

EDITED BY
RONALD E. DOEL, KRISTINE C. HARPER & MATTHIAS HEYMANN

EXPLORING GREENLAND

Cold War Science and Technology on Ice

PALGRAVE STUDIES IN THE HISTORY OF SCIENCE AND TECHNOLOGY



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Ronald E. Doel • Kristine C. Harper • Matthias Heymann
Editors

Exploring Greenland

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Editors

Ronald E. Doel
Florida State University
Tallahassee, Florida, USA

Matthias Heymann
Aarhus University
Aarhus, Denmark

Kristine C. Harper
Florida State University
Tallahassee, Florida, USA

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CONTRIBUTORS

Ronald E. Doel is Associate Professor of History at Florida State University, Tallahassee.

Kristine C. Harper is Associate Professor of History at Florida State University, Tallahassee.

Matthias Heymann is Associate Professor, Centre for Science Studies, Department of Mathematics, Aarhus University, Denmark.

Anne LifLund Jacobsen is an Assistant Professor at the Danish National Archives in Copenhagen, Denmark.

Henrik Knudsen is an archivist and senior researcher at the Danish National Archives in Viborg, Denmark.

Janet Martin-Nielsen is a postdoctoral researcher, Centre for Science Studies, Department of Mathematics, Aarhus University, Denmark.

Henry Nielsen is Professor Emeritus, Centre for Science Studies, Department of Mathematics, Aarhus University, Denmark.

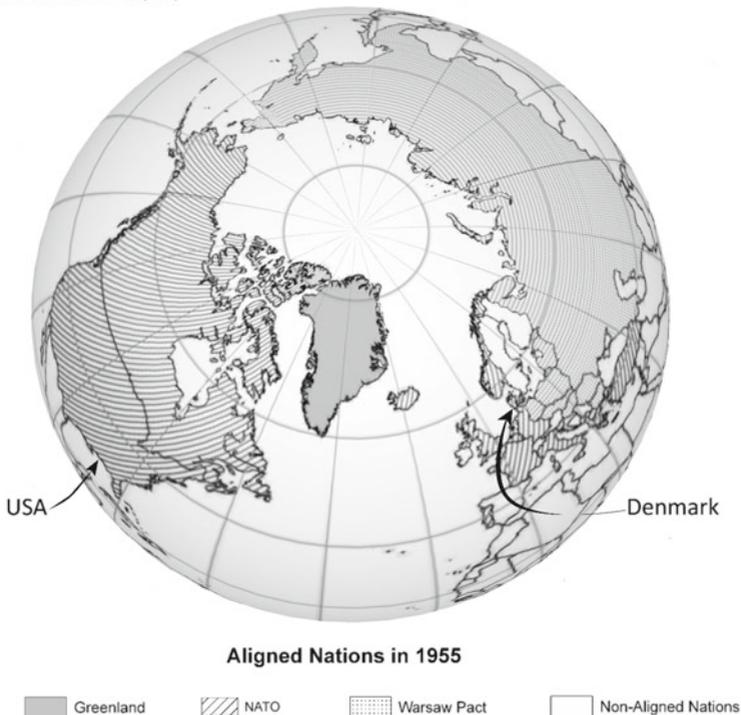
Kristian H. Nielsen is Associate Professor, Centre for Science Studies, Department of Mathematics, Aarhus University, Denmark.

Christopher Jacob Ries is an exhibition researcher at the Natural History Museum of Denmark in Copenhagen, Denmark.



...we must not think of Greenland as being a barrier or as being militarily unusable when it is not such a barrier and not militarily unusable to Russia; since this vast area that lies halfway and athwart airline routes from the heart of our military might to the heart of Russia's military might it has great geographical military value.

--Admiral Richard E. Byrd, *Report on the usability and the logistical support of Greenland for military operations and study on polar strategy*, Book 1, 1951 (classified secret), prepared for the Joint Chiefs of Staff, xi. Box 6 of 15, RG 27, Records of the Polar Operations Project, formerly classified subject files, 1942-63, National Archives and Records Administration II (USA)



Frontispiece maps. Credits: Map 1: Greenland physical map courtesy Uwe Dederling/Natural Earth Public Domain mapset, with overlay by James Mogle, College of Social Sciences and Public Policy, GIS, Florida State University, and the editors. *Map 2 (global):* courtesy of James Mogle, College of Social Sciences and Public Policy, GIS, Florida State University.

Greenland and the World

	DENMARK-GREENLAND	INTERNATIONAL	USA-GREENLAND
	1939: total population in Greenland 18,708 (West 17,352, North 277, East 1,079)		
1940	9 April: Denmark's occupation by German forces begins	Dec. 1941: Attack on Pearl Harbor	9 April 1940: 40: USA agrees to supply Greenland with goods and provide military protection. American and Canadian consulates established 9 April 1941: Negotiations with Danish dipl. rep. Henrik Kauffmann, Washington: USA accepts Danish sovereignty over Greenland in return for right to establish military bases. Danish government protests; sacks Kauffmann
1945	5 May: German occupation ends; Greenland Geological Survey (GGU) established 1946: Total population in Greenland 21,412 (West 19,718, North 322, East 1,372)	July: USA becomes nuclear power; WWII ends in August	Oct. 1941: Sondrestrom AB established at Sander Strømfjord Returned to Greenland Government in 1992, but still houses small USAF detachment 1943: First Thule Air Base constructed. Still in use by USAF 1944: Total US personnel at bases in Greenland: 5,795 5 May 1945: Danish Government ratifies 1941 agreement with USA 1946: USA offers to buy Greenland from Denmark (\$100 million); offer rejected
1950	1949: Denmark joins NATO Government commission publishes reorganization of Greenland report. Many reforms implemented same year 1951: Ionospheric station established in Godhavn; new US-Denmark agreement, Greenland and the Defense Area (effective 8 June 1951) 1952: Scandinavian Airlines (SAS) begins Copenhagen-California route via Thule (24 hrs); Station Nord and A/S Nordisk Mineselskab established	1948: Berlin blockade 1949: USSR becomes nuclear power June: Korean War begins	Nov. 1950: USA seeks Danish permission to build Thule AB 1951: Construction of Thule Air Base begins (Operation Blue Jay). Involved 120 shipments, 12,000 men, 300,000 tons of cargo June 1951: New US-Denmark agreement, Greenland and the Defense Area Sept. 1952: Construction of Thule AB made public (completed following year)
1955	1953: Greenland colonial status officially ends (incorporated into Denmark); indigenous population at Uummannaq (near Thule AB) relocated to Qaanaaq 1954: SAS begins routes from Sdr. Strømfjord; half of Greenland's population now living in cities 1955: Only 40% of Greenland population makes a living by hunting and fishing	1953: Korean War ends	1954: US research camp TUTO (Thule Take-Off) established east of Thule AB 1955, summer: total personnel, Thule AB, 6,551
1960	1958: first regular inland air flights in Greenland; uranium is discovered in Kvanefjeld Government commission tasked to establish guidelines for Greenland's further development 1961: Greenland becomes member of European Free Trade Association	June 1, 1957: IGY begins Dec. 31, 1958: IGY ends	US Army research camp FISTCLENCH established on ice cap east of Thule AB 4 Nike Missile sites are readied for operation at Thule AB Camp Century is established; Camp FISTCLENCH abandoned 1959, summer: total personnel at Thule: 7,291 (civilian 2,179)
1965	1964: Commission of 1960 publishes report; cryo-lite mining in Ivigtut ceases Greenland Mineral Resources Act adopted; Greenland Geological Survey (GGU) reorganized 1966: total population in Greenland 39,600 (West 36,076, North 658, East 2,866) 1967: Greenland's largest city, Nuuk (Godthåb) surpasses 5,000 population	1961: Berlin Wall crisis 1962: Cuban Missile crisis 1963: Limited Test Ban Treaty: prohibited all testing of nuclear weapons except underground Vietnam War intensifies	1961: Ballistic Missile Early Warning System (BMEWS) radar constructed near Thule AB US begins downsizing operations at Thule AB
1970			1967: Camp Century closes 21 January 1968: US B-52 bomber carrying four nuclear weapons crashes near Thule AB 1968, summer: total personnel at Thule AB, 1,189 (civilian 514)

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Introduction: Exploring Greenland's Secrets: Science, Technology, Diplomacy, and Cold War Planning in Global Contexts

*Ronald E. Doel, Kristine C. Harper,
and Matthias Heymann*

Smoke was rapidly filling the cockpit. The plane—a massive US Air Force B-52 bomber flying a secret reconnaissance mission, its seven crewmembers now quite alarmed—was roughly six miles above the ice cap crowning the enormous expanse of Greenland. Local time was nearly 4 p.m. That far north in midwinter (21 January 1968, a Sunday), the sky was already bluish-purple dark. A gleaming last-quarter moon hung low in the south. The only hint of civilization on the dim icy landscape below was lights belonging to the US Thule Air Base in northwestern Greenland, some 500 miles from the North Pole, a tiny, comforting glow on the distant horizon.

Only later would crewmembers realize what had caused the fire. One of the seven, trying to free space in the cramped cockpit, had stuffed three

R.E. Doel (✉) • K.C. Harper
Department of History, Florida State University, Tallahassee, FL, USA

M. Heymann
Centre for Science Studies, Department of Mathematics, Aarhus University,
Aarhus, Denmark

foam pillows under his seat. There, further wedged in by a metal box, the pillows blocked airflow from a crucial heating vent. As the B-52's cockpit grew frigid in flight, a shivering crewmember toggled an emergency heater. Hot air blasted in from the engine manifolds. It struck the foam pillows, igniting them as if by a blowtorch. Flames leapt out from under the seat. Crewmembers shouted to one another over the roar of the engines, aiming fire extinguishers on the blaze. When the flames instead intensified, the plane's pilot radioed Thule, requesting an emergency landing.¹

The Thule base toward which the crippled B-52 was descending was one of the largest military bases the USA had ever constructed. But at the time, relatively few Americans knew that it existed, and fewer still understood the great strategic significance Greenland had gained in the Cold War struggle between the USA and the Soviet Union. World War II veterans who had served in the North Atlantic theater remembered Greenland as a crucial refueling stop in the air ferry route from North America to Britain and Western Europe, midway between Newfoundland and Iceland.

By the early Cold War, new technological advances in long-range bombers had led to new missions. In 1952, American audiences opening the pages of *Life* magazine read about the construction of the Thule base—requiring the labor of more than 10,000 soldiers and engineers to complete. Less than ten years later, they marveled about a unique nuclear-powered city American military forces had constructed under the ice cap. Camp Century (so-named since it was situated 100 miles east of Thule) was revealed to them in dramatic footage aired on the popular Sunday evening television show, “The Big Picture.”² But why did Greenland—so remote, so close to the North Pole—really matter? For leaders in the Pentagon, geography was key. Midway between North America and Northern Europe, Greenland was situated just 3000 miles (4800 km) away from the vital Soviet cities of Moscow, Murmansk, and Leningrad (now St. Petersburg)—a short distance for bombers (See Chap. 2).³

Danish citizens were also concerned about Greenland during the early Cold War (Denmark had long ruled Greenland), but they heard little about military activities there. The stories that most intrigued and concerned Danish citizens were not the same as those broadcast to American audiences. Danes knew that after Denmark fell to the Nazis in 1940, Denmark's ambassador to Washington had made an agreement the following year, allowing the USA access to Greenland until “it is agreed that the present dangers to the peace and security of the American continent have passed.”⁴ This vague diplomatic phrase had seemed a good idea at

the time—indeed, it made possible the forceful and fateful Allied push into France and Western Europe after 1944. But many Danes became wary after the USA remained firmly entrenched in Greenland after World War II ended in 1945, and became even more concerned after word leaked that US Secretary of State James Byrnes had horrified Denmark's Foreign Minister in 1946 by asking whether it might sell Greenland to the USA for \$100 million (3.1 billion 2015 USD), hoping that Denmark would welcome the boost its treasury would receive.⁵ While Denmark had remained firmly aligned with the West during the Cold War—it was a founding member of the North Atlantic Treaty Organization (NATO) in 1949—extensive activities in northern Greenland by the US military seemed to Danish citizens (and not a few leading politicians) a violation of their national sovereignty. The construction of nuclear-powered Camp Century carved into the ice cap in 1959–60—celebrated as a technological achievement in the USA—instead irritated the Danish people, who believed their country had embraced a no-nuclear policy at home.⁶

But neither American nor Danish audiences before 1968 fully appreciated the extent of US military activities in Greenland in the early Cold War. Danish leaders had suspected, but never felt certain, that the US military had been storing nuclear weapons on its territory. This indeed was the case, and had been for some time. The burning B-52 descending toward Thule, just one asset in the Pentagon's northern arsenal, was carrying four atomic weapons. Each had a yield of 1.1 megatons, roughly 80 times the explosive force that had devastated Hiroshima a generation before. The mission of the now-crippled B-52 bomber—part of the US-devised North American Continental Defense strategy—was to closely monitor the Ballistic Early Warning System at Thule, one of the most strategic sites for North American continental defense. If communications between it and warning centers in the USA were broken for any reason, the B-52 Stratofortress was to investigate—and then be ready to strike Soviet targets if so ordered.⁷

Yet this was only part of the reason why American military leaders were so deeply invested in Greenland in the early Cold War. An equally covert—and crucial—Pentagon goal was to carefully assess Greenland, indeed the entire Arctic, as a potential theater of war. Since the shortest great circle route between the Soviet Union and North America bisected the high Arctic, military planners realized a hot war might occur in this newly strategic, frigid space. (Veteran polar explorer Richard Byrd argued that if the USA failed to take advantage of Greenland for possible air attacks against the Soviets and to defend against Soviet attacks, “it is my opinion

that this Nation is courting military disaster.”⁸) Yet a vast gap yawned between what Western researchers needed to know to operate weapons and monitoring systems successfully in the Arctic, versus what they actually knew. How did storms and weather systems move through this region? How quickly did sea ice form in winter, and thin in the summer? How would geomagnetic fluctuations and the aurora affect radio communications and navigational equipment? How would ocean currents influence ship movements and submarine operations? Was there evidence that the northern climate was indeed warming, requiring revised war plans? Did the ice cap mask seismic signals from Soviet nuclear tests? These were crucial issues for Cold War strategists. Understanding the physical environment of Greenland and the larger Arctic was essential to successfully employ the new weapons systems of the early Cold War, including long-range bombers, guided missiles, and (by the late 1950s) nuclear-powered submarines and defense warning radars. At Thule, and at other US installations throughout Greenland and the Arctic, researchers had sought answers to remedy these deficiencies.⁹

At half past four local time that evening in Greenland, as the B-52 continued its emergency descent, the plane’s electrical power system failed.

* * *

The massive island toward which the wounded bomber was rapidly dropping had just over 40,000 inhabitants in 1968—less than the population of Copenhagen back in 1700—scattered across an area 50 times the size of Denmark, or roughly 1.5 times the land area of Alaska. The island’s first inhabitants, including the Inuit Thule, were descendants of rugged individuals who already had begun venturing along the rim of the North American Arctic Ocean by 1000 BC, their migration rivaling that of Polynesian voyagers.¹⁰ European settlers, while more recent arrivals, were no less legendary. Erik Thorvaldsson (Eric the Red), banished from Iceland in 982, had led hundreds of fellow disaffected Vikings to southern Greenland. The two settlements established by his followers, at their height, had supported nearly 6000 people and 300 farms, with sheep, goats, and miniature cattle; they also built more than a dozen churches.¹¹ Eric’s group had limited interactions with the indigenous Inuit (whom they called “skraelings”) living further north.¹² When the local climate had turned frigid in the mid-fourteenth century—making southern Greenland far less green, with increased sea ice hindering their trade with Denmark—settlers began abandoning these

encampments, decamping for good by 1450.¹³ The island of Greenland nevertheless formally remained a colony of greater Denmark from the eighteenth century forward.¹⁴ After splitting from Denmark following the Napoleonic wars in 1814, the new nation of Norway laid claim to Eastern Greenland in a period of increasing nationalist sentiment in the early twentieth century. Norway lost its claim in The Hague in 1933, and Greenland came solely under Danish rule. But Danish efforts to maintain sovereignty claims, like elsewhere in the colonial north by the early twentieth century, had shifted from economics (trade) to science (detailed strategic knowledge about landscapes and natural resources).¹⁵ It was this issue that fueled an increasingly bitter dispute in the 1930s between the Danish explorer Lauge Koch—internationally known for his explorations of Greenland—and other prominent Danish geologists after Koch claimed superior knowledge of Greenland through aerial mapping (using photographs from airplanes) rather than ground-truthing by dog-team-pulled sledges. Knowledge equaled sovereignty: so vital were these issues for Danish nationhood and self-identity that the Koch controversy commanded front-page attention in leading Danish newspapers for nearly a decade.¹⁶

By the 1930s, natural scientists were increasingly drawn to Greenland's immense ice cap—second only to Antarctica as a relic of Earth's last ice age. The enormous ice dome filling Greenland's vast interior had fascinated researchers since the nineteenth century, and the famed Norwegian polar explorer Fridjof Nansen had first traversed its southern part in 1888. Interest rose further in the twentieth century after the German glaciologists Albrecht Penck and Eduard Brückner, drawing on their fieldwork in the eastern Alps and a half-century of prior investigations, published evidence that four ice ages had occurred, interspersed by warmer interglacial periods.¹⁷ The first research station on the ice cap, named Eismitte (Ice-center), was established in 1930 by German geophysicist Alfred Wegener, who sought both meteorological data (appreciating its importance for understanding European weather) and evidence for his theory of continental drift. That November, trekking back to the coast from Eismitte, Wegener died on the ice cap just 118 miles from his destination.¹⁸ After 1945, in addition to US researchers, Danish authorities permitted a small number of other Western European nations to send expeditions to Greenland's center, including the *Expéditions Polaires Françaises*.¹⁹ Much later, glaciologists and paleoclimatologists, building on new evidence and discoveries, would conclude that Greenland's ice cap had first originated some 45 million years ago during the Eocene epoch—a time

when the tectonic plates of India and Asia had collided, pushing up the Himalayas, and when cooler, drier conditions gave rise to vast savannahs and grasslands that encouraged humanity's ancestors to come down from trees to establish themselves on the plains of Africa.²⁰ They also came to recognize that Earth's climate in the past had shifted dramatically, with rapid warming (up to 15°C, or 59°F) occurring within decades.²¹ Back in 1968, many of those insights remained in the future. But researchers already recognized that the first ice cores being drilled deep into the ice cap at Camp Century were revealing a great deal that was unexpected about the Earth's past.²²

Neither the prior settlement of Greenland nor what insights its ice cap might provide into Earth's past (and possible future) climate were likely on the minds of the seven terrified B-52 crewmembers as they prepared to abandon their aircraft, now a blazing inferno. When the pilot judged the plane close enough to the Thule base to make rescue feasible, he ordered his crew to jump. Six, equipped with parachutes, fired their ejection seats at 4:37 p.m. local time. (The last crewman, the co-pilot, had no choice but to use a lower hatch at the bottom of the aircraft.) Moments later these crewmembers, isolated from one another, were abruptly thrust into frigid silence, swaying under parachutes in the vast night sky. Stung by the bone-chilling air, they looked down at a frozen, ancient landscape rushing up to meet them (Fig. 1.1).

* * *

Just two minutes later, at 4:39 p.m. local time, the now-abandoned Stratofortress bomber crashed some seven-and-a-half miles (12.5 km) west of Thule. Flying at nearly 600 miles per hour, it struck the frozen Wolstenholme Fjord like an immense hammer blow, cracking the solid ice surface. Enormous concentric ripples formed, later freezing in place. The plane's fuselage, along with its cargo of nuclear weapons, disintegrated—although the small primary non-nuclear fuses for the bombs did detonate, scattering radioactive contamination. Wrecked pieces skidded madly across the snow-cruled surface. The heaviest parts sunk to the sea floor below. Burning aviation fuel splashed across an area the size of four football fields. As thunderous reverberations from the crash faded, intense curtains of flame leapt into the night sky.²³

Rescue teams fanning out from Thule Air Base soon located five of the B-52 crewmembers who had parachuted from the crippled plane.



Fig. 1.1 Thule Air Base viewed from the air. Constructed in secret by 12,000 workers in 1951, this base—one of the largest ever created by the United States—was nearly equidistant from North America, Western Europe, and the Soviet Union. Weapons on long-range bombers based there included nuclear bombs. *Credit: U.S. Air Force photograph.*

Eventually they rescued one more shivering survivor. (The seventh crew-member, forced to use the emergency lower hatch, was fatally injured during his escape; his body was later recovered.) It would be one bright

spot of this horrific accident: that most crewmembers survived was a reflection of the pilot's good judgment, the abundant resources the US military had invested in its technological systems, and luck that the incident had unfolded so close to the Thule base.²⁴

But in Copenhagen and Washington, the mood was much grimmer. Lights burned late in US State Department offices in Foggy Bottom. Early next morning, Monday, 22 January, Denmark was briefed about what had happened. The accident was about to unmask a Cold War secret long helpful to both nations, one that American and Danish diplomats knew would infuriate Danish citizens, damage US credibility, and rekindle concern about US foreign policy throughout Western Europe and around the globe. Until this time, US authorities had managed to conceal its placement of nuclear bomb-carrying bombers on this remote Danish territory, a flagrant violation of Denmark's 1957 declaration to ban nuclear weapons on its soil, and in its waters and airspace. The behind-the-scenes story was one rich with Cold War intrigue. In 1957, responding to a letter from the US ambassador in Copenhagen about this policy, Denmark's then-Prime Minister Hans Christian Hansen sent back a private, highly confidential response: these US queries "do not ... give rise to any comments from my side." Washington had accurately interpreted the Prime Minister's coy response as a green light to carry out its covert plans for North American continental defense in Greenland. All that would now unravel. The situation was made far worse by its timing: Danish citizens were poised to head to the polls to elect a new Danish parliament in just two days.²⁵ Diplomats in Copenhagen quickly hammered out a workable cover story, announced by Prime Minister Jens Otto Krag: when a US bomber carrying atomic weapons on a Strategic Air Command patrol became stricken, Thule base was the closest emergency facility; Denmark had served humanitarian ends by allowing the plane to attempt a landing there.²⁶

At first, the cover story seemed to work. But for many it was too little, too late. Public opinion in the West was already swinging against the idea of avoiding nuclear Armageddon by keeping massive stockpiles of nuclear weapons at hair-trigger readiness. Another B-52 bomber above Palomares, Spain, had dropped four atomic weapons following a mid-air collision just two years earlier, in January 1966; these accidents helped make the prevailing Cold War doctrine of mutual assured destruction seem more a *Dr. Strangelove* parody than sober foreign policy.²⁷ With the war in Vietnam intensifying—North Vietnam's Tet Offensive began at the same time as the Thule crash—the

weapons lost in Greenland were troubling reminders of mounting casualties and the ever-present anxiety about a final atomic catastrophe.²⁸

In many ways, the B-52 crash at Thule happened at a propitious moment. The year 1968 marked a year of global revolution: the beginning of mass protests and rebellion on university campuses, on the streets, and even within military units, as social unrest sparked demands for violent change.²⁹ Around the world, a great wave of decolonization gained momentum—quickly recognized as one of the crucial transformations of twentieth-century global history.³⁰ Grass-roots environmental activism, already gaining steam, would burst forth on the US stage only two years later: the first Earth Day rallies drew 20 million participants across the country, focusing new attention on pollution and pesticides.³¹ On Christmas Eve that year, Apollo 8 astronauts Frank Borman, Bill Anders, and Jim Lovell, the first humans to orbit the Moon, read from the book of Genesis in a live broadcast, taking soon-to-be-iconic photographs of earthrise above the Moon.³² Already by then the USA was beginning a gradual drawdown from Greenland (it had abandoned Camp Century in 1966, and US Secretary of Defense Robert McNamara had cancelled the Strategic Air Command's entire Airborne Alert program in July 1968). In future years, the Thule crash would slip from the collective memory of the Cold War, and with it Greenland's role as a strategic outpost. Greenland instead, by the 1990s, was represented by images of melting glaciers, a poster-child of planetary vulnerability in a warming, ecological age.³³

* * *

What can we learn by examining developments in distant Greenland—particularly relating to science and technology—during the four decades of the Cold War? At first glance, Greenland seems remote from the key conflicts and turning points that defined the Cold War. Greenland had no Gulag, in sharp contrast to the Soviet system of captive labor that remained on tap for massive infrastructure projects in the Russian Far North.³⁴ Greenland was never subject to aboveground nuclear weapons tests—in contrast to Amchitka, Alaska, and Novaya Zemlya in the Soviet Far North.³⁵ Greenland was never contested territory in the way that the archipelago of Spitzbergen—Norway's far northern possession, 1000 miles to the east, now known as Svalbard—had been since World War II.³⁶ In contrast to far northern Canada—where interactions between US servicemen and local indigenous communities in remote sites where Distant

Early Warning (DEW) line radar facilities were built resulted in a generation of children who never knew their American fathers—Danish authorities in Greenland worked hard to minimize such contacts.³⁷ Although US researchers and military officials worried that the Arctic (including Greenland) might become ground zero for World War III—the well-connected US military geographer Paul Siple noted in 1946 that “with improved air warfare the Arctic once a barrier is a potential if not the logical invasion route” to America—all of the global hotspots in the Cold War, from Algeria and Korea to Vietnam and Afghanistan, occurred in the mid-latitudes or the tropics.³⁸ What, then, can we gain by looking carefully at US involvement in Greenland after 1945, particularly by focusing on public as well as secret scientific and technological developments achieved in this vast, remote, sparsely populated, ice-covered land?

Greenland reveals three Cold War issues with remarkable clarity. First, it illuminates the extraordinary strategic importance that Greenland, indeed the entire Arctic, had for the USA during the Cold War. Already by 1946, Pentagon leaders had begun coveting Greenland as “the world’s largest island and stationary aircraft carrier.”³⁹ This public declaration matched the military’s internal assessment: “The possibility of utilizing the Greenland Ice Cap for any military or civil operation,” one analyst wrote in 1949, “is no longer dubious, but a certainty.”⁴⁰ The US military indeed invested deeply in northern Greenland, building Thule Air Base, the under-the-ice nuclear-powered city called Camp Century, and a handful of separate research installations on the ice cap. As fantastic and futuristic as Camp Century seemed to be, it was not the most audacious scheme proposed. US Army planners sought to initiate Project Iceworm, involving hundreds of Minuteman missile launchers (equipped with nuclear weapons) on rail lines buried in tunnels spanning some 50,000 square miles of the ice cap, equivalent in size to England. These Minuteman missiles were to be moved continuously under the ice, so that no Soviet missiles or bombers could take all of them out—a plan to preserve the US retaliatory strike force half the distance away from the Soviet Union as North Dakota and Montana. For several reasons, Iceworm was never built: it was primarily a bid for relevance from the US Army (amid famous interservice rivalries); advances in other weapons systems (including the Navy’s Polaris missile, successfully tested in 1960) made it less relevant; and cap ice flowed more rapidly than military engineers optimistically anticipated.⁴¹ But nuclear cities and buried railroad lines with nuclear missile launchers were a northern, terrestrial counter-

part to the actually-pursued Apollo lunar missions, similarly propelled by the Soviet–American standoff. (While Camp Century was fully known to Danish citizens when it was constructed, they would not learn about Project Iceworm—hidden in plain sight—until the late 1990s, even if Danish researchers working there did have their suspicions.)

Second, Greenland makes clear how vitally important the physical branches of the environmental sciences (the earth sciences, also called geophysics) were for the Pentagon during the Cold War, and how much new knowledge was gained. While this knowledge had utilitarian value for the US military and for continental defense, it also provided new insights into Earth's physical environment. Greenland mattered in part because it was a vital, unknown territory. As one of the few frontiers left on the planet, new weather stations scattered across its northernmost expanse would yield meteorological data necessary to forecast Europe's weather and to build global circulation models, just as detailed knowledge about the island's geology would allow support crews to build resilient landing strips and installations. But Greenland also became a scientific laboratory, a place where instruments recorded new details of auroral activity (crucial for communications and navigation); where sounding rockets recorded ionospheric details; where ocean currents bordering Greenland were carefully measured; where seismic activity was monitored; and where deep ice cores were drilled. Greenland was not a major site for research during the singularly influential International Geophysical Year of 1957–58—Denmark's tight funding limited the establishment of new stations, and both Danes and Americans were happy to limit foreign visitors—but the deep ice cores first drilled there in the 1960s were singularly important contributions to charting past ice ages, warm interglacial periods, and the extraordinarily rapid (several decades) shifts to warmer climates that helped cause sea level rise.⁴² Without the Cold War, researchers would still have sought ice cores. But only nation-states initially could afford the enormous costs of drilling infrastructure, and the Cold War—like so many modern conflicts—has-tened the production of scientific knowledge.⁴³

Lastly, Greenland illustrates the practice of smaller-state politics in the Cold War, an important aspect of diplomatic history often overshadowed by the dominant standoff of the USA and the Soviet Union, and the attention-grabbing intrigues involving divided Germany and the client state hot wars in Korea and Vietnam. Denmark was a faithful US ally through the Cold War, and relations between Washington and Copenhagen remained cordial—but tensions did arise, some quite

challenging, that required deft maneuvering. Danish citizens (and their leaders) wanted America to respect its sovereignty over Greenland, obey restrictions it placed on research activities, and hear about actions US personnel were taking. In practice, this did not always occur: US officials belatedly informed their Danish counterparts about the massive effort to construct Thule Air Base; began building Camp Century before gaining Danish approval, and initiated planning for Project Iceworm at the highest levels of the US government without involving Denmark. Yet at the same time, Washington did advise (often overwhelmed) Copenhagen leaders of specific experiments it wished to pursue, occasionally yielding when told *nej* (no), as in the case of high-altitude balloon launches Copenhagen feared could harm international détente in the 1960s. The relationship was complicated. Danish wishes were respected more often than many Danes imagined, despite ambiguous and troubling cases such as housing nuclear weapons at Thule. But, simultaneously, Denmark began addressing its own long-standing role as colonizer. By 1953, Denmark made the island a Danish *amt*, or county. Later (1979), the Danish Parliament offered Greenland home rule (self-government), and by 2009, Greenlanders would gain increased self-determination in foreign policy, judicial affairs, and natural resource exploitation.⁴⁴ The end of the Cold War thus accelerated a process already in motion when Greenland was solely a “fortress of defense” for the USA.⁴⁵

* * *

This volume provides a vivid portrait of these relationships and challenges, contributing to our broader understanding of the Cold War as well as the role of the Arctic in understanding larger environmental issues of great contemporary concern. It is not the final word on these matters. In truth, there are many Greenlands. For instance, we still know little about how Greenland’s Inuit peoples experienced the changes and challenges brought about by the Cold War, apart from a few tantalizing details. In the early 1950s, Danish authorities relocated an indigenous settlement near the rapidly emerging Thule Air Base, hoping to limit destabilizing contacts with Americans.⁴⁶ Yet some contact continued: native Inuits were recruited to assist in the emergency cleanup of radioactive contamination from the B-52 crash in Wolstenholme Fjord in early 1968, almost certainly because they had tacit knowledge and skills demanded by this task.⁴⁷ But we did not find evidence that Greenland Inuit also contributed to Western

understanding of the physical environment, as occurred elsewhere in the Arctic.⁴⁸ In fact, Denmark strictly forbade foreign scientists from making use of Inuit in local operations.⁴⁹ We also know that certain US activities in Greenland remain sensitive to this day—including various Project Iceworm records in the Eisenhower Presidential Library—and remain classified.⁵⁰

Our views of the Cold War Arctic remain kaleidoscopic, and surely new surprises will emerge. For instance, we know little about how Soviet leaders and military planners regarded the US presence in Greenland—a potentially large story—even as it is now becoming clear that Soviet submarine commanders boldly sailed along the eastern shores of Greenland, appreciating how effectively they could operate at the edge of America's defense perimeter.⁵¹

* * *

This volume is divided into three major sections. Part One, “Arctic Challenges in the Cold War,” opens with the question: why did the US military and federal government so urgently want to create bases and pursue environmental research in Greenland? In Chap. 2, Ronald E. Doel notes that a central reason was Greenland's location, making it crucial for North American continental defense. US military leaders understood that Greenland was just several thousand miles away from the key cities of Moscow and St. Petersburg as well as major industrial centers. But even more important were technological factors: long-range bombers and guided missiles, key weapons systems of the early Cold War, worked effectively only when the physical environment in which they would operate was adequately understood. North American continental defense, Doel argues, was a technological system, requiring not only aircraft, missiles, submarines, early warning radar systems, engineers, and scientists, but also a great store of vital new knowledge about the Arctic environment—making Greenland a key component of this system. In Chap. 3, Kristian H. Nielsen notes that after World War II, Denmark found itself to be a very small state lying between the two behemoth Cold War adversaries, the USA and the Soviet Union. Desiring to assert its authority over its colony Greenland, Denmark sought to use science and technology to secure its sovereignty, improve its security posture, and pursue modernization on behalf of the Greenlandic people. Nielsen argues that decolonization efforts were strongly related to Denmark's desire to exploit natural resources, allow Greenlanders some measure of self-rule, and push back against its overbearing security partner, the USA.

Part Two, “Controlling Hostile Environments: Geophysical Research in Greenland in the Cold War,” presents research results from scientific efforts in Greenland, and analyzes the resulting entanglements between military and political interests concerning five geophysical disciplines. During World War II, the USA—which took control of Greenland at the behest of Denmark’s ambassador after the Germans invaded and occupied Denmark in 1940—expanded and established weather observation stations to ensure safety of flight at this critical refueling location for military flights between the USA and Europe. But after the war, Denmark sought to regain control of these stations, despite US military resistance. In Chap. 4, investigating the role of Arctic weather stations as contested scientific, political, and military installations, Matthias Heymann argues that these weather stations were important not only because they provided vital meteorological information, but because they served as symbols of sovereignty, and of political and military control. As Janet Martin-Nielsen explains in Chap. 5, early in the Cold War, glaciology was significantly transformed as it became a vehicle for the construction of continental defense and security interests, as well as a mechanism for boosting national and scientific credentials. Examining the differences between the US military’s role in Cold War glaciology with France’s civilian-led glaciology, Martin-Nielsen suggests that the Cold War created pressing needs for the US military to understand the Arctic environment for operational purposes, while French efforts were focused upon improving its chances of securing a claim on Antarctic territory by testing technologies, logistics, and scientific instruments closer to home. Geological knowledge was also being created in Greenland, due to the work of three diverse, non-overlapping groups: civilian geologists from the US Geological Survey’s (USGS) Military Branch working in northern Greenland, an international team of geologists of the Danish East Greenland Expeditions led by Danish geologist Lauge Koch in eastern Greenland, and geologists of the Danish-led Greenland Geological Survey working in western Greenland. In Chap. 6, Christopher J. Ries argues that the US group’s ultimate mission was to enhance the ability of military units to operate not only in North Greenland, but in similar terrains and climates near the Arctic, whereas Koch’s mission was to secure natural resources and enhance scientific—and ultimately political—sovereignty for Denmark. These parallel stories illustrate how time-limited interests can shape the scientific efforts of diverse groups, but the interdisciplinary efforts pursued by the USGS Military Branch foreshadowed current methods of climate research, while

the mineral deposits discovered by Koch's team are being reinvestigated for exploitation.

Ionospheric investigations, which had first become important in the 1930s due to efforts to secure reliable long-distance radio communications, became even more important during World War II. Increasing Cold War tensions and the resulting military importance of the Arctic boosted this research in Greenland, with the USA operating two stations and Denmark operating a third. Ultimately, the Danes operated all three stations while the USA continued to supply the instruments to make this research possible. In Chap. 7, Henrik Knudsen argues that unlike other contested fields of research during the Cold War, ionospheric research that required Danish scientists to collect classified data for the USA and keep it secret, resulted from an informal "gentlemen's agreement" between the US Bureau of Standards and Danish researchers, who willingly participated as equal partners. Hence, in this case, scientific and technological knowledge were a by-product of a transnational endeavor supporting military efforts.

Seismology also benefitted greatly from the Cold War when it became clear that it could offer a means for detecting nuclear bomb explosions since underground explosions created seismic waves similar to those generated by earthquakes. Military agencies, however, needed access to locations outside the USA as they installed the necessary instruments. Anne Lif Lund Jacobsen (Chap. 8) argues that American military agencies sought to get access to knowledge and localities in Greenland by engaging Danish seismologists—including the eminent seismologist Inge Lehmann, a rare female in a male-dominated discipline—in research projects and other forms of scholarly cooperation with US scientific institutions. Initially, individual Danish scientists and Denmark's Seismic Section accepted the US move into their research turf because it gave them some degree of access to the much larger and growing American seismic research community. But as Denmark's disarmament policy increasingly directed the Seismic Section's research activities, its relationship with US agencies became as politically charged as it was complex, with each side pursuing its own agendas.

The third section, "Entanglement and Transformation: Diplomacy and Politics of Science in Greenland," focuses on the broader perspectives of the entanglement of politics and science, exploring the impact of political and diplomatic agendas on science, and the use of science for political ends. In Chap. 9, Henry Nielsen and Kristian Hvidtfelt Nielsen take on the fascinating story of Camp Century, the US Army's "City under the Ice." Nuclear-powered, constructed at the height of the Cold War, it primarily

served military purposes as the test site for innovative polar construction, including the portable nuclear reactor program, as well as a bridgehead for Project Iceworm, which was intended to secretly shelter some 600 intercontinental ballistic missiles in tunnels under the ice. However, it was presented to the US and Danish publics as a purely scientific research facility. It even hosted boy scouts—one each from the USA and Denmark—and was the subject of magazine spreads and television programs. The nuclear reactor that was in place despite Denmark's peacetime stance against nuclear activities in Greenland, had to be presented as a useful trial run of possible solutions to energy needs in isolated places. Thus, the authors argue, the Camp Century story demonstrates the compromises that Denmark made as it tried to enforce its sovereignty in Greenland as the USA militarized it. While the US military continued to pursue scientific research projects in Greenland, the Arctic was a constrained space for research during the Cold War, as international collaborative scientific projects in Greenland and other Arctic areas were subject to strict political control. In Chap. 10, Henrik Knudsen examines how political and geostrategic factors shaped and limited international research activities in Greenland, and argues that a 1964 attempt to create test stations in the Arctic—along the lines of the Antarctic Treaty—was blocked by US interests which did not want to see détente-loving Scandinavians invite Soviet researchers into this contested space. But the Danish government invited them anyway, while at the same time banning US projects that might harm the international process of détente.

In the final essay (Chap. 11), Henry Nielsen and Henrik Knudsen explore the changing interest in Greenland's uranium deposits from the end of World War II until the present day. While the Danish government hoped that early expeditions hunting for uranium would come up empty to avoid interest from both the USA and the Soviet Union, by the mid-1950s, Danish interest in uranium increased as the prospect for energy independence spawned a nuclear research program, even as systematic exploration failed to turn up economically significant amounts of the mineral. The authors also argue that a second attempt to capitalize on these uranium deposits in the 1970s failed not because of extraction problems, but due to political and environmental opposition to nuclear power both in Denmark and Greenland, which dovetailed with the latter's demand for home rule. This still developing story has implications today for Greenlandic self-rule and the exploitation of uranium and rare earth minerals that could enable complete economic and political separation from Denmark.

* * *

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NOTES

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PART I

Arctic Challenges in the Cold War

Defending the North American Continent: Why the Physical Environmental Sciences Mattered in Cold War Greenland

Ronald E. Doel

Should you fly to Greenland from Denmark's capital city, Copenhagen, chances are good that you will first land in Kangerlussuaq. On clear days, as the plane descends toward Greenland's west coast, passengers watch the vast bluish-white ice cap finally yielding to stark brown mountains, dotted lakes, and fast-moving streams, some catching the sun's light in dazzling, flashing reflections. The airport terminal is tiny, cramped, often bustling. From here, one can fly south to Nuuk, Greenland's capital (population 15,000), or north to Ilulissat, on Disko Bay. Most passengers are in transit. While waiting for domestic connections, travelers are free to leave the compact airport to stroll the dusty road ringing the runway. Some stop at the single-room pizza shack across from the terminal. Others walk into the nearby settlement of Kangerlussuaq (fewer than 600 inhabitants). Near its center, they pass a cluster of squat, rectangular, two-story buildings with bright blue, yellow, and red facades, home to hotels and outfitters. At the edge of town, they encounter the Watson River, a thundering, frothy, dazzlingly fast torrent fed by melting glaciers. Back at the airport, departing passengers often look up at a large, omni-directional signpost, with

R.E. Doel (✉)

Department of History, Florida State University, Tallahassee, FL, USA

distances to destinations listed not in miles, or kilometers, but in flight hours: London (3 hours, 35 minutes); New York City (4 hours exactly); Copenhagen (4 hours, 15 minutes); Frankfurt (4 hours, 40 minutes); Moscow (5 hours, 20 minutes); and the North Pole (3 hours, 15 minutes).

What most travelers to Kangerlussuaq do not realize is that they are visiting a once vital landscape of the Cold War. Both the airfield and the runway had been built by US military forces in the early 1940s—and, after World War II ended, were strengthened and expanded by Americans. Kangerlussuaq (then known by its Danish name, *Søndrestrom*) also housed an important American weather station, which gathered information crucial for European forecasts. During the Cold War, Søndrestrom, like the larger Thule Air Base in the far northwest edge of Greenland, just 950 miles south of the North Pole, were key nodes in the vast US effort to defend the North American continent. So significant was Greenland in the plans of Pentagon leaders and White House officials that the US government twice considered purchasing Greenland from Denmark in the first decade of the Cold War, seeking full sovereignty over this territory.¹ Had the offer been accepted, the USA would have gained more territory than it had acquired in its purchase of Alaska in 1867 and even the Louisiana Purchase of 1803. It would have made the USA, already active in the Pacific Rim through its acquisition of Hawaii, the Philippines, Guam, and other territories, involved in Europe in ways that transcended the Marshall Plan and the creation of North Atlantic Treaty Organization (NATO).²

In the early Cold War, US government leaders were interested in Greenland for one reason above all: this territory occupied a crucial place—geographic as well as strategic—in deterring a Soviet attack on the USA (or, in an extreme emergency, allowing the USA to quickly strike the Soviet Union). At its root, the issue was technological, reflecting the capabilities of weapons systems at any one time. During World War II, Greenland had been particularly significant for US military leaders: it was a vital midway point for bombers, troop transports, and cargo aircraft flying between bases in northeastern North America to England and, near the war's end, Allied strongholds in western Europe (heavily loaded combat aircraft of the time could not make uninterrupted flights across the Atlantic Ocean). But by the first decade of the Cold War, as cutting-edge weapons systems evolved, Greenland became strategic militarily in even more fundamental ways. Long-range US bombers (B-29s and then B-52s) stationed at bases in Greenland, loaded with conventional and atomic weapons, could reach major targets in the Soviet Union more quickly than from

any other landmass, including northern Canada and Alaska. Greenland's significance increased from the mid-1940s through the 1950s, as guided missiles (along with submarines) became crucial new weapons systems. The geographic advantage that Greenland offered mattered no less here.³

US authorities focused intently on Greenland after 1945 for another reason: military supremacy. Pentagon leaders understood that in order for weapons systems to work in Greenland, the US military needed a confident understanding of the physical environment in which they would operate. These military officials—and their civilian scientist advisors—viewed the natural environment as a bounded, dynamic space through which the new weapons systems of the Cold War, particularly guided missiles and submarines, would pass. Long before the Cold War ended, military funding nurtured a massive, all-encompassing exploration of the Earth's upper atmosphere, magnetic fields, oceans, sea floor, and land surface. It focused particular attention on the Arctic as a distinct environmental region. It jump-started dozens of major university research programs and institutes, trained hundreds of scientists, and yielded much of the data that now forms the bedrock of our understanding of the physical environment. Its practitioners sometimes called themselves environmental scientists—indeed, top White House officials used “environmental science” to refer to its physical branches *alone* as late as 1966—even though most did not share the view of naturalists and ecologists by the 1960s that human activities were placing the Earth's environment at risk.⁴ Pentagon officials sought this knowledge specifically for Greenland—because of the crucial role its military bases would play—but also because this knowledge could be generalized to the entire Arctic, a region now seen as a likely theater for World War III. (“If there is a third war,” declared the retired chief of the Army Air Force, H.H. “Hap” Arnold, “its strategic center will be the north pole.”⁵) These officials also realized that the Soviet Union, the West's formidable nemesis after 1945, knew vastly more about the Arctic environment than did scientists in the USA.⁶

This chapter explores the ways that the USA created a structure to gain environmental knowledge to operate in the North. It first looks at how the Pentagon created a technological system that included not only the capacity to operate (and design) weapons intended for the Far North, including Greenland, but also to *acquire* environmental knowledge—itsself a key characteristic of the Cold War. It then examines the kinds of questions that researchers asked about the Arctic environment, particularly that of Greenland. It concludes by placing these developments within the

larger context of the Cold War: what we learned, and why this new environmental knowledge mattered.

