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A TUNNEL LEADING into the Swedish Nuclear Fuel and Waste Management Company's Äspö hard rock laboratory, deep beneath Oskarshamn, Sweden.

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Western Finland is home to what might become, in the early 2020s, the world's first geological repository for spent nuclear fuel. Beneath the island of Olkiluoto, a four-kilometer-long access tunnel leads deep into a subsurface lab called Onkalo, Finnish for "hiding place." Owned by nuclear waste management company Posiva Oy, Onkalo helps Finland's "safety-case" experts estimate how future geological, social, hydrological, and ecological conditions could affect the waste-disposal facility over the coming tens of thousands, hundreds of thousands, or even millions of years.

Over the next few years, Onkalo will be renovated and expanded at a depth of 400–450 meters to make space for storing up to 6500 tons of radioactive waste. Around 2120, after 100 years of accepting copper canisters containing spent nuclear fuel, the tunnel will be backfilled, sealed off, and then abandoned. Finland's KBS-3 repository design, used at Olkiluoto with key components made of copper, bentonite clay, and iron, was derived largely from neighbor Sweden's nuclear waste program. The two path-breaking Nordic repository projects have evolved in parallel.

I spent 2012–14 living in Finland, where I researched how Posiva's experts moved forward with their Olkiluoto repository ambitions.¹ I recorded around 120 interviews with geologists, managers, chemists, physicists, lawyers, activists, politicians, engineers, banking professionals, and others with insight into the country's nuclear expert culture. My aim was to explore anthropologically how my informants planned for the future. Could the ways they navigate complexity provide lessons for experts in other places and fields who also grapple with uncertain tomorrows?

Danish filmmaker Michael Madsen's 2010 documentary *Into Eternity* popularized Olkiluoto as a place where humanity reckons with geological time spans. Yet my fieldwork there assured me that Finland's nuclear experts have many lessons to teach on topics beyond those about Earth's evolution. In fact, most of my informants' insights were about the short-term horizons of office life, the aspirations of the scientific ethos, and the intricate relationships—between people, technologies, institutions, and concepts—needed to bring achievements such as nuclear energy into being.

This article tells a story about how the safety-case experts'

projects and the nuclear sector's flows of recruits and retirees became entangled with a single but extremely influential human life. I discuss the workflow and project-management disruptions triggered by that influential expert's untimely death. I protect the deceased person's identity with a pseudonym (Seppo)—a common practice among anthropologists working with sensitive or personal situations. I conclude by exploring what the story has to teach other organizations today, in this moment of an intergenerational transition in the nuclear-industry workforce across Western Europe, North America, East Asia, and elsewhere.

Specters of Seppo

Posiva's safety case is a key resource in the construction of Finland's nuclear waste repository. It is a huge portfolio of documented evidence—including reports, data, models, predictions, and maps about the region's geology—that supports Finland's nuclear industry application for regulatory permission to build and operate the facility. It also identifies the facility's hazards and prescribes how to control them. As a key developer of various methods and theoretical approaches used to model the region's ecosystem, Seppo had long been reputed to have a rich understanding of the portfolio. A leader of the project since the 1980s, he was described to me as the project's former "dictator," the one who "pulled all the strings." One insider called him the safety case's Kekkonen—a reference to Urho Kekkonen, Finland's prime minister and president from the 1950s to the 1980s.

When Seppo died suddenly in a mid-2000s bicycle accident, his loss dealt a serious blow to the safety-case project and brought it, in the words of another insider, to a temporary but "screeching halt." But death did not end Seppo's influence. As one informant told me in 2013, Seppo's "specter" lives on, haunting many aspects of the project a decade after his death: "I've never met him, but everyone talks about him. 'Seppo would have said this, Seppo would have done that, what would Seppo do here?'"

Seppo was known for his temper, a sometimes caustic personality, and acerbic straightforwardness. Always multitasking

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and looking busy, Seppo was primarily concerned with technical information. During meetings, he was often only half following along: reading through technical reports and only listening when he thought something interesting was being said. He frequently worked late into the night. He rarely talked about his private life. One colleague called him a lone ranger.

A Finnish modeler speculated that Seppo, discontent with the imperfections of the world around him, yearned to live in “the perfect world of his models.” Another informant described how Seppo would sometimes storm out of a meeting room banging doors, only to return once he had cooled down. He would, it was noted, fly off the handle at his secretaries and “directly devalue” his colleagues when he thought them to be underperforming.

