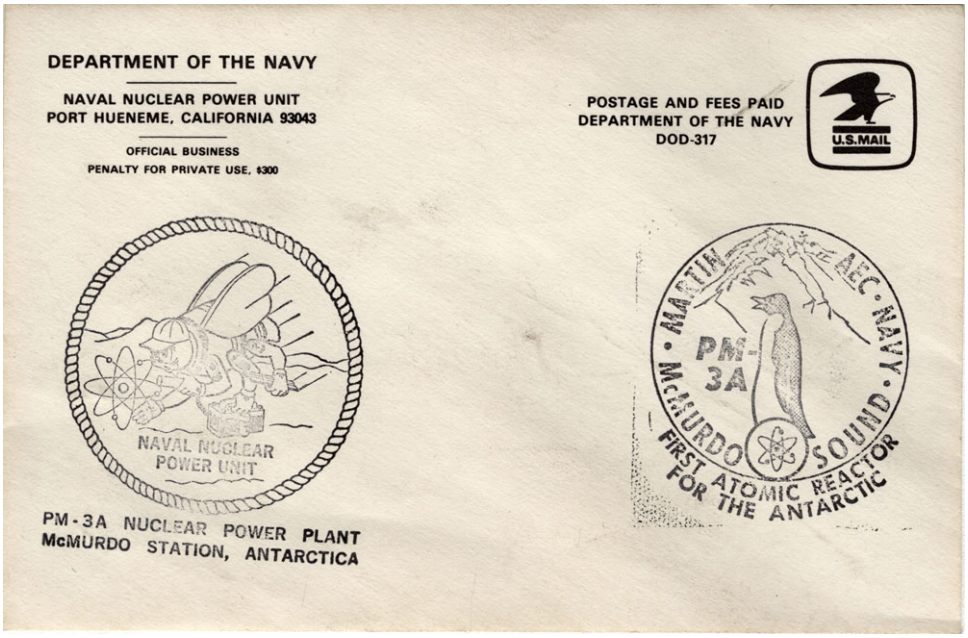

Figure 3. PM-3A rubber stamped cachet featuring Naval Nuclear Power Unit logo and a penguin and atomic symbol, PM-3A Navy Nuclear Power Unit, 1969. US Navy Seabee Museum, Collections Department, Port Hueneme, CA 93043, via US Navy Seabee Museum, Flickr.

used for peaceful purposes only" (Article I), had just been signed. Overall, Dufek paints nuclear technology as an enabling, empowering force that allows for the expansion of human activity on the continent and for the ongoing use of Antarctic resources – a depiction that has been described by Roberts as "projecting Cold War dreams of a technological utopia upon the future" (2011, p. 160). Dufek's chapter provides a vision of an Antarctic future where nuclear-related technological developments allow humans to remain at the centre and to expand both their presence and activities on the continent – casting Nukey Poo as the start of the much larger energy revolution.

The view of Antarctica as a place of resources dates to the earliest human interactions with the place (Nielsen, 2017). The first sightings of the continent were made by sealers, headed south for their hunt, and sparked a "brief period of exploration motivated by commercial concerns" (Baughmann, 1994, p. 7), while Antarctic whaling was a particularly lucrative business during the early 20th century. Early Heroic Era explorers noted the presence of coal and guano, while Australian scientist Douglas Mawson even penned a series of articles on "The Commercial Resources of Antarctica" in 1913 – as a geologist, he was particularly interested in mineral resources (Borchgrevink, 1901; Hains, 2002; Mawson, 1913). Over the coming century, growing commercial interest in the oceans around Antarctica led to the creation of the CAMLR Convention in 1980 (in force 1982), which oversees fishing in the Southern Ocean, and to the development of CRAMRA through the 1980s (not in force). It is against this background that Dufek's dreams of a nuclear-fuelled commercially successful future should be read; the initial optimism associated with the nuclear power plant, and the promise of development of the "resource frontier" (Spiller, 2015, p. 15) that came with it, can be seen as a continuation of past attitudes that framed Antarctica as a place for profit.