INTEREST IN GREENLAND: NORTH AMERICAN CONTINENTAL DEFENSE AS A TECHNOLOGICAL SYSTEM

The US government had long been interested in Greenland, indeed well before the Cold War began—a rare exception to its general indifference to the Arctic and the Far North. In 1867, just after the Civil War, US Secretary of State William H. Seward had advocated purchasing Greenland and Iceland, stressing their “superb” fisheries, Greenland’s seemingly inexhaustible cryolite (a rare mineral) deposits, and the strategic value of Greenland and Iceland in laying “interoceanic telegraph” lines from North America to Europe.⁷ While this proposal went nowhere, US officials—many aware that Greenland lay within the original lines of the Monroe Doctrine—retained their interest in this region.⁸

Three-quarters of a century later, even before the USA entered World War II, US military planners recognized Greenland’s escalating strategic importance on the world scene. “In the possession of an enemy power,” University of Michigan geologist William Hobbs observed in mid-1941, Greenland “would offer a very serious menace to our security, while if in our own hands, through greatly extending our military bases toward Europe, our position would be greatly strengthened.”⁹ This proved to be the case. After the agreement of 9 April 1941 between Danish Ambassador Henrik Kauffmann and the USA, allowing military bases on the island as long as a threat to North America existed, Greenland served as an entry-way to European footholds from North America during World War II, a midway point for World War II-era aircraft needing to refuel as they hopped across the North Atlantic Ocean. During the war, over 10,000 Allied aircraft passed through Narsarssuaq.¹⁰

Many Washington officials at first believed, indeed hoped, that the end of the European phase of World War II meant that US interest in Greenland would also fade away. The US Office of War Information’s postwar briefing materials for Denmark, written in July 1945, sought to counter Danish suspicions of American imperialism by stressing “the American principle of non-intervention in the affairs of other countries. As illustration use the protective occupation of Greenland and the United States’ intention to return that colony to Denmark after liberation.”¹¹ The Department of State, aware that the USA had gained permission to

garrison troops in Greenland and provide for its defense only “while hostilities lasted,” equally hoped that Denmark would swiftly regain sovereignty over Greenland: its European officers sensed that the presence of over 5000 US soldiers in Greenland would become a controversial issue in Danish national politics.¹²

Yet these assessments soon proved inaccurate, as emerging US–Soviet tensions, launching the Cold War, cast Greenland in a new light.¹³ Since the USA and the Soviet Union were on opposite sides of the North Pole, military planners quickly realized that the entire Arctic, including Greenland, had become a martial landscape.¹⁴ “Joint defense interests formerly were in the Atlantic and Pacific,” wrote the bio-geographer and polar explorer Paul A. Siple (by 1947, a US Army science advisor), “but with improved air warfare the Arctic, once a barrier, is a potential if not the logical invasion route.”¹⁵ Geography made Greenland extraordinarily valuable to the USA. Halfway between the North American continent and the major industrial centers of the Soviet Union, the island of Greenland—as a clever *Time* magazine writer put it—had become “the world’s largest stationary aircraft carrier.”¹⁶ This blunt assessment reflected new technological realities of the early Cold War. B-29 bombers operated by the Strategic Air Command were now capable of flying missions inside the Soviet Union from Greenland and other far northern strongholds, and the development of V-2 weapons by Germany during World War II made clear that guided missiles carrying atomic weapons—an even more potent weapon—were on the horizon.¹⁷ It was in large part for this reason that the USA sought repeatedly (although unsuccessfully) to purchase Greenland from Denmark as the Cold War began, irritating and worrying Danish citizens and their leaders.¹⁸

Authorities in the Pentagon and the Department of State recognized that the challenge of maintaining the USA’s strategic position in Greenland had an equally important analogue in its northern neighbor, Canada. Siple, as prescient about North American geopolitics as the larger Arctic, argued in 1947, that “Of geographic necessity the problem of Arctic defense is a joint U.S.-Canada problem. Any enemy which might strike will be a common enemy. Industrial Canada & U.S. will be the target.” His Canadian counterpart Graham W. Rowley, the geographer and Arctic specialist who led the Arctic research section of the Canadian Defence Research Board, agreed: for Rowley, “The defence of Canada must be considered as part of the defence of the North American continent as a whole.”¹⁹ But looming large over the issue of northern strat-

egy was whether Canada, just emerging as a fully independent nation as British influence over its foreign policy diminished following World War II, might lose sovereignty over its far northern islands if the USA built weather stations and outposts there. In Canberra, Australia—the far end of the fraying British Empire—diplomats grasped how important this issue was for Ottawa, aware that Canada was determined to extract minerals from its far northern regions and maintain its borders. “The war and the aeroplane have driven home to Canadians,” a classified telegram noted, “the importance of their Northland, in strategy, in resources and in communications.”²⁰

These novel geopolitical tensions involving the USA, Canada, and Greenland were revealed in a series of remarkable newspaper articles drafted in 1948 but ultimately never published. They were penned by Jim G. Lucas, a gifted Scripps-Howard newspaper writer, who in 1954 would win a Pulitzer Prize for International Reporting for his accounts of the Korean War. American military officials had invited Lucas to accompany US forces in the Far North, hoping that Lucas would vividly portray the challenges they would face operating there. Lucas did not disappoint. His first dispatch, from Resolute Bay, opened by declaring that “The world’s two great military powers—Russia and the United States—face across the top of the world where tentative battle lines have already been drawn.” Later, from Goose Bay, Lucas observed that, “Uncle Sam has a toehold in the north. But not a very good one.” While the USA had a number of Arctic installations, many built during the war, the northern front, stretching from northern Canada through Greenland to Scandinavia, was enormous and, for the Pentagon, problematic: “Our weakness in the north will not easily be corrected because 1. We have no territorial rights in much of the area, and... our use of bases is possible only because we are ‘guests’ of friendly Governments which could, if those chose, evict us tomorrow. 2. The northeast still is the only major theatre without a unified command.” His final article, on Greenland, reiterated these themes, arguing that US soldiers could operate well there (he added that Americans also understood Danish reluctance to allow contact with Greenland natives, who “would only be unhappy to learn how others lived.”) Lucas’s stories were spiked by US officials after alarmed Canadian diplomatic officials protested, recognizing—correctly—that these stories too clearly revealed the limits of Canada’s sovereignty over its northern archipelago. But they also clearly illustrated that the Pentagon had fully embraced the polar concept—the recognition that the shortest air route between the Soviet

Union and America's industrial heartland lay here—and sought operational control in this region.²¹

It is helpful to think of emerging US plans for North American continental defense in terms of a vast technological system. As historian of technology Thomas P. Hughes argued, technological systems contain “messy, complex, problem-solving components” that are “both socially constructed and society shaping.” These components include physical artifacts, organizations, natural resources, advanced training and specific competencies, and state power and regulations.²² In defining technological systems, Hughes had in mind the great industries that were forged in the nineteenth and early twentieth centuries, including electrical lighting and the automobile industry, but the concept applies equally well to national defense systems. Just as one can better grasp the evolution of the New England textile industry in early 1800s America by examining all the components necessary for its operation—the recruitment of skilled engineers from Great Britain, the contributions of investors, the success of upstart mills in diverting water from rivers and streams as power sources, the creation of boardinghouses near mills deemed suitable for young women from surrounding farms, the development of transportation systems sufficient to get processed textiles from mills to markets²³—we can better grasp how North American continental defense actually worked by surveying its component parts, including base operations in Greenland and the need to acquire knowledge about the Far North's physical environment.

For those who embraced the polar concept, the need to build up US operational capabilities in the Far North—necessary to build the foundation for this new technological system—was paramount. The Canadian North certainly occupied an important place in these plans. In the late 1940s and 1950s, US and Canadian authorities, overcoming continued Canadian concerns over sovereignty, cooperated to construct a series of early-warning radar stations that would stretch, like necklace beads, across the Canadian expanse. The Pinetree Line, just north of the US–Canadian border, was the first; succeeding it was the Mid-Canada Line, and finally the Distant Early Warning (DEW) line north of the Arctic Circle. The decision to build networks ever further north was in response to technological improvements in Soviet bombers and the development of the hydrogen bomb, requiring more lead times for effective warnings. It also reflected increased acceptance among Pentagon leaders that the Soviet Union might be able to construct intercontinental ballistic missiles by the end of the 1950s, meaning that the USA could not continue to rely on its nuclear offensive capac-

ity as a cornerstone of national security policy.²⁴ Constructing the DEW line stations, which began in the late 1950s, was an extraordinarily difficult technological challenge never before faced by American or Canadian engineers. It was undertaken only when military authorities became convinced that technological solutions could be found for the challenge of building in the high Arctic, and maintaining vital lines of communication between this region and command centers in the South (Fig. 2.1).²⁵

But Greenland, so geographically close to the Soviet Union, and so well suited to emerging ideas about how best to pursue North American con-

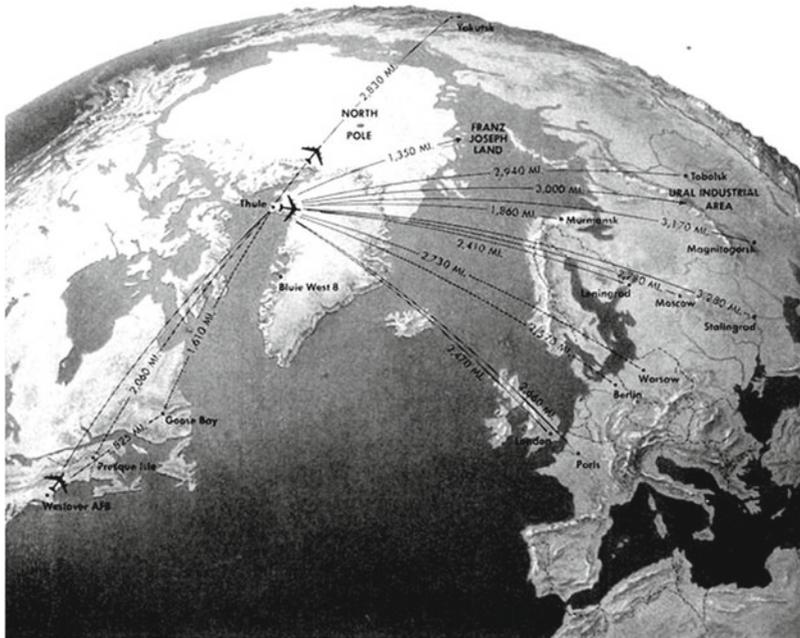


Fig. 2.1 During the Cold War, Greenland was perceived by American military leaders as crucial for maintaining North American Continental Defense—as reflected in this map, first published in *LOOK* magazine on 22 September 1950. Effective operations in this cold, remote, far northern location meant gaining crucial knowledge about the physical environmental sciences of the Arctic. *Greenland map* by James Lewicki, © Estate of James Lewicki; reproduced courtesy of Lisa Lewicki Hermanson.

tinental defense, mattered still more for US military authorities. In 1951, after President Harry S. Truman approved a recommendation by the Joint Chiefs of Staff to construct a large new air base at Thule in the northwest corner of Greenland, some 750 miles (1207 km) from the North Pole, American officials persuaded the Danish government to allow its construction. Completed in secret with the labor of some 10,000 soldiers—and made possible by the fact that Thule was the northernmost port most reliably resupplied in summer months by ship—Washington first announced the existence of Thule Air Force Base in 1953. Observers at the time noted (accurately) that building it was a challenge equivalent to constructing the Panama Canal half a century earlier. This base was the second largest operated by the USA in the early Cold War, and greatly extended the range of US air power. Danish leaders were less than enthusiastic about a massive American base on Greenlandic soil—the Danish foreign minister in 1952 noted the problem of “Danish public opinion” and Danish “desire not to get ahead of Norway in defense measures,” since Danes were wary about the Korean War and Danish leaders were well aware of Soviet pressure on its near-neighbor Norway. Yet Denmark’s entry into NATO in 1949 had effectively ended its call for American forces to withdraw from the island.²⁶

Because of Greenland’s growing centrality to North American continental defense, Washington found it necessary on occasion to bend its Cold War foreign policy to make certain that this emerging technological system would not fail. A key case emerged in summer 1952, just as the Thule Air Base was being secretly constructed. At that time, the US government quietly learned that a Danish firm was about to deliver a tanker ship to the Soviet Union, placed under contract soon after World War II had ended. This created a problem: Denmark risked losing all US foreign aid if it defied NATO restrictions forbidding the sale of strategic goods such as tankers to the Soviet Bloc. The State Department quickly realized the magnitude of this crisis, and US Secretary of State Dean Acheson arranged to meet with the Danish Foreign Minister, Ole Bjørn Kraft, hoping to block the delivery. Kraft, however, held firm: Denmark had promised to fulfill its contract before the Cold War began. But if aid to Denmark were terminated, the result would be a complete breakdown of the government’s present defense policy, with inevitable repercussions for the whole NATO effort.²⁷

Even as details of Washington’s conflict with Copenhagen over the ship became public—*Newsweek* broke the story on 4 July—US leaders had not yet reached a final decision on what to do. The Joint Chiefs of Staff, echo-

ing Acheson, initially worried that granting an exception “may be seized upon as a precedent by other countries having ‘prior commitment’ to the Soviet Bloc,” with the further risk that Congress might become unfavorable to “future military security programs.”²⁸ But within two weeks, at the highest levels in Washington, the needs of North American continental defense began to outweigh all other considerations. On 10 July, the Acting Secretary of Defense, William S. Foster, advised the Director of the Mutual Security Agency, W. Averell Harriman, that without granting an exception, further requests for US operations in Greenland “would not receive favorable consideration by the Danes.” Acheson himself asserted that not allowing Denmark leeway would affect negotiations involving US bases “and might well jeopardize existing arrangements in Greenland” now “important to the air and naval defenses of North America.”²⁹ The tanker sale proceeded. Supporting the technological system on which national security policy now depended was now a guiding consideration in US foreign policy.

GAINING VITAL ENVIRONMENTAL KNOWLEDGE IN THE COLD WAR ARCTIC

US efforts to learn more about the physical characteristics of the planet, including Greenland and the Far North, were coordinated early in the Cold War through the Pentagon’s Research and Development Board (RDB). The RDB, created in 1946 to succeed the wartime Joint New Weapons and Equipment Committee, was an important transient institution: a place where civilian scientists and their military counterparts could discuss major unsolved problems whose solution would benefit national security, including North American continental defense.³⁰ Within the RDB, the physical environmental sciences were a top priority—its geophysics panel was the first to be created—and a distinct panel on Arctic environments soon followed. RDB leaders also understood their organization’s importance in the emerging Cold War. Charles S. Piggot, a staff member of the Geophysical Laboratory of the Carnegie Institution of Washington and executive director of the RDB’s geophysics panel, told unhappy panel members that they were the nation’s top espionage target, instead of even the Atomic Energy Commission: “every effort is being made to penetrate our deliberations and get at material that is here.” It meant FBI agents were watching RDB members as closely as Soviet intelligence operatives.³¹

Many scientists advising the RDB were aware of the importance of studying both the biological and physical branches of the environmental sciences, particularly in the Far North. Writing his Army superiors in 1946, Paul Siple urged creation of what he termed a new “Institute of Man.” “Aside from guided missiles and projectiles,” Siple argued, “in fighting man is an always present factor.” Furthermore, it was impossible “to perform atomic-age combat duties in stone-age hunting clothing.”³² Siple’s views found favor within the RDB. Army advisor Robert B. Simpson worried that “[t]he pendulum of Army thought is swinging from the earlier idea that fighting in the Arctic was no different than fighting anywhere else, to the opposite extreme that fighting in the Arctic on the ground is next to impossible.” If this “swing to defeatism” continued, he added, “it may have serious consequences to the United States’ ability to fight Russia.”³³ Siple felt more optimistic on this issue than Simpson (with sufficient Pentagon emphasis, he declared, the USA could surpass the Soviet Union in Arctic fighting capacity with a decade). Yet both agreed that the Soviet Union was far ahead in understanding the Arctic environment and in Arctic warfare.³⁴

The physical environmental sciences remained a dominant concern within the RDB, not only for Greenland and the greater Arctic but also for US research efforts around the globe. This resulted from several factors. One was that military planners through the late 1940s and 1950s continued to see unsolved problems in the earth sciences as the greatest potential threat to effectively utilizing bombers, guided missiles, and submarines for North American defense. Geophysics panel head Piggot captured this sentiment best: “all progress in the geophysical sciences sooner or later will contribute to the strengthening of the nation’s strategic and tactical potential,” he declared, adding that “in many cases the development of weapons and countermeasures are predicated on advances in certain phases of geophysics”—weather control as a potential military weapon among them.³⁵ A second reason was that earth scientists were comfortable in seeing all fields of geophysics as part of a single, unified whole (they were after all component fields of the American Geophysical Union and the International Union of Geodesy and Geophysics). The biological environmental sciences, by contrast, were distinct, intellectually and professionally. When Siple pressed the issue at an RDB committee meeting, querying, “do we consider the biological factors of the earth as a portion of interest of this Committee?” climatologist Helmut Landsberg, then serving as the RDB’s Executive Director, replied that he wished they could

be. The reality, however, was that “botany and biology in general are not covered by any committee of the Board as of the moment.”³⁶ Well into the late 1960s, the term “environmental sciences” within the Pentagon and, indeed, the White House *meant* its physical branches alone.³⁷

Even with the key focus of the military on the earth sciences, officials faced a vast challenge in gaining sufficient information on the environment in strategic regions such as Greenland. One reason was that there were too few geophysicists to take up research topics that the Pentagon deemed crucial: by one estimate, the USA was short some 350 earth scientists in 1948, roughly 10% of the total number of research-oriented geophysicists then available. Hiring geophysicists away for a new project simply meant that other projects would become understaffed. This shortfall was a key reason why military agencies lavished funds on university geophysics departments throughout the USA: training sufficient numbers of new geophysicists was as crucial for the technological systems that made North American continental defense possible as guided missiles, remote air bases, and advanced radar-warning networks.³⁸

Another issue was that the quantity, volume, and diversity of data needed to support anticipated American activities in Greenland were unprecedented. While the enormous technological problem of making the atomic bomb work had been resolved during World War II, the challenge of finding ways to deliver this weapon to new adversaries such as the Soviet Union, if tensions escalated rapidly, were equally daunting. RDB geophysics panel members realized that they needed to gather information from nearly every component field of geophysics, as deficiencies in knowledge threatened US defense operations no less than an insufficient number of researchers. “The current program to increase knowledge and understanding of the environmental conditions confronting arctic operations and planning,” a 1950 RDB report concluded, “is still not adequate.”³⁹

Efforts to gain physical environmental knowledge in and around Greenland soon took several forms. Accurately aiming guided missiles required an understanding of both local gravity variations (deviations from a uniform spherical Earth, including differences in materials making up the crust and mantle) and a precise understanding of how each mapped section of the Earth fitted in to that of the entire planet. Mapping the geoid—equivalent to determining the mean sea level—for this less well-explored region was a concern shared by Canadian military authorities. Like their American counterparts, they recognized that the proximity of the Canadian Arctic (bordering Greenland) and the north geographical

pole meant that securing gravity and rotational studies would inform the “behavior of gyrocompasses and projectiles.”⁴⁰ In a similar way, US and Canadian authorities understood the importance of gaining insight into the ionosphere, including phenomena such as aurora and airglow. Already in 1946, MIT physicist and engineer Julius M. Stratton had declared that studying the ionosphere (including atmospheric noise and wave propagation) was key to understanding “factors affecting communications in the Far North.”⁴¹ (See Chap. 7)

A particularly important field was the atmospheric sciences—since weather, like climate, affected nearly all phases of operations, including the amount and distribution of sea ice surrounding Greenland and throughout the Arctic region. Meteorology was simultaneously a global and a local concern: placing weather stations throughout the Far North was essential for accurate weather forecasting throughout the northern hemisphere, and for creating a robust theory of global atmospheric circulation, essential for developing physical (and predictive) models of the atmosphere.⁴² Meteorological phenomena, members of the RDB’s geophysical panel noted, had to be understood “to provide design criteria for missile components” as well as effectively operating reconnaissance aircraft and planning general military operations.⁴³

Understanding climate variations was also a key concern for military officials and civilian scientists who appreciated the implications of what many in the late 1940s regarded as a steadily warming Arctic. Swedish-born Carl-Gustav Rossby, a world leader in meteorology then at the University of Chicago, told fellow RDB members that evidence pointed to a rapidly changing Arctic: not only were the Russians able to navigate the Arctic Ocean with steel ships, which had not been possible earlier in the twentieth century, but “fishing fleets of the Scandinavian countries are now operating in waters around Spitzbergen, which they hadn’t been doing since the 16th century...[t]hese things can only be the result of a long period change in the climate of the high latitudes.”⁴⁴ Howard B. Hutchinson, a Navy meteorologist and RDB member, agreed with Rossby: “if officers in the Navy become cognizant of these long period changes that are going on in the polar regions,” he argued, we would have “much better understanding of long range climatic changes and could possibly use them to our advantage in national defense.”⁴⁵ Neither Rossby nor Hutchinson saw this warming as anything more than a natural trend, a widely shared perspective before the idea of anthropogenic forcing gained acceptance within the nascent community of climate scientists decades later.⁴⁶ But the Pentagon did share their concern over this environmental

factor: secret internal rankings of crucial unsolved problems listed climatology of the Arctic and the Soviet Union as well as “studies of climatic variations” just below that of weather forecasting.⁴⁷ In addition, a number of scientists on the RDB wondered what role humans might be playing in amplifying natural warming. New data, a 1948 Panel on Oceanography report argued, could “help in understanding the effects of man-made changes such as canals and dams,” adding, “such predictions will be valuable in any long-range military plans.”⁴⁸

Climate change was also closely linked to two issues of great concern to the US military: forecasts of sea ice in the Arctic, including along the coasts of Greenland, and utilizing the ice cap of Greenland for defense purposes. Already by 1948, in a cooperative effort with Canada, the USA gained ice charts of the Canadian Arctic (including the straits separating Canada’s Ellsmere and Baffin islands from Greenland) that showed wind and ice movement that affected surface navigation. Three years later, annual ice forecasting began. Pentagon leaders viewed these forecasts as an “invaluable aid to efficient planning and successful execution of Arctic operations.”⁴⁹ Having these forecasts proved invaluable for US submarine commanders tasked with carrying out missions under the polar ice by the late 1950s. Gathering data on decreasing ice thickness in the polar regions also convinced Canadian Arctic researchers that polar melting was occurring in North America as well, and might, if warming continued unabated, create an “open polar sea” in summer within twenty to thirty years—a threat to Canadian sovereignty and foreign policy as well as to North American continental defense.⁵⁰

Utilizing the ice cap for national defense, military and civilian scientists also understood, meant that far more information about its properties needed to be gathered than what was known at the end of World War II. In the early 1950s, as construction of Thule Air Base began, military planners began speculating about how the ice cap could be used to advance military objectives without being cost prohibitive. While initial studies indicated that wheeled landings and take-offs were possible just from one specific part of the ice cap, too little was known about variations within its vast expanse, nearly 1800 miles from its northern to southern tip, to speculate about actual conditions, including weather and topography. One recommendation called for placing “small investigating parties” on the Greenland Ice Cap, so that weather stations, aircraft warning stations, and guided missile launching stations, perhaps eventually ice cap airfields, could be constructed.⁵¹ Studies of this kind soon began. For instance, in

1951 the Columbia University geophysicist Walter Bucher began investigating the ice surface in Greenland from the margin to the center, part of a study of “the economy of the ice in the north Greenland glaciers”—that is, the rates at which they were growing or melting.⁵²

All of these ambitious research goals—and the numerous observational and experimental programs subsequently launched in Greenland in the first decades of the Cold War—were conceived to advance US national security objectives. Military concerns set the agenda for research in this vast territory throughout the 1950s and beyond: when the CIA reviewed the state of US knowledge about the Arctic, including Greenland, in the mid-1950s, its analysts were on the same page as RDB officials not quite a decade before: climate, for instance, “was a major environmental influence” and more needed to be known about the “warming climatic cycle and its influence on future Arctic development.”⁵³ When an unnamed official had told a *Time* magazine writer that Greenland was the world’s “largest stationary aircraft carrier” back in 1947, it captured how the Pentagon viewed the island—a key component of its defense operations—and why exploring its physical environment mattered.⁵⁴

CONCLUSION

It is hardly a surprise that the US military wanted to understand an unfamiliar environment where fighting might occur, and where cutting-edge weapons systems would operate: knowledge, after all, is power. But what was genuinely new under the Cold War sun was the extent to which the physical environmental sciences benefitted through military patronage—resulting ultimately in greatly increased knowledge of Greenland, the Far North, and indeed the planet. When the Pentagon in 1961 declared that the Arctic was a “laboratory for research in the environmental sciences,” its physical rather than biological branches were what officials had in mind, and Greenland was the principal address of this “laboratory.”⁵⁵

The early Cold War was certainly a golden age for the earth sciences. It culminated in the International Geophysical Year of 1957–58, still the largest international scientific undertaking ever, and one that secured data crucial for advanced weapons systems even while simultaneously a triumph of scientific internationalism that lowered Cold War tensions.⁵⁶ Much of this research was broadly interdisciplinary, and, like much of Cold War physical science, it reflected a thirst for data on a global scale.⁵⁷ Because a key aim of these studies was to discover interrelations between a broad range of natu-

ral phenomena, it may be tempting to characterize them as Humboldtian: indeed, one military-funded US Arctic researcher then recalled feeling like a latter-day Alexander von Humboldt, free to explore whatever facet of nature caught his interest.⁵⁸ But a decidedly non-Humboldtian characteristic of Cold War scientific research in Greenland was restrictions the state imposed on the production and dissemination of knowledge. When Boston College scientists proposed a research expedition to Greenland in 1949, requesting logistical support from the Pentagon, the Truman White House turned them down, arguing that it was likely to produce “little or no information of value to the National Military Establishment, because it has been hastily planned, its personnel, with one exception, are inexperienced, and existing information with regard to the Greenland Ice Cap is essentially adequate for all military purposes.”⁵⁹ Merits of the Boston College proposal aside, its research aims were a secondary consideration to whether the knowledge likely to be gained would support the technological system underpinning North American continental defense—a restrictive, utilitarian criterion.

Hence, the legacy of US-led environmental research in Greenland in the early Cold War is mixed. Shelagh Grant, the Canadian historian, was prescient in observing that “few Danes or Canadians recognized or understood the American fascination with the Arctic and the commitment of US military scientists to expand upon their wartime research.”⁶⁰ Greenland loomed large in the American psyche in the late 1940s because the USA felt newly vulnerable to the Soviet Union, especially in the north, a part of the world it knew little about. The history of American involvement in Greenland is fundamentally a history of technology. Transportation needs had shaped US involvement in Greenland during World War II, and the basing of nuclear missiles (as well as surveillance and monitoring of Soviet military forces) defined it during the early Cold War. Securing environmental knowledge about the greater Arctic was determined by military needs for national defense. Pentagon interest in Greenland’s environment diminished somewhat by the early 1960s because of yet another technological advance: Polaris missiles were successfully deployed from US Navy submarines, making it possible to launch nuclear weapons at the Soviet Union from even closer proximity than Greenland. Perhaps, had this new weapons system failed, the Pentagon might have been tempted to pursue the US Army’s proposed Project Iceworm: medium range ballistic missiles concealed in tunnels within the ice cap, their launchers on railroad tracks to

allow them to move about, thwarting any Soviet attempt to take them out in a preemptory strike.⁶¹ (See Chap. 9) Iceworm was an audacious plan, an even more difficult technological feat than constructing Thule Air Base. Despite the success of Polaris, Thule remained a key node in North American continental defense. When President Lyndon Johnson later floated ideas for limited cooperation with the Soviets in the high Arctic in the mid-1960s, he did so with national security concerns about Greenland still firmly in mind.⁶²

Military-sponsored environmental research in Greenland in the twentieth century had unexpected consequences, just as government-sponsored expeditions in the nineteenth century did. While the geologist and explorer John Wesley Powell had been tasked with providing geologic intelligence to the state in his exploration of the Green and Colorado rivers in 1869, an eventual fruit of his expeditions was his seminal *Report on the Lands of the Arid Region of the United States*, one of the most important assessments of climate in North America, even if widely ignored at the time.⁶³ In a similar way, the ice cores later collected at Camp Century, the nuclear-powered city built some 120 miles to the east of Thule on the ice cap (in part to determine if Project Iceworm was feasible), were among the first to reveal rapid, unexpected variations in Earth's past climate, key evidence for interpreting climate change.⁶⁴ Scientists secured a vast treasury of environmental knowledge about Greenland *because* of the Cold War. This is yet another Cold War legacy—important for understanding how we gained knowledge about the physical environmental sciences in the second half of the twentieth century.

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Small State Preoccupations: Science and Technology in the Pursuit of Modernization, Security, and Sovereignty in Greenland

Kristian H. Nielsen

In a cloud of dust, the five-story wall collapsed, raining heavy concrete slabs down on the massive excavator. This last wall of the once immense building—called Block P—had been scheduled for leveling at 9:30 a.m., Nuuk time on Friday, 19 October 2012. People had gathered early to witness the big event. Instead, they watched rescue workers successfully extract the operator from the excavator’s crushed cab, and then quietly applauded as the injured man was hauled to the hospital. Relieved that he was still conscious, spectators were rightly worried about his condition. Partially disabled because of the accident, he began receiving state compensation soon thereafter.

For the witnesses, the demolition of what had been the largest apartment building in Nuuk—indeed, in Greenland—was richly symbolic. The building had been the apex of Denmark’s plans to modernize Greenland by concentrating its inhabitants in urban settings, and at one time, it had housed fully 1% of the island’s population. Now it painfully reminded them

K.H. Nielsen (✉)

Centre for Science Studies, Department of Mathematics, Aarhus University,
Aarhus, Denmark



Fig. 3.1 Block P—once the largest structure in Greenland—in 2009. A residential building that housed one percent of the island’s entire population, it symbolized Danish hopes for modernizing Greenland. On 21 June 2009, Greenland’s national day, artist Julie Edel Hardenberg hung a large Greenlandic flag on an end wall of Blok P, fashioned from rags donated by its inhabitants. *Photograph reproduced by kind permission of Peter Løvstrøm.*

of an unhappy legacy. As Else Løvstrøm, communications officer of Block P’s management association, later observed, “Block P contains all good and all bad. Many have lived harmonious lives in that building, really good lives, but others have had a really hard time. It is very mixed”¹ (See Fig. 3.1).

CHANGING GREENLAND

Løvstrøm was correct: Block P had profoundly influenced those who had lived there. Its size—the largest residential building in the Kingdom of Denmark in 1966—and its central location in Greenland’s capital, Nuuk (formerly Godthåb), made it a symbol of the rapid changes in Cold War Greenland from the 1950s through the 1980s. In just two post-World War II generations, Greenland had gone from being home to relatively isolated and dispersed communities under Danish rule to a dynamic, modern society based on technological infrastructure, urban development, democratic

governance, and international relations. These structural reforms were partly motivated by requests of the small Greenlandic political and cultural elite eager to modernize Greenland, and partly by Danish concerns over sovereignty, security policy, and Greenland's socio-economic development. For Greenlanders, Block P stood for all that was good and bad about the "Danification" of Greenland. For Danes, it represented close diplomatic, economic, and cultural ties between Denmark and Greenland.

To understand the changes Greenland experienced in the immediate postwar decades, we may do no better than to note the impressions of British writer Geoffrey Williamson, who visited Greenland in summer 1952, at the same time it was being visited by the Danish monarchs, King Frederik IX and Queen Ingrid. Arriving by air, Williamson was struck by paradoxical impressions: the otherworldliness of the vast, desolate inland ice; the silence and the solitude of the world's largest non-continental island; and the Arctic weather that shifted so quickly that he thought it might be the reason that one of the Greenlanders' favorite words was "imaka"—perhaps.²

Simultaneously, Williamson's contact with American ground crews at the mountain-rimmed airbase of Sondrestromfjord (Kangerlussuaq) reminded him of World War II's hostilities and the importance of Greenland's meteorological data for the D-Day weather forecast. He was struck by the prevalence of little motorboats—15-footers to fishing-cutters—that far outnumbered native kayaks in major west coast settlements. Why so many little boats? Greenlanders were abandoning traditional seal hunting in favor of large-scale cod fishing. Williamson also noted the ubiquity of gum chewing, introduced by Americans during World War II, along with jeeps, bulldozers, prefabricated huts, and station wagons. Many Greenlandic girls preferred the "Western look": nylon stockings, high-heeled shoes, and cigarettes. In the public library, Williamson was surprised to find Greenlandic versions of Western literature, even his own childhood favorites, such as Frederick Marryat's *The Settlers in Canada* (1844) and *Children of the New Forest* (1847).³

Williamson also was impressed by an enterprising spirit that seemed to permeate Greenland's west coast settlements. New fish processing plants for filleting, salting, or freezing cod had been built near many ship-docking sites. Shrimp canneries thrived in Christianshaab (Qasigiannguit) on Disko Bay, home to one of the world's largest shrimp-beds, and further south in Narsaq, young Greenlandic women had adapted to factory conditions "as cheerfully and as skillfully as their men [had] taken to motor-boat and workshop."⁴ At Ivigtut (Ivittuut), Williamson found another flourishing indus-

try: open-pit mining of cryolite, an important mineral for the US war effort. Long-term schemes for commercially exploiting lead, wolfram, and zinc ores were signs, Williamson wrote, of an “Arctic renaissance” in Greenland.⁵

Greenland’s booming economy was matched by contemporaneous changes in governance. In 1951, Greenlanders voted for the first time for the newly established National Council, which then elected two of its members to sit on a special Parliamentary Greenland Committee in Copenhagen. To meet Greenland’s expanding social and economic needs, legislation governing education, health, church, and trade was being proposed and acted upon. In 1953, Greenland was incorporated into the Kingdom of Denmark as a municipality, making Greenlanders Danish citizens. In Williamson’s view, Greenland was fully embracing change, and its future would become inexorably linked to international forces with economic, technological, social, and strategic implications that would make it impossible to dismiss Greenland “as a remote, frozen territory ‘out of this world.’”⁶

VIEWS FROM NUUK AND COPENHAGEN

In May 1945, British Field Marshall Bernard Montgomery and his men liberated most of Denmark from German rule, and Soviet forces took Denmark’s easternmost island, Bornholm, remaining there for about a year. After the Soviets left Bornholm and Denmark joined NATO in 1949, the Soviets demanded that Denmark never allow NATO, and especially not US, troops on the island. Throughout most of the Cold War, the Danish government did not challenge Moscow’s position.⁷ Greenland, a vastly larger island, became caught up in similar diplomatic challenges involving the USA, Denmark, and the Soviet Union.

In the immediate postwar years, Greenlandic and Danish leaders agreed to take action on Greenland’s development.⁸ Reasons varied, but the goals were the same: Greenland would remain inside the Danish realm, and joint initiatives promoting social, economic, and political development should be enacted. Greenlanders wanted to continue the lines of development that had been introduced before the war, which had taken on more momentum during the war. Living in a de facto US protectorate from 1941 to 1945, they had been exposed to American culture: American music on military radio stations, goods from American color catalogues, or interactions with US servicemen. Greenlanders became familiar with modern amenities while glimpsing the positive consequences of an open market

economy and free enterprise. The value of Greenland's exports increased considerably during the war as the price of cryolite, important for producing aluminum for airplanes, increased, and the value of landed cod doubled. Living standards improved, new jobs and business opportunities opened up, and there was a mood of independence in Greenland. Most Greenlanders wanted more socio-economic opportunities, but they also appreciated their cultural ties to Denmark and worried about Greenland's destiny in a far-from-peaceful world. Thus, their primary goal was for socio-economic and political equality with Danes.

Eager to reassert its prewar sovereignty over Greenland, the Danish government generally acknowledged that social, economic, and political reforms in Greenland were needed. But it worried that a consequence of rapid reform would be a complete separation of Greenland from Denmark. Negotiations between representatives of the Greenland Administration and the Greenland Committee of the Danish Parliament during summer 1946, led to a compromise over the Greenlandic delegation's demands for centralized provincial governance from Nuuk and the gradual abolishment of the Danish trade monopoly (administered by the Royal Greenland Trading Department), and the Parliament's Greenland Committee's more cautious approach. When the Greenland Committee allowed a 200% increase in Greenlanders' salaries, the provincial councils (and most Greenlanders) accepted postponing major reforms for another five years. Many Danes, nurturing sentimental feelings toward Greenland, were flattered that Greenlanders actively chose postwar reintegration with Denmark.

Later in 1946, however, journalists reported on the grim reality of everyday life in Greenland, shattering the sentimental view of Greenland as the land of happy natives, eagerly seeking to become full-fledged Danish citizens. Something had to be done about pervasive illness (more than a third of the population died from tuberculosis), poor housing conditions, lack of education, and extremely limited opportunities for private business initiatives. "We lose our right on the northern latitudes, if we don't cope with this problem," wrote Børge Outze, chief editor of the Danish newspaper, *Information*.⁹ He was right. The same year, the Danish government learned the full extent of America's intent to maintain—and expand—its military power in Greenland. Meeting in Washington, DC, in December 1946, US Secretary of State James Byrnes startled the Danish Foreign Minister by offering to purchase Greenland.¹⁰ Not an option? Then Byrnes had two other alternatives for the Danes: they could allow

the USA to take full responsibility for Greenland's defense, effectively extending the 1941 agreement between the USA and Danish Ambassador to Washington, Henrik Kauffmann, or, enter into a 99-year agreement allowing US military bases in Greenland (See Chaps. 1 and 2).¹¹

The Danish government thus found itself under pressure to take action on Greenland: from Danish citizens concerned about Greenland's socio-economic problems, from Danish fishermen who wanted to fish for cod in Greenland's waters, and from the Americans who wanted to use the island as a Cold War military outpost. The time for action had arrived. On 30 January 1948, Prime Minister Hans Hedtoft announced: "I agree that Danish initiative and vigor should have as much access to Greenland as possible, and I anticipate a rich development in the future."¹² Within months, the government appointed a new commission to consider wide-ranging development in Greenland and make recommendations for the future. To prepare, legal experts, scientists, engineers, and physicians were dispatched on so-called expert expeditions to study legal practices, water supply and sewage, and public health. They concluded that conditions in Greenland were deplorable and tough—but nothing prevented it from embarking on a road to modernization. And yet, Greenland's unique conditions had to be taken seriously.

CONVERGENCE AND EQUALITY IN THE DENMARK- GREENLAND RELATIONSHIP

The 1948 establishment of the Greenland Commission marked a shift in Denmark's approach to Greenland. Whereas previous initiatives had sprung from Denmark's Christian-based civilizing mission in tandem with scientific and economic motives, the Greenland Commission aimed for socio-economic and political development via techno-economic modernization to create economic and political equality between Danes and Greenlanders. In this respect, the Greenland Commission resembled other contemporary Western initiatives that advocated economic growth, technical infrastructure, and liberal democracy as a guarantee of social reform and prosperity. From Asia to Africa to Latin America, politicians, engineers, scientists, teachers, physicians, and others enthusiastically engaged in supporting the development of modern societies and sought to instill a new sense of entrepreneurship, technical competence, objectivity, and respect for diversity and free speech in place of what they viewed as native apathy and prejudice. These experts were convinced that the non-Western world could be

peacefully—and rationally—transformed into a better place, if only underdeveloped or “Third World” countries could be placed on a Western-like path of industrial and economic development.¹³ Despite the universal sense of inevitability implied by this development-through-modernization discourse, the transition to modernity was fraught with problems because the development ideal was detached from reality, and development schemes were subject to renegotiation and modification depending on their context.