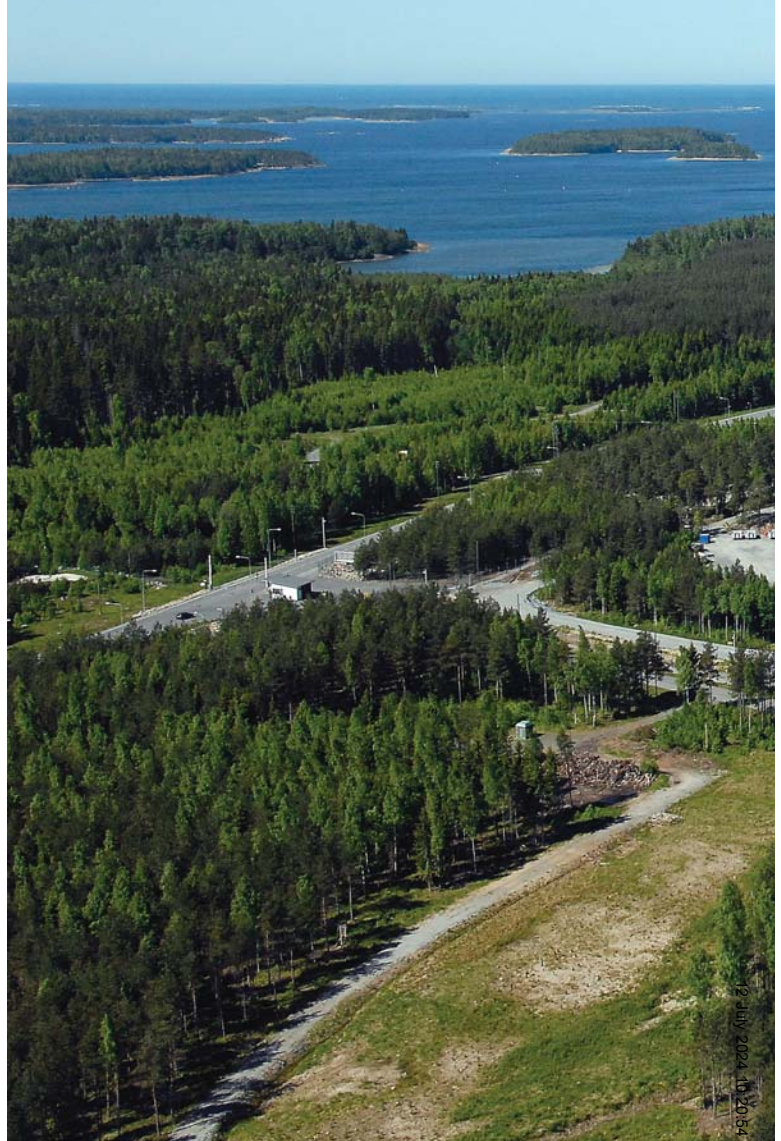
Yet many colleagues spoke of Seppo’s jovial demeanor during sauna nights, workplace parties, and trips abroad. They told of how he enjoyed cycling and traveling across the world for vacations. The workplace was where Seppo’s stubbornness, irritability, and intellectual intensity were most acute. But that intensity was thought to have its upsides. Cast as strong-willed, charismatic, extremely intelligent, and usually right, Seppo was said to have shaped the environment of the safety-case project to this day.

Alongside Seppo had worked Gustav, a physicist and engineer. Some portrayed Gustav as Seppo’s henchman. One informant cast Seppo as the tyrant with a vision and Gustav as his right-hand man, focused on the nitty-gritty calculation tasks delegated to him by his boss. An enraged Seppo fired Gustav twice. Seppo had also fired Rasmus, whose modeling expertise Seppo once allegedly denigrated as “like playing computer games.” Both Rasmus and Gustav were promptly rehired after Seppo cooled down.

Other informants recalled Seppo’s status consciousness. Gustav told me how Seppo, drunk at a party one night, became deeply upset after receiving news that Rasmus had been promoted above him in the safety-case hierarchy. Seppo then, sadly and seriously, announced that if Gustav were to ever be promoted above him it would be the lowest point in his life. Gustav described Seppo as ambiguous: an “angry bird” who sometimes wore “raging bullhorns.” Yet he respected Seppo and continued to value many of his insights long after his passing.

Two informants described Seppo’s attitude toward Posiva as “more popey than the pope”—more pro-Posiva than Posiva itself. Gustav associated Seppo’s dogmatism and formalism with the communist leanings of his youth. He explained how, even while Seppo had abandoned his political leftism long ago, his broader outlook on life, work, and science was generally shaped by a rigid mentality. He noted that Seppo simply had the brains, will, and aggressiveness to get the job done.

Understandably, Gustav had trouble empathizing with his former boss. Yet he still missed him in certain ways. Today, Gustav lamented, the safety-case project is all about market economics and competition, with every scientist thinking his or her own work is of the utmost importance, and with everyone trying to advertise their expertise to everyone else. That, he said, results in frequent conflicts between experts, money wasted on frivolous research, and excessive concern with the cosmetics of the safety case. In the 1980s, in contrast, the team felt more like a big family—a band of crusaders working to-



ward a good and honest safety assessment and nothing else. Gustav then joked to me that he sometimes imagines Seppo, sitting on a cloud in the sky and begging God to send him to hell so he doesn’t have to see the safety case “descend further into bullshit.”