Financial concerns also played an important role in the establishment of a nuclear power station at McMurdo. Writing in 1980, Muldoon compared the cost of nuclear power (0.564 cents per kilowatt hour) to the diesel fuel price (0.975 cents per kilowatt hour), highlighting the economic aspect of installing the reactor. His claim that "The US experiment with nuclear power in Antarctica began as an attempt to find a cheaper way to maintain stations in remote locations" (Muldoon, 1980, p. 1) is borne out by the fact that diesel, which cost 12 cents per US gallon to buy in the USA, was worth 40 cents per gallon after transport to McMurdo, and almost $6 a gallon once it reached the US station at the South Pole (Dufek, 1962). Cost was therefore the major factor in the USA wanting to establish nuclear power capabilities in the far south, and the $1.4 million initial price tag attached to the Martin Marietta Corporation reactor seemed a sound investment in the future. That future included development – yet other futures for Antarctica had also been mooted by this point, including framing the frozen continent as a "nuclear solution."

Antarctica as a nuclear solution

Despite explicit provisions in the Antarctic Treaty relating to nuclear waste, Antarctica has at times been viewed not only as an ideal place for nuclear power but also as the answer to issues of nuclear waste. Given the geopolitical, environmental, and health implications, the question of where to situate nuclear waste dump facilities has "historically been a difficult topic in Western democracies" (Högselius, 2011, p. 200). When scientists Zeller, Saunders, and Angino proposed in 1973 that Antarctica would be the ideal location for an International Radionuclide Depository facility overseen by the International Atomic Energy Agency, the main obstacle they foresaw was ensuring that exploitation of Antarctic resources, including minerals and water, remained feasible. Their brief proposal, presented in the *Bulletin of the Atomic Scientists*, was motivated by a perceived worldwide need for a secure nuclear waste facility. The authors presented both Antarctica's extreme climate and remoteness as key attractions, arguing that "The polar climate and the low temperature of the ice would furnish a sink for the heat given off by the radioactive waste canisters" and that the location "would remove the wastes from

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populated areas" (Zeller, Saunders, & Angino, 1973, p. 4). Most importantly, they stressed that "the radioactive waste depository would not destroy or prevent the exploitation of any practically useful natural resources" (Zeller et al., 1973, p. 50), leaving Antarctica available for instrumental use in the future. The authors – who were experts in physics and geology – also noted the challenge of altering Article IV of the Antarctic Treaty (related to territorial claims) but argued (contentiously) this was not insurmountable, particularly given the number of treaty signatories needing to dispose of material. The main criticisms of this proposal also highlight practical concerns, such as the pulverisation of canisters (Weertman, 1973, p. 2) or cast the idea as "a colossal misuse of resources" (Woods, 1973, p. 3), but do not challenge the instrumental attitude to the far south or present Antarctica as being exceptionally different to anywhere else in the world.

The idea of using Antarctica to dispose of nuclear waste was mooted and discussed on other occasions: "The Disposal of Radioactive Wastes in the Antarctic Ice Sheet" was the theme of a meeting held at the Scott Polar Research Institute on 25 September 1974. In that case, the delegates concluded that "The Antarctic ice sheet is not a suitable site for the disposal of radioactive wastes that need to be isolated from the biosphere for periods of several hundred thousand years" (SCAR Bulletin, 1975). Proposals that cast Antarctica as a distant and literal wasteland are what Brewster (1982) terms "hemispheric chauvinism" (p. 57) – for those in the Northern Hemisphere, the Antarctic can seem very distant, but for citizens of southern nations such as Australia, New Zealand, South Africa, Chile, and Argentina, the continent is a comparatively close neighbour. Although Antarctica never became a global dumping ground for radioactive material from elsewhere, the question of where to place nuclear waste would soon emerge in relation to Nukey Poo. These conversations would be of particular relevance for the so-called "Antarctic Gateway" cities (Roldan, 2015), especially Christchurch, which continues to act as a logistics hub for the United States Antarctic Program.

Assessing environmental impacts

"Nukey Poo" began producing power in 1962 and was refuelled for the first time in 1964. The power produced was used to support the running of McMurdo Station, which at the time was home to between 1200 and 1500 personnel (Klein et al., 2008). Running a nuclear power station in such an extreme environment without incident would be a major advertisement for how an advanced country could safely and successfully deploy this technology; the reactor therefore spoke to the technological capabilities of the USA and had a symbolic function that went well beyond electricity generation. The success of the station was advertised locally: an electric sign, 4 by 16 feet and featuring 40 red bulbs, was installed on Observation Hill, where the letters "PM-3A" flashed whenever the station was producing power. The Bulletin of the US Antarctic Projects Officer headlined this development as "Advertising Invades Antarctica" (1965, p. 6) – in fact, advertising already had a long history on the continent, with the sponsorship of early expeditions often resulting in widely publicised endorsements of products (Nielsen, 2023). The flashing lights drew attention to Nukey Poo, which was providing heat and light throughout the Antarctic winter and reducing reliance on oil fuel. Yet the plant's presence also came with risks to the surrounding environment.