Thus, development was loosely linked to Western ideas about the intimate relationship between knowledge and emancipation, and between industrialization and social progress.¹⁴ By the early 1950s, schemes to “improve” poorer countries were seen as important foreign policy tools, and were integrated into the Cold War context.¹⁵ In fact, both superpowers—the United States, from the time of President Harry S. Truman’s inaugural speech on 20 January 1949, and the Soviet Union, following Joseph Stalin’s death in March 1953—used nonviolent development to compete for “hearts and minds” in underdeveloped countries. Both nations assumed that development would cause the political economy of recipient and the donor countries to converge. Very few people questioned this assumption despite the paradox at its core: development aid could lead to either communist or capitalist systems, depending upon which political system was involved.¹⁶ These interventions, largely defined by national security policies, “to a very large extent shaped both the international and the domestic framework in which political, social, and cultural changes in Third World countries took place.”¹⁷

Ideas about techno-economic development and convergence were at the heart of the Greenland Commission’s vision for Greenland in 1950: concentrating its population in just a few settlements would encourage ongoing economic development in Greenland, and also ensure political, administrative, and social changes. Greenland’s sparse population did not allow for the division of labor and cost-effective use of large machines that characterized Western societies. To develop commercial activities in Greenland—for example, the cod fishery—people needed to be attracted to larger settlements on the west coast where processing facilities, modern housing, schools, hospitals, and other infrastructure could be built. The Greenland Commission could not force people to move, but it wondered if publicizing the many economic opportunities available in larger communities would entice Greenlanders to relocate voluntarily—a necessity to ensure political equality between Denmark and Greenland, and, ultimately, full autonomy for Greenland. Environmental challenges notwithstanding,

the Commission wanted Greenland to go through the same kind of modernization process that Denmark had undergone starting in the late nineteenth century, when Danish farming and industry were developed with the help of foreign capital.¹⁸

The ambitious 1100-page report addressed almost all aspects of Greenland: economics and political administration, housing, scientific activities, cultural affairs, legal system, wages, and religion. The Commission's goal was to make "Greenlanders more equal members of Danish society while also creating opportunities for Greenlanders to cultivate free associations with other people, both of which will serve to strengthen the kind of initiative in the Greenlandic population that is required to develop Greenland socially, culturally, and economically."¹⁹

The Commission also presented a small state's reaction to the emerging Cold War. As geopolitical tensions worsened between the USA and the USSR in the late 1940s, the Danish government feared the Soviet Union's response if Denmark granted the USA too much access to Greenland. For example, until Denmark joined NATO in 1949, successive Danish governments dreaded being forced to accept Soviet military bases on Bornholm as compensation for US base rights in Greenland. Because of Greenland's growing geostrategic importance and the Soviets' earlier occupation of Bornholm, Denmark was extremely sensitive to pressure, explicit or implicit, from Moscow. Once it joined NATO, the Danish government could move reforms forward in Greenland, initiating necessary socio-economic development while reasserting its sovereignty over Greenland. The government also sought to position itself as a small, peace-seeking state amid increasing Cold War hostilities.²⁰

EMERGING MODERNIZATION

The techno-economic development envisaged by the Greenland Commission accelerated modernization, signs of which had already emerged in the interwar years. As the Arctic warmed between the early 1920s and the 1940s, North Atlantic cod spread to the Arctic Ocean. As traditional seal hunting declined on the west coast, partly due to over-hunting, many Greenlanders had switched to cod. Arctic char and halibut, fished since the early 1900s, were quickly surpassed by cod fishing.²¹

By the early 1920s, Greenlanders had discovered that fishing and seal hunting were very different. The kayaks and unpowered wooden boats

used in the early days of the fishing industry lacked the capacity to land sufficient cod, and the first motorboat was not purchased until 1924. By the time Geoffrey Williamson visited Greenland in 1952, their numbers had increased dramatically. In the interwar years Greenlanders also had found that fishing was at odds with the seminomadic lifestyle and dispersed communities that had been characteristic of Greenland-based seal hunting. While sealing provided food as well as skins for clothing, and thus formed the basis for self-sustaining communities, fishing only provided food. Furthermore, fishermen needed to live close to rich fishing grounds that were adjacent to processing plants and markets, since “commuting” from home to fishing grounds cost too much in time and effort. The Greenlanders soon discovered that fishing lent itself more readily to economies of scale. By the mid-1920s, the Danish Administration in Greenland had dropped its resistance to fishing, and periodically raised the price paid for fish, thus acknowledging that cod fishing had become an important factor in Greenland’s economy.²²

Fishing vessels’ limited range, the lack of processing facilities, and the irregular distribution of cod prevented cod fishing from being a stable economic undertaking, but productivity nevertheless continued to rise. Between the early 1950s and 1962, the value of all Greenland’s exports increased fourfold, and Greenlanders’ standard of living increased dramatically. Between 1947 and 1963, the average Greenlanders’ real purchasing power doubled and the effective standard of living tripled.²³ Public health improved as well. Because while the fertility rate remained constant, the mortality rate dropped dramatically throughout the 1950s—primarily due to reductions in tuberculosis and infant mortality—and by the early 1960s, Greenland’s population was increasing 4% annually. This compared with a less than 1% increase in Denmark. As the Greenland Commission had urged, more Greenlanders moved to larger west coast settlements where they found jobs, modern housing, new supermarkets, and education and health services. As modernization continued apace, Greenland and Denmark were converging, and a “short powerful effort” promised to complete the desired transformation.²⁴

Greenland’s modernization efforts depended on direct Danish government subsidies, which quadrupled (from DKK 28 million to DKK 109 million annually) between 1950 and 1962.²⁵ At the time, the government was investing almost twice the amount of money per capita in Greenland as in Denmark, and an astounding 90% of Greenland’s total economy came from

subsidies.²⁶ Most of the funds were spent on socio-technical infrastructure projects—harbors, roads, electricity and water supply systems, telecommunication networks, factories, shops, hospitals, schools, and so on—all of which were initiated and led by Danes and based entirely on Danish expertise. Because they received higher salaries (a “deprivation allowance”) to compensate for their reduced living conditions, Danish engineers, technicians, and skilled workers flocked to Greenland to work on these projects.²⁷

The Greenland Commission stressed that Danish-led initiatives would never increase Greenlanders’ welfare and productivity to the desired level unless their programs led to permanent structural changes in the economy and population distribution. The Commission was particularly worried about establishing a well-functioning job market, which would require many more local businesses. For several years, however, the Grønlands Tekniske Organisation (GTO) was the only entrepreneurial body in Greenland.²⁸ It handled planning and project design, and carried out necessary entrepreneurial work. Gradually, Danish entrepreneurs moved to Greenland to perform the tasks as the GTO established entrepreneurial sites and workshops. With lavish funding, the GTO grew as it developed a wide range of technical expertise suited for Greenland’s many socio-technical challenges.²⁹

Danish companies often made an effort to involve local residents, holding hearings and public meetings. But despite substantial subsidies and good intentions, the GTO often was met with antipathy. Why? Many Greenlanders thought they were passively watching extensive societal transformations undertaken by GTO’s Danish engineers.³⁰ Claus Bornemann, a civil servant in the Danish Ministry for Greenland, established in 1955 to administer Greenland, concluded in 1960 that not enough had been done to develop local expertise and promote general education.³¹ However, Danish experts and decision-makers did not believe that it was necessary, or even possible, to directly engage Greenlanders in the process. As GTO Director Gunnar P. Rosendahl had observed in 1959: “The present constructions are for the most part so complicated that they can only be led by technicians and carried out by skilled craftsmen.”³² However, responding to Bornemann’s comments a year later, Rosendahl added that although many engineering and craftsman tasks required special training that Greenlanders did not possess, the GTO would make every effort to employ Greenlandic workers and provide them the necessary training, even if the short-term costs were greater.³³

The exchange between Bornemann and Rosendahl illuminates some of the tensions involved during modernization efforts, even if considerable progress had been made in the ten years since the Commission had released its report. The Greenlanders' standard of living had seen significant improvement, and many Greenlanders supported modernization efforts and closer political, economic, and cultural ties with Denmark. Still, some Greenlanders, especially those who worked closely with Danish professionals, were not pleased that Danes commanded higher salaries, and others felt detached from their land and like second-class citizens. Other Greenlanders worried about social problems, such as drinking, violence, and crimes, which seemed to stem from modernization.³⁴

In summer 1959, the National Council of Greenland urged the Danish government to create long-term objectives for the island's economic development. Specifically, it wanted an assurance of support for commercial development as Greenland's population increased. Council members thought too little was being done to promote free enterprise in Greenland. In the 1950s, the Danish government had funded most industrial and commercial development, but the expected increase in small businesses and free trade had failed to materialize. The council recognized that the GTO and its commercial counterpart, the Royal Greenland Trading Department, were absolutely necessary to undertake the challenging task of modernizing Greenland, but wanted those organizations dismantled in the future so that the Greenlanders could take a more active role in the island's commercial and technological development.³⁵

Responding to the council, the Danish government established a second Greenland Commission to evaluate political and economic development, and make recommendations for the future. Known as G-60 (since it was established in 1960), the second Greenland Commission took four years to complete its task, concluding that the first Greenland Commission had underestimated the amount of time and money required to bring Greenland's economy to a level sufficient to support political and economic independence. While the first commission had proposed a 10–15-year “transitional phase” before “Greenlandic society would reach an acceptable stage,” and “industry and commerce... a sufficient level,” the G-60 recognized that its ten-year plan (1966–1975) was “the first step” in a much longer process.³⁶

Modernization, the G-60 argued, required continued targeted investment to: (1) increase employment, (2) provide incentives for people to

move to larger towns, (3) increase efficiency and productivity in the fishing industry, and (4) prioritize general and continuing education. The proposed investment program would require DKK 2.1 billion between 1966 and 1975, doubling the annual investment of just four years before. Even though the proposal required a much larger expenditure of state funds, the Danish government generally accepted it. Like many other Western European countries at the time, Denmark was experiencing an unprecedented economic boom, and the standard of living was improving dramatically for most Danes. Denmark's successful welfare state led most Danes to concur in the idea of greatly expanding the subsidy for Greenland, aligning with international attention being focused on underdeveloped countries.³⁷

GUILT AND INFERIORITY COMPLEXES

The socio-economic and political changes wrought in Greenland during the second half of the Cold War were complex, and lie beyond this chapter's scope. The main trends included continuing efforts to start Greenland's market economy, Denmark's block grant to Greenland (DKK 3.7 billion in 2014, or 32% of Greenland's Gross Domestic Product), and efforts advancing political and economic independence.³⁸ The booming cod fishery began to decline due to a combination of cooling water off Southwest Greenland and overfishing, just as the G-60 issued its report in 1964.³⁹ During the late 1960s and into the early 1970s, Greenland's fisheries transitioned to shrimp, which remains today the most important export commodity.⁴⁰

In the same period, a political awakening in Greenland led to the formation of political parties. Earlier elections had focused on *individuals*, not their political affiliations. In October 1972, when Denmark voted to join the European Community (now the European Union), Greenlanders overwhelmingly voted no. Most were unhappy because as part of Denmark they had to join the European Community, which, they feared, would increase pressure on Greenlandic fisheries. The 1979 referendum on Greenlandic home rule (an important issue addressed below) was a direct response to this political incident.⁴¹

Prior to the establishment of home rule in 1979, social problems became more visible in both Greenland and Denmark. Already in 1972, Danish historian and journalist Niels Højlund had published a penetrating analysis of the ongoing public debate in Denmark about Greenland's affairs.⁴²

He argued that Danish debates over Greenland's status often labeled the technical solutions to Greenland's problems offered by the two Greenland Commissions (and put into practice by GTO engineers) as being flawed and the direct causes of Greenland's social problems. Many commentators of leftist, or even Marxist, persuasion suggested that modernization efforts were a sophisticated form of neo-imperialism, dubbing Greenland as "our Third World country." Højlund thought those claims were unfounded—or at least difficult to assess empirically. He was especially impatient with "wishful thinking" calling for a rollback in modernization efforts to earlier stages in Greenland's development, which was not supported by most Greenlanders since material and social conditions had already changed. Instead, he concluded that the debate was nothing more than Danish self-therapy, revealing mixed feelings of pity and guilt.⁴³

Danish guilt and political self-criticism were matched by the Greenlanders' combined sense of inferiority and independence. In 1973, the Greenlandic rock band Sumé ("Where?")—widely considered Greenland's pioneer of rock music today—released its first album, Sumut ("Where to?"). Purchased by more than one-fifth of Greenlanders, the album was a point of cultural identification, particularly for young people. The album's cover art was a reproduction of a nineteenth-century woodcut by Aron of Kangeq depicting an Inuit hunter killing a Norseman. The Inuit has cut off the Norseman's right arm, which he raises in triumph while blood pours out of the cut shoulder. Accompanying the album was a poem articulating the anger felt in Greenland. The poem was written in 1969 by Aqqaluk Lynge, who later became one of the founders of the Inuit party.

Ode to the Danaides (Danish colonialism in Greenland)

Contemptible beasts
 now I know
 the mistakes of the past:
 effective export production
 modern society in Greenland
 all the official optimists
 who are cynical in private
 and don't believe in the whole thing one bit
 Government grants are business propositions
 realism, realism
 a real mummer's play

Now I know
that Danish colonialism hides itself in ministries
(not in defense or in justice
but in Northern Affairs)
Inhuman humanistic imperialism
cold war against the cold
—when you find areas in a country
with foreign languages, habits, and laws
then the problems start!
A great deal of luck is needed to preserve them
especially when the conqueror lives in his new territory

The evangelist Hans Egede said: THE BIBLE is my weapon
the king of Denmark said: MONEY is my weapon
—either you have to win the people over
or else you have to destroy them—

Greenland
—the Danaides' trough
Completely gluttonous
they sent pigs
sent beasts
sent sewerpipes
sent colonialism
“sentism”

Greenland
—we are the indulgence vendor's coffer
—as the money of Greenland jumps
out of Greenland
my soul slowly departs

The Thule people pushed out
—strategically

The coalminers of Qullisat relocated⁴⁴
—uneconomic

The Greenlandic cod production
—unprofitable

The Greenlandic people
—unqualified

The Greenlandic culture
—urbanized

Greenland, you are bottomless
Greenland, you fall endlessly

*If you harm someone
do it so thoroughly
that you do not fear revenge*

Kalaallit Nunat, the land of the skraelings⁴⁵
you with your enchanting, untrue name—*Greenland*
Sheep in wolves' clothing
completely frozen at the top
at the bottom, emptiness
the indulgence vendor's Klondike
—the Danaides' hobby

Must they have the pleasure
—of the power and the glory
for ever and ever?

(with thanks to Macchiavelli)⁴⁶

Lyngé's poem describes the feeling of powerlessness experienced by Greenlanders due to the Danish government's modernization process combined with Greenland's conscription into North America's continental defense plans. As Greenland had become vital to US strategic interests, US military leaders had pursued plans to build Thule Air Base, which had led to the forced relocation in 1953 of the residents of nearby Uummannaq, a small settlement of Inughuit hunters (Chap. 2). A well-known event when Lyngé wrote his poem, the relocation did not really become a political cause before the mid-1980s when it emerged as the subject of intense political controversy, official investigations, compensation schemes, lawsuits, and government negotiations.⁴⁷ Many years after, in 2003, the Danish Supreme Court ruled that the Inughuits had been forcibly removed with the approval of the Danish government then in power.⁴⁸

Political shifts in the last decades of the twentieth century revealed another problem with modernity: Danes and Greenlanders were increasingly aware that the Danish government had been effectively powerless when confronted by US defense policies involving this northern island. As we now know, increasing public opposition to nuclear arms had led Danish politicians to tread carefully between maintaining good relationships with Denmark's allies and complying with their constituents' opinions. In 1957, for instance, Prime Minister H.C. Hansen had solved the "nuclear problem" by sending an informal note to US Ambassador to Denmark Val Peterson, allowing the Americans to deploy nuclear weapons in Greenland, while simultaneously reassuring the Danish people that Denmark would not accept nuclear weapons on its territory in peacetime. But by the mid-1980s, the mood was quite different, and more political dirty laundry was in public view. Danish politicians and many others were fiercely discussing in public media the so-called footnote policy that an alternative majority in the Parliament had imposed on the Danish government. Reluctantly, the government in office from 1982 to 1988 had to follow the parliamentary majority and dissociate Denmark from many important decisions in NATO—in particular those involving the buildup and deployment of nuclear weapons. Danish reservations frequently appeared as "footnotes" to NATO's official communiqués. The footnote policy led to several serious confrontations between NATO and Denmark on security policy issues. The extent to which the government *did* respect the alternative parliamentary majority was a matter of intense debate in Denmark, and many journalists and others on their own began investigating the relationship between Danish policies and those of its NATO allies, in particular the USA.⁴⁹

This led to more public revelations about early Cold War secrets. Around 1986, Danish journalist Poul Brink and a Danish historian employed by Greenpeace, Hans Møller Kristensen, became interested in the crash of the US B-52 bomber at Thule Air Base in 1968 (see Introduction). Initially, Brink was mostly interested in claimed long-term health problems of Danish workers exposed to radiation during the cleanup operation, seeking to expose what he later called "the universe of lies" that shrouded the whole Thule affair.⁵⁰ Kristensen and Greenpeace shared a desire to pursue questions about US deployment of nuclear weapons in Denmark.⁵¹ At the time, Greenpeace was campaigning intensely against US warships paying calls on Danish ports without confirming or denying

the presence of nuclear weapons, and in April 1988, a national election in Denmark was called because of the nuclear issue. The “nuclear election” pitted those who wanted to put more pressure on the Americans to provide this information against those who wanted to silently respect the USA’s “neither confirm, nor deny” policy. But neither side gained a mandate to resolve the controversy. Before and after the election, the Danish government feared the responses of the USA and Denmark’s other allies if it went too far. The Danish government compromised by very politely asking the American authorities to respect Danish policies on nuclear matters. Kristensen, a fierce opponent of Denmark’s nonconfrontation policy, concluded: “Denmark could keep saying that it did not allow nuclear weapons on its territory, and U.S. warships could keep bringing them in.”⁵²

The “footnote era,” with its critical political debates about NATO defense policies and investigative journalistic forays into the deployment of US nuclear weapons on Danish territory, influenced the Danish-American relationship in the last part of the Cold War. The disapproval of government policies in relation to US nuclear weapons in Greenland—gaining momentum in the wake of the 1968 Thule crash—in the footnote era turned into general discontent with Denmark’s unconditional acceptance of NATO’s nuclear defense policies. Although the Danish government disapproved of “footnoting” NATO communiqués, it decided to accept the situation in order to remain in power. Moreover, Denmark’s attempts to put into question central aspects of US and NATO defense policies, such as the “double-track decision” of December 1979, which linked deployments of US medium-range ballistic missiles in Europe to proposals for a mutual limitation of NATO’s and the Warsaw Pact’s nuclear forces, and the Strategic Defense Initiative proposed by the Reagan Administration in 1983, caused irritation and frustration in NATO and the United States.⁵³ On several occasions, the Reagan administration actively tried to persuade members of the Danish Parliament to give up footnoting.⁵⁴ Footnoting, however, reflected widespread disagreement in Scandinavia and the rest of Europe with what many saw as an escalation of the nuclear arms race. The double-track decision, together with the Soviet invasion of Afghanistan around the same time, marked a break with the previous period of détente. In the immediate wake of the double-track decision, the so-called Euromissiles crisis followed that involved mass demonstrations, antinuclear campaigns, and other forms of political protests all over Europe.⁵⁵ The public reaction against the deployment of new generations

of nuclear delivery systems in Europe provided new opportunities for politicians, such as the parliamentary, footnoting majority in Denmark, who wanted to take a stand against what they believed were highly confrontational and seriously dangerous NATO and US defense policies. What in Denmark and Greenland began as an issue limited to the USA's conduct at Thule Air Base spread like ripples to include much larger questions pertaining to modernization, security, and sovereignty.

CONCLUSION: POST-COLD WAR DEVELOPMENTS IN DENMARK AND GREENLAND

The Cold War's close triggered many attempts among Greenlanders and Danes to deal with guilt and inferiority complexes that had been nurtured during the closely connected processes of militarization and modernization in Greenland. Most of these issues remain today. In 1994, the Danish government commission investigating the relocation of the Inughuits to Qaanaaq, north of Thule Air Base, concluded that it had not been forced. Many people, including the Inughuits, did not agree, and the matter moved into the Danish courts. In 2003, the Danish Supreme Court agreed with the Inughuits that Danish authorities had forced the relocation, but did not grant the inhabitants of Qaanaaq the right to return to their ancestral land at Pituffik, location of Thule Air Base. Following the court's ruling, the group known as Hingitaq 53 lodged a complaint against Denmark at the European Court of Human Rights, which declared in 2006 that the application was inadmissible since the European Human Rights Convention was not in force in Denmark in 1953.⁵⁶

In the early 1990s, investigations into US activities and deployments in Greenland in the early Cold War led to the declassification of related US and Danish government documents. Requesting information under the US Freedom of Information Act, Danish researchers uncovered documents suggesting the USA had violated the Danish government's non-nuclear policies. Following the discovery of H.C. Hansen's now infamous 1957 letter in the Danish Foreign Ministry archives in 1995, the Danish government issued a short statement to the Parliament about the letter and US nuclear weapon-carrying overflights of Greenland. Danish Foreign Minister Niels Helveg claimed that he did not know of any nuclear weapons being stored in Greenland. But in response to Danish queries, the US government confirmed that nuclear weapons had been stored at Thule Air Base from February to October 1958, and again from

December 1959 to summer 1965. Following intense public debate, most likely fueled by ongoing worldwide protests against French nuclear tests in the South Pacific, the Danish government appointed a commission to produce a historical white book on “U.S. overflights of Greenland with nuclear weapons and the role of the Thule base.”⁵⁷

The historians involved interpreted the mandate in very broad terms, and the final 1100-page report *Grønland under den kolde krig* (Greenland during the Cold War) addressed questions far beyond those inquiring into the presence of nuclear weapons in Danish territory, including: negotiations preceding the US-Danish treaty on the defense of Greenland in 1951, Danish security policies in relation to Greenland, the development of Danish non-nuclear policies, all of the American bases in Greenland, the 1968 Thule incident, and much more. Upon its publication in 1997, the report made headlines in the Danish press, not least because it revealed that many more nuclear weapons had been stored in Greenland than the Americans had admitted in 1995. The report, however, did not reveal the actual numbers of nuclear weapons in Greenland.⁵⁸

News coverage of the report often used the term “double-dealing” because of the apparent duplicity of Danish political leaders. In the 1950s and 1960s, H.C. Hansen and other Danish politicians had told the public that the USA was respecting Denmark’s non-nuclear policy while they quietly allowed the US military to fly nuclear-armed aircraft over Greenland and to store nuclear weapons in Greenland. Similarly, the Danish government had pursued full NATO membership while it continued to express concerns about the security policies of its powerful NATO allies.⁵⁹

Although professional historians interested in Denmark’s role in the Cold War had produced the report, its immediate reception indicated that the subsequent discussion would be anything but academic. Indeed, ten years later, the discussion continues.⁶⁰ The resulting historical controversy has fed contemporary political discussions about Denmark’s current foreign affairs and security policies. Was Denmark to quietly accept its role as a small nation with little to say on global geopolitics? Should Denmark continue to raise its voice against the prevailing defense policy of its allies? Or, was Denmark to find new ways of exerting its influence in the world at large? Since the 11 September 2001, Al Qaeda attacks in the USA, the latter option has been pursued by a series of Danish governments.

As Anders Fogh Rasmussen—later the 12th Secretary General of NATO (2009–2014)—became the new Danish prime minister in November 2001, he promoted a new doctrine in Danish foreign policy that would embrace

the role of “strategic actor” possessing a sense of vital interests and a willingness to fight for them militarily.⁶¹ Although best known for leading to Denmark’s military engagement in Iraq and Afghanistan as part of US-led coalition forces, it also had consequences in Greenland. The Igaliku Agreement of 2004, signed by the USA, Denmark, and Greenland’s Home Rule, amended and supplemented the Agreement of 27 April 1951.⁶² The agreement, a direct response to a 2002 request from the George W. Bush administration to upgrade the Ballistic Missile Early Warning System (BMEWS) radar at Thule Air Base to advanced missile-defense standards, also contained declarations about increased economic, technical, and environmental cooperation between the USA and Greenland.⁶³

These policies and actions had consequences, particularly for Greenland. Greenland gained self-rule on 21 June 2009, six months after 75% of Greenland’s voters had approved a referendum to hand more power to its local government and take control of the island’s vast natural resources. Simultaneously, Greenlanders were recognized as a separate people under international law. Greenland remains part of the Danish realm, and Denmark maintains control of foreign affairs and defense matters. Denmark’s annual block grant of about DKK 3.7 billion (\$560 million in 2015) continues, but it will be reduced as Greenland collects revenues from its natural resources. Some speculate that in the future Greenland will experience a second modernization when thousands of jobs are created in mining, tourism, and related industries.⁶⁴ On a less optimistic note—some would say more realistic one—a 2014 report authored by a wide range of specialists, members of the Committee for Greenlandic Mineral Resources for the Benefit of Society, concluded that contrary to the hopes of many Greenlandic lawmakers, mineral and oil extraction would be no shortcut for the country to obtain economic independence from the Danish government.⁶⁵

If you ask the average Greenlander if either of these scenarios will turn out to be true, she may reply: “Imaka.”

NOTES

1. Lea Wind-Friis, “Berømt og berygtet grønlandsk bygning fik dramatisk afslutning,” *Politiken*, 19 October 2012.
2. Geoffrey Williamson, *Changing Greenland* (London: Sidgwick and Jackson Ltd, 1953), 3–10.

3. Ibid., 10–15. In 1954 the Danish Ship Inspection Agency assessed the number of motorboats in Greenland at 254. See Mogens Boserup, *Økonomisk politik i Grønland* (Copenhagen: Grønlandsudvalget af 1960), 71. Kayak numbers remain unknown.
4. Ibid., 8–10, quote on 8. The total value of landed fish in Greenland increased almost sevenfold between 1953 and 1966. See William G. Mattox, “Fishing in West Greenland 1910–1966: The Development of a New Native Industry,” *Meddelelser om Grønland* 197, no. 1 (1973): 185–87.
5. “Arctic renaissance” is the title of Chap. 2 in Williamson, *Changing*.
6. Williamson, *Changing*, 18–24, quote on 24.
7. Vojtech Mastny, “NATO in the beholder’s eye: Soviet perceptions and policies, 1949–56,” *Cold War International History Project Working Papers* 35 (2002), URL: <http://www.wilsoncenter.org/sites/default/files/ACFB01.pdf> (accessed 26 August 2015); Jakob Hornemann, *Bornholm mellem øst og vest: En udenrigspolitisk dokumentation af Bornholms stilling op til og under de sovjetiske befrielsestroppers ophold på Bornholm 1945–1946 og under den kolde krig* (Rønne: Bornholms Tidende, 2006).
8. Unless stated otherwise, the following sections are based on: Axel Kjær Sørensen, *Denmark-Greenland in the twentieth century* (Copenhagen: Museum Tusulanum Press, 2006); Erik Beukel, Frede P. Jensen, and Jens Elo Rytter, *Phasing out the colonial status of Greenland, 1945–54: A historical study* (Copenhagen: Museum Tusulanum Press, 2010).
9. Quoted from Sørensen, *Denmark-Greenland*, 92.
10. A precedent for selling Danish territory to the USA had been set in 1916, when Denmark transferred its sovereignty of the Danish West Indies to the United States for \$25,000,000 in gold, and a US declaration that it would not object to the Danish government extending its political and economic interests to all of Greenland.
11. Sørensen, *Denmark-Greenland*, 93–94. See also Bo Lidegaard, *I kongens navn: Henrik Kauffmann i dansk diplomati 1919–1958* (Copenhagen: Samleren, 1996), 410–12; DUPI, *Grønland under den kolde krig: Dansk og amerikansk sikkerhedspolitik 1945–68* (Copenhagen: Dansk Udenrigspolitisk Institut, 1997), 53–71.
12. Quoted from Sørensen, *Denmark-Greenland*, 95.
13. A useful introduction to this line of thinking about development is Gerald M. Meier and Dudley Seers, eds., *Pioneers in development* (New York and Oxford: Oxford University Press, 1984).
14. Gilbert Rist, *The History of Development: From Western Origins to Global Faith* (London: Zed Books, 1997).

15. Nick Cullather, *The Hungry World: America's Cold War Battle against Poverty in Asia* (Cambridge, MA: Harvard University Press, 2010); Nick Cullather, "Development? It's history," *Diplomatic History* 24, no. 4 (2000): 641–653; David C. Engerman et al., eds., *Staging Growth: Modernization, Development, and the Global Cold War* (Amherst: University of Massachusetts Press, 2003); Odd Arne Westad, *The Global Cold War: Third World Interventions and the Making of Our Times* (Cambridge: Cambridge University Press, 2005).
16. The fundamental assumption of convergence encoded in the ideology of development on both sides of the iron curtain is discussed in Cullather, "Development?," 642–43.
17. Westad, *Global Cold War*, 3.
18. Grønlandskommissionen, *Grønlandskommissionens betænkning*, 9 vols. (Copenhagen, 1950), vol. 5 (1), 29.
19. *Ibid.*, 19.
20. Thorsten Borring Olesen and Paul Villaume, *Dansk udenrigspolitik historie. Bd. 5: I blokopdelingens tegn 1945–1972* (Copenhagen: Danmarks Nationalleksikon, 2005), 40–56.
21. Mattox, "Fishing in West Greenland," 130–33.
22. *Ibid.*, 123–29.
23. The data are from Grønlandsudvalget af 1960, *Betænkning fra Grønlandsudvalget af 1960*, Betænkning nr. 363 (Copenhagen: Statens Trykningskontor, 1964), 21–24.
24. Sørensen, *Denmark-Greenland*, 111.
25. Grønlandsudvalget af 1960, *Betænkning*, 13–16. Up until World War II, Denmark invested less than DKK 500,000 annually in Greenland.
26. Boserup, *Økonomisk*, 7.
27. Sørensen, *Denmark-Greenland*, 130. Prior to 1964, those who had lived in Greenland for ten years before their employment had their wages reduced in comparison to employees from Denmark. That changed in 1964, when the wage depended upon the place of birth, that is, Danes were paid more. The birthplace criterion led to much disappointment and criticism in Greenland, and to the establishment of the Inuit Ataqatigiit, a leftist, separatist party, in the late 1970s.
28. The GTO was established in 1950 to supervise most construction works in Greenland and manage the new utilities. The GTO headquarters was placed in Copenhagen, close to the Ministry for Greenland, other state departments, and Danish technical expertise. See Lise Lyck, "Greenland Technical Organization," in *Encyclopedia of the Arctic*, vol. 2, ed. Mark Nuttall (New York and London: Routledge, 2005): 798–99.
29. Grønlandsministeriets anlægsudvalg, *Betænkning fra Grønlandsministeriets Anlægsudvalg vedrørende reorganisering af Grønlands Tekniske Organisation*

- (Copenhagen, 1957); Gunnar P. Rosendahl, "De seneste års tekniske udvikling i Grønland," *Tidsskriftet Grønland* 9 (1959): 342–352.
30. Hans P. Steenfos and Jørgen Taagholt, *Grønlands teknologihistorie* (København: Gyldendal, 2012), 174.
 31. Claus Bornemann, "Bliver den grønlandske arbejder forbigået?," *Tidsskriftet Grønland* 12 (1960): 459–471.
 32. Rosendahl, "De seneste års," 351.
 33. Gunnar P. Rosendahl, "Bliver den grønlandske arbejder forbigået?," *Tidsskriftet Grønland*, no. 4 (1961): 129–138.
 34. Sørensen, *Denmark-Greenland*, 117–20.
 35. The request of the National Council is reprinted in Grønlandsudvalget af 1960, *Betænkning*, 9.
 36. Ibid.; Boserup, *Økonomisk*; Grønlandskommissionen, *Grønlandskommissionens betænkning*, vol. 1, 60, and vol. 5, 35; Grønlandsudvalget af 1960, *Betænkning*, 25.
 37. Sørensen, *Denmark-Greenland*, 130.
 38. The figures are taken from Grønlands Statistik, "Greenland in figures 2015," <http://www.stat.gl/publ/da/GF/2015/pdf/Greenland%20in%20Figures%202015.pdf> (accessed 26 August 2015).
 39. Lawrence C. Hamilton, Benjamin C. Brown, and Rasmus O. Rasmussen, "West Greenland's cod-to-shrimp transition: Local dimensions of climatic change," *Arctic* 56, no. 3 (2003): 271–282.
 40. Ibid., 271; Grønlands Statistik, "Greenland," 13.
 41. Three important parties played a role in the referendum: Atassut (solidarity), a liberal-conservative party, which emphasized the traditional bonds between Denmark and Greenland; Siumut (forward), a social-democratic party stressing political autonomy and Greenland's right to fully exploit its natural resources; and Inuit Ataatigiit (people unity), a leftist, separatist party. See Sørensen, *Denmark-Greenland*, 142–43.
 42. Niels Højlund, *Krise uden alternativ: En analyse af en dansk grønlandsdebat* (Copenhagen: Gyldendal, 1972).
 43. Ibid., 159–65.
 44. Lynge here refers to the coal-mining town of Qullissat (previously spelled Qutdligssat) founded in 1924 to exploit natural resources on Disko Island. In 1966, the Provincial Council of Greenland voted to close the mine due to falling profits and the need for more labor for cod fishing, and ordered the residents to move closer to cod fishing sites. But by the time the mine closed in 1972, cod fishing had virtually collapsed. Nevertheless, the relocation continued as if nothing had changed. About 500 residents had already moved, and the remaining 500 were forced to relocate. "You'd call it imperialism," concluded one commentator in anger. See Carl Johan Ohsten, "Nedlæggelsen af kulminebyen Qutdligssat," *Tidsskriftet Grønland* 6 (1977): 165–170, quote on p. 170.

45. Kalaallit Nunat is the Greenlandic name of Greenland, which literally means the land of the Kalaallit, the indigenous Inuit people who inhabit the country's west region. "Skraeling" or "skræling" is the name the Norse Greenlanders used for the indigenous peoples they encountered in North America and Greenland in the eleventh to fourteenth centuries.
46. Written in 1970, the poem now appears in translation in Aqqaluk Lyngé, *The Veins of the Heart to the Pinnacle of the Mind*, IPI Publishers, Montreal, 2008, 107–9. Used by kind permission © Aqqaluk Lyngé.
47. Svend Aage Christensen and Kristian Soby Kristensen, "Greenlanders Displaced by the Cold War: Relocation and Compensation," in *Historical Justice in International Perspective: How Societies Are Trying to Right the Wrongs of the Past*, ed. Manfred Berg and Bernd Schaefer (Cambridge: Cambridge University Press, 2012), 111–131.
48. Henrik Karl Nielsen, "Den danske Højesterets dom om tvangsflytningen af Thules befolkning," *Nordisk Tidsskrift for Menneskerettigheder* 22, no. 3 (2004): 315–329.
49. Nicolai Petersen, "Fodnotepolitik," *Magasin fra Det kongelige Bibliotek* 21, no. 3–4 (2008): 10–21.
50. Poul Brink, *Thule-sagen. Lognens univers* (Copenhagen: Aschehoug, 1997). Brink became the first journalist to see the notorious H.C. Hansen note of 1957, which, in 1995—six years after the end of the Cold War—mysteriously surfaced from the archives of the Ministry of Foreign Affairs. See Chap. 9 in this volume. Nikolaj Petersen, "The H. C. Hansen Paper and Nuclear Weapons in Greenland," *Scandinavian Journal of History* 23, no. 1–2 (1998): 21–44.
51. Hans M. Kristensen, *Atomfrit hav* (Copenhagen: Greenpeace, 1988).
52. Hans M. Kristensen, "Neither Confront nor Deny," *Bulletin of the Atomic Scientists* 48, no. 2 (1992): 3–4.
53. Nikolaj Petersen, "'Footnoting' as a political instrument: Denmark's NATO policy in the 1980s," *Cold War History* 12, no. 2 (2012): 295–317. Denmark's footnoting of US and NATO policies began when the Danish Minister of Foreign Affairs, attending the NATO ministerial meetings in December, proposed postponing the decision for six months to test the Warsaw Pact's willingness to initiate arms control talks.
54. Fredrik Doeser, "Domestic politics and foreign policy change in small states: The fall of the Danish 'footnote policy,'" *Cooperation and Conflict* 46, no. 2 (2011): 222–241, 229.
55. Leopoldo Nuti, Frédéric Bozo, Marie-Pierre Rey, and Bernd Rother, eds., *The Euromissiles Crisis and the End of the Cold War* (Redwood City, CA: Stanford University Press, 2015).
56. European Court of Human Rights, "Hingitaq 53 and others v. Denmark," <http://hudoc.echr.coe.int/sites/eng/pages/search.aspx?i=001-72219> (accessed 26 August 2015).

57. DUPI, *Grønland*, 15. On protests against the French nuclear tests, see Philip Shenon, “France, Despite Wide Protests, Explodes a Nuclear Device,” *New York Times*, 6 September 1995, <http://www.nytimes.com/1995/09/06/world/france-despite-wide-protests-explodes-a-nuclear-device.html> (accessed 21 August 2015).
58. DUPI, *Grønland*.
59. This second duplicity is explored in depth in Poul Villaume, *Allieret med forbehold: Danmark, NATO og den kolde krig. Et studie i dansk sikkerhedspolitik 1949–1961* (Copenhagen: Eirene, 1995); Nikolaj Petersen, “Fodnotepolitik,” *Magasin fra Det kongelige Bibliotek* 21, no. 3/4 (2008): 10–21.
60. DIIS, *Danmark under den kolde krig: Den sikkerhedspolitiske situation 1945–1991*, 4 vols. (Copenhagen: Dansk Institut for Internationale Studier, 2005); Bent Jensen, *Ulve, får og vogteren Den Kolde Krig i Danmark*, 2 vols. (Copenhagen: Gyldendal, 2014). The 2005 report, commissioned by the Danish government, was much more sympathetic to Denmark’s security policy during the Cold War than was the report by Jensen, who led the Center for Koldkrigsforskning (Cold War Studies), funded by the Danish government between 2007 and 2010. The historians involved accused each other of using history for political purposes. Since then, historians have continued the discussion. See, for example, Carsten Due-Nielsen, Rasmus Mariager, and Regin Schmidt, eds., *Nye fronter i den Den kolde Krig* (Copenhagen: Gyldendal, 2010); Rasmus Mariager, Torsten Borring Olsen, John T. Lauridsen, and Poul Villaume, eds., *Den kolde Krig og Danmark* (Copenhagen: Gad, 2011). The title of the Due-Nielsen et al. book translates as “new frontiers in the Cold War,” where “frontiers” refers not only to the geopolitical frontiers during the Cold War, by also to the frontiers in the current debate about Denmark’s role in the Cold War.
61. Sten Rynning, “Denmark as a strategic actor? Danish security policy after 11 September,” *Danish Foreign Policy Yearbook* (2003): 23–46.
62. “Defense Greenland,” <http://www.state.gov/documents/organization/170358.pdf> (accessed 26 August 2015).
63. Nikolaj Petersen, “The Arctic challenge to Danish foreign and security policy,” in *Arctic security in an age of climate change*, ed. James Kraska (Cambridge: Cambridge University Press, 2011), 145–164; Jørgen Dragsdahl, “Denmark and Greenland: American Defences and Domestic Agendas,” *Contemporary Security Policy* 26, no. 3 (2005): 486–504.
64. Rambøll, “Greenland: A land of opportunities,” <http://www.ramboll.com/megatrend/feature-articles/greenland-a-land-of-opportunities> (accessed 26 August 2015).
65. Committee for Greenlandic Mineral Resources to the Benefit of Society, *To the benefit of Greenland* (Nuussuaq and Copenhagen: Ilisimatusarfik and University of Copenhagen, 2014).

PART II

Controlling Hostile Environments:
Geophysical Research in Greenland

In Search of Control: Arctic Weather Stations in the Early Cold War

Matthias Heymann

War came to the Arctic in 1940, and unlike World War I just 25 years before, this war between nations was tactically influenced by the weather. Timely, reliable weather data from the Far North, including Greenland, the Canadian Arctic, and the North Atlantic, were crucial for forecasters charged with predicting how conditions might affect critical military operations in Western and Central Europe. The tactical use of weather grew after 1945, as the Cold War intensified and meteorological data became essential for military and commercial aviation, and for operating guided missiles, positioning troops, and assessing the Soviet military's operational capacity.¹

The requirements for weather data would prove particularly significant, indeed contentious, during the first half of the Cold War. Field data were important in all branches of the physical environmental sciences, but routine observations of temperature, humidity, atmospheric pressure, and wind speed were vital for accurate operational forecasts. High northern latitude measurements were crucial not only for predicting the weather at US installations in Greenland, but also for those throughout Europe. These data were the foundation for understanding changes in the northern climate at a time when many meteorologists thought the poles were

M. Heymann (✉)

Centre for Science Studies, Department of Mathematics, Aarhus University, Aarhus, Denmark

getting warmer—and hence might open up the Arctic to military maritime operations—and they were also the basis for theoretical studies of Earth’s atmosphere.²

Yet the need for weather stations in Greenland and northern Canada also created a distinct set of challenges for foreign and national policy development: who would build these stations? Who would supply and staff them? Scientific outposts such as weather stations were not simply clusters of instruments. They were powerful markers of nationality: the flags flying at these installations symbolized political sovereignty, territorial integrity, and state power.³ For both Canada and Denmark (overseeing Greenland), the weather station “problem” illuminated the evolving postwar relationship between these smaller states and the USA, a superpower.⁴ Complicating the situation was a figure who became central in promoting new US-established weather stations in Canada and Greenland, although he was neither a meteorologist nor a scientist, but an ambitious, self-confident engineer and polar explorer seeking a new postwar role. Unfortunately, he lacked an appreciation of smaller states’ sovereignty, which was vital to understanding Denmark’s relationship with Greenland and Canada’s desire to control its Arctic territory.

ARCTIC WEATHER STATIONS: WARTIME TO PEACETIME

In 1939, Denmark was operating 16 weather stations in Greenland: 14 on the accessible west coast, and 2 on the east coast. Allied military services knew they would need continuous access to weather data from northern latitudes to successfully prosecute the war in Europe. Germany knew it too, and made repeated attempts to install and operate small weather stations on Greenland’s largely inaccessible, sparsely populated east coast, but its efforts were thwarted by US forces and a Danish sledge patrol.⁵

After Germany occupied Denmark in April 1940, the USA assumed responsibility for Greenland’s defense—the island was vital for US security—and in 1941 signed the Greenland Agreement with exiled Danish Ambassador to the USA Henrik Kauffmann. US forces immediately began constructing air bases, landing strips, and weather stations (see Map 1, page viii), the latter crucial for supporting the North Atlantic aircraft ferry route from the USA to the UK via Newfoundland, Labrador, Greenland, and Iceland.⁶ At war’s end, 13 Danish and 14 American weather stations, all controlled by the US Army Weather Service, were operating on the island.⁷

Weather data from the Canadian high north were similarly important. By April 1942, US forces developed a plan to expand weather observation stations to the Canadian Far North along Lancaster and Melville Sounds, at Dundas Harbour (Devon Island), Fort Ross (Somerset Island), and Winter Harbour (Melville Island) since the lack of weather data from the region meant weather forecasts supporting US military air services ferrying planes and materiel from North America to Europe via Canada and Greenland were often unreliable. But the US military wanted more than weather data. It also wanted ice and hydrographic information (important for transiting ships), magnetic data (important for antisubmarine warfare), and ionospheric observations (important for radio wave propagation). Thus US military officials sought to establish these stations, alone or in collaboration with the Canadian government. Canada, which asserted that sufficient weather data were already available, was willing to provide additional weather data on request, but declined to establish additional weather stations, with or without US involvement.⁸

US interest in Arctic weather stations remained strong after the war. Initially, the data were required to support military operations and commercial aviation, a growing need as the Cold War intensified and the number of long-haul flights between North America and Europe increased with a booming US economy and the rebuilding of European infrastructure. And by the early 1950s, numerical weather prediction models, written for the new electronic digital computers, were increasingly data-hungry. In the early days, regional weather data were sufficient to create regional prognostic charts, but by the mid-1950s, increased computer power allowed work to begin on hemispheric models, which required data from the Far North to create forecasts for the entire Northern Hemisphere. More sophisticated versions of these early forecast models would later be developed into climate models in the late twentieth century.⁹

But in the immediate postwar years, the most important questions concerning weather stations were not scientific, they were operational. And the sticking points in negotiations between the USA and Denmark, and the USA and Canada were related to political power and national sovereignty rather than science.

Weather stations were costly to build, maintain, and staff. Meteorological equipment is expensive and requires careful, routine calibration, a difficult task in remote areas subject to continually harsh weather conditions. Furthermore, to aid large-scale forecasting efforts, assembled weather data must be shared immediately. Therefore, weather stations must have access

to reliable communications devices and their associated infrastructure, that is, radios, teletypes, receivers, transmitters, and, if using landlines, the wires to connect them—not a trivial undertaking in remote Arctic regions. With the end of the war, American military services rapidly demobilized as their budgets shrank to fit their peacetime footing. Funds for military hardware and maintenance went to essentials: aircraft, ships, tanks, and weapons of all kinds. Thus, money for maintaining the extensive network of weather stations that had been established all over the world during the war quickly dried up. Military units maintained the fewest weather stations required for safe operations, and closed down the rest. When military meteorologists suggested that the US Weather Bureau operate these far-flung stations, Weather Bureau Chief Francis W. Reichelderfer made clear that his perpetually underfunded agency could not do so no matter how important the data were.

Since neither the military services nor the Weather Bureau had the funds to keep these weather stations open, the US government sought to turn them and their operations over to their host nations out of scientific and fiscal self-interest. It wanted the data for operational purposes, but it did not want to pay for it. Canada could afford to take over the stations in its territory, so that turnover went well. But Denmark, despite its desires, had neither the funds nor the manpower to operate all the weather stations in Greenland. The resulting tensions between the US and Danish governments over keeping the weather stations open and fully operational was exacerbated by Denmark's concerns over the continued US military presence in Greenland.

TRANSFERRING WEATHER STATIONS IN GREENLAND: NEGOTIATING WITH DENMARK (1945–1946)

German-occupied Denmark had been effectively isolated during the war, banned from international negotiations and blocked from getting information from its colony, Greenland.¹⁰ After V-E day, the Danish Greenland Administration in Copenhagen, directed by Knud Oldendow, took back responsibility for the island from the USA, but only reluctantly accepted responsibility for the weather stations that had been added during the war years. Oldendow knew the stations were not in peak condition, and new installations and equipment would cost over DKK three million [\$7.7 million in 2014]—money that the Danish government did not have. The USA had loaned a considerable amount of meteorological equipment to the stations, operated by joint Danish-American staffs and with American supplies.¹¹ On the other hand, the need for weather stations in Greenland

was widely acknowledged, especially since southern Greenland was located on the great circle route from North America to Europe, a major transatlantic connection.