When safety-case experts cast Seppo as powerful, competent, and reputable, yet also morally ambiguous and best kept at arm’s length, they were alluding to his role—in life and in death—as what an anthropologist might call an exemplar: an individual a community holds up on a pedestal and who shapes people’s imaginations and how they live their lives. Their anecdotes were rife with the ambivalent attitudes toward authority that anthropologists have long reported from fieldwork sites where memories of ancestors, forebears, or dead elders retain a long-term influence.

The afterlives of expertise

Seppo’s surviving colleagues had some control over his persona. Memories of the man did not rest in peace in a frozen past. They restlessly affected safety-case experts’ professional worlds in the present. Stories about Seppo could be told sometimes like fables, other times like hagiographies, and still other times like nostalgic retrospectives; they also were told to facilitate technical troubleshooting. The memories were not only preserved but edited, wittingly or unwittingly, through living experts’ selective accounts. He was sometimes remembered as



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THE OLKILUOTO NUCLEAR WASTE REPOSITORY, whose access buildings are shown in the foreground, will be the eventual home of spent fuel from Finland's four operating nuclear reactors. The influential leader profiled in this article spearheaded the safety analysis and environmental modeling that informed the repository's design and construction. Its network of deep tunnels (white) for sequestering the spent fuel are shown schematically in the bottom-right inset. The management company, Posiva Oy, calculates that the eventual tunnel length will total about 42 km across an area that spans up to 3 km². (Photo and image courtesy of Posiva Oy.)

a precedent or model to which safety-case experts strove to conform. At other times he was seen as an emblem of a backward mentality found in past project phases. Sometimes the subjective memories tightened group harmony; other times they were divisive and threw diverse perspectives into relief. Although Seppo has been replaced as a project leader, memories of him still shape nuclear experts' worlds.

In life, Seppo had strategically asserted his renown as a man set apart, elevated above those working for him. He accomplished that elevation by using his standoffish personality to secure exclusive control over a highly valued and specialized body of nuclear waste knowledge. Yet Seppo was never promoted to a management position. He was left to achieve power informally by developing a cult of personality coupled with a reputation for competence.

Seppo's surviving colleagues recalled their lost mentor's eccentric gruffness, great competence, and salty bluntness in ways that resemble how Lawrence Livermore National Laboratory scientists recall the quirks of prominent nuclear weapons designer Seymour Sack (1929–2011). Like Seppo, Sack

was not especially well known outside his own expert circles. Within them, he was elevated as a legendary mentor and brilliant thinker with a unique personality. In the 1990s Sack's mortality became a key focus in Livermore's work to archive indispensable insiders' knowledge before it was taken to the grave with them.

One informant called Seppo the "grand old man" of Finland's repository safety-assessment work. A similar term of endearment—"the kindly old gentleman," or simply "KOG"—is among the descriptions insiders in the US Navy use when reminiscing about Hyman Rickover (1900–86), developer of the USS *Nautilus*, the world's first nuclear submarine. Powerful friends in government helped him remain on active duty long after most other admirals had retired. Like Seppo, Rickover is remembered for more than just his innovations and competence. He also left behind a cult of personality and management philosophy that years after his death still pervade the organizations he helped build. Many remember Rickover for his extremely high standards, crustiness, abrasiveness, aggressiveness, and sharp tongue.

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A SAFETY-CASE EXPERT'S OFFICE adorned with a geologic timetable, a map of Finland, piles of reports, a photo from a geology fieldwork trip, and a picture of the structure of montmorillonite, a mineral found in the bentonite clays that are central to Finland's and Sweden's waste repository concepts. When it comes to safety analysis—evaluating the geological, hydrological, and ecological structure and likely evolution of the area intended to safely contain nuclear waste—offices are where the action happens.

Although Seppo never achieved Rickover's great fame, or even Sack's notoriety, he did greatly influence Posiva's path-breaking repository project. That influence established him as a mythic predecessor figure. Yet Seppo's indispensableness came at a cost. Efforts by Posiva's safety-case experts to revive workflows after his death, to recover fragments of his ideas, and to regain effective project organization lasted months. Surviving colleagues recalled scrambling to reallocate the workplace roles left unfilled by his vacancy. Some searched folders in Seppo's computer for clues offering glimpses of his lost thinking. Others tried to interpret margin notes he had scribbled in earlier drafts of his reports. Posiva had to hire new personnel.

Seppo's death left Posiva to face how when singular experts die, leave the organization, or abruptly change roles, latent overreliances on them can become liabilities. Death revealed Posiva's dependence on a unique expert who was not keen to document his scientific work's methodological assumptions. The safety-case project had relied so heavily on Seppo that it became, as one insider said, a sort of one-man show.