Antarctica has often been cast culturally as a pure land, uncontaminated by human interference; as Brewer noted in 1963, "the Antarctic continent has a "clean" environment, not yet polluted by civilization" (p. 49). This framing of Antarctica as unpolluted had a practical underpinning; any contamination of the surrounding environment would constitute a threat to the controlled research field just as much as a moral failure. For instance, Spiller (2015) documents how Alan Waterman, Chief of the National Science Foundation (NSF), harboured concerns that background radiation could be elevated in the surrounding area due to the operation of the nuclear power plant. Antarctica continues to be figured as a "pure" wilderness today (Tin, 2016, p. 307), although recent research reveals that the continent is not as untouched as it may appear. Traces of both the Industrial Revolution and radioactive material from radioactive testing elsewhere in the world have been found in the layers of Antarctic ice cores (Delmas et al., 2011), demonstrating the global scale of human impacts on the far south and adding a further layer to Antarctica's nuclear history.

The potential environmental impacts of a nuclear power plant in the Antarctic were recognised from the start, and pre-operational and post-operational environmental surveys were undertaken at the McMurdo site. Environmental monitoring of the nuclear power plant site was initially undertaken by the US Public Health Service. In order to ensure that NSF requirements regarding operations were being met, they made "measurements of the radiological background ... both pre-nuclear and post-nuclear plant operation" (Brewer, 1963, p. 50). The early years of operation of PM-3A were not without incident – a hydrogen fire broke out in the first year but was contained without any environmental contamination. The United States Navy then took over the monitoring programme during the austral summer of 1963–1964. Such monitoring measures pre-dated the existing Antarctic environmental evaluations that are currently in use by three decades, as environmental monitoring was not mandated until the introduction of the Madrid Protocol (in force 1998). However, environmental protection was a growing concern within the USA at the time. Doel (2003) suggests that:

> by the 1960s, two distinct 'environmental sciences' had emerged: one biology-centered, focused on problems in ecology and population studies, and funded in part by agencies and managers concerned about human threats to the environment; the other geophysics-centered, focused on the physical environment, and responsive to the operational needs of the military services that supported it (p. 653).

Today, human threats to the environment are a central topic at Antarctic Treaty Consultative Meeting, but operational needs played a more important role in the life of Nukey Poo. However, in hindsight, this early monitoring regime around the plant bears much more resemblance to Antarctica in the year 2000 – when monitoring of ice, water, atmosphere, and human impacts was becoming routine – than does Dufek's vision of a nuclear power-fuelled metropolis.

Cleaning up after Nukey Poo

The life of PM-3A was to be much shorter than the anticipated 20 years. Although it did reach key milestones, twice setting records for the "longest continuous operation of a military reactor" (US, 2010), a combination of cost and faults led Nukey Poo to cease generation in September 1972. Cracks had appeared in the containment vessel on three occasions during the reactor's life and were welded up each time, but not before shield water had soaked into the surrounding backfill (Wilkes & Mann, 1978, p. 35). After

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routine inspections revealed leaked irradiated coolant, concerns over possible chloride stress corrosion led to an official announcement of closure being made at the start of the following season (Muldoon, 1980). Financial concerns were also a factor in the closure of the reactor; it "took two officers and 23 men to operate," making it a very labour-intensive operation (Wilkes & Mann, 1978, p. 35). When it became apparent that repairing the insulation would cost $1.5 million, the Navy decided instead to spend $800,000 to dismantle the reactor (Wilkes & Mann, 1978,). Although as Spiller (2015) details the reactor continued to be publicly celebrated as a development that brought the ice age and the atomic age together, perceptions of the reactor site were beginning to shift.