Immediately after V-E Day, Greenland Governor Eske Brun began negotiating the future of weather services on the island with officials from the American District Weather Control Office, who agreed that the weather stations should be transferred to Danish control as soon as possible.¹² In July 1945, the American Legation in Copenhagen asked that Danish radio personnel, mechanics, and cooks be sent to the Greenland weather stations by 1 August. The USA would fund the salaries, but wanted assurance that the stations would continue to operate.¹³ Unable to secure personnel on short notice, a smaller group of Danish naval personnel were assigned to the weather stations instead. But they were unavailable until late August, so the US Army decided to close down three smaller weather stations in September and transfer the combined Danish-Greenlandic staff to neighboring stations.¹⁴

In fall 1945, negotiations continued between the new Greenland Governor, the Dane F.B. Simony, and the American District Weather Control Office. Simony, recognizing the importance of the weather observations for both US and Danish weather services, asked the Danish Greenland Administration to quickly send eight more people to Greenland. When that was impossible, he made a pitch for 16 staff members over 12 months. The Greenland Administration agreed, but the personnel were not available and as a result fewer weather observations were taken and reported.¹⁵ While the Americans complained about the Greenland Administration's "apparent unwillingness to cooperate" vis-à-vis sending personnel to Greenland, it is equally apparent that the Americans wanted to dump the problematic weather stations on a nation recovering from the war.¹⁶ Nevertheless, the Americans met with the Greenland Administration once again in October 1945 to work out a deal that would last until 1 July 1946. The Danish government committed to sending 16 more staff by late April 1946, but once again personnel were not available to man the stations.¹⁷

This pattern—American requests, Danish agreement, and Danish failure to deliver—continued into early 1946. What was going on? A 15 April 1946 meeting at the Greenland Administration provides a few hints. Director Oldendow did not want responsibility for the weather stations, while Helge Petersen, head of the Danish Meteorological Institute (DMI), suggested that the Greenland Administration operate only the

14 stations that had been accepted by the Provisional International Civil Aviation Organization (PICAO)—the interim UN agency that set international rules and regulations insuring flight safety—as sufficient for civil aviation safety.¹⁸ However, Vice Admiral A.H. Vedel, Director, Ministry of the Danish Navy, questioned whether it could find enough people to staff them.¹⁹ Max Sørensen, legal advisor at the Danish Foreign Ministry, made a different recommendation: take over all of the US installations and send the American forces home—an action that would secure Danish territorial sovereignty.²⁰ And by early May, the Danish government adopted Sørensen’s recommendation, and for “national reasons,” that is, an effort to distance itself from possible US control in Greenland, refused financial support for the stations from the US government.²¹

While these discussions were underway in Denmark, the American Legation sent a military delegation led by Brigadier General Caleb V. Haynes (Commander of the Newfoundland Base, which was responsible for the Army Air Force in Greenland) to Godthaab to discuss the matter with Governor Simony. Unbeknownst to them, Simony could sign nothing without permission from the Greenland Administration in Copenhagen. Disgusted by this turn of events, the delegation—with Governor Simony in tow—flew to Copenhagen on 22 May 1946, on an Air Force C-54, simultaneously ruffling the feathers of both the US ambassador and the Danish government. The latter was upset that one of their officials had flown on a US transport, while the former was embarrassed that a high-ranking US military officer had seen fit to swoop into Copenhagen because of a dispute over weather stations. Having committed an unseemly diplomatic gaffe, General Haynes did not participate in the subsequent discussions at the Foreign Ministry.²²

The meeting desired by the American legation finally took place on 27 May 1946. Danish officials emphasized their strong desire to take over all weather stations as soon possible, but they lacked personnel to staff even 18 of the 24 open stations. Two days later, the Danish Foreign Ministry explained that the Danish government wanted not only to participate in the weather reporting system, but sought—presumably with an eye to sovereignty issues—to gain “independent control over such reporting... with a view to assuming, as soon as possible, full responsibility for the whole Greenland weather net” and to fund the entire operation.²³

Because the Danish government had failed to deliver on earlier weather station commitments, members of the American Legation were dubious and their attempt to secure a written agreement was rebuffed. After much

wrangling between the Legation and the Foreign Ministry, the negotiators figured out a way to make it appear that the weather station agreement had been worked out in Greenland—not in Copenhagen—and that it had not involved military agencies, to downplay the role of the US military in Greenland. The Danish government agreed to operate and staff 18 weather stations in Greenland, and transmit their weather observations. The Greenland Administration would fund salaries, clothing, and food, and maintain consistent standards while taking and transmitting weather reports, and the US government would provide equipment and supplies.²⁴

BUILDING ARCTIC NETWORKS: THE JOINT ARCTIC WEATHER STATIONS IN CANADA (1942–1946)

As the war wound down, some US military officers began looking ahead to the postwar years and what they might mean for US interests in northern latitudes. One of them was US Army Lieutenant Colonel Charles Hubbard, who had been exploring the possibility of introducing US weather stations into the Arctic. Although the *New York Times* would later describe Hubbard as “one of the most colorful of North America’s explorers and meteorologists,” Hubbard was *not* a professional meteorologist: he had taken some science courses while a student at Harvard, but his appreciation of weather’s importance stemmed from many flights undertaken in the Far North. Nor was his boyhood like “that of any other American boy.”²⁵ Born to a wealthy Midwestern family, Hubbard had attended elite schools and accompanied a private expedition to Labrador at age 14. Like his Harvard-educated brother, Wyant, the African adventurer, he nurtured a deep yearning for exploration.²⁶ He became a writer, led an expedition back to Labrador to search for gold in 1933, and in 1936—in the midst of the Great Depression—led a three-month cruise to the Caribbean on his private 57-foot yacht. By the time World War II had reinforced perceptions of the Far North’s importance for commercial aviation and national defense, Hubbard was well-known for his polar exploits and well-positioned to make a case for expanding Arctic aviation.²⁷ His lack of geopolitical sense, however, meant he was not the ideal person to drive the push for installing US weather stations in Arctic Canada and Denmark.

In 1944, while loosely affiliated with the Massachusetts Institute of Technology’s (MIT) Meteorology Department—one of five wartime sites for training military meteorologists—Hubbard prepared an Army- and Navy-funded report for the National Academy of Sciences’ (NAS)

Research Board for National Security. He argued for the establishment of permanent Arctic weather stations via a program dubbed Project Arctops (for Arctic topography). Thinking of the USA and the Soviet Union as allies, Hubbard emphasized that data from Arctic weather stations were needed to improve weather forecasts for military operations and future great circle transpolar flyways, including flights from Kansas City, Missouri, to Russia. He also played the standard trump card: other nations were ahead of us in Arctic meteorological observations, including the Soviet Union (137 weather stations), Norway (75), Sweden (5), Finland (3), and Denmark/Greenland (9). But in North America? Four in Canada and three US stations in Alaska.²⁸

Not content to just write and deliver the report to the NAS, Hubbard moved completely outside of his chain of command and contacted Canadian Deputy Minister of Mines and Resources Hugh Keenleyside in autumn 1944, making a pitch for more weather stations in the high north, adjacent to Greenland. And he may also have contacted another deputy minister of the same organization. Apparently nothing came of those contacts, and several months later he met with the Canadian Ambassador to the USA, Lester Pearson, and Escott Reid, a prominent Canadian diplomat serving with Pearson, to make another attempt. Pearson demurred. Canadians would not relish US weather stations on their territory. But, according to Pearson, Hubbard had undiplomatically expressed doubt about “the extent of [Canadian] sovereignty” in the Arctic districts.²⁹ Not only was Hubbard tone-deaf: he was making direct contacts with foreign officials, bypassing the State Department.

In general, Canadian authorities thought the USA had respected Canadian autonomy during key undertakings during World War II—including, for example, the construction of the Alaskan-Canadian (ALCAN) Highway linking Alaska with the lower 48 states—but the potential US challenge to Canadian sovereignty was real. Canadian leaders were concerned not simply with the installation of some weather stations, but with US ships sailing through what had previously been considered sovereign Canadian waterways and undertaking missions considered the domain of ruling states.³⁰ Graham Rowley, the Arctic section leader of Canada’s Defence Research Board, recognized that both naval and aviation pathways from North America to the Soviet Union necessarily involved Greenland and Canada’s Ellsmere Island, and that the need for more weather stations was genuine. Yet “the Danes would probably be happier about American meteorological activities,” he noted wryly, if the

US acted more diplomatically: it did not help that Hubbard, the head of America's Arctic projects, had published a piece called "Should Greenland be American?" in the widely read *Colliers* weekly in late 1945.³¹

Canadian officials were not the only ones who viewed Hubbard and his ideas with a jaundiced eye. According to R.M. Macdonnell, Secretary of the Canadian Section of the Permanent Joint Board on Defense, senior officers of the US Army Air Force's Arctic, Desert, and Tropic Information Center had advised him "to treat proposals emanating from this source [i.e., Hubbard] with—to put it mildly—a certain amount of reserve," and Macdonnell told Pearson that Hubbard was not viewed with favor by the center's Arctic component.³²

Hubbard's efforts to find his way back to the Arctic had reached a roadblock with both US military and Canadian government officials. Not easily deterred, he sought a different path to success and found it with US Senator Owen Brewster (R-Maine) and his colleague Representative Margaret Chase Smith (R-Maine), both of whom introduced the exact same legislation in support of Arctic weather stations in their respective houses of Congress in 1945. One might reasonably ask: what was this Army officer doing by apparently trotting off on his own and selling this idea to legislators? Writing to an old friend, Hubbard noted that he was in the process of leaving the Army and because he was due to "go out of uniform on 5 March... [he had] to find some good way to make a living."³³ Hubbard certainly recognized the importance of creating weather stations for aviation, but his primary interest was in expanding aviation's empire and being central to that effort. In late 1945, Hubbard had spoken about the potential of creating transarctic flights from America's heartlands to Moscow—a hope shared by US businessmen and farmers who saw new markets emerging—but he recast this support in terms of national security and defense after Cold War realities set in.³⁴ In short, Hubbard was maneuvering for a postwar career while he was employed on a US government contract.

In any case, Hubbard helped Brewster draft the legislation, which was introduced in the Senate in March 1945. The proposed bill, S. 765, concerned "the establishment of meteorological observing stations in the Arctic region of the Western Hemisphere, for the purpose of improving the weather forecasting service within the United States and on the civil international air transport routes from the United States." Note, however, that this bill was proposed under the presumption that the nations in which the USA intended to place those stations would be happy to have them

there. As Hubbard wrote to the Assistant Secretary of Commerce in May, “The ultimate objective, however, presupposes the establishment of Arctic meteorological stations in areas controlled by both the Canadians and the Danes. I am especially concerned about the maintenance of friendly relations and cooperation with the Canadians.”³⁵ Just the Canadians? What about the Danish government?

The bill passed the Senate in October 1945. Testimony heard before the House vote provides clues to the political, military, and scientific thinking behind this legislation. In her introduction, Representative Smith related the meteorological community’s interest in the Arctic:

1. Basic weather forces originate in the Arctic areas north of [North America.]
2. These forces influence weather movements and conditions within the USA and on the northern air routes.
3. Knowledge of Arctic weather characteristics is essential for more accurate forecasts and long-range predictions.³⁶

Moving on to national defense issues, she relayed the statements of Army Air Force Commanding General Henry H. “Hap” Arnold, who argued that because the polar region had been “conquered by aviation,” in the next war, weapons and planes would follow a route through this region. For those weapons to take advantage of the environment, Arctic weather data were required. Representative Smith also stressed that Arctic weather data would lead to “greater accuracy and earlier predictions” of adverse weather in the USA, which would be extremely important to the nation’s economy and an essential prelude to the development of transpolar flight routes. Arguing that the USA was dependent upon scientific research development for its security, Smith claimed: “Any scientific program for the fuller development of our assets will be incomplete if it does not include Arctic weather research and study.”³⁷

With witnesses at the ready, committee members did ask a rather obvious question: Had the Weather Bureau checked with any other nations to see if they would be willing to have US weather stations built, maintained, and operated on their territory? Without saying so directly, Weather Bureau Chief Francis Reichelderfer’s answer was “no.” Since the Canadian government, in particular, had collaborated with the USA on establishing stations during the war, he believed that they would agree to any “reasonable arrangement” if the stations would also benefit them. Of course, he

noted, the USA would get more economic benefit from the stations than the Canadians because its economy was larger, and the increased accuracy and timeliness of the forecasts would provide US business and industry with the greater payback. Reichelderfer also noted that in the past, the USA had offered to help the Canadian government with meteorological stations, but that “an element of national pride enters into it,” and they had always found a way to provide weather services without American help.³⁸

Military leaders also supported the bill. Colonel D.N. Yates, US Army Air Force Weather Service, testified that there was “nothing more important from a security standpoint than the establishment immediately of additional stations in the Arctic.” Because the Arctic region was the only blank spot on Northern Hemisphere weather maps, it was imperative to fill it in. Not only would better forecasts result, such information was an absolute requirement if military units were going to be operating in the region.³⁹ Similarly, the Secretary of War and the Secretary of the Navy also supported the legislation as long as the Weather Bureau’s actions did not interfere with the work of the military weather services.⁴⁰ The war was over, but it was time to start looking ahead to the next one—and the theater of operation would be in the Arctic.

The bill was signed into law in February 1946, giving the Weather Bureau authority and funding to develop an international “basic meteorological reporting network in the Arctic,” which would involve establishing, operating, and maintaining weather stations with *or without* the cooperation of the countries in which they would be built.⁴¹ Indeed, Brewster—a political conservative and ally of Senator Joseph McCarthy—was a firm supporter of securing American hegemony over Greenland, publicly declaring in late 1945, that “Greenland must be acquired... Colonel Hubbard is absolutely right. Greenland is a military ‘must’ for America.”⁴² It was yet another reminder that Hubbard and his allies had only a tenuous grasp of national sovereignty.

With a public law and funding behind him, Hubbard pushed his project, dubbed “Joint Arctic Weather Stations” (JAWS) ahead. In its final version, the project included the construction and operation of six weather stations: one in Thule, Greenland, and five in Arctic Canada. On 1 May 1946, the USA formally asked the Canadians to approve the Arctic weather station program: a principal weather station in 1946 and three (later amended to four) additional satellite stations in 1947 in the Canadian high north. US Embassy personnel delivered a memorandum from the US State

Department to Canada's Department of External Affairs on 1 May 1946, which requested its support for the Arctic weather station plan. After reiterating the main points discussed during the congressional hearings, US Embassy personnel pointed out that the USA could either undertake the program on its own, or with the cooperation of the Canadian government, and "had no thought of interfering in any way with Canadian sovereignty." Perhaps not, but the Canadians were not eager to have the USA setting up shop in the frozen north, and invited the Americans to discuss the proposal in more detail.⁴³

Some 20 American and Canadian officials and diplomats, including representatives from Mines and Resources, and the Meteorological Service, met to discuss the weather stations. Hubbard, now a civilian (even though he was referred to as "Colonel Hubbard"), discussed the project's details and pressed Canadian officials for a quick decision. The funds were available and he needed to get materials and supplies in place during the summer before weather and ice conditions made ship support impossible. While Canada's Meteorological Service was supportive—what meteorologist would ever turn down additional data from a data sparse region?—other Canadian officials were uneasy, if not downright suspicious, of US intentions in the region. As the discussion moved to higher echelons in the Canadian government, US officials ramped up the pressure for a quick decision, and as the pressure increased, the probability that Canadian officials would agree to the project decreased. Comments by some lower level bureaucrats in Washington, DC, about raising "the Stars and Stripes in unoccupied Arctic territory" did not produce a favorable outcome for the Americans. And although Canadian officials carefully stressed that a collaborative effort on Arctic weather stations might be possible in the future, it was clear that the Canadians—from the Prime Minister on down—had no intention of being pushed around by the USA.⁴⁴

In January 1947, Canadian sovereignty concerns related to high latitude weather stations were allayed when the Canadian and US governments agreed to Permanent Joint Board on Defense Recommendation 36, which promised to "safeguard the sovereignty and protect the interests of the country in whose territory joint exercises are undertaken."⁴⁵ But the Canadian government's primary reason for claiming leadership over the weather stations was to calm domestic discussions vis-à-vis US activities on Canadian territory, even though the Americans carried out most of the work.⁴⁶

Between 8 and 16 April, the USA flew 106 tons of supplies from their staging location in Thule—the closest location with the requisite infrastructure

to support this mission—to Slidre Fjord, southwestern Ellesmere Island, for the construction of the Eureka Station. Staffed by three Americans and three Canadians, the weather station began meteorological operations later that month.⁴⁷ In July 1947, a resupply mission consisting of three ships reached Thule, then Eureka Station, and continued on to Melville Island to build the third station. Sea ice blocked their approach four times, so they diverted to the alternate location—Resolute on Cornwallis Island—and built the weather station there. It commenced operations in September. The Resolute Station became the hub for stations built at Isachsen on Ellef Ringnes Island, and Mould Bay on Prince Patrick Island in April 1948. In April 1950, the northernmost station on the northern coast of Ellesmere Island—Alert Station—was built, and began operations.

The Canadian stations were operated with 50–50 Canadian and American staffs, but extensive, costly sea supply voyages to the Canadian stations were funded by the USA, and only a few Canadian observers and scientists participated. Canada was slow to assume a more active role in the weather station program because it lacked personnel and resources to operate and resupply the stations, only taking over the resupply missions after 1950. The Canadians also downplayed the military aspects of the weather stations program because, according to historian Daniel Heidt, they “worried, rightly, that important northern joint projects could be jeopardized by negative public opinion.”⁴⁸ Consequently, the government observed a no-publicity policy.

The last Arctic weather station passed into Canadian hands on 31 October 1972, three months after the last US personnel departed Resolute.⁴⁹

JOINT ARCTIC WEATHER STATIONS IN GREENLAND AND DENMARK (1946–1950)

On 30 April 1946, one day before a similar request had landed at Canada’s Department of External Affairs (see above), the Danish Foreign Ministry received an official request from the USA asking that the US Weather Bureau be granted permission to build a weather station near the Thule airstrip for “complete upper air and magnetic observations,” as part of the JAWS project. This request complicated on-going negotiations over existing stations, and was met with (to the Americans) unwelcome silence. Two weeks later, the American Legation in Copenhagen sent a follow-up telegram requesting a response. Silence. Finally, on 25 May, US Ambassador

to Denmark Josiah Marvel made a personal call on Undersecretary Frants Hvass at the Foreign Ministry, only to be told that the Danish government was willing to consider the request, but needed significantly more details. Legation personnel asked again two days later during a conference on weather stations.⁵⁰ Time was slipping away.

On 29 May, Foreign Minister Thorkil Kristensen sent a positive response to the Americans. Denmark accepted the construction of a new weather station to be operated by Denmark, but the Americans would need to provide upper-air training to the Danish staff.⁵¹ Feeling pressured by the USA, the Danish government thought it unwise to decline and decided to assume responsibility for the new station. The American Legation and the Danish Foreign Ministry subsequently worked out a mutually acceptable written agreement: the Thule weather station was being expanded (rather than built from scratch) for the purpose of providing atmospheric observations (surface and upper air) and magnetic observations. The USA



Fig. 4.1 The meteorological station in Thule, Greenland, August 1948, before the Thule Air Base was constructed. The long building on the right housed the station's Danish contingent. North Star Bay is in the background. *Courtesy National Archives, U.S. Weather Bureau records.*

would fund the station's installation and equipment, unless the Greenland Administration could do so, and would staff the station until Danish personnel arrived (Fig. 4.1).⁵²

Hubbard—who had assumed that both Canada and Denmark would agree to the weather station installations—had been staging construction materials in Boston in preparation for loading cargo ships. Within a week of the agreement's signing ceremony, two cargo ships, an aircraft tender, three long-range flying boats, an icebreaker, and a survey ship with a hull reinforced to withstand ice were en route to Thule, arriving on 22 July. Since Hubbard also had materials ready to go to Canada, when the Canadians declined to participate, he sent those materials to Thule as well. Within a few weeks, an existing airstrip at Thule had been repaired and enlarged, and a new weather station with ample storage space had been constructed. Regular surface and upper-air observations commenced on 6 September 1946.⁵³

The Americans' arrival and the activity that followed in Thule sent shockwaves through the Danish government, which wanted most of the Americans to be en route to the USA by summer's end.⁵⁴ With the ink still wet on the station plan, the Foreign Ministry started pressuring the Greenland Administration and the DMI to send Danish staff to Thule to help staunch the flow of Americans to the new station. DMI head Helge Petersen directed Viggo Laursen, who ran the meteorological observatory in Ivigtut in Southwest Greenland, to pack up, move to Thule, and build the new magnetic observatory.⁵⁵ Greenland Administration head Knud Oldendow explained the rationale behind the move to Laursen: to ensure this was a Danish station, the government needed to “neutralize the American effort” by sending Danes to the new Thule weather station. Laursen was that Dane, and he would liaise with the American forces.⁵⁶ Laursen, convinced he had been handed a political, not a scientific, mission, thought it was premature to establish a magnetic observatory at Thule. His boss, Petersen, under extraordinary pressure from the Foreign Ministry, felt obligated to give in, and agreed that no real scientific work would take place during the first year.⁵⁷ The Greenland Administration tasked Laursen to begin negotiating with the Americans so that the station could be turned over as previously agreed.⁵⁸

As the new Thule weather station was being built in summer 1946, the Danish government, which had grown increasingly uneasy about the continued presence of US military personnel in Greenland, was striving to take over the extant Greenland weather stations that the USA had been

trying to dump into their laps since 1945. And yet, by 1947, the USA was looking for a legitimate excuse to keep its personnel in Greenland as the West and East settled into the Cold War and the US military warily eyed its Soviet counterparts stationed at the end of the polar flight route from the USA. “Since any decrease of United States’ participation in the Greenland weather service is to our disadvantage from a military point of view,” a Joint Meteorological Committee (Joint Chiefs of Staff) report stated in October 1947, “all practicable measures should be taken to prevent such decrease.”⁵⁹ Indeed, the Secretary of Defense wanted to keep as many military personnel in Greenland as possible, and staffing the weather offices was one quick solution.⁶⁰ As new assessments of Greenland’s strategic importance called for a rapid build-up of US forces, the perception of the weather stations shifted from being a costly nuisance that could be shifted onto Denmark to being a vanguard for military bases.

At the same time, the Danish government was realizing that it could not afford to run the Greenland weather stations, which were both politically and scientifically important.⁶¹ Thus, the status quo was accepted as a temporary compromise on both sides. While the US Department of Defense and the Joint Chiefs of Staff pressed to secure long-term base rights and expand the US military presence in Greenland, the State Department thought it might be more fruitful to move more slowly since Danish public opinion seemed to be shifting from “Let’s get the Americans out of Greenland,” to “Maybe the Americans have a legitimate claim for asking for rights in Greenland.”⁶² Similarly, the Danish government accepted that it was not realistic to make the US forces leave Greenland. But the Danish government had no interest in negotiating base rights, a politically loaded topic, since it feared pressure from the Soviet Union if it granted base rights to the USA. Consequently it put negotiations on hold in spring 1948.⁶³

Until the USA handed the stations over to Denmark in July 1950, a series of annual agreements stipulated manpower and the provision of supplies and equipment. The initial policy of quickly handing over the weather stations and other facilities to Denmark was quietly abandoned, giving way to a much slower transfer of responsibilities that met the needs of both nations. The Danish and US governments conducted joint annual inspections of the facilities, and US facilities in Greenland were allowed to deal directly with appropriate Danish representatives concerning weather observations without going through US State Department channels—a decision that greatly improved communication.⁶⁴ To comply

with International Civil Aviation Organization (ICAO) weather reporting rules, Denmark built a new weather station at Danmarkhavn on Greenland's east coast in 1948.⁶⁵

In 1949, the USA initiated a new round of negotiations that speeded up the process of handing the weather stations over to Denmark in 1950, and eventually led to the 1951 Defense Agreement between Denmark and the USA, which granted the USA military rights in Greenland in defined defense areas. In return, the USA accepted full Danish sovereignty over Greenland, significantly allaying Danish concerns. In practice, however, Denmark ceded military sovereignty over Greenland to the USA.⁶⁶ Immediately after the agreement was signed, the USA launched the secret Operation Blue Jay to build its largest overseas air base at the Thule site. Ironically, the Danish-American weather station at Thule would close in 1952 because the Americans established their own weather service inside the Thule Air Base. Denmark also agreed to move its magnetic observatory to Thule because of its location within the Thule defense area.⁶⁷

CONCLUSION

Meteorology was one of the most fundamental sciences for the military—and research in this field, as its most distinguished mid-twentieth century practitioner, Swedish-American Carl-Gustav Rossby, had declared in 1947, “depends upon the availability of data.”⁶⁸ Basic weather information was crucial for aviation, and became no less crucial for North American Continental Defense. Arctic weather stations built during the Cold War also proved vital for the advance of meteorology and theoretical models of atmospheric circulation. They led to better weather forecasts in the Arctic (and globally, once numerical weather prediction models became operational in the mid-1950s).⁶⁹

Weather stations were simultaneously scientific instruments and representations of the nation-states that operated them. Smaller states did not have the resources to build and fully occupy enough stations to meet military requirements, and it is no wonder that around the world, leaders watched carefully as negotiations over the delicate issue of sovereignty played out.⁷⁰ While representatives of the US Department of Defense and the Joint Chiefs of Staff did seek to expand US military presence on Canadian and Danish territory through the expanded network of weather stations, the US State Department—which had a better grasp of Danish and Canadian sensitivities vis-à-vis sovereignty issues—advocated patience:

it successfully restrained the US military's zest for action and tolerated the political peculiarities of America's Nordic friends and neighbors. This strategy earned benefits for the USA in two ways: it gained a large degree of military control in the Canadian North and, especially, in Greenland; and a degree of *political* control via bilateral understanding and cooperation, with the USA exploiting the asymmetric power relationship in a sophisticated manner.⁷¹

All this matters, for events could have turned out differently. The early Cold War was a time when the sovereignty of smaller states was often at risk from superpower actions—the Truman Doctrine extended US hegemonic control over Western Europe, and Soviet forces exerted authority over East Germany and the Balkan States in 1947.⁷² Both Canada and Denmark, smaller states sandwiched between two superpowers that were taking a too-intense interest in their respective northern territories (largely uninhabited and hence appearing to be not under their political control), initially viewed US intentions with not unfounded suspicion. Yet the weather station challenge was one instance where the authority of smaller states was generally respected, perhaps because they were inherently scientific centers and not overtly military related.⁷³ In retrospect, the negotiations might have stumbled badly: US military leaders, including their colorful advocate, Charles Hubbard, did not fully appreciate the importance of sovereignty for Canadian and Danish identity and national autonomy in the way that US diplomats did. Given the importance of weather observations and forecasts for national security and for aviation, the USA would almost certainly have established weather stations throughout the postwar Arctic even had Hubbard never been born. That these developments proceeded smoothly *despite* Hubbard's clumsy handling of sovereignty illuminates the willingness of leaders in all three governments to compromise, to avoid public controversies, and to avoid the appearance of military activity. By overstating their control over the weather stations and stressing their civilian character, Canada and Denmark avoided the fates of other small states during the Cold War.

NOTES

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2. See, for example, Kristine C. Harper, *Weather by the Numbers: The Genesis of Modern Meteorology* (Cambridge, MA: MIT Press, 2008); Paul N. Edwards, *A Vast Machine: Computer Models, Climate Data, and the Politics of Global Warming* (Cambridge, MA: MIT Press, 2010); Elena Aronova, Karen S. Baker and Naomi Oreskes, “Big Science and Big Data in Biology: From the International Geophysical Year through the International Biological Program to the Long Term Ecological Research (LTER) Network, 1957–Present,” *Historical Studies in the Natural Sciences* 40, no. 2 (2010): 183–224.
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4. See, for example, Jørgen Dragsdahl, “Denmark and Greenland: American Defences and Domestic Agendas,” *Contemporary Security Policy* 26, no. 3 (2005): 486–504.
5. J.A. Kington and F. Selinger, *Wekusta: Luftwaffe Meteorological Reconnaissance Units & Operations, 1938–1945* (Ottringham, England: Flight Recorder Publications Limited, 2006); John A. Kington and P. G. Rackliff, *Even the Birds were Walking: The Story of Wartime Meteorological Reconnaissance* (Stroud, England: Tempus Publishing, 2000); Franz Selinger, *Von “Nanok” bis “Eismitte,”* Schriften des Deutschen Schifffahrtsmuseums, vol. 53 (Hamburg: Convent, 2001); J.D.M. Blyth, “German meteorological activities in the Arctic, 1940–1945,” *Polar Record* 6 (1951): 185–226; David Howarth, *The Sledge Patrol, a WWII Epic of Escape, Survival and Victory* (Guilford, CT: Lyons Press, 2001); Malcolm Francis Willoughby, *The U.S. Coast Guard in World War II* (Annapolis, MD: Naval Institute Press, 1989 [1957]), 95–110.
6. Stetson Conn, Rose C. Engelman, and Byron Fairchild, *Guarding the USA and its Outposts* (Washington, DC: Center for Military History, US Army, 2000), 442–458; John D. Carter, “The North Atlantic Route,” in *The Army Air Forces in World War II*, vol. VII, *Services Around the World*, ed. W.F. Craven and J.L. Cate (Chicago: University of Chicago Press, 1958), 92–94; and Alexander Forbes, *Quest for a Northern Air Route* (Cambridge, MA: Harvard University Press, 1953).
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8. Gordon W. Smith, "Weather Stations in the Canadian North and Sovereignty," *Journal of Military and Strategic Studies* 11, no. 3 (2009): 14–17.
9. Harper, *Weather by the Numbers*, Chaps. 6, 7, and 8.
10. Axel Kjør Sørensen, *Denmark-Greenland in the twentieth century* (Copenhagen: Museum Tusulanum, 2007), 78.
11. Knud Oldendow, *Tilstandene I Grønland 1946* (Copenhagen: J. H. Schultz, 1947), 77.
12. Dispatch No. 24, Arvid Holm, American Consulate Godthaab, 8 October 1945: Transfer of Army weather stations to Danish control; Minutes, December 1945, 2–3 (RG 84, Box 3). The Weather Control Office did not *control* the weather, although its personnel probably wished they could do so. Its mission was to supervise the weather stations and provide weather data to operational forces.
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14. Greenland Administration, Draft Memorandum to Folketing's Financial Committee, stamped 29 June 1945; Christmas Møller to State Department, 23 July 1945 (Danish National Archives Copenhagen, 1956 Meteorologisk Institut, Box 3: 1945–1952 Meteotjenesten i almindelighed, Folder 1 5910/1946 Meteotjenesten i almindelighed) [**hereafter DNA Meteorologisk Institut, Meteotjenesten**]. Dispatch No. 24, 8 October 1945; Minutes, December 1945, 2 (RG 84, Box 3).
15. Minutes, December 1945; Dispatch No. 24, 8 October 1945 [**hereafter Dispatch No. 24**]; Sykes to Chief, Air Weather Service, Washington, 15 June 1946; Arvid Holm, American Vice Consul, Godthaab, Dispatch No. 26, 24 Oct. 1945 [**hereafter Dispatch No. 26**] (RG 84, Box 3); Dispatch No. 129, 18 June 1946, 2 [**hereafter Dispatch No. 129**] (RG 84, Box 9).
16. Dispatch No. 24.
17. Dispatch No. 26; Contract between the United States and the Greenland Administration, 22 October 1945, 2 (RG 84, Box 3).
18. On ICAO, see David MacKenzie, *ICAO: A History of the International Civil Aviation Organization* (Toronto: University of Toronto Press, 2010).
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24. *Ibid.*, 6, 9–11; Haynes to Simony, "Operation and Manning of Weather Stations in Greenland," 7 June 1946 (DNA Copenhagen, 1956 Meteorologisk Institut, Box 1: 1945–1952 USA's forhold til danske vejrstationer (Thule), Folder 2 Thulesagen 1945–46) [**hereafter DNA, Meteorologisk Institut, Thulesagen**].
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26. "Mrs. Charles J. Hubbard," *New York Times*, 1 October 1930; Kimberly Fain, *Black Hollywood: From Butlers to Superheroes, the changing role of African American Men in the Movies* (Santa Barbara: ABC Clio, 2015), 34.
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33. Hubbard to Louis, 16 February 1945 (NARA, RG 27, Box 1 of 2, "Polar Obs. Hubbard cor. 1944–46"). [hereafter Hubbard cor.].
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36. Representative Margaret Chase Smith, "Arctic Weather Reporting Stations," House Agricultural Committee Hearings, 22 January 1946, 1–2.
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38. Testimony of Francis W. Reichelderfer, 22 January 1946, 4, 6, 9.
39. Testimony of Colonel D. N. Yates, AAF, 22 January 1946, 17–20.
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46. Smith, "Weather Stations," 49.
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50. Dispatch No. 129, 8.
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52. General Haynes to Governor Simony, 7 June 1946, "Operation and Manning of Weather Stations in Greenland (DNA, Meteorologisk Institut, Thulesagen)"; Dispatch No. 129, p. 9 (RG 84, Box 9).
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55. Petersen to Laursen, 13 June 1946 (DNA Meteorologist Institut, Thulesagen).
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72. Melvyn P. Leffler, *For the Soul of Mankind: the United States, the Soviet Union, and the Cold War* (New York: Hill and Wang, 2007).
73. While Shelagh Grant argues that Canada compromised its autonomy by acceding too often to US demands on its Arctic territories [Grant, *Sovereignty or Security? Government Policy in the Canadian North, 1936–1950* (Vancouver: University of British Columbia Press, 1988); Grant, *Polar Imperative*], most historians who have examined US-Canadian Arctic relations in the early Cold War now argue that the United States accepted Canadian sovereignty campaigns; see, for instance, Lackenbauer and Kikkert, “Sovereignty and Security.”

Security and the Nation: Glaciology in Early Cold War Greenland

Janet Martin-Nielsen

At the middle of the twentieth century, wrote Swiss glaciologist and newly arrived American immigrant Henri Bader in 1949, the discipline of glaciology was hobbled by “the low returns of scattered and isolated research by single individuals” and by “an orgy of hypothesizing [...] based on quite insufficient observational and experimental data.”¹ This was especially true of the polar regions, which had historically received less attention than the more accessible Alpine glaciers of central Europe. “There are so many things we do not know about ice that a fruitful general discussion is very difficult,” Bader lamented. In the two decades following Bader’s critical assessment, glaciology underwent significant transformations: during the early Cold War, it became a vehicle for the construction of continental defense and security interests, as well as a mechanism for boosting national and scientific credentials. This chapter illustrates these transformations in the context of Greenland.

The dramatic expansion of the geophysical sciences, including glaciology, in the early Cold War is widely recognized. In the past decade, Ronald E. Doel and Fae L. Korsmo, among others, have built a solid foundation for understanding this expansion in terms of US military patronage and new

J. Martin-Nielsen (✉)

Centre for Science Studies, Department of Mathematics, Aarhus University, Aarhus, Denmark

academic, government, and military institutions.² Less attention has been paid to parallel situations outside the USA. This chapter brings a second nation into the spotlight. The leading role of the US military in Cold War glaciology in Greenland is discussed in the first half of the chapter—but we then cross the Atlantic to look at French civilian-led glaciology. Together, these cases illustrate shifts in the intellectual map of the discipline.

EARLY GLACIOLOGY IN GREENLAND

Before World War II, glaciological work in Greenland took place in the context of classical, or heroic, exploration: individuals and small teams, minimal equipment and technology, little-to-no outside communication, and grueling physical and psychological conditions.³ In 1912–1913, Danish polar explorer and military captain Johan Peter Koch and German geophysicist Alfred Wegener overwintered on Greenland’s ice sheet and then crossed the island at its broadest point the following spring. From their prefabricated winter station “Borg” (Castle) on the ice margin in Dronning Louise Land, Koch and Wegener’s scientific work marked the first full winter attempt to understand the physical properties of a polar glacier. By navigating across the island in the spring and summer of 1913, Koch and Wegener also debunked the long-standing myth of a green, ice-free area in central Greenland.⁴ The conditions over the course of the expedition were adverse in the extreme, and while the men survived, all of the Icelandic ponies used for transport succumbed to cold, exhaustion, and snow blindness, and had to be slaughtered—and when provisions ran out in the final days, the expedition dog was shot and cooked.⁵

Wegener is intimately connected with Greenland: it was on his next expedition to that island, in 1930, that the father of continental drift and his Greenlandic sherpa, Rasmus Villumsen, perished on a sled-and-ski traverse over the ice sheet. Wegener’s ambitious interwar expedition established three scientific stations in Greenland, including one at the center of the ice sheet, named *Station Eismitte* (literally, *middle ice*).⁶ Over the winter, three German scientists—Ernst Sorge, Johannes Georgi, and Fritz Loewe—carried out glaciological and meteorological work at Eismitte to provide the first year-round collection of scientific data from deep in the ice sheet’s interior. Of particular importance was Sorge’s study of snow layers in a 16-meter-deep hand-dug pit, which showed that the density of snow as a function of depth changes over time only with climate changes.⁷

In the same years, Swedish glaciologist Hans W. Ahlmann and Norwegian-born oceanographer and meteorologist Harald Ulrik Sverdrup

conducted the first systematic glacier measurements in Iceland and on the Norwegian island of Spitsbergen. As war loomed in Europe, Ahlmann extended these studies to northeastern Greenland.⁸ The lead up to the war also saw a British glaciological team over winter in northwestern Greenland in 1937–1938. While their scientific studies included mapping the ice sheet, describing the accumulation and ablation of snow and ice, and surveying glacial flow and topography, the difficulties of operating on the ice sheet meant that glaciological research always played second fiddle to survival. “The scientific work in Greenland,” wrote expedition member J.W. Wright, “had always to be subordinated to such considerations as establishing depots, laying in a good stock of dog food for the winter, and other preparations [...]”⁹ It is precisely this type of limitation, together with the continued subordination of polar glaciology to alpine glaciology, which prompted Bader’s criticisms of the discipline in 1949.

Bader was not the only glaciologist to speak out about the troubled state of the discipline in the early postwar years. Ahlmann, the dean of Swedish glaciology, was also adamant about the need for more polar-based research. “[T]he snow, ice and glaciers of these regions [polar regions] only recently became objects of interest and study,” he lamented in a lecture to the Scott Polar Research Institute in Cambridge, England, in 1948: “The conclusion cannot be avoided that no one has yet gone deep enough to be able to explain [...] polar glaciers.”¹⁰ Glaciologists needed to leave behind the old natural history style of scientific investigation, he continued, and introduce controlled measurements and experiments to the world’s polar ice sheets. “For many years it [glaciology] was treated rather lightly, mostly by geologists who happened to be also enthusiastic mountain climbers,” concurred the University of Aberdeen’s Patrick D. Baird and the California Institute of Technology’s Robert P. Sharp in 1955: “Until recently,” they continued, “little [polar] glaciological work has been attempted.”¹¹ The need for more work, Baird and Sharp concluded in sympathy with Ahlmann, was especially pressing given “the extent of the recent rather alarming retreat of glaciers”—a situation which would, in the following years, bring increased environmental interest to Greenland.

During the first two decades of the Cold War, the concerns expressed by Bader, Ahlmann, Baird, Sharp, and others would be assuaged as polar glaciology entered a new phase of vigorous, organized, and well-funded work. The need to shift from the “low returns of scattered and isolated research by single individuals” to “work[ing] in groups and concentrat[ing] our effort,” as Bader puts it, was met as countries including the USA and

France poured scientific, financial, and logistical resources into glaciological investigations in Greenland.¹² This new era of glaciological research saw unprecedented scientific study and technological commitment, as well as massive military intervention in the polar world.

DEFENSE AND SECURITY: THE US CASE

As the Cold War opened, US military personnel agreed with Bader's assessment of the discipline, considering fundamental knowledge of the properties of snow, ice, and permafrost in polar regions to be "unsystematic and unsatisfactory."¹³ Over the following decades, the military spearheaded glaciological studies through the Army's Snow, Ice, and Permafrost Research Establishment (SIPRE), founded in 1949, as well as through the Research and Development Command of the Army's Transportation Corps, founded in 1942. The military's need for basic glaciological research was "unusual [and] made necessary by the fact that wide areas of knowledge of the fundamental properties of snow and ice have never been established by civilian research," wrote glacial geologist Richard F. Flint in a 1950 memo on the effects of snow, ice, and permafrost in military operations—a situation created in large part by the weakness of academic glaciology in the USA during the interwar and early postwar years. "[T]he Department of Defense has been obliged to bring basic knowledge of snow and ice up to the level of knowledge of other substances, such as steels and other metals," continued Flint: "Usually military research does not have to reach so far down toward the foundations of science as it has to do in this exceptional case."¹⁴ In face of this situation, the US military brought a highly funded, technologically rich, and big-team approach to the discipline to Greenland.

The glaciological research conducted by the US military in Greenland during the early Cold War covered five main areas: fundamental snow, ice, and permafrost studies; overland vehicular transport studies; air transport studies (including unprepared landings on and takeoffs from the ice sheet); ice sheet construction studies; and ice core drilling (including deep core drilling to the bottom of the ice sheet). These projects took place at the major US facilities on the island, from Thule Air Base to Camp Tuto to Sondrestrom Air Base to Camp Century, as well as at temporary camps on the vast ice sheet. In the 1950s, Henri Bader himself led this research. Trained in glaciology in Switzerland in the interwar period, Bader immigrated to the USA soon after World War II and joined Rutgers University

as a professor before being named as SIPRE's chief scientist.¹⁵ Under his leadership, SIPRE embarked on a five-year glaciological study to understand pressures and deformation inside Greenland's ice sheet beginning in 1954. From the outset, this work had a clear military purpose: the team of more than a dozen scientists aimed to understand the plasticity of ice "for the purpose of ascertaining the limiting size of a room or tunnel that can be excavated in the ice without collapse or excessive deformation forming" and, ultimately, to enable the development of "satisfactory design criteria for military installations on high polar ice caps."¹⁶

The thinking behind this research project was strategic in face of a Soviet enemy believed to be proficient in Arctic warfare: military facilities built on the vast, barren, and monochrome expanse of Greenland's ice sheet were highly visible—and thus highly vulnerable. "Any type of surface constructed installation in this part of the world [...] is visible for miles because of the barren countryside that surrounds it," wrote SIPRE glaciologist Donald Rausch in a 1956 interim report from the project, making it "exceedingly vulnerable in case of attack."¹⁷ To hide military facilities from enemy eyes, US planners hoped to bury camps, operations buildings, and even entire military bases inside the ice—all installations, in short, except for airplane runways and radar towers. These hopes, however, were complicated by the movement of Greenland's ice, which flows slowly from the central regions of the island toward the coasts. At the beginning of Bader's study, US planners feared that this then little-understood movement, combined with the weight of overburden from accumulating new snow, would cause sub-surface rooms and tunnels to deform and collapse. After five years of work, including digging deep into the ice under Camp Tuto and carefully measuring deformation over time, the study provided a positive answer: rooms and tunnels in the ice sheet were, SIPRE's glaciologists declared, feasible for military purposes, and under-ice installations would have a maximum expected lifespan of ten years.