Today, Posiva avoids empowering any one expert as the safety-case project's all-seeing eye. Seppo's workplace role has been filled by a group of fewer than 10 specialists called the SafCa group: a decentralized team overseen by Posiva managers and consultants from abroad. Posiva has also upped its reliance on corporate bureaucracy, knowledge-management database platforms, external reviews, auditing, and documentation requirements. Safety-case knowledge is now seen as more transparent and traceable.

Predecessor preservation

This anthropological vignette can be read as a predecessor parable with insights for nuclear-expert organizations elsewhere. The transference of knowledge from a senior professional down to younger protégés likely always involves layers of context-dependent interpersonal dynamics. After all, what ultimately became crucial in Seppo's case was human relationships; in particular, the ways his standoffish charisma affected his acolytes created real liabilities for Posiva. The case suggests that other organizations should be wary when cults of personality, no matter how small their scale, form around experts.

Analysis of interpersonal relationships also suggests that merely interviewing a soon-to-retire expert to mine his or her vital knowledge—a common nuclear-sector practice—may fall short of capturing the expert's total impact. To even scratch the surface, an organization must interview dozens of colleagues who helped develop, adopt, and disseminate the expert's knowledge.



Nuclear energy faces looming human resource and expert succession challenges. Throughout the 1980s and early 1990s, the Three Mile Island and Chernobyl accidents deterred many science- and engineering-minded youths from nuclear professions. As Posiva struggled to contain the aftermath of Seppo's death, a global "battle against knowledge loss"² was raging in a nuclear industry that had a "weird generation gap"³ and few midcareer nuclear experts.

An International Atomic Energy Agency (IAEA) report⁴ noted that in the US as of 2010, just 13% of engineers, 14% of operations employees, 6% of maintenance employees, and 4% of radiation-protection employees were younger than age 33. The report advised US nuclear companies and government agencies to hire about 500 trained graduates yearly to compensate for baby boomer attrition. The utility company Électricité de France, which generates most of its energy output through nuclear power, expects to see 40% of its trained nuclear staff—more than 4000 professionals—retire in the decade following 2010. The report authors advised the utility company to recruit about 13000 PhD- or MS-level engineers and about 10000 BS-level operators and technicians in that span.

Between 2006 and 2010, China's 11th National Plan called for recruiting more than 20000 "high" professional or graduate employees even as the country, "like some North American and European countries, face[d] challenges in attracting students into specialist nuclear power fields."⁴ A 2012 Finnish govern-



MASSIVE METAL CASKS will encapsulate Finland's spent fuel rods for long-term storage. The outer canister (left) is a cylindrical sleeve of copper, one meter long and five centimeters thick, intended to protect a cast-iron insert (right, here with one fuel rod) from the corrosive effect of groundwater for at least 100 000 years. The cast iron itself resists the mechanical stresses of bedrock. When all its square holes are filled with spent fuel rods, the insert will be slid into a canister that is then welded shut with a copper cap and buried 400–450 meters underground. (Photo courtesy of Posiva Oy.)

ment study showed how as one-third of Finland's nuclear energy specialists reached retirement age, about 2400 replacements would be needed by 2025. If one were to include the trained recruits needed for nuclear waste management and Finland's proposed new reactor projects, the figure would rise to 4500 new employees.

Seppo's death is just one episode in a larger, global expert-loss drama. IAEA analyses have described how, in under-



A FINNISH SCIENTIST HOLDS absorbent clay that the waste-management company Posiva Oy is considering using to backfill the tunnels before its Olkiluoto repository site is sealed and abandoned around 2120. A similar clay that also absorbs groundwater and swells will be used to snugly encase fuel-rod-containing canisters in their tombs deep underground.

staffed conditions, abrupt unplanned retirement, quitting, outsourcing, downsizing, job transfer, or death can destabilize nuclear projects.⁵ Problems can worsen when an expert with "valuable and unique knowledge," whom "peers and management recognize as someone 'we can least afford to lose,'" is lost.⁶ Seppo's story is therefore a cautionary tale.

Studying Seppo's character and influence anthropologically is not about capturing exactly what he thought, precisely what he did, or how he did it. Rather, it's about examining the effects of "what would Seppo do here?" moments, in which surviving colleagues brought recollections of the man to bear on their present work.

I propose that nuclear experts pause for a moment to consider how they can best preserve the memory of an expert's thinking patterns in their work lives. Cultivating that style of self-reflection can help nuclear experts better understand their predecessor's insights that they may already be preserving. The practice can also instill a richer sense of how to usefully summon the insights to troubleshoot any problems that arise. Such a skill will be vital as the nuclear workforce worldwide experiences extensive turnover in the years to come.

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