The story of Nukey Poo does not end with its closure – rather, the clean-up operation opens a new chapter in the history of the plant. Removing PM-3A from the Antarctic region was not as straightforward as establishing the reactor, partly due to low-level contamination in the surrounding area. Harsh conditions made the usual practice of using thick concrete to shield the tanks impossible, so "the crushed gravel backfill idea was thought up as a cheap substitute" (Wilkes & Mann, 1978, p. 33). This rock was high in sodium, which could dissolve in groundwater, and turn into radioactive sodium-24. The Antarctic Treaty provisions prohibiting the disposal of radioactive waste material meant that "any soil showing traces of radioactive contamination was removed along with the dismantled reactor" (Priestley, 2012, p. 148). In the PM-3A context, radioactive waste was defined as anything above the release levels of "4 x 10^{-4} μc per cc for unidentified gases, 1 x 10^{-8} μc per cc for argon-41, and 1 x 10^{-8} μc per cc for liquids" (Brewer, 1963, p. 54). The question of what constitutes radioactive waste has been debated, however. Muldoon (1980) explains that when the US Navy sought a US standard that could be applied to the soil, they realised

> standards for maximum permissible concentrations (below which something is not considered radioactive) of various radionuclides had been developed for air and water, but not for soil (p. 3).

This was a new area of monitoring work – the fact it was initiated indicated a change from past priorities and was also a recognition that the technology in use was fairly new. Approaches to what Antonello and Howkins term "technocratic environmentalism" were also new, with the USA introducing environmental impact statements in 1970 (Antonello & Howkins, 2020, p. 55) when Nukey Poo was already in operation. Although slightly radioactive effluent was spilling down a drain pipe and soaking into the soil over the course of the reactor's life, Wilkes and Mann (1978) observed that

> The Naval Nuclear Power Unit decided that this did not necessarily constitute a violation of the Antarctic Treaty, which bans disposing of radioactive waste, because the treaty did not define the term radioactive waste (p. 36).

Nevertheless, the US Navy did honour the spirit of the Antarctic Treaty by removing the surrounding contaminated material – and this process deserves attention in its own right.

In a reversal of Zeller, Saunders, and Angino's proposal to use Antarctica as a nuclear waste facility, radioactive material from the far south needed a place to rest outside of the continent. During the clean-up of the PM-3A site, the backfill, components, and fuel from the plant were "shipped to the Department of Energy's Savannah River Plant near Barnwell, South Carolina, for disposal" (Muldoon, 1980, p. 3). 12,200 tonnes of low-level contaminated rock (mostly contaminated by caesium-137) was also transported to Port Hueneme California (Muldoon, 1980). This was not without controversy: at a state level, Californian officials protested that "there is no site in California approved for the dumping of radioactive waste" (TIME, 1978). At the international level, the ship transited through New Zealand, which had declared itself to be a nuclear-free zone and was not equipped to deal with heavily irradiated people in case of an accident (Calcott, 1996). Priestley notes that both uranium-235 and mixed polonium and beryllium neutron sources also transited aboard US logistics vessels through the Christchurch port of Lyttleton on their way to Antarctica in earlier years, though this went largely unnoticed by the public (2012). At the time of the PM-3A clean-up, New Zealand media featured sensational headlines such as "Hush-Up Over Deadly Cargo" (The Christchurch Star, 20 September 1975), highlighting the negative public sentiment towards nuclear power in that nation, where a very different "sociotechnical imaginary" was at play too in the USA.

Nevertheless, the remains of a symbol of US progress returned to its shores, leading a New Zealand journalist to assert "it is safe to say a small corner of a United States field will be forever Antarctica" (Calcott, 1996, p. 14). This anonymous pile of gravel was out of place in the far south due to regulations on contamination, yet it is also foreign to the soil of the continent where it is now buried. This is an incident firmly rooted in the pre-Madrid Protocol era, yet the clean-up process foreshadows later requirements. The Madrid Protocol provides comprehensive protection for the Antarctic region – it established the requirement for environmental impact assessments to be undertaken prior to any activity, banned the introduction of non-native species, and introduced the requirement for nations to clean up sites of past activity wherever possible. This clean-up requirement raises ethical questions, both in terms of cultural heritage and the extent to which alteration of a landscape is considered acceptable (Senatore, 2023). In the case of PM-3A, restoring the site to an uncontaminated state involved removing much of the hillside altogether; as Wilkes and Mann (1978) put it, "The Navy has now dug a 9,000 cubic meter hole to 'restore' the site to its 'original' condition" (p. 36). "Original" in terms of contamination levels is not the same as "original" morphologically and reveals the gap between what is technologically feasible and what is ideologically desirable. The clean-up of the reactor site also highlights the role that value judgements play in making decisions that shape landscapes. Given that "the values that people bring to the Antarctic are rooted in their experience elsewhere, at home, outside the Antarctic" (Neufeld et al., 2014, p. 249), the "untouched" landscape has in fact been shaped by imported priorities ever since humans first ventured onto the continent. By the end of the Cold War, attitudes towards Antarctica had shifted; as Spiller (2015) puts it, the USA was "a nation bent on environmental preservation rather than frontier conquest" (p. 15). Although the human relationship with Antarctica has changed since PM-3A was installed, the episode reveals how national interest can manifest in different ways at different times.