The US Army Corps of Engineers put this new knowledge to work in the construction of Camp Century in 1959–1960. Known as the "city under the ice," Camp Century was a 225-person nuclear-powered military facility buried entirely inside Greenland's ice sheet (see Chap. 9 in this volume). With Bader's studies in hand, the Corps of Engineers was able to process snow to increase its density, hardness, and strength; to dig tunnels and excavate rooms in the ice using hand tools, mining tools and explosives; and to shape snow roofs so as to prevent them from collapsing

in under the weight of further snow accumulation. The under-ice camp built in 1959–1960 could have featured in a science fiction movie: Camp Century boasted flush latrines, a recreation hall and theater, a ten-bed infirmary and an emergency operating room, laundries, a post room, a library, scientific laboratories, a small nuclear power plant, and a chapel with an altar carved of ice, all buried completely inside the ice sheet. The construction of Camp Century represents the overcoming of two of the chief challenges of operating in Greenland (or, indeed, in much of the polar world): the lack of natural resources for construction purposes and the high cost of importing traditional materials such as wood, cement, and bricks to the island. By transforming snow and ice into “material[s] of significant mechanical strength” through new engineering processes (in the words of Elmer F. Clark, commander of the US Army Engineering Arctic Task Force and the US Army’s Greenland R&D program from 1955 to 1957), US personnel transformed the basis of Greenland’s environment into a versatile construction material (Fig. 5.1).¹⁸

At the North Atlantic Treaty Organization (NATO), the US military’s abilities to use snow and ice as construction materials, and specifically to build under-ice camps, captured the attention of polar planners. Thanks to this work, asserted an over-confident 1961 NATO scientific planning report, “[b]y 1970 [the] construction of sub-surface military bases on large permanent glaciers will have been perfected.” An alliance-wide effort, this report was produced under the leadership of Theodore von Kármán, an aeronautical engineer and NATO advisory chairman who had been directly tasked by NATO’s Military Committee to analyze and predict the impact of scientific work on military endeavors. “Buildings in permanently ice covered lands will be constructed of ‘icecrete’ [and] will be comparable in strength and cost to concrete buildings used in the mid-latitudes,” von Kármán’s report continued: thanks to the US military’s work, “[t]he capability of installing any type of military facility in glacial ice and on permafrost [is] a reality.”¹⁹

The construction of Camp Century is only one example of US military glaciology at work in Greenland during the early Cold War (albeit a dramatic one). Another notable project from Henri Bader’s term as SIPRE’s chief scientist is a series of studies on vehicular trafficability on snow and ice conducted through the 1950s.²⁰ Designed “to solve the problem of transporting men and machines over snow,” as described by



Fig. 5.1 Thermal drill employed to bore into the Greenland Ice sheet at Camp Century, 1964, with segments of extracted ice cores placed in carriers in the foreground. Initially motivated by efforts to understand the stability and plasticity of the surface of Greenland's ice cap, drilling into the deep, ancient ice under Camp Century ultimately yielded profound insights into rapid changes in Earth's past climate. *Courtesy U.S. Army Corps of Engineers.*

civilian SIPRE scientist Alan C. Skinrood, these studies modified vehicles (including M-7 snow tractors, pontoon Sno-Cats, and M-29C weasels) to enable them to draw heavy loads efficiently over Greenland's ice sheet and other polar theaters.²¹ In a set up designed to save money by minimizing the time needed in remote field locations, many of these tests were initially conducted at the Army's Keweenaw Field Station in Michigan before being finalized on location in Greenland.

With big technologies, funding, and logistical power, US Cold War glaciology in Greenland, as well as across the Arctic and Antarctic regions, stands out from earlier glaciological investigations. In 1962 alone, for example, the budget of the Cold Regions Research and Engineering Laboratory (SIPRE's successor organization, created in 1961) was the equivalent of \$13 million today.²² This budget then declined in the aftermath of the Mansfield Amendment, when the National Science Foundation took over large portions of the US military's glaciological work. In the US tradition of Big Science, most commonly associated with the World War II Manhattan Project, large-scale investments in science and technology were seen as the key to conquering the ice sheet. Further, one of the major research programs pursued by US glaciologists in Greenland—the transformation of snow and ice into versatile, sophisticated materials—represented a shift in emphasis in the polar regions. Whereas prewar glaciological work was built around understanding glacial advance, retreat, erosion, and deposits, US Cold War work brought polar glaciology into the realm of engineering. At NATO, scientific planners emphasized the strategic importance of this engineering approach for military operations in the polar regions: “Applied studies leading to the development of new methods of constructing facilities using locally available snow, ice, and permafrost have demonstrated the feasibility of maintaining forces in some of the ice covered lands,” asserted von Kármán's 1961 assessment of long-term scientific capacities.²³ “The construction of sub-surface Camp Century, Greenland, and the use there of atomic power to light, heat and furnish water for human consumption have reduced the logistical effort formerly required to support troops [in polar regions] by more than 50%,” continued the assessment in recognition of the difficulties of operating and supporting military personnel in the Arctic. With their emphasis on the practical uses of snow and ice, US glaciologists in Greenland filled in a little explored region on the discipline's intellectual map—one which brought Cold War strategic necessity and military-driven science and engineering to the ice sheet.

NATIONAL STANDING AND SCIENTIFIC PRIDE: THE FRENCH CASE

While the US-dominated glaciological research in Greenland during the early Cold War, the French also undertook significant glaciological work there, and also saw the island as imperative to national interests, albeit for different reasons. France's interest in Greenland lay not with security concerns, but with national credentials, scientific standing, and far away territorial claims.²⁴

French Cold War glaciological work in Greenland was headed by Paul-Emile Victor, an anthropologist and explorer who had made his name in French scientific and societal circles during two interwar expeditions to Greenland. Conducted by dogsled and walking, Victor's interwar expeditions had many of the characteristics of the expeditions discussed earlier in this chapter; that is, defined by the subjugation of scientific inquiry to survival needs. During World War II, Victor left his native land and joined the US Army Air Forces, where he ran cold environments training camps in the Colorado Rockies and commanded an aviation search and rescue center out of Nome, Alaska. Victor's experience with the US military opened his eyes to the potential of new technologies to transform polar expeditions. "Here I became familiar with parachuting techniques and the performance of aircraft and weasels [polar tractors] under northern conditions," wrote Victor soon after the war: "I soon realized that by the use of an aircraft with mechanized vehicles it would now be possible to transport the heavy equipment necessary for the work [I] had contemplated in Greenland."²⁵

Following his wartime experiences, Victor wanted to bring modern technologies to the ice sheet. Envisioning an age of polar exploration rooted in new technologies and focused on scientific investigation, Victor founded *Expéditions Polaires Françaises* (French Polar Expeditions) as an organization to conduct scientifically oriented French polar expeditions. *Expéditions Polaires Françaises* was officially created on 2 July 1947, with the approval of French President Vincent Auriol. Victor was officially charged with studying Greenland's ice sheet and assuring French presence in Terre Adélie, the French Antarctic claim dating from 1840. In the immediate post-World War II years, the Terre Adélie claim was contested by several nations including—most worryingly to Victor—Australia. Given the encroaching interests of other nations, wrote Victor in a letter to the French Ministry of the National Economy, France needed

urgently to send an expedition to secure the claim.²⁶ In order to do so, Victor continued, Expéditions Polaires Françaises would first undertake a major expedition to Greenland: a polar region close to home and close to Victor's heart which was relatively easy to reach, and which could act as a test zone for the technologies and logistics which would then be brought to Antarctica. "There was no question of undertaking such a program, with such aims, with dog sleds and walking," wrote Expéditions Polaires Françaises expedition physician Gérard Taylor, capturing the essence of Victor's vision: the new organization actively rejected older methods of transportation and embraced polar tractors (or weasels), airplanes, and helicopters.²⁷

By portraying the nascent organization as integral to upholding France's claim to Terre Adélie, Victor gained 40 million francs (USD 1.2 million in 2012) of state funding for his first expedition to Greenland alone.²⁸ The French Air Force, too, contributed fixed-wing aircraft and flight crews after a lobbying campaign in which Victor argued that Expéditions Polaires Françaises represented an unprecedented opportunity for the French Air Force to learn from US military aircrews on the US bases in Greenland.²⁹ Victor's confidence in his US connections stemmed from his wartime service with the US Army Air Forces and was only partially borne out in the following years: unenthused about French presence at US military facilities in Greenland, Danish authorities denied permission for the French Air Force to work out of US bases on the island and, instead, French planes were forced to fly out of Iceland.³⁰ Using similar lobbying techniques, Victor also raised funds from the private sector: food giant Nestlé supplied Expéditions Polaires Françaises with Nescafé instant coffee and instant cocoa, and other companies provided supplies ranging from canned meat to tent cloth to chronometers to cameras.³¹ The French public contributed, too, through the purchase of Victor's many books, including his children's story, *Apoutsiak: Le Petit Flocon de Neige* (Apoutsiak: The Little Snowflake), published in 1948.

Expéditions Polaires Françaises' first expedition took place in central Greenland between 1948 and 1953. Designed to be, as Victor wrote in grand terms to the French Minister of the Economy, "the last spectacular expedition undertaking the last set of incomplete scientific investigations in the whole of the Arctic," it was, first and foremost, a scientific expedition.³² With a comprehensive and meticulously planned scientific program, Victor and his team aimed to study what they described as "this immense ice wasteland, its anatomy, its physiology, or if you prefer, its

life and influence.”³³ Their scientific program included glaciological, seismological, meteorological, and geodetic research across the central and southern portions of Greenland’s ice sheet, as well as the establishment of a scientific station at the very center of the island, in the same place as the German “Station Eismitte” of 1930–1931. Called *Station Centrale*, a name chosen in homage to the German expedition, the French station was manned through the winters of 1949–1950 and 1950–1951 by teams of eight and nine men, respectively.

In a direct response to Ahlmann’s challenge to better understand polar warming, Expéditions Polaires Françaises placed climate-related glaciological research at the helm of its scientific program in Greenland. One facet of this research focused on the recovery of ice cores. Inspired by Ernst Sorge’s snow pit work at the German station in 1930–1931, the French team conducted ice core drilling at Station Centrale.³⁴ With a newly developed hydraulic diamond drill powered by a weasel motor, the French were able to reach deep down into Greenland’s ice sheet.³⁵ In August 1950, after 23 days of drilling, they extracted a 151-meter-long ice core—the deepest ice core in the world to date. However, even though the ice core was successful in terms of depth, it was difficult to analyze: the drilling motion damaged the core samples to such an extent that analyses of physical properties were not reliable. Still, the proof of concept offered by such a deep ice core provided a positive stimulus for the continuation of ice core research in Greenland and elsewhere.

Expéditions Polaires Françaises glaciologists also took up another of Ahlmann’s challenges, issued in his 1948 address to the Scott Polar Research Institute, to move glaciology beyond the realm of natural history by systemically collecting exact measurements of polar ice sheet characteristics. Over the four years of their expedition to Greenland, the French team conducted accumulation, ablation, temperature, lateral movement, and ice thickness measurements along more than 8000 kilometers of ice sheet traverses. These data provided the first large-scale, comprehensive overview of the physical properties and dynamics of a vast portion of Greenland’s ice sheet. In particular, Expéditions Polaires Françaises glaciologists confirmed long-held suspicions that the ice sheet is shaped like a convex lens hemmed in on the eastern and western edges by coastal mountain ranges, and underneath by a rocky substratum. Together with seismic measurements of the ice sheet’s thickness, this work also enabled the French scientists to estimate the volume of Greenland’s ice sheet at 2,750,000 cubic kilometers. This estimate is within a 5 % error of today’s

estimate of 2,850,000 cubic kilometers. If all this ice were to melt, glaciologist Albert Bauer and seismologist Jean-Jacques Holtzscherer asserted, the world's seas would rise by an average of seven meters.³⁶ While they did not take this idea any further, the framing of the ice volume result in terms of the potential consequences of warming was a harbinger of the environmental theme which would, in the mid-to-late 1960s, become increasingly important in glaciology.³⁷

The glaciological results of the first *Expéditions Polaires Françaises* expedition to Greenland were warmly received by European and North American scientists and succeeded in Victor's goal of making France's mark on the international snow and ice research scene. Danish researchers, in particular, lauded the expedition's scientific work. "I hope to be able before long to congratulate you personally on the magnificent results so far attained by your expeditions," wrote Danish geologist and explorer Lauge Koch to Victor in November 1951: "Your achievements in meteorology and glaciology [...] have attained very great results [of] which your country and you personally might be proud."³⁸ "I congratulate you for the remarkable fashion in which your expeditions were prepared and the brilliant fashion in which they were realized," agreed Ahlmann, writing to Victor in 1954: "They bring immeasurable value for international science."³⁹

Central to Victor's design was to showcase *Expéditions Polaires Françaises* as an organization capable of using modern technologies to overcome the natural barriers of the polar regions and to enable large-scale, mechanized, non-military scientific expeditions in the Arctic.⁴⁰ By doing so, he hoped to boost France's standing in the world of polar research and to secure his own place as the dean of French polar expeditions. Two key sets of modernizing features were essential to Victor's narrative: transport technologies, and physical and psychological comforts. The chief obstacle to prewar expeditions on Greenland's ice sheet was the difficulty of transporting supplies and equipment from the ice-free coast onto the ice sheet itself (and any distance across the ice sheet). Indeed, it is precisely this difficulty that led to the deaths of Alfred Wegener and Rasmus Villumsen in 1930.⁴¹ With this in mind, Victor directed *Expéditions Polaires Françaises* to develop an airdrop system to provide supplies (including large quantities of fuel) to men camped at Station Centrale throughout the winter. "Thanks to the development of transportation technologies and the possibility of air support," wrote Bauer and Holtzscherer in their report from the French station, "the EPF [*Expéditions Polaires Françaises*] were

able to pursue work on a much vaster scale than the work undertaken [previously].”⁴²

The French deliberately built physical and psychological comforts into their Greenland expedition in order to motivate the men through the long, cold, isolated, and dark winters. In addition to standard rations, the overwinterers in Greenland enjoyed wine, melon, chocolate, and salad greens, as well as copious quantities of instant coffee, butter, and cigarettes. Gramophone records and regular radio contact with Paris broke the silence of the ice sheet. Air drops brought personal packages from family members, connecting the overwinterers to those back home. This emphasis on physical and psychological comforts continued to be important in later French expeditions. Writing in 1953, as one Expéditions Polaires Françaises team was returning from Terre Adélie and another was headed back to Greenland, expedition radioman and amateur filmmaker Mario Marret noted that expedition teams were too busy to wash their clothing by hand: “At the risk of making you smile,” he wrote, “let it be known that we consider a washing machine to be indispensable.” “[W]hy neglect interior decoration, which can be done with so few materials and which has such a strong psychological effect?” he continued: “What are a few kilos of wallpaper and glue, or of paint, against the pleasure which a pleasant interior brings? How difficult is it for the dishes to be the same as those the team members might eat off at their homes? For the drinking glasses to be real glasses and not metallic cans? We cannot attach too much importance to these details which neither cost money nor time, but only a little bit of ingenuity, and which bring so much well-being.”

The French polar organization wasted no time in making its mark: in its first decade, Expéditions Polaires Françaises conducted ten expeditions with a total of 110 participants in Greenland and Terre Adélie. The next decade saw another 23 expeditions to these two locations as well as two expeditions to Iceland. By 1967, over 1000 scientific and technical personnel had taken part in Expéditions Polaires Françaises expeditions, traversing more than a quarter of a million kilometers of ice and snow.⁴³ The long-term success of the organization’s first expedition to Greenland exceeded even Victor’s high expectations. The technological and logistical knowledge gained during this expedition enabled the French to install a permanent base in Terre Adélie (named *Base Dumont d’Urville*), and Expéditions Polaires Françaises won contracts for carrying out France’s Antarctic territorial interests from the base. Other countries, too, recognized the technical proficiency of the French organization

and lined up to gain its assistance with their own polar expeditions. The USA hired Expéditions Polaires Françaises as scientific consultants in Greenland between 1952 and 1958, even mounting a joint expedition to conduct seismological measurements of ice thickness across the north of the island; in 1955, the Snow and Ice Commission of the International Union of Geodesy and Geophysics selected Victor's organization to lead the *Expédition Glaciologique Internationale au Groenland* (International Glaciological Expedition to Greenland), a joint French–Danish–Austrian–Swiss–Federal Republic of Germany venture; and in 1961, the USSR Academy of Science asked the French to join a glaciological study at the Soviet Antarctic stations. As for Victor, his newfound international reputation gained him prestigious positions including chief of Expédition Glaciologique Internationale au Groenland and president of the Scientific Committee on Antarctic Research. Underpinning these reputations was the impressive glaciological research conducted by Expéditions Polaires Françaises in Greenland from 1948 to 1953.

CONCLUSION

Two main factors underlie the situation of polar glaciology described here. First, the opening of the Cold War created new and pressing practical needs to understand and operate in the polar regions. In the USA, these needs were directly related to continental security concerns: with Greenland's geographical position as a stepping-stone between North America and the USSR, military control of the island was a strategic necessity. But US operations in Greenland required a sophisticated understanding of the island's environment—that is, a scientific understanding of ice and snow. As such, glaciology became intimately connected with the US polar science strategy. As part of the US military machine, glaciology gained unprecedented amounts of funding and support and was co-opted into a massive organizational framework. In France, it was the country's desire to secure its Antarctic claim in the new postwar geopolitical situation which motivated the government to sponsor Paul-Emile Victor's polar expeditions first to Greenland, where technologies, logistics, and scientific instruments could be tested close to home, and then to the southern continent. With Victor's interest in scientific investigations of Greenland's ice sheet, the discipline of glaciology was again one of the chief beneficiaries of this endeavor.

While the interests of adventurers, mountaineers, and geologists dominated glaciology in the nineteenth and early twentieth centuries, in the post-World War II era glaciological research programs took new turns. US work on the ice sheet pushed an engineering-based investigation of snow and ice, and the French work forged an environmental path in glaciology (as did US work as well, albeit not discussed here). This environmental agenda (and especially ice core research) would, in the following years, bring the discipline into the scientific and public spotlight for its ability to illuminate past climatic conditions.⁴⁴ Today, glaciology is commonly identified not only as a geophysical science but also as an environmental science. This is not to say that the old research programs were forgotten—glacier mass balance and mapping studies, for example, were an important part of postwar Danish glaciology in Greenland and of the 1957–1958 International Geophysical Year—but rather to underline shifts in the discipline’s intellectual map in the early Cold War era. It is also not to say that engineering and even environment-based investigations were absent from glaciology prior to the Cold War, but that they intensified during this era, especially in the polar regions.

As for Bader, his opinion of the discipline of glaciology, which had been so negative in the late 1940s, improved greatly by the mid-to-late 1960s. The past two decades of polar research, he wrote in a report to the US Chief of Naval Research in 1967, had elevated glaciological knowledge to a significantly stronger level. The parallel improvement in polar technologies and operational know-how in Arctic regions had created the logistical capacity and infrastructure necessary for large-scale and long-term glaciological research projects. The challenge now facing the discipline, he argued, was no longer a lack of basic knowledge, but the need to apply the knowledge gained over the previous two decades to climate-related issues. “The Arctic is [...] probably the single most important region of climatic instability,” he wrote, and “the awesome prospective consequences of the vanishing of the Arctic Ocean pack-ice cover [and] the climatic consequences [of polar warming] would be disastrous.”⁴⁵ In light of the climatic implications of the polar regions, he concluded, “[w]e must ‘know the environment’ much better, not out of curiosity, but from possibly vital necessity.” Bader’s emphasis on climatic interests in glaciology, and his confidence that the scientific, technological, and logistical basis for understanding these interests in the polar regions was firmly established, marks a striking contrast to his anxious evaluation of the discipline two decades earlier.

NOTES

1. Henri Bader, "Trends in Glaciology in Europe," *Geological Society of America Bulletin* 60, no. 9 (1949): 1309.
2. Ronald E. Doel, "Constituting the Postwar Earth Sciences: The Military's Influence on the Environmental Sciences in the USA after 1945," *Social Studies of Science* 33, no. 5 (2003): 635–666; Ronald E. Doel, "Quelle Place Pour les Sciences de l'Environnement Physique dans l'Histoire Environnementale?" *Revue d'Histoire Moderne et Contemporaine* 4 (2009): 137–164; Fae L. Korsmo, "The Early Cold War and US Arctic Research," in *Extremes: Oceanography's Adventures at the Poles*, ed. Keith R. Benson and Helen M. Rozwadowski (Sagamore Beach, MA: Science History Publications, 2007); Fae L. Korsmo, "Glaciology, the Arctic, and the US Military, 1945–58," in *New Spaces of Exploration: Geographies of Discovery in the 20th Century*, ed. Simon Naylor and James R. Ryan (London: I.B. Tauris, 2010).
3. Classification into 'ages of exploration' has many flaws, but is still useful as a brief descriptor.
4. After his pioneering 1888 crossing of Greenland's ice sheet, Norwegian explorer Fridtjof Nansen declared that the interior of the southern portion of the island was entirely ice-covered, but he made no claims about the central and northern portions of the island. See Fridtjof Nansen, "Journey Across the Inland Ice of Greenland from East to West," *Proceedings of the Royal Geographic Society and Monthly Record of Geography* 11, no. 8 (1889): 479.
5. Johan Peter Koch and Alfred Wegner, *Wissenschaftliche Ergebnisse der Dänischen Expedition Nach Dronning Louises-Land und Quer über das Inlandeis von Nordgrönland 1912–1913* (Copenhagen: Meddelelser om Grønland, 1930); Johan Peter Koch and Alfred Wegener, *Durch die Weiße Wüste; Die Dänische Forschungsreise Quer Durch Nordgrönland 1912–1913* (Berlin: Julius Springer, 1919). It is beyond the scope of this chapter to discuss nineteenth-century glaciological and exploratory work in Greenland in any detail; see Rud Kjems, *Horisonter af Is: Erobringene af den Grønlandske Indlandsis* (Copenhagen: GEC Gads Forlag, 1981); Børge Fristrup, *The Greenland Ice Cap*, trans. David Stoner (Copenhagen: Rhodos International Science Publishers, 1966).
6. For a comprehensive overview of the 1930–1931 Wegener expedition, see Else Wegener and Fritz Loewe, eds., *Greenland Journey: The Story of Wegener's German Expedition to Greenland in 1930 to 1931 as Told by Members of the Expedition and the Leader's Diary*, trans. Winifred M. Deans (London: Blackie & Sons, 1939); see also Mott T. Greene, *Alfred Wegener:*

- Science, Exploration, and the Theory of Continental Drift* (Baltimore: Johns Hopkins University Press, 2015).
7. Ernst Sorge, "Glaziologische Untersuchungen in Eismitte," in *Wissenschaftliche Ergebnisse der Deutschen Grönland Expedition Alfred Wegener 1929 und 1930–31. Bd. III* (Leipzig: F.A. Brockhaus, 1935).
 8. Hans W. Ahlmann, "Researches on Snow and Ice, 1918–40," *The Geographical Journal* 107, no. 1/2 (1946): 11–25.
 9. J. W. Wright, *Contributions to the Glaciology of North-West Greenland* (Copenhagen: Meddelelser om Grønland, 1939), 1.
 10. Hans W. Ahlmann, "The Contribution of Polar Expeditions to the Science of Glaciology," *Polar Record* 5, no. 37–38 (1949): 324–326.
 11. Patrick D. Baird and Robert P. Sharp, "Glaciology," in *Arctic Research: The Current Status of Research and Some Immediate Problems in the North American Arctic and Subarctic*, ed. Diana Rowley, 29–40 (The Arctic Institute of North America, 1955), 29–31.
 12. Bader, "Trends," 1310.
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40. The crafting of this narrative is discussed in detail in Martin-Nielsen, *Eismitte*, Chap. 2.
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Uncommon Grounds: Danish and American Perspectives on Greenland's Geology (1946–1960)

Christopher Jacob Ries

The USA's post-World War II investigations of Greenland's soils and rocks owed much to techno-scientific developments nested within the US military's vast technological, financial, and human resources. German-occupied Denmark, cut off from Greenland, had a tiny geoscience community frustrated by its lack of scientific prospects and opportunities for action. Thus, war's end released Danish scientists and politicians' pent-up ambitions to reclaim Greenland as a vehicle of international scientific agency that would rekindle prewar hopes of finding significant mineral resources to support the ailing Danish national budget.

Simultaneously, the Danish geosciences community was haunted by internal conflict, a legacy of prewar professional infighting and postwar geopolitical realities. Prior to World War II, Danish geologist Lauge Koch had conducted large-scale expeditions in East Greenland on behalf of the Danish Greenland Administration, effectively monopolizing geological investigations on the island. His monopoly might have been more palatable had he employed Danish geologists, but instead he had relied almost entirely on non-Danish geologists, leaving his Danish colleagues profes-

C.J. Ries (✉)

Natural History Museum of Denmark, Copenhagen, Denmark

sionally and economically stunted. A nasty, escalating conflict, including a very public lawsuit, ensued, which ultimately touched the entire Danish scientific community.¹

Attempting to keep scientific investigations in Greenland on track, the Director of the Greenland Administration, Jens Daugaard-Jensen, sought to assemble several Danish scientific organizations—minus Lauge Koch—to undertake a systematic investigation of West Greenland’s natural resources.² But the war intervened, all Danish exploration activities stopped, and Danish scientists spent the war years preparing for postwar investigations.³ And Koch? He hunkered down in Switzerland, completing maps and publications from earlier expeditions.⁴

In 1945, Knud Oldenow—Director of the Greenland Administration since Daugaard-Jensen’s death in 1939—prepared to execute a proactive strategy to pursue Greenland’s mineral wealth and thus ensure Denmark’s monopoly over these natural resources (see Chap. 11 on uranium). Oldenow and Viggo Jarl, Director of the Danish mining company Kryolitselskabet, proposed to undertake two geological investigations of Greenland: a purely scientific geological investigation to assess the overall state of its natural resources and an investigation of economically valuable resources. The latter would identify specific locations that could profit from practical geological investigations.⁵

And what of the Danish geologists who had spent the war years plotting their return? On 17 July 1945, Alfred Rosenkrantz and Sole Munck left Copenhagen for Central East Greenland to carry out investigations in Koch’s old territory. Two days later, University of Copenhagen geology professor Arne Noe-Nygaard, a former Koch student, met with Oldenow to discuss establishing a state institution to conduct geological investigations in Greenland—the Greenland Geological Survey (GGU). Aimed at strengthening Danish geology’s professional base, Noe-Nygaard hoped the GGU would turn Greenland into a valuable training ground for a new generation of Danish geologists. And it would also keep Koch—whom Noe-Nygaard considered to be a “scoundrel” and “sexually a swine”—out of the picture, lest he continue to “poison Danish geology.”⁶

Lauge Koch, however, had no intention of being shut out of Greenland and had no faith in the small band of Danish geologists. Having already mapped large parts of East Greenland, Koch was ready to resume his activities. Though his aim was to grasp the entire region’s geology, he was more than willing to pursue practical geological investigations. As for Oldenow’s plan to pull six extant scientific organizations into a single investigatory team to find valuable minerals in Greenland? It was “hopeless.”⁷

Recapping the postwar situation: Danish geoscience consisted of entangled eager, ambitious geoscientists with strong Arctic appetites and interpersonal relations ranging from interested to downright hostile. Oldendow was attempting to strike a balance between the factions: the GGU on one side and Koch on the other. What all parties shared, however, was the problem of balancing academic and institutional aspirations against practical economic interests regarding Greenland's geology under grim financial conditions and growing international interest in the Danish colony.

New geoscientific undertakings began in 1946. Losing no time in organizing mapping programs in both West and East Greenland, GGU field teams were already in place by the summer. Oldendow set up an interdepartmental board to coordinate Danish scientific activities, including military and marine operations, mapping, meteorology, radio services and expedition logistics, aimed to "increase effectiveness" while securing "reasonable savings."⁸ Eager to return to his Greenland explorations, Koch met with this board to make his case for continuing his work in East Greenland.

Politically, Koch argued, Northeast Greenland would remain the island's "un-restful corner." Denmark had an unstable sovereignty agreement with Norway, the USA was interested in establishing military bases, Soviet coal mines in Spitsbergen were just 30 minutes away by air, and all three foreign parties wanted meteorological and other scientific data from the region. Koch predicted, "[I]f Denmark does not continue the scientific investigations in East Greenland, foreign nations will undoubtedly send scientific expeditions to these parts."⁹ The geological maps resulting from his prewar expeditions were in press, and Koch proposed to lead a six-year effort to complete the geological mapping of East Greenland, the vast swatch of geological time present in this region having already proved to be "something of a gold mine." So far they had yielded internationally important scientific results as well as traces of coal, oil, and gold, the richness of which required further investigation.¹⁰ Koch also suggested the possible presence of uranium and thorium: "Naturally, a geological map always has a certain practical value," he stressed, "in that maps, as new minerals enter the spotlight, can aid in determining the likelihood of finding these minerals."¹¹ However, Koch claimed that he needed to look beyond Denmark for qualified personnel, since the small Danish corps of geologists was not up to the challenges of East Greenland. Given a promise of three years of state funding, in summer 1947 Koch sailed to East Greenland with a crew of 30. The GGU was working in South and West Greenland with a Danish crew of 18. For the next 12 years, these two

uncooperative parties worked separately: the GGU in the West and Koch in the East.¹² As Koch had predicted, the US military turned its sights on North Greenland, not for finding natural resources, but for siting military installations. The unique agendas and lack of collaboration among the research programs illuminate a complex blend of sovereignty issues, geostrategic concerns, and political, scientific, and economic aspirations invested in Greenland's terrain in the early Cold War.

THE HERCULES AND THE LEMMINGS: USGS MILITARY GEOLOGY IN NORTHERN GREENLAND, 1946–1960

During the early Cold War, the US military's ability to launch a nuclear strike on the USSR depended upon US Air Force (USAF) bombers flying across the Arctic. Thus, northern Greenland quickly attracted attention as a possible stepping-stone for strategic air operations. But its use required the development of a network of military installations, that is, bases, weather stations, landing strips, and transport routes, throughout the region, and for that, detailed knowledge of the land was required.¹³

Despite US military activity in Greenland during the war, the island's northern region was still largely unknown to Americans at war's end. The best extant information stemmed primarily from small-scale dogsled traverses undertaken by Danish explorers between 1900 and 1930. While their published results provided valuable data, they described the basic geography and environment in broad, uneven strokes.¹⁴

Furthermore, Danish expeditions in Greenland through the 1930s were generally characterized by scientific flag waving, providing opportunities for Danish scientists to stand out in the international community while shoring up Danish sovereignty. US postwar interests, however, included weather conditions and short-term terrain dynamics, and engineering problems influenced by shifting geostrategic realities in foreign territory. Few data from earlier explorations met the requirements of practical military engineering and operations.

In 1946, the USA took a first step toward remedying this situation by installing a landing strip at the World War II-era weather station at Thule in northwest Greenland, making it an operational base for aerial reconnaissance and systematic photogrammetric mapping extending eastward across Peary Land to Kronprins Christians Land on the far northern rim of the East Greenland coast. During the 1940s and 1950s, the resulting data formed the basis for developing and producing two series of topographical

maps of Greenland: the USAF World Aeronautical Chart (1:1,00,000) and a series of US Army maps (1:2,50,000) based on USAF maps and Army ground surveys.¹⁵

After participating in an aerial survey of Northeast Greenland between Scoresbysund and Peary Land in July 1947, General Caleb Vance Haynes (Commanding General, Newfoundland Base Command), recommended installing a weather-observing station in North Greenland.¹⁶ Simultaneously, the Danes were establishing a station near Brønlund Fjord near its junction with Independence Bay as a headquarters for the Danish Peary Land Expedition (1947–1950) to be led by Danish archeologist Eigil Knuth. Haynes was not interested in the Danish station because it did not include a robust weather-reporting program.¹⁷ Moreover, the expedition's cartographic results would not be of practical use to him. Ultimately, it produced just a single 1:50,000 map of Brønlund Fjord.¹⁸ Knuth's Peary Land Expedition (1947–1950) was the largest Danish expedition in the region for more than a decade, but the USA needed to take independent action to obtain data needed for its infrastructure expansion.

Haynes identified eight possible locations for further US military development in North and East Greenland, but needed engineering surveys to select the most optimum site.¹⁹ The Danish–American defense agreement allowed the USA to carry out military and scientific investigations inside established base areas, but investigations outside those areas required Danish government consent, which was influenced by its dual interests of appeasing its powerful ally and protecting its political and scientific sovereignty.²⁰ Danish ambivalence was apparent in 1950 when the USA formally proposed establishing a military meteorological station and emergency airstrip in Northeast Greenland. Wary of yet another US-controlled defense area in the region, the Danish government instead agreed to establish a joint Danish–American weather and radio station, operated under Danish authority and supported financially and logistically by the USA. Construction of “Station Nord,” on the northeastern-most tip of Kronprins Christians Land, began in July 1952, and after considerable US prodding, included an emergency airstrip.²¹

Despite Denmark's concession, the US military continued to lobby for a US-controlled alternative to Station Nord throughout the 1950s as it extended military investigations and dominance in the region. Three US Army organizations—the Frost Effects Laboratory; the Snow, Ice, and Permafrost Research Establishment; and the Arctic Construction and Frost Effects Laboratory—were involved in operations to extend military

and scientific knowledge in the Arctic.²² Similarly, the USAF Geophysics Research Directorate of the Air Force Cambridge Research Laboratories (AFCRL) spearheaded its Arctic Terrain Research Program, focused on Arctic and subarctic terrain features to see if they could support its operational activities.²³ These groups initially relied on data amassed from previous and ongoing Danish expeditions, including those led by Knuth and Koch. However, as a military mission, the USAF wanted to keep Danish involvement to a minimum, while seeking advisors who were familiar with military requirements. Therefore, the military tapped institutions more closely aligned with their interests to undertake geological survey work.²⁴

USGS MILITARY GEOLOGY: POSTWAR INVESTIGATIONS OF SOILS AND ROCKS IN NORTHERN GREENLAND

Established in July 1942 to gather terrain and related strategic intelligence information for the war effort, the US Geological Survey's (USGS) Military Geology Unit (MGU)—whose scientists were dubbed “The Army’s Pet Prophets”—began compiling extant literature, maps, and photographs into “terrain intelligence reports,” often in response to military requests of great urgency.²⁵

One of its most important tasks was to draw natural boundaries significant to military operations. The MGU assessed the stability and carrying capacity of soils, surface covers, drainage capability, and the availability of construction materials and water supplies. Its studies quantified a wide range of terrain features in order to analyze the cumulative effects of environmental variables, facilitate comparisons between different regions, assess the compatibility of various types of military technology to particular environmental scenarios, and predict how seasonal variations might affect this compatibility. According to a press release, “In the hands of the geologists who served with the Military Geology Unit, maps virtually became crystal balls into which they could gaze to find the safest places for our fighting men to quench their thirst, eat, march and fight.”²⁶

These same scientists would determine the state of soils and rocks in Northern Greenland during the early days of the Cold War. At war’s end, the MGU was transformed into a permanent branch of the USGS: the Military Geology Branch (MGB). Its geologists reoriented their professional expertise to peacetime applications, but continued to gather terrain

data and prepare geological maps of foreign and domestic areas for possible military use.²⁷

Within a couple of years, rapidly deteriorating relations between the USA and the Soviet Union triggered the remilitarization of the geological agenda for both the MGB and the USGS.²⁸ Developing new geological knowledge for direct military purposes was again a priority, and as US desires for military dominance expanded throughout the globe during the early Cold War, it was up to the MGB to describe the ice-free regions of the Arctic, and, in particular, to evaluate the effects of permafrost.²⁹ As US military activity and aspirations in the northernmost parts of Greenland intensified in the late 1940s, the MGB was called upon to apply its expertise.

Despite no previous Arctic fieldwork experience, MGB geologist William E. Davies became a pivotal figure in planning and executing these efforts. Like many other MGB staff members, Davies had graduated from the Massachusetts Institute of Technology in 1939, with a major in geology and a minor in geophysics. After earning his master's degree in geology in 1941, he joined the Army Map Service, advancing to Chief of the Map Research Department in charge of gathering intelligence data for maps pertaining to strategic planning of ground and air operations. He stayed on as a civilian after the war, until joining the West Virginia Geological Survey, for which he identified caves as possible civil defense shelters. His first task after joining the MGB in 1949 was to select the site for the first underground military installation in the USA: the "underground back-up Pentagon."³⁰ He would eventually move from sheltering caves to Greenland's frozen north.

In September 1952, just a few months after Station Nord's selection, Davies outlined a plan for a regional geological mapping of North Greenland (1:2,50,000) tailored to US military concerns. He proposed a series of intensive, detailed studies of selected 20-square-mile parcels at strategic sites ranging between Thule and Peary Land, which would be chosen based on a thorough examination of available maps and aerial photographs. At each site, geologists would "make observations on geologic processes along with their investigations of the aerial geology. Permafrost features, frost action, and peri-glacial effects [would] be given considerable attention." Since most sites were in the same geologic sequence, data could then be extrapolated between the sites with the use of aerial photographs, so that "detailed observations at each site would give a general picture of the geology over a distance of 400 miles with sites of investigation 100 to

200 miles apart.”³¹ Davies also recommended a single traverse through an area lying on a different geologic sequence: a route from the edge of the Inland Ice at Cape Cohn via Ingolf Fjord to Station Nord.

Davies’s plan fits perfectly with US military plans. The initial steps took place in 1953 during “Operation Ice Cap”: a major field operation involving more than 30 scientists representing botany, geology, and a variety of earth sciences. They would determine the possibilities of movement on and between the Inland Ice and ice-free lands around Thule Air Base for the US Army Transportation Corps.³² As originally planned, Davies and two other geologists would complete the traverse between Cape Cohn and Station Nord as part of a major effort to “provide an over-the-ice supply route to a projected Air Force Base at the end of Cape Nord from Thule on the west coast...and to establish suitable land approaches to the ice cap route.”³³ However, lacking required Danish permission, Davies and his colleagues conducted geological mapping in the larger Thule area instead.³⁴ In 1955, the French-American anthropologist and explorer Paul Emile Victor published a report on the “natural geographical defenses” of Northeast Greenland, pointing out sites at Station Nord, Fyens Lake, and Centrum Lake for air base construction, as well as several possible overland routes by which these sites might be approached from Thule via the Inland Ice.³⁵ (See Chap. 5) As Greenland continued to be seen as a possible staging area for medium- and long-range aircraft and missile systems to reach deep into Soviet territory,³⁶ Davies became a pivotal figure in the efforts of the emerging MGB/USAF Austere Landing Site Program to develop Northern and Northeastern Greenland in support of Arctic airborne operations.

By 1956, some 70,000 aerial photographs had been examined and correlated with reports and maps from previous Greenland expeditions, to produce crude photogeologic maps of some 30 possible airfield locations in northern Greenland.³⁷ Over the next four years, members of the MGB and the AFCRL Geophysics Research Directorate conducted low-altitude aerial reconnaissance and detailed on-the-ground investigations at selected sites across the ice-free areas of Northern Greenland from Thule to Kronprins Christians Land, ground-truthing the remotely sensed data. Operation Groundhog 1957–1960 subjected these areas to detailed terrain reconnaissance, runway construction, and test landings with two different types of cargo aircraft: a C-124 and a C-130 Hercules. For larger areas, team members investigated available freshwater and construction materials, identified significant terrain features, and noted general geological,

botanical, and meteorological conditions. For the runways, micro-relief maps combining information about soil types, drainage conditions, plant growth, and lemming activity were supplemented by maps and charts describing soil stability and compaction patterns in relation to seasonal permafrost levels.³⁸

Operation Groundhog 1960 marked the culmination of these efforts with terrain investigations, runway construction, and test landings at Centrum Sø as well as ground surveys at a large number of other sites scattered across Peary Land. At the same time, the Army was conducting Operation Lead Dog 1960, which tested the ability of tractor trains to carry large loads of men and equipment over the icecap in support of military activities.³⁹ These joint investigations were designed to address terrain characteristics crucial to the establishment and support of a US military base in Northeast Greenland in addition to Danish-controlled Station Nord, but none was ever established. Operation Groundhog 1960 brought MGB fieldwork in Northeast Greenland to a close. Ultimately, only three landing sites—Brønlund Fjord, Polaris Promontory, and Centrum Lake—were constructed and still exist, but they were not used for their intended military purpose.⁴⁰

What factors contributed to the changing significance of Greenland in US military thinking during the late 1950s and early 1960s? The introduction of the B-52 long-range bomber, which could fly directly from the USA to targets within the Soviet Union, reduced Greenland's importance as a forward aircraft base and refueling stop.⁴¹ In addition, the Ballistic Missile Early Warning System built in 1959 at Thule Air Base allowed the US strategic air fleet to become airborne before their home bases could be destroyed by an intercontinental missile attack from the USSR.⁴² These developments, when combined with the increasing diversion of resources to Vietnam from the late 1950s onward, huge investments in the escalating space race in the wake of Soviet *Sputnik 1* in 1957, and the 1965 failure of Camp Century, all contributed to the changing status of Northern Greenland in US continental defense.⁴³

LAUGE KOCH: GEOLOGICAL EXPLORATION AND EXPLOITATION IN EAST GREENLAND

In contrast to the MGB's efforts to determine optimum base sites in North Greenland, Lauge Koch's mission was to explore and exploit East Greenland's mineral resources. Starting in 1947, he sent four two-man geo-

logical parties to various sites between latitudes 72° and 74°N, while technical staff restored his old field station at Ella Island in King Oscars Fjord, allowing parties to over winter. In 1948, his transport options improved with the addition of a seaplane and his geological parties increased to eight.⁴⁴ That summer, Director of the Greenland Administration, Knud Oldendow, and Danish Prime Minister Hedtoft sailed to Nuuk to negotiate a reordering of Danish policy toward Greenland with local politicians. Koch accompanied them for part of the trip, spending long hours discussing mineral exploration prospects and winning Hedtoft's support.⁴⁵ Oldendow remained ambivalent. His colonial administration had been widely and publicly criticized for being too conservative, centralistic, and inefficient.⁴⁶ Now, with Hedtoft joining those calling for increased autonomy for Greenland, Oldendow was getting ready to fold.⁴⁷

Meanwhile in East Greenland, one of Koch's teams discovered a number of loose blocks of high-value lead ore at Mestersvig in King Oscars Fjord, prompting Koch to speak of "Greenland riches" worth hundreds of millions of kroner to the Danish state.⁴⁸ With Hedtoft's support and lead prices up, Koch persuaded Oldendow's reform-friendly Vice Director, Eske Brun, to bypass the Commission for Scientific Investigations in Greenland and increase his expedition funding.⁴⁹ On 1 January 1949, Brun became Director of the Greenland Administration, and Koch realized that he had gained a new, powerful ally (Fig. 6.1).⁵⁰

Three years of intense exploration and prospecting followed the discovery of lead in Mestersvig. The 1949 campaign included a ship, two seaplanes, and 97 people, including seven geological parties and 48 people involved in mineral prospecting. They found not only high-value lead-zinc-bearing veins at two sites near Mestersvig (Blyklippen and Sorte Hjørne) but also traces of molybdenum, wolfram, and copper in the Werner Mountains.⁵¹ In year two, the campaign had 120 participants: nine geological field parties and a prospecting crew of 86. The crews were airlifted in from Iceland, and three ships brought in supplies and building materials.⁵² A mining camp, complete with a canteen and storage facilities, was built near Blyklippen, and a road was built between Blyklippen and Mestervig's harbor to accommodate horses and an automobile. While Koch coordinated general scientific geological investigations, a team of miners started prospecting and diamond drillings at Blyklippen and Sorte Hjørne.⁵³ In 1951, investigations and prospecting continued, and by year's end, 100 meters of tunnel had been blown, several shafts dug out, and 35 tons of ore sent to Denmark for further assessment. Returning to Denmark, Koch

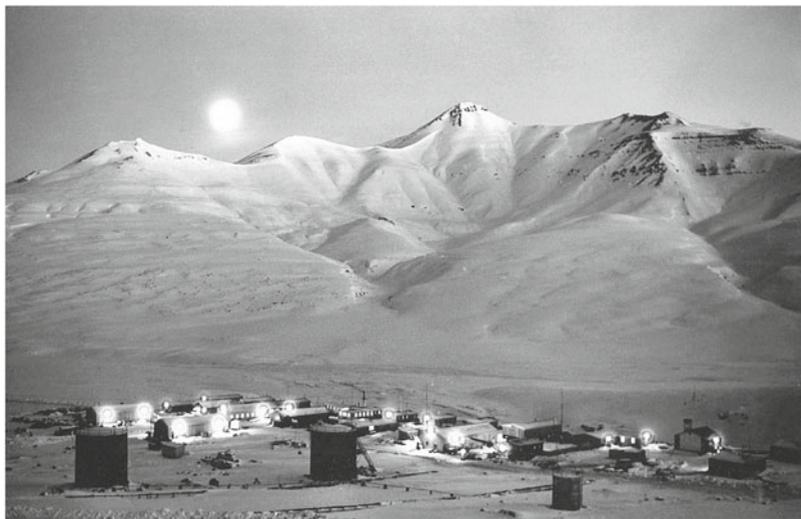


Fig. 6.1 Mestersvig mine, eastern Greenland, circa 1953. This mine—identified by a team led by the Danish geologist Lauge Koch—ultimately produced over five hundred thousand tons of ore, as well as 58,000 tons of lead and 74,000 tons of zinc concentrates, making it one of Greenland’s most productive mines in the early Cold War. *Courtesy Det Kongelige Bibliotek. Billedsamlingen.*

informed Prime Minister Erik Eriksen of the very promising results and the start of ore exploitation at Blyklippen.⁵⁴ Eriksen had already established a “Lead Board,” composed of major Danish industrial businessmen, to provide advice. He also commissioned a report to further determine how to maximize this commercial exploitation “in the interest of Danish society.”⁵⁵

In 1952, a new company, Nordisk Mineselskab A/S (or Nordmine), was established to continue investigations and begin mining operations in Blyklippen. The Lead Board became a company board; Eske Brun was its chairman and Koch its geological consultant. With 15 million kroner in capital, shares in the company were divided among the Danish state (27.5%) and various private Danish and foreign companies. Nordmine was granted an exclusive 50-year concession—excluding cryolite and radioactive minerals—for a 1,18,000 square kilometer area in East Greenland between 70° and 74°30’N.⁵⁶

The Danish state also built and maintained East Greenland’s first airfield at Mestersvig, enabling air transport, while the barracks near Blyklippen

were expanded to accommodate up to 100 persons. In 1953, Nordmine hired an independent prospecting expert, effectively replacing Koch, and the next year the mining camp was expanded with the addition of a large power station and an ore-processing plant. Roads were improved between the camp and the harbor, which was also expanded, and sufficient supplies were stockpiled to enable two years of continuous production in case regularly scheduled shipments failed.⁵⁷

By 1955, approximately 5,40,000 tons of profitable ore had been detected—less than expected—but market prices for lead and zinc were exceptionally high, so mining commenced in earnest.⁵⁸ The first lead–zinc concentrates were shipped from Mestersvig to Rotterdam in 1956, and mining activities continued apace with winter crews of around 50 and summer crews of up to 150. By 1961, 5,43,000 tons of ore had been extracted, and 58,520 tons of lead and 74,000 tons of zinc concentrates shipped out. With no more profitable ores discovered in the area, and lead and zinc prices plummeting, the mine was closed. The final tally: establishing and operating the mine had cost about 99 million kroner, and the resulting income was 107 million kroner.

The small profit was reinvested in molybdenum prospecting in the Werner Mountains in the late 1950s.⁵⁹ As investigations and mining continued at Blyklippen, Nordmine's concession area was also explored. Between 1958 and 1960, work was concentrated on a major molybdenum deposit at Malmbjerg (25 km south of Blyklippen) and then taken over by the newly formed Arktisk Mineselskab A/S.

In 1961, Arktisk Mineselskab received a 50-year concession to explore and exploit molybdenum and related metals in the vicinity of Malmbjerg, where investigations quickly revealed world-class ores containing at least 150 million tons of 0.23% molybdenum content.⁶⁰ However, the glacier-surrounded molybdenum deposits were not easily accessible. Arktisk Mineselskab spent several years developing exploitation plans, but the market price for molybdenum did not warrant the required investment, and the project was abandoned.⁶¹

Between 1968 and 1984, Nordmine continued regional mineral exploration while waiting for molybdenum's market price to improve, finding large, diverse new mineral deposits. It brought none to production. Nordmine was liquidated in 1991, having never produced tangible results. Thus ended Danish mining ventures in East Greenland at the time.⁶²

A WELL-OILED MACHINE: INTERNATIONAL SCIENCE FOR NATIONAL GAINS

Economic hopes had driven Nordmine's greatly improved logistics and state funding for Koch's scientific East Greenland expedition activities even though the commercial payoff was disappointing. However, the coupling of economic and scientific interests was not without problems. Indeed, Koch's postwar activities were so intimately tied to mineral discoveries that the resulting marginally successful prospecting activities directly contributed to the abrupt shutdown of his enterprise in 1958.⁶³

Prewar, Koch had relied on private funding from the Carlsberg Foundation and other Danish sponsors, which supplemented basic Danish state support. Postwar, Koch remained relatively isolated from the Danish scientific community, and some of those who opposed him in the late 1930s now sat on the boards of the most powerful foundations and competing institutions. Therefore, he had to seek funds from the Greenland Administration, the generosity of which fluctuated with the perceived economic prospects of his explorations. In 1953, Koch managed to gain a five-year state grant of about 5,00,000 kroner per year to complete the geological mapping of Central East Greenland between 72° and 76°N.⁶⁴

Before the war, significant logistical installations had been established throughout the region.⁶⁵ The larger stations provided steady overwintering facilities, and radio stations, motorboats, and Greenlanders with dogsleds allowed for year-round field investigations. Ships, seaplanes, and well-manned scientific field teams enhanced expeditions during the summers.⁶⁶ Backed by Cold War hopes of Denmark's economic and geopolitical consolidation, Koch revitalized and expanded his logistical and professional networks to produce a complete analysis of the geological framework of East Greenland. Much to the chagrin of Danish geologists, Koch also revitalized his prewar predilection for hiring geologists from outside Denmark, mainly from Switzerland, England, and Sweden.⁶⁷

Koch created an international crew of specialists, mobilizing specific professional strengths of each nation: the Swiss worked in the tectonic fold belts of the alpine regions; the British on the low-lying sedimentary rocks; and the Swedes on mining, mineral prospecting, or high-profile paleontological studies.⁶⁸ Koch supervised and organized the overall scientific program, selected expedition members, and coordinated results, publications, and maps.⁶⁹

The Swiss connection makes a poignant point about Denmark's seriously deficient geological manpower. Although roughly similar in size and population, compared to Denmark, Switzerland was a geoscience superpower. Whereas Denmark had one university with one geology department consisting of three professors, Switzerland boasted seven universities, each with a geology department, employing a total of 30 professors and ten associated professors. Geology was also taught at technical universities in Zürich and Lausanne. Consequently, Switzerland was able to produce a yearly crop of geologists for export to international oil companies.⁷⁰

Koch used young Swiss doctoral students, who were eager to finish their studies and get on to their future high-paying oil-patch jobs, as cheap labor, hiring them at low wages for about 18 months (the beginning of one summer to the end of the next), whereby they contributed to his program while also gathering materials for their dissertations. Once they finished their reports and accompanying map, they returned for one more summer to make revisions. Koch helped arrange for publication, they finished their degrees, and were out the door to awaiting employment.⁷¹

Expedition members benefitted logistically from the Mestersvig mining efforts, particularly from airborne assets that allowed them to take photographs, conduct reconnaissance, and execute spot helicopter landings to gain materials that supplemented materials in theses and on maps. When Swiss structural geologist John Haller completed a 13-sheet manuscript geological map of the region between 72° and 75°N in 1958, Koch began to make preparations for expanding his explorations in the Scoresbysund region between 70° and 72°N.⁷² But his operation was brought to a grinding halt. Why?

SHUT-DOWN

As the Mestervig lead deposits dwindled, Nordmine pressured the Greenland Ministry to allow Koch to extend his operation further south, arguing that they needed the maps for further prospecting. Working with the Ministry, they struck a deal for the state to finance Koch's completion of geological mapping between 70° and 72°N.⁷³ But the deal fell through.

In March 1958, the Greenland Ministry called Koch home from Switzerland, where he was making arrangements. While he was out of the country, the GGU/Atomic Energy Commission had requested 6.2 million kroner for uranium exploration in Southwest Greenland, and Nordmine had requested one million kroner for molybdenum explorations in the Werner Mountains. Finance Minister Viggo Kampmann

decided to cancel all funds for Koch's Scoresbysund campaign. Despite Koch's efforts and Eske Brun's backing—which Koch thought would turn the situation around—the funding was not restored. Koch lost all funding for his organization, even related Carlsberg Foundation funding for a multidisciplinary investigation.⁷⁴ What happened?

First, the Scoresbysund topographic survey, on which Koch would have based the next set of geological maps, was incomplete, and it would not have been ready for another four years.⁷⁵ By that time, Koch would have reached the retirement age of 70, and there was little prospect that his organization would have remained intact.

Second, Kampmann could not have overlooked the Greenland Ministry's extravagance of funding two separate geological agencies: the GGU and Koch's organization.⁷⁶ The GGU had been operating with limited funding and manpower since 1946, but in 1956 it had become a state institution with a full-time director. The subsequent expansion of activities involving an emerging generation of home-grown Danish geological candidates assisted by growing numbers of foreign—mainly British—geological specialists made the prospect of joining all geological exploration of Greenland under one institution seem within reach.⁷⁷

Third, the alliance among Koch, Nordmine, and Eske Brun was challenged from within. According to Koch, Nordmine's management board was divided over the question of focused molybdenum prospecting in the Werner Mountains, versus a systematic geological survey of the larger Scoresbysund region. When Koch's most powerful allies on the board died shortly after his 1958 campaign, sentiment shifted against him. Koch lost his funding, ending Danish geological exploration of East Greenland for almost a decade.

CONCLUSION

US interest in North Greenland geology was born in the Cold War heyday of US military involvement in the region, when the need for global applications of military technology encouraged a new culture of expediency, collaboration, and disciplinary flexibility among US scientists involved in military operations. In the MGB, civilian scientists from a variety of educational backgrounds worked under contract with US military services to address common problems related to conducting military operations in unfamiliar, and often unforgiving, environments.

Multidisciplinary scientific efforts had always been present in Arctic exploration. What was new in the MGB Greenland investigations was

the application of a truly interdisciplinary approach to understanding the environment in toto. Attempting to optimally predict, stabilize, and use terrain characteristics, MGB scientists described, quantified, mapped, and modeled a wide range of environmental features and dynamic processes in order to correlate them with the shifting demands of rapidly developing weapons systems. In the process, they took the first steps toward a new, systematic, and pragmatic approach to understanding the Arctic—and Northern Greenland—as a complex and dynamic environmental system.

After the cessation of US North Greenland explorations in 1960, the Greenland Geological Survey (GGU) moved in to pursue a long-standing Danish ambition of completing the systematic geological mapping of the nation's northernmost bedrocks, subjecting them to an entirely different scientific regime. While US explorations were mainly concerned with the temporal and practical use of the land for military purposes, Danish explorations had a more traditional academic or economic interest in Greenland's geology as well as the additional symbolic desire to demonstrate and uphold age-old Danish national sovereignty claims over Greenland. In the long run, US Cold War investigative agendas in Northern Greenland—justified by short-lived military concerns—differed too much from contemporary Danish interests in the region.

Generally speaking, contemporary Danish exploratory efforts were either mono-disciplinary, as was largely the case of the GGU and Koch expeditions, or multidisciplinary in the traditional sense of the word, as in the case of Eigil Knuth's Peary Land Expeditions. But they were not interdisciplinary. On Danish expeditions, scientists from different disciplines might work side by side in the field, but each pursued disciplinary-specific scientific agendas. Thus, while the American investigations in northern Greenland instigated new interdisciplinary practices in Arctic exploration that both combined and transcended more traditional scientific practices, their methodological influence on later investigations remained limited.

In comparison with the US focus on military concerns with surficial geology and terrain dynamics, we may identify a particularly Danish approach to Greenland geology during the early Cold War that attempted to balance the academic interests in mapping and interpreting the structure of bedrock against more prosaic pursuits of profitable minerals. Nevertheless, it would be a mistake to speak of a completely homogenous Danish effort during this period. Quite apart from personal and institutional hostilities, there were important differences in approach and scientific outlook of the two Danish organizations.

While Lauge Koch's East Greenland group was dominated by non-Danish scientists with backgrounds in alpine geology (working mainly in the 400 million-year-old Caledonian fold belt composed of a wide variety of crystalline and sedimentary rock units), the GGU relied mainly on a group of younger Danish geologists investigating the western regions, dominated by granitic and gneissic crystalline rocks more than 1800 million years old. And while Koch's expeditions, operating on a slim and constantly challenging political mandate, commanded only a diminutive administrative staff in Copenhagen to organize work based on short-term contracts with foreign scientists and technical personnel, the GGU, which was initially challenged by a shortage of qualified scientific personnel, was designed from the start to develop into a national geological survey with a permanent staff of Danish geologists, technicians, and administrators.

Lastly, while the USGS and Koch's ad-hoc exploration programs, intimately tied to short-term Cold War agendas of geopolitical or economic crises for their success and failure, ended up relying upon the persistence of single scientific actors for continued processing and scientific synthesis of results, the GGU—established with a view to long-term national scientific exploration—would outlive them both to finally include all of Greenland under one agenda for systematic geological mapping.

In 1960, with this goal finally within reach, Arne Noe-Nygaard chose to speak of a new phase in the development of the science of geology: "a tendency to 'return to the field' because the conditions for mapping and interpretations of the pioneering age were different and too insufficient to provide a solid foundation for the results [of modern geology]."78 Noe-Nygaard's remark ignored the considerable achievements of the MGB and Lauge Koch. Independently, their operations revolutionized geological fieldwork in Greenland—technologically, logistically, and scientifically—setting new standards for regional mapping and practical site-specific investigations. It appears that his words were an attempt to blot out their achievements so as to boost, secure, and celebrate the GGU's and Denmark's narrative of a newly unified geological sovereignty over Greenland.

NOTES

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 10. See Ries, “Retten, magten og æren,” 197–203; Ries, “Inventing the four-legged fish,” 37–78.
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Battling the Aurora Borealis: The Transnational Coproduction of Ionospheric Research in Early Cold War Greenland

Henrik Knudsen

A distinct form of physical environmental sciences research took root in the Far North early in the Cold War when three ionospheric stations—two US and one Danish—were established in Greenland. The US Army secretly built a station at Narsarsuaq Air Base in southern Greenland in 1950 and five years later, a second one on North Mountain near Thule Air Base, as part of US International Geophysical Year efforts. In 1951, a Danish station came on-line in Godhavn. These stations were part of the global network of ionospheric stations established and directed by the National Bureau of Standards' Central Radio Propagation Laboratory (CRPL), and they were also connected to a special Arctic program initiated in the late 1940s by the US Joint Chiefs of Staff (JCS) and CRPL. But by 1966, Denmark controlled all of the stations, which were operated by the Danish Meteorological Institute's Ionosphere Laboratory.¹ No longer beholden to US military interests, Danish ionospheric physics had become an independent scientific enterprise pursuing its own research agenda.

H. Knudsen (✉)
The Danish National Archives, Viborg, Denmark

The emergence of ionospheric research in Denmark and Greenland can best be understood from a transnational perspective within the context of USA–Denmark relations in the early Cold War. Before the US military and scientists became interested in the Arctic ionosphere, Danish scientists had paid it scant attention, despite long-standing traditions of Arctic geomagnetic and auroral investigations. Denmark’s Arctic ionospheric research emerged with the opening of the Godhavn (Qeqertarsuaq) station, and coevolved with US developments. US funding—military *and* civilian—was instrumental to the growth of Danish ionospheric research, far surpassing its influence on other geophysical fields. And that funding likely contributed to the subtle—or not so subtle—adoption of values and practices common to US ionospheric scientists (Fig. 7.1).²



Fig. 7.1 The ionospheric station at Godhavn (Qeqertarsuaq), one of three ionosphere sounding stations established in Greenland during the 1950s. *Courtesy of Torben Stockflet Jørgensen.*

AURORA, RADIO SCIENCE, AND IONOSPHERIC PHYSICS BEFORE WORLD WAR II

During the interwar period, Western societies became increasingly dependent upon shortwave radio for point-to-point communication and commercial broadcasting. Radio quickly assumed a cultural role—comparable to the Internet today—providing a fast means of receiving and sharing news and knowledge over vast distances. Shortwaves travel long distances because they are reflected numerous times between Earth and the ionosphere—the upper atmosphere layer ionized by the Sun’s ultraviolet radiation. The height, electron density profile, and layering of the ionosphere continually change with geomagnetic latitude, Earth’s diurnal cycle, and the 11-year solar sunspot cycle, making radio wave propagation and reception highly variable.

Using ionospheric sounders—developed in the mid-1920s—scientists could create images—ionograms—of the ionosphere and acquire structural and compositional data of the upper atmosphere. The “scaled” ionograms yielded information on the relative heights of the ionospheric layers and the “critical frequencies,” below which a radio wave is reflected by, and above which it penetrates through, an ionospheric layer. Combining data from multiple locations and comparing them with historical data, scientists could predict future propagation conditions, enabling radio users to select optimal frequencies for specific paths. Ultimately, radio scientists and the International Union of Radio Science (URSI) assumed a central role in the exploration of the upper atmosphere.³

Due to the low incidence of solar radiation and the effects of solar particles, ionospheric conditions near the geomagnetic poles—the northern one is near Greenland—are substantially different. The auroral oval—centered on the geomagnetic pole—is where the ionosphere (and shortwave radio transmissions) are frequently disturbed by solar electrons and magnetospheric particles funneled into the upper atmosphere. Inside this zone, ionospheric conditions are usually quieter, but occasionally solar plasma streams—emitted from solar flares and coronal mass ejections—hit this region and trigger radio blackouts that may last for several days. These disturbances are more frequent during active periods in the 11-year solar sunspot cycle. Although radio blackouts may be annoying for most people, for those depending on instantaneous radio communication—for example, those aboard ships or aircraft—they can create operational hazards. Hence, scientists and engineers were very interested

in gaining greater understanding of the ionosphere and its reactions to these solar events.

During the late 1920s solar maximum, newspapers reported a number of spectacular low-latitude auroras that were linked to simultaneous disturbances of shortwave radio.⁴ High latitude radio listeners and polar explorers—shortwave radio’s early adopters—reported prolonged radio blackouts in the Arctic, along with periods of exceptionally good reception from remote parts of the world, that is, “freak” receptions.⁵ By this time, the polar regions had become known as “the most difficult regions of the earth for radio communication.”⁶ Auroras were increasingly seen as the cause of unreliable, disturbed, or freakish transmissions, and sometimes as a “barrier” to shortwave radio traffic. Edward Manley, a veteran radio operator for the American Bartlett East Greenland expedition of 1930, used sudden instances of radio blackout as an indicator that an aurora was on the way.⁷

Early plans for investigating the polar ionosphere from Greenland had been advanced by URSI in 1931, the year of its General Assembly in Copenhagen. Members were planning for URSI’s participation in the Second International Polar Year (IPY)—scheduled for 1932–33—to examine the relationship between radio disturbances and geomagnetic variation. Distinguished Danish radio scientist Peder Oluf Pedersen, and aurora and geomagnetism expert Dan la Cour took part, and URSI’s leaders accepted their suggestion to develop a program for investigating the ionosphere during the IPY. Thule, Greenland, was a recommended investigation site, but equipment delivery problems doomed that effort.⁸ An ionospheric sounder at Tromsø, Norway, provided data that established a connection between auroras, geomagnetic storms, and radio disturbances, but scientists were unable to produce a clear, detailed picture of the polar atmosphere.⁹

By the mid-1930s, as discussions of commercial passenger airplane flights between North America and Europe increased, renowned aviator Charles Lindbergh saw the aurora borealis and its “adverse effect on radio operation” as a major obstacles to be overcome.¹⁰ Auroras were disrupting Arctic communications—and the problem could not be fixed by increasing transmission power, using more sensitive receivers, or switching frequencies. Thus, from the late 1930s the development of large-scale ionospheric prediction techniques provided direct benefits to military services searching for reliable and effective radio communications. The urgent demand for worldwide coverage gave these efforts tremendous momentum during World War II, and extensive military funding enabled the Allies to lay the foundation of a global network of ionospheric stations early in the war.¹¹

IONOSPHERIC PHYSICS DURING THE WAR

By the late 1930s, John H. Dellinger, chief of the US National Bureau of Standards' (NBS) radio section, was calling for more "consistent observations" of ionospheric conditions in polar regions, and making plans to launch a special expedition to gather ionosphere and radio propagation data in Greenlandic waters during summer 1940. However, these plans were disrupted by the outbreak of war in 1939 as well as a change in plans of the expedition's leader: Louise Arner Boyd.¹²

The expedition became an urgent military matter, however, even before the USA entered the war in late 1941. In late 1940, NBS director Lyman Briggs tied ionospheric data in high northern latitudes and the auroral zone to national defense, noting that it was important to fill the knowledge gap "in connection with the efficiency of radio communication in our national defense."¹³ Briggs was focused on geophysical data that could improve the operation of North Atlantic radio circuits as the USA worked to increase its military, technological, and scientific readiness while preparing for war.¹⁴ Subsequently, Greenland appeared on Washington's geopolitical radar screen, and encouraged by Denmark's ambassador, in April 1941 the USA took full responsibility for Greenland's defense during the war, a decision requiring vigorous efforts to take control of this environment.¹⁵

The semisecret Boyd expedition set sail in July 1941, traveling for four months along Greenland's west coast, climaxing near the geomagnetic pole in the Nares Strait in northwest Greenland in mid-August, and returning via the coasts of Baffin Island and Labrador. Its main objective was to gather data on ionospheric storms associated with auroras, particularly sporadic ionization of the E-layer (100 km altitude), and absorption and disruption of radio communications.¹⁶ According to Dellinger, the Boyd expedition succeeded in obtaining unique data within the auroral zone, which constituted the "missing link" in NBS's emerging radio-weather forecasting service. The forecasts—began in 1941—were circulated monthly to US military units and their counterparts in England, Canada, Australia, and New Zealand.¹⁷

Dellinger was eager to place a permanent ionospheric station in Greenland, particularly since propagation research was rapidly expanding in the wake of the USA's entrance into World War II. The newly formed JCS established the Joint Communications Board, whose Wave Propagation Committee (WPC) coordinated the national research effort, including the creation of the Inter-Service Radio Propagation Laboratory (IRPL) at the

NBS in summer 1942. The IRPL centralized research on radio propagation and radio weather, providing support to the military: radio-weather prediction, radio equipment design, radio countermeasures, interception of enemy signals, and new high-frequency direction finding techniques, known as huff-duff; the latter used to locate surfacing German submarines.¹⁸ Another wartime IRPL project developed methods of forecasting ionospheric disturbances that plagued North Atlantic radio circuits extending through the auroral zone. Because of their military significance, ionospheric data, handbooks on radio propagation, radio-weather predictions, and prediction methods were classified after Pearl Harbor.¹⁹

During summer 1942, the WPC launched a plan to establish four ionospheric stations that would increase knowledge of Arctic conditions, for which they only had scattered observations.²⁰ From the beginning, a Greenland station was of prime importance. Dellinger and the Navy favored Julianehåb at Greenland's southern tip because it would provide more data from the auroral zone.²¹ While "vitaly interested" in propagation data, the Army Air Force favored Thule in extreme northwestern Greenland, to maximize support for North Atlantic air routes to Europe for which it had experienced "a definite problem of [radio] dissemination."²² However, this potential interservice squabble came to naught; equipment delivery problems prevented the establishment of the Greenland station. The first major expansion of the US ionospheric network occurred in 1942–43 as four new stations were placed on Baffin Island, Iceland, Hawaii, and Trinidad.²³

The Army and the Department of Terrestrial Magnetism operated the overseas stations, the numbers of which grew steadily during the war. The wartime IRPL was disbanded in 1946 and its duties were transferred to a new civilian NBS laboratory—the Central Radio Propagation Laboratory (CRPL)—partly funded by the military services and overseen by the Radio Propagation Executive Council, which included military members and whose chairman was regularly chosen from the Army Signal Corps. CRPL was a civilian agency, but it primarily served military customers.²⁴

EARLY COLD WAR: CRPL'S ARCTIC PROGRAM

As the Cold War unfolded, US military planners began to focus on the vast Arctic region separating the USA and the USSR, convinced that the Soviets would attack via the short polar route—made more obvious by polar projection maps.²⁵ Regardless of future weapons system develop-

ment, an effective continental defense strategy required secure, reliable radio communications in the Arctic and improved methods of predicting the environmental circumstances that threatened them.

In early 1946, the JCS Joint Communications Board directed the Joint Wave Propagation Committee (JWPC) to investigate radio wave propagation in the Arctic. By March 1947, the JWPC had found that Arctic radio propagation patterns differed “considerably” from the rest of the world, and had been less studied due to the Far North’s remoteness and relative inaccessibility. “Current interest in the Arctic regions as an area of strategic importance for defensive operations,” the committee argued, “makes it necessary to increase our knowledge of radio propagation in this area.” The JWPC recommended developing “a comprehensive program” under “a central agency,” focused on ionospheric reflection, absorption, and fading; atmospheric, cosmic, and precipitation noise; and geomagnetic effects on electromagnetic wave propagation.²⁶ The Joint Chiefs passed the recommendation to the Pentagon’s Joint Research and Development Board (JRDB) for action.

The JRDB also recognized gaps in scientific knowledge related to Arctic radio propagation. Scientists knew little about the Arctic ionosphere and the propagation of the whole spectrum of radio waves from very low frequency (VLF) to very high frequency (VHF) in the Arctic environment. Research and development of the latter was assigned to the Army Air Force, which eventually spurred the development of VHF backscatter and troposcatter links that proved to be more robust alternatives to shortwaves in the Arctic. Arctic ionospheric propagation efforts were assigned to the Army in cooperation with the CRPL under its proposed Arctic Ionosphere Program, thus cementing a partnership that lasted for several years and became instrumental in establishing ionospheric stations in Greenland.²⁷

Thus the Army was responsible for operating overseas ionospheric stations and providing the data to CRPL, which studied the geophysical properties of the upper atmosphere and radio propagation. CRPL also provided radio-weather predictions for both military and civilian users: a general three-month forecast published in a booklet, and six-hourly forecasts for the vital North Atlantic and North Pacific radio paths, which warned of sudden radio disturbances and blackouts in the key Arctic paths linking the USA with Western Europe and the Far East.²⁸ CRPL’s Arctic Program was designed to strengthen these forecasting efforts.

SECURITY AND SOVEREIGNTY: THE ARCTIC PROGRAM IN GREENLAND, 1947–55

To obtain data for its Arctic program, CRPL requested the services of thirteen ionospheric stations—seven new—on the northern rim of the North American continent, starting in Alaska and extending east over northern Canada and Greenland to Iceland. The plan called for two or three stations in Greenland (Julianehåb, Thule, and/or Peary Land). CRPL justified the large number of permanent facilities and the substantial expense involved (\$1.5 million, or \$15 million in 2012) because “great irregularities” in Arctic data “indicated that little reliability [could] be placed in ionospheric measurements at a given place conducted by periods of time of less than several years.”²⁹ CRPL planned to run the program over at least one full solar cycle (11 years). Developed during 1946–47, the program was finally approved and adopted in 1949 due to its strategic urgency and the confidence military leaders had in CRPL.³⁰

The USA first had to settle sovereignty issues with host countries. Negotiations with Canada led to several new or improved Canadian-operated stations across the Arctic.³¹ The USA took a different approach with Denmark, which did not have an active research program. At war’s end, the USA was operating four air bases, two naval bases, and 11 radio- and weather stations in Greenland. Denmark opposed new US facilities in Greenland—while fighting to take control of existing facilities—to maintain its neutral anti-block policy and regain effective sovereignty over the island, a policy continued after Denmark joined NATO in 1949, when diplomatic negotiations began about future defense arrangements between the two nations. Throughout this period, the building of any new facilities in Greenland—no matter how small—was an explosive political issue in Denmark.³²

In 1948, Danish radio experts were approached by leading British and American ionospheric researchers about the possibility of conducting investigations in Greenland. The International Radio Consultative Committee (CCIR) emphasized the importance of worldwide ionospheric measurements, especially in the “critical regions around the magnetic equator and the auroral zone.” The CCIR’s Western participants (Eastern bloc members were less keen) recommended establishing three ionospheric stations in Greenland in “the Extreme South, Middle and Extreme North West.”³³ Similarly in 1948, the URSI General Assembly recommended establishing as many pole-to-pole ionospheric stations as possible along the 60 W

and 20 E meridians.³⁴ Before the assembly meeting, leading Danish radio scientists received invitations from URSI and tentative proposals from both the NBS (Dellinger), and from R. F. Smith-Rose, head of the British National Physical Laboratory's Radio Department. Upon their receipt, the moribund Danish URSI—dormant since Pedersen's death in 1941—was revived with Jørgen Rybner, Professor of Telecommunications at the Technical University of Denmark (DTH), as chairman.

Rybner, who had assisted Pedersen's work on radio propagation, spent much of the 1948–49 academic year studying communication and network theory at MIT, Cornell, and Columbia, and upon his return to Denmark, invested his efforts into initiating and developing ionospheric research in Greenland.³⁵ Starting from scratch when research money was tight, funds had to be cobbled together from multiple sources. One of Rybner's first moves was to transfer the national URSI committee from the Royal Academy of Science and Letters' academic setting to the technology-oriented Academy of Technical Sciences.

The reenergized committee favored the British proposal, resulting in an effort to measure radio noise in East Greenland for the British Radio Research Board and a new plan to establish a British-equipped ionospheric station at Godhavn, Greenland. In early 1949, the Danish URSI committee's plan also gained support from the Commission for Scientific Investigations in Greenland—Denmark's central governmental agency for polar research. The committee's proposal pointed to rising foreign interest in ionospheric data from Greenland, noting that F. T. Davies—leader of the Radio Propagation Laboratory in Ottawa, Canada, which operated the ionosphere station in Clyde—was interested in data from Godhavn. If Denmark did not establish a station there, then Davies would seek permission to do so.³⁶ Here we see a common theme in Arctic small-state versus large-state interactions: a larger state's scientific interest in the smaller state's remote areas, spurs the latter's willingness to invest in scientific activities to maintain sovereignty and autonomy in those areas. Thus the proposal appealed to Denmark's wish to boost its sovereignty in Greenland—which Rybner forcefully spelled out in a funding application to the Carlsberg Foundation. Denmark, he argued, ought to take a lead in solving the problem of radio propagation in Greenland, since it “otherwise can be expected, that foreigners will present their wish to take it up for their own purposes.”³⁷ As American activities in ionospheric research accelerated in the 1950s, it became an article of faith among scientists and administrators that matching investments in the field would “serve to

underscore Danish interests in this part of the country,” and thus reinforce Danish sovereignty.³⁸ The rationale: sovereignty in Greenland could be protected and exercised if Denmark’s government and scientists remained proactive in the face of rising scientific interest by matching foreign activities one-by-one.

As in the 1930s, the British-supplied equipment failed to appear. But this time, the URSI committee revived its communication with the NBS/CRPL, which by August 1950 offered to lend the Danes an ionosonde and to cover some of the installation costs—an offer that came, unsurprisingly, with strings attached: due to the sensitive, military-related nature of the data and the onset of the Korean War, the Danes would have to share the basic data with the NBS/CRPL alone, although the possibility of publishing the results of their scientific investigations remained open. On this basis, a “gentlemen’s agreement” was struck between the Danish committee and the NBS—extraordinary because it involved neither the USA nor the Danish government, and Denmark had long maintained a traditional commitment to international scientific collaboration, only abandoning its neutral stance in 1949. Indeed, Denmark had little classified military research underway at the time.³⁹ Why not a formal written agreement? Politically such a solution would have been controversial on both sides of the Atlantic, and would have exposed JCS’s Arctic interests.⁴⁰

Although there might have been other equipment solutions—for example, buying it from the Americans—the committee accepted the terms, noting that they in “all circumstances felt obliged to follow the American demands regarding publication of data.”⁴¹ Danish scientists adapted to the imposed constraints, voluntarily consented to the secrecy rules, and abandoned their traditional values of openness, recognizing their need for US know-how and funding. Furthermore, the wording suggests they shared the US political agenda. Despite the secrecy demands that conflicted with some of their statutes, Rybner’s encouragement helped persuade several scientific foundations—including the Rask-Ørsted and Carlsberg—to cover additional expenses. Indeed, Danish scientific icon Niels Bohr offered to encourage the Carlsberg Foundation to support the station.⁴² After 1952, the Danish Meteorological Institute—and therefore the Danish government—assumed financial responsibility for the station, while the national URSI committee retained scientific leadership.⁴³

How should we interpret the role Bohr and these foundations played in supporting a project steeped in secrecy? Bohr’s role is particularly striking, because in June 1950 this world-renowned scientist had sent an open

letter to the United Nations pleading for an open world. This apparent about-face appears to have been a result of the Korean War and increasing tensions between the USA and the Soviet Union. Danish scientists and institutions were faced with a choice between the ideals of openness and public knowledge, and the weighty issues of Western security. Faced with threats to Western democracies—and acting out of a shared political agenda and loyalty toward the USA—they chose to suspend their scientific ideals, making this a rare case of American norms of defense-related scientific practice spreading to Denmark.

SMALL-SCALE SCIENCE ON THE PERIPHERY: RESEARCH AND SECRECY

Beginning almost from scratch, Rybner and the Danish committee did not possess the experience to effectively operate the ionosonde and collect ionospheric data. To correct this deficiency, in summer 1951, Rybner sent one of his most talented young engineers—Søren T. Lyngsø—to CRPL to receive intensive training in ionosonde operations and scaling (i.e., transforming the layer traces on the graphic ionogram into standard values of virtual heights, critical frequencies, and maximum usable frequencies). Since scaling was a subjective task dependent upon tacit knowledge, Lyngsø learned to analyze the ionograms by practicing on increasingly difficult cases. Returning to Greenland, he helped install the equipment and provided further training to the engineer (Hans Bengaard) who would be working on the project for the first two years.⁴⁴ Because Godhavn's ionograms were very difficult to interpret—sporadic E and F layers were a frequent occurrence—the station's operator would occasionally leave the station to consult with CRPL colleagues. Eventually, CRPL sent supervisory personnel to Greenland to provide assistance.⁴⁵

As station operations ramped up, Rybner was working to establish a research unit at the DTH, employing graduate engineers—who were more likely to develop new ideas on the job—at the field stations instead of less expensive technicians.⁴⁶ Activities remained at low levels for the first four years, with one field engineer at Godhavn and Rybner in Copenhagen. The first research effort—undertaken in 1955 by Eigil Ungstrup, a young graduate student in Rybner's department—focused on the problems of radio blackouts associated with auroras. Ungstrup sought to determine why ships at the southern tip of Greenland experienced problems receiving

shortwave transmissions from Denmark while ships at higher latitudes did not. He discovered that the D-layer (at 80 km altitude) in the auroral zone was absorbing the shortwave signals, which also accounted for poor reception of radio from Denmark on the North American East Coast.⁴⁷

Ungstrup published his results solely in Danish publications: *Ingeniøren* and *Vor Viden*. His two papers were the only ones published by Danish ionospheric researchers before the IGY began in 1957. With the exception of data gathered during the 1954 solar eclipse—shared with Swedish radio-physicist Olof Rydbeck and internationally as part of an URSI effort—the Danes kept to their original agreement. They did not share data with third parties and kept a low profile in Godhavn.⁴⁸ CRPL researcher's commended their Danish colleagues for their "conscientious respect" for the 1951 agreement.⁴⁹

Eventually, the US military lifted the classification restrictions on Arctic ionospheric data.⁵⁰ During spring and summer 1954, several leading American ionospheric scientists urged the JCS to adopt a less restrictive policy on ionospheric data to pave the way for international data exchanges during the upcoming IGY.⁵¹ The effort met some success in June 1954, when the JCS adopted a policy meant to allow free circulation of data except "results of particular military significance," that is, those pertinent for military communication systems operations in the Arctic. Although restrictions on certain data—including hourly data on the Arctic ionosphere—remained in place, they were now in the least restrictive category ("For Official Use Only"). Although the Korean War had ended and Stalin was dead, the Cold War continued. Now limitations on releasing Arctic ionospheric data were retained while the US attempted to force the Soviets to engage in a reciprocal data exchange.⁵² In October 1954, when the Soviet Union announced its decision to participate in the IGY, the path was opened for a resolution on international exchange of ionospheric data, adopted by the Special Committee for the IGY in Brussels in September 1955. Exchange of Arctic ionospheric data between the two superpowers, however, proceeded slowly on a quid pro quo basis in the period between the Brussels meeting and the IGY's starting date.⁵³ Because the new policy was not widely disseminated, the Danes only found out that the classification restrictions had been lifted when Rybner queried the CRPL about how they should handle ionospheric data from Godhavn during the IGY. The date? June 1957—almost two full years after the decision had been made.⁵⁴

EXPANDING IONOSPHERIC ACTIVITIES: WHISTLERS, THE IGY, AND THE TURN TO GEOPHYSICS

From the time of Godhavn's opening, Rybner was looking for ways to expand Denmark's ionospheric activities in Greenland. When plans for the upcoming IGY reached Denmark in 1953, he proposed adding an ionospheric station in Thule to CRPL, which informed him that it was already planning such a station. However, if the plan fell through, CPRL would consider making an ionosonde available to Denmark.⁵⁵ Accepting CRPL's primacy and prerogative on the issue, Rybner did not ask again. So while Denmark continued to emphasize its interests in Greenland to a national audience, the Danish ionospheric researchers tended to accept a subservient role vis-à-vis the ionospheric stations instead of underscoring Denmark's sovereignty over Greenland.

True to their word, two year later, the Army Signal Corps and CRPL established an ionospheric station on North Mountain near Thule Air Base. At the same site, the Air Force Cambridge Research Laboratory (AFCRL) established a geophysical observatory—Geopole Station—in 1957. During the IGY, these stations anchored a number of US IGY projects at Thule. The observation program at Geopole focused on understanding the interrelation of cosmic rays, solar particles, the geomagnetic field, auroras, and polar airglow, thus using the geomagnetic pole's opening in Earth's magnetic shield to understand the complex Sun–Earth relationship.⁵⁶ Of interest, the development of upper atmosphere research facilities at Thule—a major US air base where the USA operated freely—took place without the involvement of the Danish government.

Physics of the upper atmosphere was at the heart of the IGY, with ionospheric physics, aurora and airglow, and rocketry comprising 71% of the \$6.2 million that the USA spent on its IGY Arctic Program.⁵⁷ With strong links between Rybner's department in Copenhagen and the USA's Greenland efforts, the IGY became a turning point for Danish ionospheric research on the island—the number of Danish scientists at the Greenland stations grew from one to four with the addition of two new projects in Godhavn. The IGY-driven transformations are most clearly visible in the field of “whistler studies,” which the Danes undertook at Godhavn during this period—in what was yet another instance of the transnational flow of ideas and research techniques.⁵⁸

Whistlers—highly dispersed audio-frequency VHF emissions originating from thunderstorms—sound like a musically descending tone

when transformed into audio signals. They are significant because they can be used to map electron densities in the magnetosphere—a topic of importance for space-related activities. The whistler research program drawn up by Stanford University’s Robert A. Helliwell and Dartmouth’s Millett G. Morgan involved 26 stations with listening stations proposed for Godhavn and Thule.⁵⁹ However, Godhavn was outside the American defense areas, and when the Danish IGY Committee got wind of the plan, they asked Rybner to explain to his American colleagues that they would need Denmark’s permission to use the Godhavn site—which he did.⁶⁰ As a result, Helliwell decided it was best to have the Danes take the measurements in Godhavn—a move that initiated a new, fruitful line of research in Denmark—one of only four stations to have operated completely successfully during the IGY.⁶¹

The whistler work at Godhavn was funded by a combination of Danish research grants and a large grant from the Air Force Research and Development Command, European Office. The Air Force’s interest is unclear, but the magnetosphere was a hot topic as the space age emerged and the knowledge of naturally occurring electromagnetic noise was a general military priority. The contact with the Air Force had come through Danish scientist Poul Brandt Rehberg, a chief scientific advisor to NATO and member of the Defense Research Council.⁶² Air Force contract support continued after the IGY, with the Danes receiving \$63,000 between 1957 and 1964 (\$460,000 in 2012) for their work on VLF noise—roughly equivalent to the 350,000 DKK received from national sources. The new funding fueled the growth of the newly (and officially) designated Ionosphere Laboratory, the number of research personnel increasing from two to seven by 1960.⁶³ In 1961, the program was expanded to include measuring VLF noise at Narsarsuaq, and additional measurements along Greenland’s west coast using portable equipment. In 1964, a new VLF station was established at the Inuit settlement Qaanaaq, 100 miles north of Thule AB.⁶⁴

The VLF project—the first major research effort by Danish ionospheric researchers—generated two publications in *Nature* and the first two doctoral dissertations in the field. It also created a strong link between the Ionosphere Laboratory and Helliwell’s Stanford group, with ideas and personnel moving both ways.⁶⁵ The project signaled a shifting emphasis away from early propagation work—heavily focused on US national security needs and requirements—to a more genuine geophysical research agenda with a free exchange of data suitable for academic research.

THE DANES TAKE OVER THE STATIONS: 1957 AND BEYOND

The Danish URSI committee took over the Narsarsuaq station on a contractual basis in 1957 when the US military pulled out, and by 1960 the Danish government continued on under the same terms as the Godhavn station.⁶⁶ By this time, the Danish engineers operating the stations had become very experienced, so CRPL asked Godhavn's Bengaard to help direct ionospheric work at Little America, Antarctica, during the IGY's Operation Deep Freeze. Later he would undertake a similar position at the Barrow Field Station in far northern Alaska. Similarly, Godhavn's Frede Iversen went to Antarctica after the IGY to head ionospheric work at Byrd Station in 1959.⁶⁷

Besides radio-weather predictions, ionosphere data could be used for other military and intelligence measures. In fall 1961, CRPL asked the Danish stations to sweep the ionosphere every five minutes from September through November. Ungstrup explained to Narsarsuaq's field engineer that the Americans expected a "Russian Argus experiment"—a nuclear explosion in space—and instructed him to "keep eyes open for any unanticipated observations."⁶⁸ Ungstrup was well informed and intended to serve the Americans in the best possible way. His conjectures were right; the intensified measurements were part of Project Beta-Beta, a special study on the detection of nuclear tests conducted by CRPL for the Defense Atomic Support Agency, which was responsible for nuclear weapons effect studies. In the late 1950s, the USA had conducted several high-altitude nuclear tests, the Argus experiments among them. These tests revealed that nuclear bursts had significant effects on the lower ionosphere. Beta-Beta was an effort to evaluate if ionosphere data from high-latitude stations (Reykjavik, Thule, Godhavn, Narsarsuaq, Barrow) could be used to detect nuclear tests.⁶⁹ The target dates suggest that the project was looking specifically for signatures from Soviet tests conducted at Nova Zemlya (e.g., the incredible 57 megaton "tsar bomba") and the high-altitude tests from Kapustin Yar. Disturbances were detected but the tricky part was to distinguish artificial from natural interferences. Beta-Beta was terminated prematurely on 8 November 1961.⁷⁰

In the summer of 1962, the Ionosphere Laboratory forwarded ionospheric data from the Greenland stations from 1961 requested by S.W. Littman, a senior scientist at the Hughes Aircraft Company and expert on nuclear interference of the ionosphere. The interesting thing

to note here is the nonproblematic, day-to-day handling of such requests even when coming from a US military contractor. It was business as usual, and more than that, since the correspondence was jam-packed with friendly greetings illustrating sustained networking efforts.⁷¹

In 1960, the Army-operated ionospheric station at North Mountain moved to Camp Tutu, near Thule. In 1961, CRPL, dissatisfied with its operation, began pressing the Danes to take responsibility for the station, because lower-level Army personnel taking measurements were not up to the scientific task. Since the Danes had a long record of outstanding performance—and had been publishing papers jointly with the Americans—they seemed the logical choice to take over the station.⁷²

Rybner, eager to move his agenda forward, asked the Greenland Department to evaluate the merits of moving the station to Dundas near Thule AB, or to Qaanaaq. Neither was acceptable to the department's Telecommunications Office, because having the station at either location would be "seriously harmful to radio reception and to telecommunications between" Qaanaaq and Dundas.⁷³ Thus, the Army continued to operate the Camp Tuto station until the camp closed in 1966. It was then transferred to the Danes, who moved it to Qaanaaq, site of the Danish VLF station (funded by the US National Science Foundation). By 1966, the Danes finally controlled all three ionospheric stations in Greenland.