History and memory

Today, all that physically remains at the site of the PM-3A reactor is a missing hillside and a small plaque (Fig. 4) that "details achievements of PM-3A, Antarctica's first nuclear power plant" (United States, 2010). The plaque – which was designated as Historic Site and Monument (HSM) 85 under the Antarctic Treaty System by Measure 15 (2010) ATCM XXXIII-CEP XIII, Punta del Este – was installed by the NNPU Group in the summer of 2010–

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Figure 4. Plaque Commemorating the PM-3A Nuclear Power Plant at McMurdo Station (HSM 85), 27 January 2012, photo by Sergey Tarasenko (CC).

2011, with a twin installed at Port Hueneme, California, where the control room for PM-3A is on display (Rejcek, 2010). It highlights the human history associated with the plant, focussing on the efforts of the US Naval Construction Force, or "Seabees" who erected and operated the plant – the Seabees logo featuring an atomic symbol that was used on postal cachets in the 1960s is also reproduced. The plaque joins a diverse range of artefacts and sites that mark everything from Heroic Era expeditions (Cape Evans Hut, HSM16) to obsolete vehicles (oversnow heavy tractor "Kharkovchanka," HSM92). Such historic site designations are not without controversy, particularly as they occur within a specific political environment – as Evans (2011) reminds readers, "it is important to be aware of the political nature of history, of divergent social values held by different groups within the community" (p. 97). van der Watt (2017) goes further, explicitly examining how "looking to dominate the process of producing Antarctic environments – of environmental discourse – has become a powerful strategy in Antarctic politics" (p. 584).

Designating a site as historically significant is another way of asserting power over a particular area, much as the PM-3A reactor signalled an ongoing US presence when it was first installed. For the USA, a plaque celebrating the successes of Nukey Poo as an Antarctic "first" is therefore consistent with earlier narratives of mastery and domination in the far south. Indeed, the plaque foregrounds the capabilities of Nukey Poo – the "only nuclear power plant to have operated in Antarctica" – by drawing attention to the "record power run 4400 h 1971." The plaque's emphasis on a record parallels the long-held obsession with "firsts" in Antarctica – from Amundsen's first team to reach the South Pole in 1911 to the Australian Antarctic Division's first wind farm in 2003 (Australian Antarctic Division, 2018; Magill, 2004) – and foregrounds human technological achievement. It is therefore consistent with a narrative of Antarctic history that places the USA in an important role as an enabler at the frontiers of science and exploration (Spiller, 2015). Senatore notes how "most of the protected HSMs represent a 'memorable past', in which national narratives and interests are connected" (2023, p. 5). In this case, the plaque presents a positive view of this episode in Antarctic history; it is a celebration, put in place by those who worked with Nukey Poo, that both commemorates past labour and acts as a flashpoint for nostalgic memory about a particular episode in Antarctica's past. The HSM designation ensures the site continues to have a profile on the international stage long after the removal of the reactor itself.

The way past endeavours – including the installation and removal of PM-3A – are narrated continues to have implications for those living in the present and in the future. In examining the symbolic conflict inherent in different framings of nuclear history at the Bradbury Science Museum, Taylor (1997) asks "what sort of future is likely to emerge from the form of memory that they practice?" This question can be usefully applied to Nukey Poo, especially in light of contemporary developments. Renewed interest in small-scale nuclear reactors – particularly in the Canadian Arctic – has prompted M.V. Ramana to assert that "the nuclear industry continues to practice selective remembrance" (2015), with the negative aspects of past approaches ignored. In the case of Nukey Poo, those negative aspects include a more personal side that has only recently gained public attention. Recent reports of illness suffered by those involved in the clean-up of the PM-3A (Field, 2011) add another human dimension to the reactor's legacy – in January 2018, the New Zealand Defence Force released a Public Advisory on Potential Radiation Exposure at McMurdo Station. This noted that although the risk was low, it is "possible that those stationed at either McMurdo or Scott Base may have been impacted by power plant operations" (NZDF, 2018). Such a warning drew the attention of New Zealanders, as it reinforced fears about nuclear power that have long dominated in that domestic context. How the site should be remembered (bringing an awareness of the past to the fore) or commemorated (with the associated connotations of honour and celebration) and how the afterlives of the now absent reactor should be narrated therefore continue to be questions of contemporary relevance.