Simultaneously, the military's interest in ionospheric data was declining and the number of stations worldwide dropped from a high of 167 during the IGY to 110 in 1969.⁷⁴ The decline occurred for a number of reasons. Scientific interest had shifted to *in situ* measurements and later to the new incoherent scatter radar; in addition, new communication systems, including troposcatter, meteor scatter, low-frequency systems, and the proliferation of undersea cables and satellite communications made military and civilian sectors less dependent on high-frequency communications. Funding that had gone to ionospheric research shifted to the magnetosphere (the satellites' environment), and to the new emerging topic of space weather.⁷⁵ Consequently, the equipment that the Danes inherited from the Army Signal Corps and CRPL during the 1960s was the techno-scientific hardware of the past, not the future.

CONCLUSION

Being vital to shortwave radio propagation, ionospheric data became an important example of strategic environmental knowledge in the early Cold

War as military planners began to emphasize transpolar air routes and the projection of strategic power into polar areas. The American focus was not on Greenland—rather, activities in Greenland were part of a larger programmatic effort to secure high-latitude ionospheric data from the northern rim of North America. Danish interests—scientific, technological, and political—also mattered, but in terms of causal weight, the US focus on the Arctic environs was the strongest.

Danish ionospheric scientists accepted funding from American sources, both military and civilian (although the civilian sources, such as CRPL, were focused on military needs), to keep their scientific undertakings viable. Their acceptance entailed the concomitant requirement for secrecy. Did Danish researchers yield to economic and political pressure when they embraced the collection of data that had to remain secret? The evidence indicates that they acted voluntarily, agreeing to keep the data secret out of a shared geopolitical agenda and a sense of loyalty toward the USA. When looking back on the Cold War period, Danish scientists often claim to have been naïve and not having known about the military implications of their work, but it does not hold up in the case of ionospheric research.⁷⁶ Researchers such as Rybner and Ungstrup knew exactly how their data were being used by the military and were equally well aware of the geopolitical implications of their work. They saw assisting the US military not as a necessity, but as a way to build professional identity, boost enthusiasm, inspire dedication, and encourage a commitment to their scientific discipline. Yes, they played a subordinate role to their American scientific counterparts, but so too did Denmark play a subordinate role to the USA on the world stage. While this state of affairs was discordant with the prevailing Danish political focus on sovereignty protection, which the same scientists also mobilized as a vehicle to secure support for their activities, Danish ionospheric scientists used both the larger geopolitical situation and the domestic political situation to their advantage in pursuing their research agendas in Greenland.

NOTES

1. Available literature is predominantly in Danish. See, for example, Jørgen Rybner, "Ionosfæreforskning," *Geofysikken i Danmark 2* (1960): 55–66; Jørgen Taagholt, "Dansk ionosfæreforskning," *Meteorologisk Institut 1872–1972* (1972): 225–252, and "Danish Arctic Ionosphere Research," *Arctic* 25, no. 4 (1972): 251–262.

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Danish Seismic Research in Relation to American Nuclear Detection Efforts

Anne Lif Lund Jacobsen

As the Cold War unfolded, detecting underground nuclear explosions became a matter of national strategic interest in the USA. When it became apparent that seismic monitoring could offer a remote method of detection—by monitoring shock waves whose signatures matched those of atomic weapons—the USA stepped up its seismological research efforts starting in the 1950s. Denmark, a small country located between two nuclear-capable superpowers, supported America but decided not to pursue nuclear power. Consequently, Danish seismologists found themselves navigating both pro- and antinuclear interests as they pursued their research agenda.

While earthquakes have been studied for centuries, compared to other geophysical disciplines, seismology was relatively small and received little attention until the mid-twentieth century, hampered by a lack of established methods and standardized calibrated instruments. In the USA, for example, fewer than 50 scientists worked in seismology.¹ The field was even smaller in Denmark, where, until the 1950s, the Danish Geodetic Institute's Inge Lehmann was the only scientist conducting systematic seismic research. Once seismology offered the prospect of detecting underground nuclear explosions, US government funding for

A.L.L. Jacobsen (✉)
Danish National Archives, Copenhagen, Denmark

seismic research increased by a factor of 30 between 1958 and 1961.² The resulting research opportunities attracted researchers from all over the world, including Lehmann.

Kai-Henrik Barth has argued that despite increased military funding, university-based seismic research remained largely unchanged by the Cold War and was not caught up in the military–industrial complex until the 1960s, when military funding composed a larger share of their budgets.³ However, Ronald E. Doel suggests that this was not always the case. From 1947 until the mid-1960s, 90% of the funding for Columbia University’s Lamont Geological Observatory came from military sources.⁴ By comparison, very little is known about seismic research in Denmark and how Cold War geopolitics affected it. What role did US-funded seismic research play in the development of Denmark’s own nuclear detection strategy? What interest did the USA take in Danish seismic research? And how did Denmark use that interest to its own advantage?

SEISMOLOGICAL RESEARCH AT THE DANISH GEODETIC INSTITUTE

The Danish Geodetic Institute, under the Ministry of Defense, became Danish seismology’s institutional home in 1926. That same year, mathematician Inge Lehmann was hired to establish its new Seismic Section. Educated at Copenhagen and Cambridge Universities, she qualified as a geodesist in 1928 and was then officially appointed chief of the new section. As the only academically trained member of the small staff, Lehmann was solely responsible for all seismological research and most administrative tasks too. The section’s main task was to operate three seismic stations: one near Copenhagen; one at Scoresbysund (Ittoqqortoormiit), East Greenland; and one at Ivigtut, Southwest Greenland. The stations sent their seismograms to the section office to be read and catalogued. Section personnel noted significant waves and published the data in bulletins that were exchanged among seismic institutions throughout the world.⁵

As the only professional seismologist in Denmark, Lehmann’s professional network extended outside the country. She maintained regular contact with colleagues in Germany, England, France, and Italy, exchanging ideas and offering critiques by mail. Despite Lehmann’s isolation, her research was influenced by discussions among leading scientists about fundamental questions relating to time curve propagation. Her study of time curves of the direct longitudinal P-wave and the transverse S-wave eventu-

ally led to her influential 1936 paper on the deflection of P-waves, indicating the Earth had an inner core. Lehmann was less interested in specific geophysical questions related to Danish and Greenlandic geology.⁶ While the Geodetic Institute's director favored research activities and participation in international scientific meetings (if they could be accomplished without additional cost), the section budget covered only administrative tasks. Therefore, the Seismic Section never had a formal research agenda. Much of Lehmann's seismic wave research was accomplished between administrative tasks, or in her spare time, and without funding.⁷

While Lehmann led the Seismic Section, the two Greenland stations became caught up in international politics. In preparation for the 1933 Hague trial to settle Denmark's and Norway's sovereignty claims over East Greenland, authorities asked the Seismic Station to prepare a report about its activities at Scoresbysund to support Denmark's claim.⁸ When Nazi Germany occupied Denmark, the US Coast and Geodetic Survey (USC&GS) assumed management of the Greenland stations. The USA provided essential supplies—including the special paper to record seismic waves—and the USC&GS received the seismic data, publishing portions in its own bulletins. After the war, Lehmann had to ask the USC&GS for permission to publish Ivigtut's 1944 and 1945 data in the Seismic Section's bulletin.⁹

World War II interrupted the routine exchange of data and ideas among researchers in Europe, so Lehmann was unable to obtain new data for her research. With the postwar European seismic research community in ruins, Lehmann instead turned her attention to microseismic movement in Greenland based on data from the section's stations. After her retirement in 1953, Lehmann's successor at the section, Henry Jensen, continued doing microseismic studies. Under Jensen's direction, seismic research expanded during the 1960s, aided by new, more sensitive seismographs donated by the USA.¹⁰

Until the early 1960s, the Geodetic Institute's—and thus Denmark's—postwar seismological research followed the pattern of the preceding three decades: providing the international community with seismic bulletins and the results of basic research that primarily focused on Danish territories. The institute had no well-developed research policy, and the research agenda seems to have flowed from individual interests. Although the Geodetic Institute was a government organization, the Danish government rarely requested research or advice, and made no demands for applied research. Outside of Denmark, however, seismic research was becoming increasingly important to the US and Soviet governments.

Seismology thus became a contested discipline influenced by political and military objectives.

EARLY COLD WAR USES OF US SEISMOLOGICAL RESEARCH AND ITS CONNECTION TO DENMARK

In the USA, seismologists took advantage of early nuclear bomb tests to enhance their knowledge of the Earth.¹¹ Conventional explosives had helped them determine rock stratification and crystal structure in Earth's upper layers.¹² Using the same methods with more powerful nuclear explosions, seismologists could study its deep interior.

The US military had used seismic techniques to study the characteristics of nuclear bomb explosions early in the nuclear program, and soon developed long-distance detection methods. Indeed, Harvard seismologist L. Don Leet had placed seismographs near the Alamogordo, New Mexico, site of the first atomic bomb blast, on 16 July 1945. Later, California Institute of Technology geophysicist Beno Gutenberg used seismic data to estimate the time and place of the then-secret Alamogordo test.¹³

The first nuclear bomb explosion announced in advance was the 30 June 1946 underwater test at Bikini Atoll. Several seismic stations recorded the resulting Earth waves, giving scientists a glimpse of what a nuclear future could mean for seismic science.¹⁴ But after 1946, nuclear bomb tests were classified; until 1952, studies on nuclear-explosion seismology could not be published in the open literature.¹⁵

From the beginning of nuclear-based seismic detection research, military applications and basic scientific research overlapped as the military sought to identify the locations of nuclear tests and seismologists sought to answer fundamental questions. The distinction between the two was further blurred since US seismologists often worked simultaneously on both classified military and unclassified basic research projects. Early in the Cold War, the USA took a special interest in Greenland because it was relatively close to Soviet test sites and experienced few earthquakes.

Two separate cases—one in 1951 and one in 1952—demonstrate an early link between US interests in long-range detection of nuclear blasts and data from Greenland. The first arose when the American military realized it needed an efficient monitoring system in advance of Soviet-developed nuclear weapons. The US Air Force (USAF) established its secret Office of Atomic Energy-1 (AFLOAT-1) in August 1948 to develop and deploy

methods of discovering foreign atomic tests and other nuclear weapons-related activities.¹⁶ AFLOAT-1's scientists and contractors initiated a far-reaching program of basic and applied research, primarily within radiological, sonic, and seismic sciences along with air sampling.¹⁷ By early 1950, they had developed several detection techniques that were carried out from field stations in the "Interim Operational System," (IOS) and in 1951, they added several more seismic location methods.¹⁸ As AFLOAT-1 rapidly expanded, new seismic stations co-located with US military installations were incorporated into the IOS.¹⁹ The newly established Thule (Greenland) Air Base became part of the system (as Team 220); seismic detection devices were installed in October 1952.²⁰ However, Thule soon proved to be too noisy for detection purposes because nearby glaciers produced "ice-quakes," and seismic monitoring of possible nuclear bomb tests was temporarily discontinued.²¹

The second motivation for US interest in Greenlandic seismic research blended scientific and military interests. In the late 1940s, Lehmann had been researching the relationship between microseismic movement in Greenland and the weather, but could not explain variations in the late stages of the S-phases.²² American geophysicist W. Maurice Ewing was working on a similar problem for the USAF while studying his newly discovered Lg phase, a surface wave that traveled through the continental crust.

During World War II, Ewing had done military research at the Woods Hole Oceanographic Institution, and from 1946 to 1949, he ran a project on atmospheric sound channels codenamed Project Mongol as part of AFLOAT-1.²³ After joining Columbia University in the mid-1940s, Ewing founded the Lamont Geological Observatory in 1949, well aware of military interest in his work. Lamont's research agenda included seismology, and in July 1951, Ewing visited European seismic stations to study surface waves. While creating contacts around the Continent, he explicitly asked to see seismograms from Greenland.²⁴

During that trip, and again during a December 1951 seminar on microseisms in Rome, Ewing invited Lehmann to come to Lamont. Her interest was piqued. Lehmann saw a rare opportunity to escape from the stale research environment in Europe and collaborate with a colleague "...on something I have not been able to get to the bottom of," as she put it to the Geodetic Institute's Director—not bothering to explain the scientific nature of "something."²⁵

In January 1952, having been given three months leave without pay, Lehmann discovered she was unable to purchase US dollars from

the Danish National Bank because her director had not stated the trip's importance to her work.²⁶ Stepping in, Ewing secured free military air transport and a subsistence allowance under his contract with the Air Force Cambridge Research Laboratory (AFCRL).²⁷ To persuade AFCRL to support Lehmann, Ewing emphasized that beyond contributing to the contracted work on Lg phases, Lehmann would bring data with her. "These would be of extreme value to us," Ewing argued, "for they include copies of recordings at Russian stations which would not be available to us otherwise."²⁸ Military funding in hand, Lehmann traveled to the USA in February 1952. In addition to conducting research at Lamont, she also attended meetings of the Seismological Society of America and the American Geophysical Union, and in Pasadena examined seismic records at Caltech. When Lehmann published the research results from her time in Lamont, she acknowledged Ewing as the inspiration and the AFCRL's Geophysics Research Division as her patron.²⁹

These cases show how the US military obtained research data from Greenland during the Cold War. The first was to obtain data directly: having free access to Thule Air Base, AFLOAT-1 could install a seismic station and conduct research in Greenland without involving the Danes. The second relied on military funding passed through American scientists to non-US seismologists. The USAF funded Lehmann not only because of her excellent research abilities, but also because she could provide them with data otherwise difficult to obtain during the increasingly polarized Cold War. USAF funding buoyed Lehmann, accustomed to meager research budgets, because she was eager to expand her research and somewhat indifferent to her patrons' objectives. In 1953, at age 65, Lehmann retired from the Seismic Section; thereafter she alternated between working at US universities and in Denmark, benefitting from US military-funded research projects addressing fundamental seismological science. Consequently seismological research in Greenland and Denmark became associated with long-range detection of nuclear weapons through these American contacts (Figs. 8.1 and 8.2).

Seismology in Denmark Gravitates Toward American Strategic Interests

The co-opting of Danish seismic science toward US strategic interests happened gradually. Denmark increasingly had to balance its national interests against US interests. In Greenland, new initiatives had to be negotiated



Fig. 8.1 Austin Jones of the U.S. Coast and Geodetic Survey building a seismic vault in Greenland for the International Geophysical Year, August 1957. *Courtesy Rigsarkivet: Geodaetisk Institut, 1920-1988, Sagligtordnede sager, Seismiskafdeling.*

within the complex Danish–American relationship in North Greenland. We see evidence of this difficult balance in the case of a seismic installation at Station Nord in Northeast Greenland—the Seismic Section’s contribution to the International Geophysical Year (IGY)—whose operations reflected the politicizing of scientific research in general (and seismic research in particular) in Greenland.

In 1956, the Seismic Section sought Danish Defense Ministry approval to establish an interim seismic station at Station Nord—a Danish-operated weather station in Northeast Greenland connected to significant US military interests. Originally proposed as a joint US–Danish station, the Danish government feared that the USA was contemplating establishing a second large base in North Greenland outside its existing defense areas. Not wanting the USA to form a permanent presence on Greenland’s east coast, Denmark promptly offered to establish and operate a weather station in the area, which was equipped with an emergency airstrip.³⁰ Given the political environment, the Seismic Section could not ask the USA for funding to operate the interim seismic station, and therefore had to rely



Fig. 8.2 Inge Lehmann, Denmark's distinguished geophysicist, is escorted by Maurice Ewing, director of Columbia University's Lamont Geological Observatory, to receive an honorary degree from Columbia University in 1964. *Courtesy Geological Survey of Denmark and Greenland (GEUS).*

on its own meager resources to fulfill its international obligations, and to establish and run the station.

With permission from the Defense Ministry, the Seismic Section appealed to the Greenland Ministry to operate the station during the IGY. The Greenland Ministry agreed, subsequently employing student Erik Hjortenbergt to take the seismic readings and operate an aurora camera.³¹ By IGY's end, the international scientific community wanted to continue the readings, and with permission from the Greenland Ministry, an agreement was reached with the station's radio personnel to continue the work on an overtime basis.³²

During the IGY, the USAF also had a seismic research program underway in Greenland, with AFCRL installing a seismograph near Thule Air Base. The Danish Seismic section, however, was unaware of the US program, and seismologist Jørgen Hjleme learned of it only because he had

had to wait out a snowstorm at Thule while en route to Station Nord to install the seismograph. While at Thule, he was invited to inspect the US installation, but was not given any details about the research program.³³ The lack of communication was not surprising; the US military was allowed unlimited research within their allocated Defense Area. However, the incident illustrates how Danish–American scientific collaboration in Greenland was not guaranteed.

THE ROAD TO THE GENEVA CONFERENCES AND THE LIMITED TEST BAN TREATY

Increased numbers of atmospheric and underground nuclear weapons tests caused an international outcry over the environmental consequences of heightened levels of radioactivity. Scientists throughout the world began voicing their concerns in the mid-1950s.³⁴ As the frequency and power of nuclear blasts increased, scientific, public, and political groups pushed for a nuclear test ban treaty.

During the 1950s, the USA and the Soviet Union began discussing the grounds on which a nuclear test ban could be initiated with a view to curbing the arms race.³⁵ On 1 July 1958, the two nations agreed to discuss such a plan in Geneva at a meeting dubbed the Conference of Experts. The conference was led by scientists entrusted to negotiate on behalf of their respective governments, and they found it to be both technically and politically challenging.³⁶ The two superpowers agreed that seismological methods could be used to detect nuclear explosions, but strongly disagreed on the accuracy of existing scientific methods. Politically, the Soviet Union favored a mutually agreed upon ban before agreeing to specific policing methods, while the USA would not consider a treaty until the scientists had agreed on the monitoring system's details because it did not want the detection method to disadvantage its position.³⁷ The negotiations continued to focus on seismological techniques to detect nuclear explosions, and despite significant scientific disagreements on the sensitivity of underground detection methods, the panel of experts agreed on a joint report that addressed detection methods and proposed a system of worldwide seismic control posts and onsite inspections directed by an international organization.³⁸

Shortly thereafter, in October 1958, the USA's Operation Hardtack II demonstrated—according to US scientists—that it was more difficult to detect and identify small underground explosions than Conference of

Experts participants had thought. A year later, a second working group met to discuss the technical implications of the new seismic data for underground detection. The two sides continued to disagree; the Soviet scientists challenged the instruments and theories behind the new data, and the US scientists defended their methods and argued for a reevaluation of the 1958 joint report. Ultimately, the scientists were unable to agree on instrumentation, theories, data handling, and key seismological concepts.³⁹

When the experts failed to agree, negotiations moved to traditional diplomatic channels. The 1962 Cuban Missile Crisis spurred political momentum to a level necessary to reach an understanding about nuclear arms control, and in August 1963, the Limited Test Ban Treaty, which prohibited nuclear tests in the atmosphere, space, and underwater—but not underground—was signed.⁴⁰

US PATRONAGE AND THE GLOBAL SEISMOGRAPHIC NETWORK

In the wake of initial failures to reach a scientific agreement with the Soviet Union on test detection techniques, the USA created Project VELA to develop and implement methods for monitoring the test ban. A subprogram—VELA UNIFORM, managed by the Advanced Research Project Agency (ARPA) and overseen by the USAF—was designed to improve the “state of the art” of seismology and specifically dealt with seismic research and field monitoring aimed to develop better methods of detecting underground nuclear explosions.⁴¹ US academic institutions received most of the research funding, including for North American seismological research in the military–academic–industrial enterprise.⁴² At the same time, some programs became more international, pulling in participants from outside the USA.

Denmark’s Inge Lehmann received VELA UNIFORM funding in the form of travel grants and visits to the Lamont Geological Observatory organized by geophysicists Maurice Ewing and Jack Oliver. Her research into discontinuities in Earth’s upper mantle depended upon seismic data from US nuclear tests conducted under VELA UNIFORM’s auspices, and in 1964, she presented evidence for a velocity discontinuity at a depth of 200 kilometers.⁴³ The Seismic Section also benefitted from Project VELA by becoming part of the World-Wide Standardized Seismographic Network (WWSSN) in 1962, and later by participating in a seismic array study conducted on Greenland’s ice sheet in 1966–67.

On 5 July 1960, the Geodetic Institute received a query from the US Coast and Geodetic Survey: would the Seismic Section be interested in becoming part of a global program of seismic stations? The US-funded network would consist of identical seismographs distributed to interested countries. The only conditions: all seismographs had to be made available via the International Union of Geodesy and Geophysics (IUGG) and the Seismic Section had to build and operate the stations. As no extended international standard or calibrations existed at the time, a network of identical seismographs placed around the globe would provide a series of uniform seismographs, which would greatly benefit scientific efforts and could potentially be used for nuclear explosion surveillance.

The Seismic Section was familiar with the USC&GS due to its long-standing practice of data exchange. Therefore, the section initially treated the query as a basic science project without political and military implications. In its response to the USC&GS, the section expressed its admiration “of the great program proposed in basic seismology” and great interest in “collaboration on the lines given in the program.”⁴⁴ Knowing of US interest in Greenland, section head Henry Jensen recommended Station Nord and Godhavn as being especially well-suited for the new equipment and emphasized that the two stations—in connection with the USC&GS stations in Thule and Resolute Bay (Canada)—would form a nice network to study mantle waves as well as microseisms originating off Greenland’s southwest coast. The section was eager to participate in what they perceived would be a collaborative science project motivated by the opportunity to modernize the Greenland stations.⁴⁵ Its only reluctance concerned the economic obligation to provide suitable buildings and assume possible increased operating costs.⁴⁶

In April 1961, the USC&GS informed the Seismic Section that the facilities at Station Nord, Scoresbysund, and Godhavn had been selected to receive US seismographs. But by summer, Cold War tensions were rising due to concerns over Germany’s future status and the section had to adopt a more cautious position. The USA and the Soviet Union disagreed over the supervision of Germany, and during the subsequent Berlin Wall crisis, the Soviets resumed their nuclear testing program, suspended since 1959 as part of nuclear test ban negotiations. Simultaneously, the Danish government had begun negotiations with West Germany for military assistance, further straining its diplomatic relationship with the Soviet

Union.⁴⁷ Prompted by a series of nuclear tests announced by the Soviets, in November 1961, the Seismic Department conducted an exercise to see how quickly it could obtain seismic data from the Greenland stations, which led to a request for telephones for all of the stations since “it would be too late to make the request when the situation” arose.⁴⁸

Given the newly strained relationship with the Soviet Union, the Seismic Section reevaluated the political implications of participating in the US-funded network of seismic stations. An undated memorandum, likely prepared by the Seismic Section for the Danish government, raised several concerns. Since the terms of equipment use were unclear, they feared that the Greenland stations would be controlled by the USA, thus threatening the section’s tradition of maintaining full control over national stations and compromising the tradition of free and open data exchanges among research institutions. However, the section held that “Denmark can hardly reject the offer” without just cause without affecting its relationship with the USA. The Danish government had no political reasons to reject the seismic network offer since the USA had described the network as a purely scientific project aimed at improving the prediction of destructive earthquakes. However, the Seismic Section was now aware of the military implications of the network as they wrote, “If problems of detection and therefore control of nuclear explosions is behind the project, it does not change the fact that the final aim is humanitarian.” Despite having doubts about the network’s underlying purpose, the section acknowledged that the resulting data would likely improve earthquake prediction, and therefore encouraged its endorsement by the Danish government. In addition, Denmark could not reject the offer because if the section or another Danish agency refused to provide the needed Greenland stations, it would be “very difficult to prevent the United States in establishing them themselves.” Therefore, it seemed preferable to keep the stations under some measure of Danish control if the alternative were no control at all—the likely outcome if Denmark refused to participate. Given the situation in Greenland, and Denmark’s diplomatic relations with the Soviet Union, the Seismic Section recommended telling the Americans that Denmark would like to collaborate in the network by building and running the requested stations, but would prefer to purchase the seismic instruments. In the likely event that the USA refused the purchase offer, Denmark would then be in a better diplomatic position, having demonstrated a willingness to act independently.⁴⁹

Denmark's awareness of its inability to effectively regulate and control American activities in Greenland is likely a key reason behind its overall policy of accepting and cooperating with most of the USA's proposed seismic research activities. As predicted, the USA did not allow Denmark to purchase the instruments, but it did provide another set of seismic instruments to the Copenhagen station so that all Danish stations were equipped with WWSSN instruments. Thus Danish seismology—willing or not—was co-opted by the American agenda. The Seismic Section correctly understood the broader political implications of its ties to US strategic interests. Thereafter, the section adopted a more standoffish approach to seismic projects of US origin.

By 1962, diplomatic relations between Denmark and the Soviet Union were on the upswing, and the construction of the three Greenlandic stations was completed the same year.⁵⁰ As a result, in September 1962, the American Embassy—with the Seismic Section's permission—issued a press release stating that the new seismic station in Godhavn would be outfitted with seismic instruments from the USA worth approximately \$20,000, and others would be installed at Scoresbysund and Station Nord.⁵¹ The statement emphasized the international and cooperative nature of the arrangement, stressing that the data would be restricted, but available for all scientists to use, and that the network provided new prospects for basic seismic research.

ATTEMPTS TO EXCHANGE SEISMIC INSTRUMENTS

The WWSSN was not a truly global network; Communist Bloc nations had their own network. Data from both networks were shared through the IUGG, but difficult to compare since the USA used the long-period Press-Ewing seismograph and the Soviet Union used a similar Kirnos seismograph, a problem acknowledged by scientists from both networks.⁵² In September 1961, Eugene Savarensky of the Institute of Physics of the Earth, Academy of Science, Moscow, suggested to Lamont's Ewing that they exchange seismic instruments to overcome the problem of technical differences.⁵³ Ewing passed the matter on to ARPA, which consulted further with AFTAC, the State Department, the Executive Office of the President, and the USC&GS, and determined that such an exchange was in the best interests of the US government. Since US-standard seismic installations were already placed in many countries, the Communist Bloc could easily obtain the equipment's unique technical features, whereas

the USA had no opportunities to gain knowledge about Soviet equipment. The USC&GS, acting on behalf of ARPA, was authorized to proceed with the exchanges, using Lamont as the exchange point. Why this convoluted scheme? ARPA was adamant that the exchange “be between academics, not between governments.”⁵⁴ By insisting that any equipment exchange take place within the scholarly community, ARPA could use the long-established tradition of knowledge exchanges between scientific institutions, making them matters of advancing science, not politics. The exchange also fit the public image of WWSSN as a purely science-driven network aimed at generating uniform global data for mankind’s betterment. However, the window of opportunity closed in 1962, and nothing came of the attempt. The USA, however, remained keen on accessing a Soviet seismograph.

In August 1963, the Soviet Union, UK, and the USA signed the Limited Test Ban Treaty, which banned nuclear tests in the atmosphere, underwater, and in space. Denmark—which had pursued a nonnuclear national defense strategy since 1958, and since early 1963, no longer included transfers of nuclear weapons to its national forces in times of crisis as part of the NATO defense agreement—ratified the treaty in December 1963 as a first step in reducing armaments, and began to actively support a ban on underground tests.⁵⁵

As discussed above, the success of a total ban on underground testing relied on establishing primarily seismic methods for detection and verification of underground nuclear explosions. A comparison between two seismographs would improve the reliability of detection and verification. The issues surrounding the desirability of being able to compare data were raised to the international level in April 1964 at the Intergovernmental Meeting on Seismology and Earthquake Engineering in Paris, where a resolution was passed supporting the exchange of seismographs. Seismic Section Chief Henry Jensen attended the meeting, and reported back that Denmark should offer the Copenhagen station as the location for such a combined station because of its geographical location and the fact that it was already equipped with a Press-Ewing seismograph. Jensen held that Denmark should actively seek out institutions in both the USA and the Soviet Union to make the exchanges.⁵⁶

If, or how widely, Jensen’s ideas were discussed is unknown, but the lack of correspondence at the time suggests that they were not followed up. The situation changed in October 1964, however, when L. W. Swanson, Assistant Director, Offices of Science, USC&GS, met with Einer

Andersen, Director, Geodetic Institute of Denmark, to persuade the institute to facilitate the exchanges.⁵⁷ Having had no success in securing the instruments through Lamont, ARPA was looking for a third part to effect the exchange. ARPA hoped that the Soviets might look more favorably on an exchange if Denmark made the request. As the Geodetic Institute had a tradition of exchanging data with the USC&GS and was also a member of the WWSSN, American institutions would have no trouble accessing the data.

Andersen was aware of the USA's agenda behind the request, and it was only after consulting with Gunnar Seidenfaden, the former Danish Ambassador to the Soviet Union, and the Danish Foreign Ministry, that he wrote to the USSR Geophysical Committee suggesting an exchange. Quoting the resolution from the UNESCO Intergovernmental Meeting, Andersen proposed Jensen's idea of installing a twin set of instruments at the Copenhagen station so it could serve as a connecting station between the two seismic networks. Pushing his own agenda, he hoped that the Soviet Union would agree in time to permit an announcement at the upcoming European Seismological Commission meeting in Copenhagen.⁵⁸ Although the idea had originated with the Americans, Andersen—on behalf of the Danish government—tried to claim the exchange as a Danish/European accomplishment by suggesting Copenhagen as the site of the joint station. However, the Soviet Union failed to respond and Andersen later learned that Ewing and Savarensky had privately exchanged seismographs.

Andersen's activities can be seen as an attempt to accommodate American strategic interests by letting the USA use the Geodetic Institute as a scientific cover for the exchange. But another interpretation is that Denmark, through the Geodetic Institute/Seismic Section, was practicing its own nuclear disarmament policy, playing lip service to the USA in the process. Given how seismic research had become increasingly intertwined with both American and Danish strategic interests/politics, it is likely that both possibilities played a role.

OPERATION BLUE ICE

One of VELA's most exciting engineering outcomes involved the construction of the large aperture seismic array (LASA) in Montana, during 1964 and 1965.⁵⁹ LASA's multiple sensors were designed to increase the signal-to-noise ratio, thereby improving the capability of observing small, remote seismic events such as underground explosions. At the same time,

the Danish government began considering how to actively contribute to the international effort of detecting and identifying underground explosions including, by early 1965, tentative technical discussions about placing a seismic detection station in Greenland. It became more than a technical possibility when detection seismology was discussed in August 1965 at the meeting of the Nordic Council of Ministers, the official intergovernmental body for the Nordic nations. At the meeting, the Swedish foreign minister suggested a Nordic collaboration on seismic detection. Supported by Denmark and Norway, the Danish minister assured his counterparts that Denmark would look positively on any Nordic request to locate detection facilities in Greenland. As a result, a joint Nordic technical committee of scientists was appointed in January 1966 to report on suitable seismic detection methods (mainly LASA) and to recommend how such methods could be employed on national levels within a joint framework. Later they would advise on the political, economic, and technical problems on a Nordic level.⁶⁰

In an unrelated effort, the Air Force Office of Scientific Research (AFOSR) was preparing to fund a seismic array study on Greenland's ice cap. To effectively police a test ban, it was necessary to develop and implement methods to discern the difference between explosions and naturally occurring seismic noise. Greenland's ice shelf was thought to be an ideal listening site: there was little seismic noise that would camouflage secret underground nuclear blasts, and it was close to the Soviet Union's preferred nuclear test sites in Siberia. In February 1966, AFOSR approached the Arctic Institute of North America (AINA) to establish and operate such a station. AINA, a private Canadian research institute with strong ties to both US and Canadian governments, received a significant portion of its funding from the military in the 1950s and 1960s, especially from AFCRL.⁶¹ In May 1966, ARPA funded the project, effectively disguising what could become a politically problematic military project in Greenland as an international civilian research project.⁶²

In April 1966, the Danish Ministry of Foreign Affairs contacted the Seismic Section as it sought Danish cooperation for a project on seismic noise studies in Greenland, however, without more detailed information the section was unable to make a definitive proposal.⁶³ But at a meeting held at the Geodetic Institute later in the month, eight US scientists and State Department officials presented an operational plan prepared by AINA. Seismic Section members Hjelme and Hjortenbergt attended along with four scientists representing other Danish research interests. The

project had already been codenamed operation BLUE ICE, and except for making a few suggestions of a technical nature, the Seismic Section personnel did not question the operational plan, but Danish scientists did request collection of specific data of interest to them. The attendees spent most of the time discussing the LASA installation in Montana, and the required size of an installation for nuclear detection, and specifically if other countries had been approached about housing American LASA stations. The US delegation kept its answers deliberately vague and did not directly answer the housing question.⁶⁴ The discussion showed that section personnel were well aware of the reasons for American interests in Greenland and keenly interested in the possibility of getting a LASA station on Danish territory.

BLUE ICE's military origins became clearer on 11 May 1966 at the annual meeting between the Danish commission for scientific investigation in Greenland (Kommissionen for videnskabelige undersøgelser I Grønland) and representatives from the US forces, when Major William D. Kleis presented the USAF research program. Kleis stated that Project BLUE ICE was "to determine the suitability of the Greenland Ice Cap as a location for LASA equipment used to detect underground nuclear explosions." To do so, the USA would place a base camp near 78°N and 40°W, and man it from June to September 1966, February 1967, then June 1967 through the summer. AINA would be in charge of operations at the base camp; Geotech, Dallas, would handle the technical program. Danish scientists—a glaciologist, a magnetics expert, and someone with seismological knowledge, though not necessarily a professional person—would only be involved in carrying out the measurements. Large snow samples would be collected for Danish scientific use elsewhere.⁶⁵

Since the Danish scientists would primarily be involved in activities that were not original VELA UNIFORM-funded BLUE ICE objectives, one may speculate that including these activities was an American attempt to secure support from the KVUG/Danish scientific community to help get the project approved. Subsequent American public presentations on the activities emphasized the joint nature of the program, and sometimes credited Henry Jensen as its initiator.⁶⁶

THE INGE LEHMANN STATION

On 19 June 1966, construction began on BLUE ICE's base camp, which was located on the ice cap some 730 kilometers east of Thule and 20

kilometers to the northeast of the abandoned North Ice Station, previously used by the British North Greenland Expedition in 1952–54. From 19 to 24 June, 60 tons of equipment, supplies, and personnel were flown in by the Alaska Air Command. Once operational, biweekly flights ferried visitors, personnel, and supplies to the base camp.⁶⁷ This illustrated the tremendous logistical resources available to US scientists; in contrast, Danish seismic stations in Greenland were serviced annually by ship.

Scientific work began on 24 June, immediately after the base camp's completion. Four individual scientific measurement programs were planned: a seismic noise study, a program of magnetics measurements, a collection of ice to measure the level of cosmic ray-produced Si^{32} , and a collection of ice cores for crystallographic studies. In addition, scientists took weather observations every three hours. The important seismic research program was proclaimed a joint undertaking of the Danish Geodetic Institute and AINA, which meant that Erik Hjortenbergt (Seismic Section) and Eduard Douze (Geotech/AFORS) would together process and analyze the station's seismic data.⁶⁸ In reality, Hjortenbergt spent little time at the station, visiting only two weeks in summer 1966. Later, however, he participated in the almost 40-day long traverse from the station to Camp Century—codenamed BLUE TREK—in August 1967, measuring seismic noise.⁶⁹ Seismic recordings were taped, flown out on the biweekly resupply flights, and analyzed by contractors who then advised operators via radio about any needed adjustments to the seismometers' settings.⁷⁰

The researchers kept in close communication with Thule AB. Three times a day, they called in weather observations, seismograms, and other information to the Air Force's 1983rd Communications Squadron at Thule, which could patch phone calls directly to Washington, DC, and Alaska, and from there to the rest of the world if necessary. In case of emergencies, the HF frequency used by the station was monitored at all times, and an aircraft was sent out to check on the station if 72 hours passed without contact.

At summer's close on 17 August 1966, a ceremony was held "in honour of the distinguished Danish seismologist Dr. Inge Lehmann, who has performed considerable seismic research in the United States."⁷¹ The AINA had suggested inviting Lehmann, probably including her name as a show of good will toward their Danish colleagues, but it was clearly unaware of the now frosty relationship between Lehmann and the Seismic Section. Lehmann declined.⁷² Three Danish organizations were represented at the ceremony (The Danish government, the Meteorological Institute, and the

Geodetic Institute), while six American military, research, and industrial organizations were present. Curiously, a representative from the Belgian Embassy in Washington, DC, was also present.

THE LEGACY OF BLUE ICE AND BLUE TREK

Data collected by BLUE ICE and BLUE TREK provided evidence that the Greenland ice cap was a good site for a seismic array station. A year earlier, in September 1966, Hjortenbergs had traveled to the USA to inspect the LASA site in Montana and meet with key scientists. In a confidential letter to the Seismic Section, he reported that AINA was willing to establish and run a permanent station in Greenland with seismic personnel selected and trained by the section. AINA's executive director had also hinted that there might be American funding for a data processing center in Denmark.⁷³ That was just what section personnel wanted to hear. Likely knowing that they had been invited to participate in the seismic project to provide legitimacy for a US military project, section personnel had complied because they saw an opportunity to gain valuable knowledge about LASA technology and seismic noise in Greenland—knowledge that they needed to participate in growing cooperation among the Nordic countries on detection seismology. Getting a LASA station in Greenland or access to LASA equipment would only strengthen their position on detection seismology and advance Denmark's disarmament defense strategy.

However, the USA never asked Denmark if it could operate a LASA station, probably because the operational cost was high, especially as the US Army downsized its operations in Greenland and could not be expected to provide logistical support. And in 1968, the joint Norwegian–American-operated Norwegian Seismic Array Station (NORSAR) was established, diminishing the strategic argument for a LASA station in Greenland.

When Nordic seismologists met in Bergen in June 1968, Hjelme reported on the seismic section's analysis of data from the Inge Lehmann station and revealed its negotiations with the Americans to transfer the station's seismic equipment to Station Nord.⁷⁴ However, US military interest in Greenland was waning; negotiations faltered, and the equipment was never transferred. Without resources for a Danish detection station, the section instead began collaborating with NORSAR, a collaboration that was further strengthened in 1969 when members decided to establish the annual Nordic Seminar on Detection Seismology, which continues to this day.

In 1971, VELA UNIFORM ended; American funding for new seismic research projects shrank; and Lehmann, the Danish seismologist who had contributed the most to the program, was awarded the American Geophysical Union's William Bowie Medal at the age of 83, and subsequently retired. Maintenance and technical support for the WWSSN had stopped in 1967 due to a congressional order, and as US military interests in Greenland continued to dwindle, so did communications between the US military and the Geodetic Institute/Seismic Section. But for the Seismic Section, the BLUE ICE/BLUE TREK project marked the beginning of its engagement in international nuclear disarmament. As evidence of the importance of this project, Hjelme was the Danish representative in the Group of Scientific Experts (GSE) for technical nuclear test ban monitoring from its beginning in 1976 to his retirement in 1995, when he was succeeded by Erik Hjortenberg, who for most of his career worked in detection seismology and supported a nuclear test ban.

CONCLUSION

The history of Cold War seismology has been written primarily as a US-centered story. When Barth argues that military patronage transformed seismology, but concludes that "seismologists did not lose control of their discipline,"⁷⁵ he bases his argument on seismological research in the USA. American seismology was not identical to seismology on the international stage. Certainly seismology was influenced by military patronage, but as my analysis shows, the mode and timing of influence varied.

I argue that in the case of seismology in Denmark, American patronage largely remained camouflaged as collaboration between scientific institutions. As such, collaborations followed long-established networks predating the Cold War, and American military agencies were able to use or exploit the research tradition within seismology of freely exchanging data and ideas among scientific institutions. The attempted USA/Soviet Union seismograph exchanges between 1961 and 1964 suggest that it was a deliberate strategy employed by US military agencies when dealing with non-US research institutions.

American scientific institutions co-opted the Seismic Section to link Danish seismologists to American efforts for nuclear arms control. By engaging Danish seismologists in research projects and other forms of scholarly cooperation with US: with US scientific institutions, American

military agencies sought to gain access to knowledge and localities in Greenland that otherwise may have been difficult to obtain. Individual scientists and the Seismic Section initially accepted this state of affairs because it gave them some degree of access to the growing American seismic community and a part in knowledge exchanges. Not before 1961, when Denmark began to formulate its own policy for disarmament, did the Seismic Section acknowledge the political motives behind American support. As Danish state policy increasingly directed the section's research activities, the relationship to US agencies became more complex and politically charged, with each side pursuing its own agendas.

When one looks at efforts to detect nuclear weapon blasts, Greenland's territory was only of interest to the USA because it was part of a larger, interlinked trans-territorial network of stations in which seismological detection played a main role. An ice cap detection station only had value for the USA insofar as it improved an already existing grid of stations, but for Denmark, a Greenlandic detection station was pivotal for its position within a Nordic disarmament strategy. Thus Denmark's interest in Greenland stemmed from the former's need to demonstrate sovereignty over its northern territories as well as supporting its own disarmament defense policy.

Seismological research in Denmark was influenced early on by American military patronage, and from the 1960s on, equally influenced by its own national strategic interests. In this endeavor seismologists in the Geodetic Institute's Seismic Section were willing participants in the politicization of their discipline.

NOTES

1. Kai-Henrik Barth, "The Politics of Seismology: Nuclear Testing, Arms Control, and the Transformation of a Discipline," *Social Studies of Science* 33, no. 5 (2003): 746.
2. *Ibid.*, 744.
3. *Ibid.*, 747–48.
4. Ronald E. Doel, "Constituting the Postwar Earth Sciences The Military's Influence on the Environmental Sciences in the US after 1945," *Social Studies of Science* 33, no. 5 (2003): 641.
5. Geodaetisk Institute 1978, 65–67.
6. Inge Lehmann, "P", *Publ.*, *Bur. Centr. Seism. Internat. Serie A*, 14 (1936): 87–115.