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Finally, questions over energy security in the Antarctic remain. Writing in 2005, Lawrence, Ashley, and Storey concluded that "nuclear power (for example, in the form of a Radioisotope Thermo-electric Generator) is ruled out [in the region] by cost and environmental considerations" (p. 3) (though, as Harvie (2018) reports, a small number of Automatic Weather Stations on the continent have been powered by such radioisotope thermoelectric generators). Instead, attention has turned to renewable energy sources, including wind and solar (Woehler, Ainley & Jabour, 2014). As Tin et al. (2010) argue, "the ambition to run entire stations or field camps on 100% renewable energy is increasingly common and feasible" (p. 1715). Belgium's Princess Elisabeth Station makes use of both solar and wind energy and markets itself as the first "zero emission" Antarctic station (International Polar Foundation, 2013). This claim serves an aspirational purpose, acting as an example for those back home – the suggestion that if it can work in Antarctica, it can work anywhere carries echoes of the PM-3A pilot for portable nuclear power. Although Princess Elisabeth Station is limited to summer operations and does continue to have fuel-based backup capacity, it continues to be symbolic of an environmentally friendly energy future. Fuel remains costly across the continent, so technologies are often used in combination. On Ross Island, the former home of Nukey Poo, the installation by New Zealand of three 330 kW Enercon E3 wind turbines in 2009/2010 allowed for renewable energy to be fed into the McMurdo Station power grid and reportedly cut CO_2 emissions by 1242 tonnes per year (Antarctica New Zealand, 2023). The good-news stories that accompanied this development parallel the earlier optimism that surrounded the installation of Nukey Poo, but these are tempered by an awareness of the complexities of operations and logistics. As the challenges faced throughout Nukey Poo's lifespan aptly demonstrate, solutions are rarely as simple as they may first appear.

Conclusion

The tale of Nukey Poo started full of promise and ended as an expensive exercise in gravel removal. Wilkes and Mann (1978) summarise the transformation, reflecting that:

> No one could have guessed 14 years ago that the concluding act for this reactor – a reactor which was going to revolutionize Antarctic living and provide electricity for only two-thirds the cost of diesel generated power – would be two shiploads of radioactive dirt being sent halfway around the world (p. 36).

The episode is situated within the wider history of commercial activity in the Antarctic, as the new power source was initially envisaged as a way to enable further development, including mining activity. Although most of Dufek's vision never came to fruition, the HSM designation indicates that Nukey Poo is still recognised as having played an important role in the US's Antarctic past. The episode also raises questions of heritage and memory and offers an opportunity to reflect on the imagined futures of our past.

When Admiral Dufek wrote in 1960 "Antarctica will be a fantastic land in the future" (p. 172), he had a very different vision in mind to the Antarctica we see today. According to contemporary rhetoric, the far south is not a place to be improved upon with human innovation, so much as a place to be protected from human impacts (Nielsen, 2023). The framing of Antarctica as a "resource frontier" has given way to a vision of Antarctica as a valuable and fragile platform for scientific enquiry. Antarctica is important for humans in both formulations but in different ways. Cohen and Duckert (2015) argue that "to think that the world is ours to ruin or to save are two expressions of the same hubris" (p. 5) – both views frame humans as the only beings with agency over the future of the planet Earth. Although philosophically similar, the positions sanction different activities. In the case of Nukey Poo, attempts to restore the landscape following the reactor's dismantlement are emblematic of an attitudinal shift from a desire to dominate the landscape to a desire to conserve it. Humans are still the ones with agency in both scenarios, but the ways in which the non-human landscape is thought of differ – from a resource to be used and an environment to conquer to a place to conserve and an environment in need of protection. Nukey Poo therefore provides a useful lens through which to reflect on the evolution of attitudes towards Antarctica and to consider human relationships with the ends of the earth.

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