7. Although internationally recognized, Lehmann's work was relatively unknown in Denmark, likely due to her academic isolation and gender.
8. Udenrigsministeriet 1961 (Danish National Archives [hereafter DNA], Geodaetisk Institute 1925–1988, Journalsager, 3.1 Udenrigsministeriet 1925). For a Danish perspective, see Bo Lidegaard, *Dansk udenrigspolitisk historie*, vol. 4 (Copenhagen: Glydendal, 2003), 267–70. For a Norwegian perspective, see Einar-Arne Drivenes, "Ishavsimperialisme," in *Norsk Polarhistorie II*, ed. Einar-Arne Drivenes and Harald Dag Jølles (Oslo: Glydendal Norwegian Publishing, 2004): 175–257.
9. Lehmann to N.E. Nørlund, 4. februar 1946 (DNA, Geodaetisk Institut, 1920–1988, Sagligt ordnede sager, Seismisk afdeling).
10. E. Sørensen, *Geodaetisk Institut 1928–1978* (Copenhagen: Geodaetisk Institut, 1978), 80–82. The donation of the new seismographs are discussed later in this chapter.
11. Carl Romney, *Detecting the Bomb: The Role of Seismology in the Cold War* (Washington, DC: New Academic Publishing, 2009), 33.
12. K. E. Bullen, *An Introduction to the Theory of Seismology* (London: Cambridge University Press, 1963), 200–201.
13. Romney, *Detecting the Bomb*, 1; Beno Gutenberg, "Interpretations of records obtained from the New Mexico atomic bomb test," *Bulletin of the Seismological Society of America* 36 (1946): 328–330.
14. Bullen, *Seismology*, 291–92.
15. *Ibid.*, 292.
16. AFLOAT-1 was later renamed the Air Force Technical Applications Center (AFTAC) in 1958. Mary Welch, "AFTAC Celebrates 50 Years of Long Range Detection," *AFTAC Monitor* (October 1997): 8–9.
17. Charles A. Ziegler and David Jacobson, *Spying Without Spies: Origins of America's Secret Nuclear Surveillance System* (Westport, CT: Praeger, 1995), 179–185.
18. Welch, "AFTAC," 12.
19. By mid-1949, 11 US government agencies, three private companies, a foundation, a university, and the British government were all connected to AFLOAT-1 and the Interim Operational System; see Ziegler and Jacobson, *Spying*, 196, 199.
20. Romney, *Detecting the Bomb*, 36.
21. *Ibid.*, 38.
22. Inge Lehmann, "On the microseismic movement recorded in Greenland and its relation to atmospheric disturbances," *Ponteficiae Acad. Scient. Scripta Varia* 23 (1952): 73–109.
23. See Ziegler and Jacobson, *Spying*, 41–46. Mongol was the forerunner of the problematic Skyhook balloon program (See Chap. 10.).

24. Ewing to Lehmann, 18 June 1951 (DNA, Inge Lehmann, W58-270714); Saxov to Lehmann, 21 April 1951 (DNA, Inge Lehmann, W58-27713).
25. Lehmann to Nørlund, 14 December 1951 (DNA, Geodaetisk Institut, 1920–1988, Sagligt ordnede sager, Seismisk afdeling).
26. Lehmann to Ewing, 28 January 1952 (DNA, Inge Lehmann, W55-271059).
27. Ewing to Major C. V. Hendricks, 4 February 1952 (DNA, Inge Lehmann, W55-271064).
28. Ewing to Commanding Officer, AFCRL, attention Dr. J. A. Peoples Terrestrial Sciences Laboratory, Geophysics Research Division, 3 January 1952 (DNA, Inge Lehmann, W55-271038).
29. I. Lehmann, “On Lg as read in North American records,” *Annali di Geofisica* X (1957): 351–370.
30. Danmarks Udenrigspolitiske Institute (DUPI), *Grønland Under den kolde krig. Dansk og amerikansk sikkerheds politik 1945–68* (Copenhagen: Dansk Udenrigspolitikens Institut, 1997), 200–208.
31. Record 141401–141505 (DNA, Ministeriet for Grønland 1957–1989). Coincidentally, Hjortenberg was also the Danish seismologist involved in the US-funded seismic array study on Greenland’s Ice Cap in 1966, illustrating how small the Danish research community was.
32. Record 142101 (DNA, Ministeriet for Grønland 1957–1989).
33. Rapport vedr. Rejse I 1957 til Nord og Ivigtut af Hjelme, 13 November 1957 (DNA, Geodaetisk Institut, 1920–1988, Sagligt ordnede sager, Seismisk afdeling).
34. Bruce A. Bolt, *Nuclear Explosions and Earthquakes: the Parted Veil* (San Francisco: W. H. Freeman, 1976), 89.
35. Barth, “Politics of Seismology,” 749.
36. Romney, *Detecting the Bomb*, 69–78.
37. Benjamin P. Greene, *Eisenhower, Science Advice, and the Nuclear Test-ban Debate* (Stanford, CA: Stanford University Press, 2007), 134–36, 168.
38. Romney, *Detecting the Bomb*, 97–101.
39. Kai-Henrik Barth, “Science and Politics in Early Nuclear Test Ban Negotiations,” *Physics Today* 51, no. 3 (1998): 36, 39.
40. Greene, *Eisenhower*, 234. The Threshold Test Ban Treaty (1974) restricted underground tests to a maximum yield of 150 kilotons. The Comprehensive Test Ban Treaty (1996) banned all underground tests.
41. Charles C. Bates, “VELA UNIFORM, the Nation’s Quest for Better Detection of Underground Nuclear Explosions,” *Geophysics* 26 (1961): 499–507.
42. Barth, “Politics of Seismology,” 766.

43. Inge Lehmann, "On the travel times of P as determined from nuclear explosions," *Bulletin of the Seismological Society of America* 54 (1964): 123–139. Today the discontinuity bears Lehmann's name.
44. Draft letter addressed to Rear Admiral H. Arnold Karo, USC&GS, circa July 1960. (DNA, Geodaetisk Institut, 1920–1988, Sagligt ordnede sager, Seismisk afdeling).
45. E. Sørensen, *Geodaetisk Institute 1928–1978* (Copenhagen: Geodaetisk Institut, 1978), 70.
46. Jensen to Andersen, 15 July 1960 (DNA, Geodaetisk Institut, 1920–1988, Sagligt ordnede sager, Seismisk afdeling).
47. DUPI, *Grønland Under den kolde krig*, 414–416.
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PART III

Entanglement and Transformation:
Diplomacy and Politics of Science in
Greenland

Camp Century—Cold War City Under the Ice

Henry Nielsen and Kristian H. Nielsen

On Thursday, 20 August 1959, top-level Danish government officials from the Ministry of Foreign Affairs, the Ministry of Defense, the Ministry of Greenland, and the Atomic Energy Commission convened an emergency meeting in Copenhagen to discuss unauthorized American military activities in Greenland. According to the 27 April 1951 agreement between Denmark and the USA concerning the defense of Greenland, the USA was allowed to establish a number of military bases, the largest and most important of which was Thule Air Base in northwestern Greenland. The “defense areas,” where the US military held almost unlimited authority, included the bases’ immediate surroundings (a few square kilometers). The USA had to obtain Danish permission to conduct scientific research, carry out military operations, or build new installations outside the defense areas.¹

The cause of this crisis—and the reason behind the hastily convened meeting—was that the USA had violated this agreement. Two days before the emergency meeting, while attending a party, US Ambassador to Denmark Val Peterson had pulled Danish Minister of Foreign Affairs Jens Otto Krag aside for a private conversation.² Peterson informed Krag that the US Army had begun to construct a nuclear-powered scientific facility

H. Nielsen (✉) • K.H. Nielsen
Centre for Science Studies, Department of Mathematics, Aarhus University,
Aarhus, Denmark

within the ice sheet, approximately 200 kilometers from Thule Air Base, and that he was sorry that the work had been initiated without Danish government permission. The US Army had submitted its application to build the facility in May 1959, but had received no reply from Danish authorities. It would be better if Denmark did not ask the US Army to stop the project, Peterson added, but instead opted for a peaceful solution.³

Krag was shocked to learn about the US initiative for two reasons. According to the defense agreement, the Americans were clearly obliged to await Danish permission before starting new projects outside the defense areas. He also realized that if the USA installed a nuclear power station on a military base in Greenland, it could be interpreted as a breach of Denmark's policy banning nuclear weapons on its territory in peacetime, a policy that had been declared officially by H.C. Hansen, then-Prime Minister *and* Minister of Foreign Affairs, at the top-level NATO meeting in Paris in December 1957.⁴ Although Denmark had been a founding member of NATO in spring 1949, neutralist—and even antimilitary—feelings were still widespread in the Danish population at large and among the members of Folketinget (the Danish Parliament). In fact, Det Radikale Venstre (the Danish Social Liberal Party), one of three parties in the coalition behind the Social Democratic-led government, was a reluctant NATO supporter, and would under no circumstances accept nukes on Danish territory. Even though a nuclear power station could not be used as a weapon against the Soviet Union, Krag knew that the very mention of nuclear materials in Greenland could trigger a highly contentious public debate. Why? Because Krag shared a secret with (probably) only two other persons in Denmark, Prime Minister H.C. Hansen and Nils Svenningsen, director of the Ministry of Foreign Affairs: that Hansen, after meetings with the US ambassador Val Peterson in November 1957, signed a letter that could only be interpreted by US officials as a *de facto* Danish acceptance of American plans to store “munitions of a special kind on the defense areas of Greenland.”⁵ Krag was aware, of course, that this was an explosive secret that might bring down the government if it came out in the open during discussions of the US violation of the 1951 agreement between Denmark and the USA on the defense of Greenland.

But Krag had other reasons to worry. The military installation—dubbed Camp Century—was planned to be much more than an exciting techno-scientific “city under ice.” Unknown to Krag, it was the forerunner of a huge military installation in Greenland that would include an extended network of mobile nuclear missiles placed under the ice sheet. That project—called Iceworm—would cover 135,000 square kilometers and include 600 “Iceman” Intercontinental Ballistic Missiles (ICBMs)

that could be fired from 2100 different launch points. However, by the mid-1960s, Iceworm would be shelved due to “a mixture of technical problems, inter-service rivalry, and political second thoughts, both as to Iceworm’s feasibility as a NATO project and its acceptability with the Danish Government.”⁶ Although “the Iceman never came,” as Danish historian Nikolaj Petersen put it, the Camp Century story is fascinating: an effort to use scientific research and the popularization of technological achievement to camouflage a military project of unprecedented scope.

THE GEOPOLITICS OF GREENLAND IN THE COLD WAR

We must realize that in reality the Arctic Ocean is a Mediterranean Sea in the middle of the populated land masses of the northern hemisphere. We must make certain that this sea cannot be crossed by an enemy who considers it less difficult than we do. Technically the research and development to cope with the Arctic will not be insurmountable if we put our minds to it.⁷

-- Paul Siple to Major General H.S. Aurand, 10 October 1947.

Increasing tension between East and West, and improvements in the speed and combat radius of bombers, caused the Arctic to emerge as a potential zone of geopolitical conflict after World War II. Members of the US Joint Chiefs of Staff (JCS) and other government leaders began worrying that the USA could be vulnerable to a Soviet attack launched over the North Pole (see Chap. 2). As a forward military position, Greenland became increasingly important to US plans to contain Soviet aggression.⁸ Already during World War II, the US government had signed an agreement with exiled Danish Ambassador Henrik Kauffmann relating to the defense of Greenland against Nazi Germany; the USA would respect Danish sovereignty over Greenland and Denmark would accept the US military presence “until it has been agreed that the existing danger to the American continent has passed.”⁹ As the postwar relationship between the USA and the Soviet Union deteriorated, the Joint Chiefs added Greenland to their list of primary US bases in the Atlantic region, which included those in the Canary Islands, the Azores, and Iceland.¹⁰ The Joint War Plans Committee on the Strategic Importance of the Arctic and Sub-Arctic Regions, appointed by the JCS in 1946, made this very clear:

Within the next ten years the strategic importance of Greenland will increase progressively. When certain technical difficulties of operation from Arctic bases can be overcome and the problem of logistic support be solved, the

northern part of Greenland could provide a base area for the projection of strategic air operations.¹¹

Subsequently, in 1951–52, the small airstrip at Thule was transformed into one of the most important US air defense bases. As the USA and Denmark renegotiated their World War II agreement on Greenland’s defense, Thule Air Base’s secret expansion continued.¹² Approximately 12,000 men, jointly led by civilian contractors and the US Army, undertook the construction. In a rapid, secret operation code-named Blue Jay, they built the three-kilometer long runway to service some of the US Air Force’s largest bombers: B-36s, B-47s, and, after 1955, B-52s. They also installed six aircraft hangars and barracks for 5000 personnel—quickly planned and built in the wake of the Korean War, which had heightened US fears that the Soviets wanted to conquer the world. With the base completed, and the new agreement successfully negotiated between the USA and Denmark, Greenland became a strategic Arctic node in what historian Chalmers Johnson has called the US “empire of bases.”¹³

EISENHOWER’S “NEW LOOK” STRATEGY: IMPACTS ON DENMARK AND GREENLAND

Dwight D. Eisenhower became the US president at the height of the Korean War, pledging to end the hostilities there and contain communism. In 1953, he introduced a new national security policy—called the New Look—reflecting his concern for balancing Cold War military commitments with the nation’s financial resources. The basic premise of the new policy was that the USA should not tolerate a new local war like the Korean War, for which the USA had paid a very high prize in human lives as well as money. About 37,000 US soldiers died in the Korean battlefields, and the US defense budget almost quadrupled during the war.¹⁴ The USA could be exhausted by such wars, which the Soviet Union only fought by proxy. Eisenhower wanted to avoid, in his own words, “an unbearable security burden leading to economic disaster.”¹⁵ Instead, the USA should replace its expensive conventional forces that had fought World War II and the Korean War with a new, more efficient, less expensive defense system based upon nuclear weapons that could be delivered to their targets by means of long-range bombers and rockets. Thus, New Look emphasized increased reliance on strategic nuclear weapons, to be transferred from the control of the civilian Atomic Energy Commission to

military commands—the Air Force’s Strategic Air Command, in particular—while simultaneously reducing conventional forces and the defense budget. The New Look strategy rose to prominence in October 1953, when Eisenhower signed National Security Council document NSC-162/2, which spelled it out in detail.¹⁶

As New Look gained momentum, US Secretary of State John Foster Dulles coined the term “massive retaliation” to describe how the nation would respond to any military provocation from the Soviet Union: with nuclear weapons. Speaking to the Council on Foreign Relations in January 1954, he emphasized that, “The way to deter aggression is for the free community to be willing to and able to respond vigorously at places of its own choosing.”¹⁷ This statement reflected a major difference between the Truman and Eisenhower administrations’ security policy: while Truman regarded the use of nuclear weapons in armed conflicts as the very last resort, Eisenhower and Dulles deliberately threatened to use such weapons even in local conventional conflicts that were initiated by the Soviet Union or her allies.

Since US government officials believed that the USA held the upper hand in nuclear forces, the term “assured destruction” soon came into vogue to indicate that the Soviets would be utterly destroyed should they decide to attack. However, rapid advances in the Soviet nuclear missile program during the late 1950s meant that a “balance of terror” was in place. By the early 1960s, the confident “assured destruction” of the mid-1950s had become “mutually assured destruction,” or MAD: full-scale use of high-yield weapons of mass destruction by two opposing sides would result in the complete, utter annihilation of both the attacker and the defender, becoming a war with no victor nor armistice, but only effective reciprocal destruction.¹⁸

The advent of ICBMs escalated the Cold War conflict and affected the mutual deterrence strategy. The Soviet Union launched its first successful ICBM in August 1957, and the USA declared its first generation of armed ICBMs operational in January 1959. By the mid-1960s, the US Air Force deployed its improved second-generation ICBM Minuteman series, which featured increased reliability, higher kill probability, and improved launch and command and control facilities. Contemporaneously, the US Navy was developing an almost equally expensive medium-range, submarine-launched Polaris ballistic missile system (MRBMs). Lagging behind in ICBM technology, the Army had to take the bulk of budget cuts necessary to balance the build-up of a credible nuclear deterrence with the

New Look's requirement for overall reductions in national defense expenditures.¹⁹ From 1953 to 1957, the Army's share of the defense budget was halved, and its manpower reduced by one-third. In comparison, by the late 1950s, the Air Force's share of the defense budget had risen to no less than 49%.²⁰ According to American Army historian William C. Baldwin, it was in trying to regain its past prominence that the Army began carving out a niche for its own MRBM program, known as Project Iceworm.²¹

PROJECT ICEWORM GETS UNDERWAY

In 1960, the analytical arm of the US Army Engineer Studies Center—the Planning Studies Division—published two significant studies on the challenges of employing ICBMs as part of MAD. The first report²²—*The ICBM Duel*—argued that US ICBMs would not be able to neutralize Soviet ICBMs because the USA lacked sufficient intelligence about their location. Worse, even if the USA could locate them, five to ten US missiles would be needed to destroy each ICBM. Regardless of its offensive capabilities, the US could not prevent an initial or retaliatory blow against North America.²³

The second report—*Strategic Value of the Greenland Icecap*—published in March 1960, expanded the concept that US missile defenses had to be invulnerable to Soviet attacks.²⁴ One option was to use Greenland's icecap to hide the missile force. The report proposed basing a modified version of the Air Force's Minuteman missile in an extensive cut-and-cover tunnel network, "in which men and missiles are protected from weather and to a degree, from enemy attack."²⁵ Dubbed Project Iceworm, the intra-ice missile installation would provide several advantages to the Army. Located closer to enemy targets, the Iceworm missiles—called Iceman—could have two stages rather than three and still arrive in substantially less time and with greater accuracy than three-stage Minutemen missiles launched from the North American continent. Moreover, the Iceman missiles would be "hidden and elusive." Carried by a railroad system, the missiles could be randomly moved—undetected—to new positions. Although the icecap was "softer" than the hardened silos planned for the Minuteman system, the Iceworm's flexible network would negate this disadvantage.²⁶

Conceived by the Army in response to the Air Force's Minuteman and the Navy's Polaris systems, Iceworm was based on an extended Arctic research program focused on environmental conditions in Greenland that was managed by the US Army Polar Research and Development Center

(PR&DC). In 1954, the PR&DC had established Camp Tuto (Thule Take-Off) near the edge of the icecap close to Thule AB; three years later, Camp Fistclench was built on—and inside—the icecap about 220 miles east of Thule. Working at these two sites, several teams of engineers and scientists from military and civil organizations investigated basic properties of ice, snow, and permafrost, and developed the first concepts for construction and transportation in—and on—snow and ice (See Chap. 5). They concluded that it was possible to build tunnels in the icecap and locate entire army bases therein. In 1958, the Office of the Director of Research and Development, Office of the Chief of Engineers, decided to develop a new, larger camp—known as Camp Century because it was planned to be 100 miles east of Camp Tuto. The planning group behind Camp Century wanted “to test new methods of Polar construction and to determine their worth for use in future installations which may be required in ice cap areas of the world,” thereby demonstrating the feasibility of the Iceworm concept.²⁷ Upon inspecting the proposed Camp Century site in May 1959, Commanding Officer, Headquarters, PR&DC, Colonel John H. Kerkering, and Captain Thomas C. Evans, the officer-in charge of construction at Camp Century, decided to relocate it about 30 miles further east from Tuto, on a large plateau, 6500 feet above sea level.²⁸ With the site selection complete, the USA needed to convince Denmark to agree.

RELUCTANT APPROVAL FROM COPENHAGEN

On 4 November 1958—ten months before Val Peterson briefed the astonished Jens Otto Krag at the Copenhagen party—US Embassy Secretary Ward P. Allen had informed Axel Serup, a high-ranking officer at the Danish Ministry for Foreign Affairs, that the US Army would be seeking Denmark’s permission to build another scientific camp on the Greenland icecap. The new camp would be extraordinary compared to previous ones: it would be nuclear-powered, and would be located entirely inside the icecap. Serup took up the matter with his colleagues and—given the Danish government’s well-known sensitivity to American activities outside the defense areas in Greenland—probably also with Krag, the Minister of Foreign Affairs. Subsequently, Serup wrote a memorandum recommending that the Americans either give up the idea or build the camp outside of Greenland—in Alaska or Northern Canada, for example. As he wrote: “We have come to the conclusion that experiments with

nuclear reactors in Greenland will give rise to a number of problems that we rather [...] would like to avoid.”²⁹

The problems that Serup mentioned in his note, dated 19 November, most likely refer to Moscow’s possible reactions should Camp Century become reality—a very serious Cold War concern for Denmark. In March 1957, the Soviet Union had reacted sharply to Denmark’s decision to acquire Honest John and Nike missiles (with only conventional warheads) to strengthen its air defense, threatening to deploy nuclear weapons against Denmark in a war. The Danish government feared that the Soviet Union might again terrify the Danish and Greenlandic population by threatening to detonate nuclear bombs over Denmark and Greenland if the USA were allowed to pursue a nuclear path on Danish territory—including Greenland.³⁰

Serup concluded his note: “Mr. Allen thanked me for the response, and he did not appear to be completely unsympathetic to our attitude, which he would report to Washington.” Thus, the Danish diplomats had reason to hope that the Americans would see things their way. They were wrong. On 29 May 1959, the US Embassy in Copenhagen presented the formal request (signed by Allen) to the Ministry of Foreign Affairs for permission to construct a nuclear-powered camp (Century) under the icecap.³¹ The problems to which Serup had referred again became pertinent. When Val Peterson informally told Jens Otto Krag that the construction of Camp Century had begun without Danish permission, Krag felt compelled to call the emergency August meeting in Copenhagen. One attendee, Hans Henrik Koch, chairman of the Danish Atomic Energy Commission’s Executive Board, pointed out that “there must be other purposes for the nuclear reactor than the ones given by the Americans, i.e., investigating the possibilities of supplying remote areas in the polar regions with electricity and heat,” and that he, in this respect, “worried that the installation of the reactor served also military purposes.” The Director of the Ministry of Foreign Affairs, Dr. Erik Schram-Nielsen, added that his “staff feared that the press would raise the issue, addressing the very question of nuclear weapons in Greenland.” Taking the matter very seriously, the participants ultimately agreed to ask the Danish liaison officer stationed at Thule AB to go to the Camp Century site to determine the extent of construction efforts.³²

A few days later, the liaison officer reported back: construction had only just begun, and the reactor and other technical equipment would not arrive until spring 1960. The Ministry of Foreign Affairs still had time to

address the situation. On 26 August 1959, Dr. Schram-Nielsen informed Secretary Ward P. Allen from the US Embassy that the Danish authorities were still evaluating the American application, and that they needed more time to do so. Meanwhile, Denmark asked the USA to refrain from informing the press about the project, “as such indiscretion would create great difficulties for the Danish authorities.”³³

This Danish appeal for press discretion arrived too late. Three days earlier, *The Sunday Star*, an American weekly, ran a story about Camp Century featuring photographs of “Peter Snow Millers”—Swiss-made snow removal machines—digging tunnels into the icecap. Headlined “City Under Snow in Greenland to House Army Post,” the article presented—for the first time in the press—the remarkable story of Army engineers building “complete facilities including heat, light, and a hospital for 150 men beneath the frozen wastes of the ice cap.” Even extremely low temperatures below minus 50 °C would cause little problem, as “the men will live in insulated houses built in the ice caves hewed by the engineers.” Logistics involved in transporting liquid fuel to the base were problematic, but they would be “mitigated by the prospect that the Army, if the Danish Government assents, will be able to install a nuclear power plant under the ice of Century. Such a plant is already being fabricated by Alco Products Inc. of Schenectady [...] to produce 1,500 kilowatts of electricity. It will be delivered in some 30 pieces next May and should be generating by the following October.”³⁴

With the publication of *The Sunday Star*’s article about Camp Century, Danish attempts to keep the project under wraps failed. On 7 September 1959, Krag briefly advised the Foreign Affairs Committee that, “we have received from the American government a request for permission to install for civil purposes a nuclear reactor in the vicinity of Thule. The government did not have reservations about responding in a positive manner to the request.”³⁵ Thus the Danish government, realizing that it could not keep Camp Century out of the public eye, tried to convince the Parliament and—as we shall see in the following—the Danish public that the project was entirely civilian.

BUILDING CAMP CENTURY, A MILITARY-SCIENTIFIC BASE UNDER THE ICE

In June 1959, two months before Peterson notified Krag of Camp Century’s construction, a large tractor convoy—called a heavy swing—began its slow journey across the northwestern perimeter of the Greenland icecap from

Camp Tuto to the planned location of Camp Century.³⁶ Large Caterpillar D-8 or D-9 tractors drew rows of sled trains carrying construction materials and supplies over the 138 miles of ice cap. Total tonnage handled in this manner included 1000 tons in summer 1959 and 4600 tons in 1960. A typical swing consisted of nine tractors hauling three 2750-gallon diesel fuel tanker sleds and from 25 to 40 cargo sleds, each of which was carrying between 10 and 20 tons of cargo. The swings also included a command wanigan (a wanigan is a sled-mounted van—"wanigan" being the Eskimo word for a shelter or bunkhouse), and mess, sleeper, generator, and maintenance wanigans. Two such swings, each manned by about 24 men, were continually on the trail between Tuto and Century during the summer months. At speeds of one to two miles per hour, the trip took four to six days. In winter months or during storms, the trip could take up to two weeks. Personnel were transported to and from Camp Century by aircraft, if the weather allowed, or in light, continuous track, oversnow vehicles known as Polecats, capable of traveling up to ten miles per hour.

Upon arrival in June 1959, the 100-man crew began working 12-hour shifts in the 24-hour sunshine of the polar summer. Using the Peter Snow Millers—which could handle 1200 cubic yards of snow per hour under ideal conditions—they began cutting trenches. When these trenches were about ten meters deep, they covered the opening with corrugated steel arches. Finally, the workers used the Peter Millers to seal in the trench roofs with snow in layers 6–12 inches deep. They allowed each snow layer to cure and strengthen for one or two days before adding more snow. When done, three feet of snow crowned the arches. Within a few weeks, the hardened snow formed a strong and durable roof, which blended in with its surroundings—effectively hiding the trench below.

In an astonishingly short time, these tunnels came to constitute a city—with living quarters, a library, work spaces, recreation facilities, a theater, and a church—all buried beneath the ancient Greenland ice cap, just 800 miles from the North Pole. Camp Century's trench system consisted of a series of parallel main tunnels in which buildings and other structures—including the nuclear power reactor—were housed. The main vehicular access trench—called Main Street—was large enough to accommodate tractor-drawn sled trains. Main Street extended through the center of the camp, running perpendicular to, and connecting to, the main structure trenches. The tunnels were from 18 to 26 feet wide, and 30 to 1100 feet long (Main Street), depending on need. However, most buildings were standardized and prefabricated to minimize on-site assembly time.

Buildings to be heated or scheduled to hold heat-producing equipment were placed on wooden supports, since wood is a poor conductor of heat and would keep the structures from melting into the icy ground. The ventilation system expelled heat and gases from the tunnels, ensuring clean air and maintaining the below-freezing temperatures required to keep the tunnels intact (Fig. 9.1).

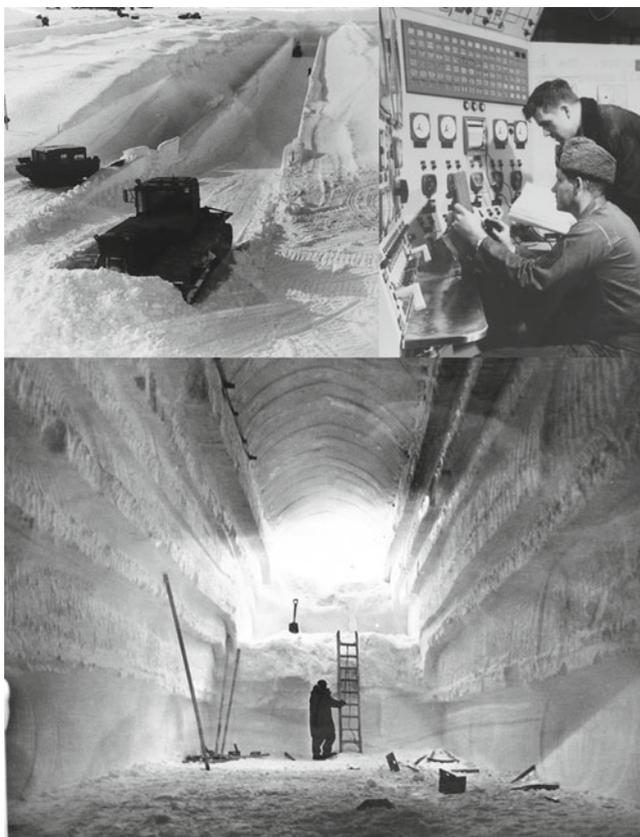


Fig. 9.1 Three views of Camp Century, Greenland, circa 1960: (*top left*) Digging a subsurface “main street,” using a Swiss-designed Peter Snow Miller plow; (*top right*) the central console of Camp Century’s nuclear generator; (*bottom*) building a main corridor of Greenland’s underground nuclear-powered city. *Credit: National Archives, U.S. Information Agency picture story #568.*

In summer 1959, the Camp Century construction team members—who had jocularly nicknamed themselves “Iceworms”—lived in a temporary surface camp of Jamesway huts (portable and easy-to-assemble huts, designed for Arctic weather conditions). By summer’s end, the basic work on Main Street and four smaller, intersecting trenches had been completed. Diesel generators supplied the camp with electricity and heat. The camp produced fresh water by melting a shaft into the ice. By using steam jets, the resulting pool of water was sufficient to satisfy camp requirements. The sewage system was based on more-or-less the same principle: dumping water-borne sewage into a pit that rapidly melted its way down into the icecap. The original design called for venting the sewage dump and locating it at least 500 feet away from the nearest occupied building to prevent accumulation of odorous fumes in living or working areas—avoiding problems that had plagued cities worldwide since the Middle Ages. But as Camp Century was nearing completion in September 1960, the approach of the dark winter season, coupled with the large amount of work awaiting completion, resulted in locating a non-vented sewage sump within 150 feet of the nearest (T-5) building, which was to serve as living quarters. As an official report noted, with uncommon honesty, “the odor of sewage became almost unbearable in the nearest quarters by the following summer and traces of sewage odor were detectable throughout Trenches 18, 19, and 20.” While “[s]ubsequent venting of the sump reduced the odor to a more tolerable level,” the odoriferous problem was not completely eliminated.³⁷

The camp was divided into five main sections: reactor, quarters, services, labs, and standby power. The nuclear plant—designed to be airlifted using Air Force cargo planes—could have pieces no larger than $9 \times 9 \times 30$ feet, and weighing no more than 30,000 pounds. The reactor design was the result of the Army’s nuclear power program to develop small pressurized-water and boiling-water nuclear power reactors for generating electrical and space-heating energy at remote, relatively inaccessible sites.³⁸ Known as PM-2A (Portable Medium-power), the plant was the first portable-type reactor. After the parts arrived in Greenland, they were transported across the icecap on heavy swings in late summer 1960. Operating at a uranium-235 enrichment of 93%, the PM-2A supplied Camp Century with heat and power for a year on just 44 pounds of uranium (compared to the more than 400,000 gallons of oil required by diesel generators to do the same job). The plant achieved initial criticality and became operational on 2 October 1960. Except for downtime required to conduct routine mainte-

nance or effect repairs, it operated continuously until 9 July 1963, at which time it was closed down. The reactor was removed in summer 1964.³⁹

More than a military-scientific base—there was nothing else like it at the time—Camp Century was often referred as “the city under ice.” US Army leaders certainly tried to make life there as comfortable as possible. George Washington University’s Human Resources Office, under contract to the Army, assisted in applying the results of human factors research to aid camp officials in reducing irritating pressures on the isolated men. The promotion of Camp Century as a subsurface small town in the Arctic also provided the Army with the opportunity to downplay its military significance. In books, films, and articles, Camp Century was often presented as “a cool but comfortable American community in miniature [...], purely a research base, designed to permit year-round studies of weather and snow in a highly strategic area.”⁴⁰

COPENHAGEN SCRUTINIZES PRESS REPORTS

An informal supplement to the 1951 agreement concerning the defense of Greenland required that the US State Department and Denmark’s Ministry of Foreign Affairs would agree that all publications relating to US military operations in Greenland had to be submitted to the Danish Embassy in Washington, DC, for prepublication review. The embassy would forward materials to Copenhagen for comments and recommendations that would be returned to the authors. This agreement stipulated that all articles about—and photographs of—Greenland would be made available to Danish journalists at no cost. Unsurprisingly, American journalists were unhappy with this arrangement. At a 7 February 1957 meeting, US Embassy staff members in Copenhagen informed leading officials from the Ministry of Foreign Affairs that American journalists were complaining about the prolonged processing time by Danish authorities. Arguing that the US and Denmark had mutual interests in the arrangement, Danish officials responded that “it was very important not to give the Danish public the impression that the US has taken over parts of Greenland, not the least since this could provide an anchor for anti-American sentiments.”⁴¹

The Danish authorities expressed concern that the flow of information from Greenland to Denmark was more or less entirely dominated by the Americans. In response, in summer 1957, US authorities agreed to invite about ten journalists from Danish newspapers, news agencies, and the national broadcasting corporation to Greenland.⁴² All transportation and

most of the expenses for the trip were to be borne by US government, except for when the journalists were visiting parts of Greenland outside the defense areas. Sigvald Kristensen, Public Relations Officer, Ministry of Foreign Affairs of Denmark, noted that from the American activities the Danish public might get the idea that “Greenland in reality was American territory.”⁴³ He added that a wholly American invitation to the Danish press might open up a public debate as unfavorable to the US authorities as to the Danish ones. Consequently, the draft for the invitation to the Danish press was signed by Norman Nordstrand, Press Relations Officer, US Embassy, and by Sigvald Kristensen on behalf of Ministry of Foreign Affairs of Denmark.⁴⁴ For reasons unknown, the invitation was postponed until May 1960, when about 20 Danish journalists visited Thule AB and Camp Tuto.⁴⁵

In summer 1959, when Danish authorities realized that Camp Century would be built whether they granted permission or not, they tried to stop all “indiscrete” releases of information pertaining to the facility, including its strategic significance and the presence of its nuclear reactor. This strategy proved to be untenable, especially after the US Army launched its publicity campaign about the unusual project. The public relations initiative formed part of a wider campaign to “sell” the Army as an important service in the wake of budgetary cuts and inter-service rivalry.⁴⁶ Many journalists and one television crew—led by prominent CBS reporter Walter Cronkite—were invited onto the icecap to visit the city under ice. On 22 January 1961, CBS screened the episode about Camp Century, called “City Under Ice,” as part of Cronkite’s *The Twentieth Century* show.⁴⁷ The US Army also produced a 30-minute feature about Century—broadcast in 1961 as part of the Army’s “The Big Picture” series, which ran on ABC-TV from 1951 to 1964.⁴⁸ In 1964, after Camp Century had been prematurely closed down during the winter season, the color footage was used in the Army’s Research and Development Progress Reports with an added introduction explaining the location and purpose of Camp Century.⁴⁹

Whether American journalists and writers liked it or not, Danish authorities did review and comment on their Camp Century stories before they were released for publication. For example, writer Walter Wager arrived at Camp Century in early spring 1960 to gather information for an article that appeared later that year in *The Saturday Evening Post*.⁵⁰ What the magazine’s readers did not know was that Denmark’s Ministry of Foreign Affairs, in consultation with the Ministry of Defense and the Ministry of Greenland, had recommended three significant changes to Wager’s original manuscript: “the remarks on page 1 about the location of missiles, on

page 13 about the ownership of Denmark over Greenland, and on page 14 where the Greenlanders are referred to as Eskimos.”⁵¹ While the latter two comments referred to factual errors, the first comment required that Wager *delete an entire section of the article*. Wager’s original text had left no doubt about the future military applications of Camp Century—a genuine threat to the credibility of Danish officials regarding Danish security policy:

In the future, similar Arctic tunnel-clusters may house rocket batteries to knock down enemy bombers and ICBMs heading over the North Pole towards the United States; they may also house planes and paratroopers of crack airborne teams assigned to wreck launching pads and H-bomb depots in aggressor territory, or American long range missiles ready for instant retaliation. Invisible to both aerial and radar reconnaissance but constantly cocked like an ever-ready Sunday punch, they could seriously discourage any power-crazed foreign regime considering another Pearl Harbor. Some optimists feel their existence may even prevent World War III.⁵²

We do not know how Wager received and responded to Copenhagen’s comments. Also, we have no information about how the Army ensured that there was no sensitive information in public features about Camp Century. However, we do know that Wager did make the changes requested by Copenhagen. The published article says nothing about Denmark owning Greenland, nor does it mention Eskimos. Most importantly, the section quoted above was extensively edited to make it much more neutral: “In the future, lessons learned at Camp Century could be applied to other regions of the Arctic if the need ever arose to build additional early-warning or air-defense facilities at locations where extensive operation is now impossible.”⁵³

Other reports about Camp Century also experienced the effects of Danish and US censorship. For instance, Italian journalist Luigi Romersa, writing for the magazine *Il Tempo Illustrato*, had visited Greenland in autumn 1961. His original November 1961 manuscript—preserved in the Danish National Archives—also became a concern to Copenhagen, particularly officials at the Ministry of Greenland. In his introduction, Romersa stated that several US military bases were “scattered over the 1,726,240 square kms of Greenland, but the most important of all is the so-called Camp Century, a gigantic anti-atomic fortress, dug deeply like a catacomb below the ice, near the Pole.”⁵⁴ The statement was seen as potentially dangerous in the hands of the Soviet Union or Danes opposed to NATO. If the Soviets were led to believe that Camp Century was “a gigantic anti-atomic fortress” and that US bases lay “scattered” all over

Greenland, they might feel obliged to react sharply again, just as they did three years before when Denmark acquired Honest John and Nike missiles (see above). Moreover, the statement might also inflame anti-American sentiments in the Danish public. Therefore, the Ministry of Greenland recommended that Romersa correct the mistakes, because the purpose of Camp Century “first and foremost is scientific and that, at least, to call it ‘a gigantic anti-atomic fortress’ is deceptive.”⁵⁵

As time passed, Danish efforts to rein in narratives about American activities within and outside defense areas in Greenland became increasingly unrealistic. Journalists did not like having their articles reviewed, and worked to circumvent the process. Moreover, the information culled from one story by Danish and US authorities might appear in another. As a result, the Ministry of Foreign Affairs terminated the arrangement in 1963. Journalists and writers visiting Greenland could produce whatever they wanted without being concerned about comments from Copenhagen, even though they probably still needed to respond to US censors. In the meantime, a dramatic development was taking place at the US Defense Department that would have consequences for the city under ice.

ICEWORM MELTS—CENTURY IS CRUSHED

Shortly after taking office in January 1961, President John F. Kennedy initiated a review of American nuclear strategy. Kennedy and his advisers wanted to break with Eisenhower’s massive retaliation strategy, send MAD to the dustbin, and create a more flexible response to Soviet aggression. The review included a thorough examination of the costs of the proposed US Long- and Medium-Range Ballistic Missile systems, including Minuteman, Iceworm, and Polaris. In February 1962, a small study group convened by the Department of Defense at the request of Paul Nitze, Assistant Secretary of Defense for International Security Affairs, completed the 34-page review of Iceworm.⁵⁶ Henry C. Ramsey of the State Department’s Policy Planning Staff, chairman of the study group, communicated the study to the Chief of the State Department’s Policy Planning Council, Walt W. Rostow, who transmitted it to Deputy Secretary of State Foy Kohler. In his cover letter, Rostow wrote that the group’s study “concludes that Iceworm has very attractive possibilities as a NATO system and that it is possible to obtain Danish acquiescence and association in the system if further evaluation confirms that the military premiums are as high as they now appear to be.”⁵⁷ Unsurprisingly, given

“her subjective aversion to all matters nuclear,” Denmark was seen as the major obstacle for the implementation of Project Iceworm.⁵⁸ The full force of neutralist and pacifist attitudes latent in Denmark and the rest of Scandinavia probably would be summoned against the concept, and the Danish government would have serious political difficulties in squaring Iceworm with its policy of not allowing nuclear weapons on its “metropolitan territory in peacetime.”⁵⁹ Seemingly unaware of the controversy in the Danish government about the nuclear reactor at Camp Century, the study group speculated: “Denmark, however, might not apply this policy to Greenland.”⁶⁰ Concluding that Denmark, after all, might acquiesce to Project Iceworm, the study group argued: “If it could be clearly demonstrated that Iceworm would contribute materially to the survival of Denmark and her NATO allies, the Danes might take the plunge.”⁶¹

Little is known of the events that followed, but the Iceworm, Minuteman, and Polaris systems were further evaluated for cost and feasibility. In 1963, Defense Secretary Robert S. McNamara canceled Project Iceworm while retaining the Minuteman and Polaris missile systems. Although Iceworm had received a positive review, in addition to cost, the Air Force and Navy fiercely opposed it, and Danish concerns about nuclear weapons on Danish territory and maintaining sovereignty over Greenland did have to be considered. Moreover, there were technical problems that needed to be solved before Iceworm could become operational.⁶² First, officials did not know whether Minuteman missiles could be modified to operate at -11°F . Second, problems with tunnel deformation at Camp Century raised doubts about the feasibility of maintaining Iceworm’s several thousand miles of proposed tunnels. Indeed, most of the tunnels—especially the one where the PM-2A nuclear power plant had been installed—were closing rapidly. Consequently, trimming snow from the tunnels was absolutely necessary for the camp’s survival, but the cost would be too high.⁶³

Camp Century’s rapidly deforming tunnels, and Iceworm’s cancellation, were the major reasons behind the Army’s decision to discontinue year-round operations in Greenland in 1963. During summer 1964, workers disassembled the nuclear power plant, removed it from the camp, and sent it back to the USA. The Danish Atomic Energy Commission supervised the operation, which, except for the discovery of considerably higher than expected levels of residual radiation around the primary unit, seemed to have proceeded as planned. Per the agreement between the Americans and the Danish Atomic Energy Commission, all solid waste was removed from Greenland and disposed of in accordance with Danish regulations,

that is, placed in concrete casks and dumped into designated locations in the ocean or deposited in designated burial grounds in the USA.⁶⁴

Veteran *New York Times* science journalist Walter Sullivan—who had published a major book on the International Geophysical Year of 1957–58 and was intimately familiar with Arctic research—explained to readers that the camp had been “squeezed out of existence” due to the “inexorable compression of Arctic snows [...] shrinking the reactor tunnel.” He concluded:

Camp Century has largely served its purpose [...] Today such bases seem less necessary. Polaris submarines that can keep constantly on the move beneath the polar ice appear far more reliable. Furthermore, the only ice-covered region in the North is Greenland, which is Danish territory. The Danes are very sensitive about American activities here.⁶⁵

Weapons systems technologies proved decisive. In summer 1966, the US Army abandoned Camp Century. Valuable material was transported to Thule AB, and then on to the USA. Everything else was left in the trenches, buried under the icecap. In late May 1969, an Army team visited Camp Century to do a pictorial study of the dramatic effects of trench closure. They found that the snow load was deforming metal arches, and crushing wooden structures and the steel reactor building. By including five photographs made in 1960 and 1962, they were able to compare the conditions in 1969 to those of the earlier period. The photos showed that where men had been able to walk upright, only crawl space remained. Snow had encroached upon most buildings. Camp Century, once a city under ice and a prime example of the endless frontier of science and technology applied to Arctic conditions, had been turned into an imploding ghost town.⁶⁶

NOTES

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Cold War Greenland as a Space for International Scientific Collaboration

Henrik Knudsen

On 27 June 1968, Danish Prime Minister Hilmar Baunsgaard met with two of his government ministers and discussed several projects proposed by the US military that would take place in Greenland. They accepted all but one: a spectacular space research project that would involve launching rockets from Thule Air Base, the largest single scientific project that had been proposed for Greenland. This event is a reminder that research activities in Greenland and throughout the Arctic—despite the highly publicized success of the International Geophysical Year (IGY)—were subject to strict political regulation. Government officials exerted political authority by setting down boundaries, which led to approval or disapproval of requests. The “whys” and “hows” behind these decisions provide insight into geopolitical rationales that shaped research activities in the Arctic during the Cold War. To be successful, geophysicists working in Greenland had to learn how to maneuver within extant political constraints.

Denmark and the USA had different, sometimes incompatible, reasons for restricting international research in Greenland. The Pentagon’s strategic interest in Greenland stimulated both a hectic schedule of military research activity and a firm interest in keeping Eastern Bloc scientists out, while Denmark sought to balance its allegiances to the USA, its inclination

H. Knudsen (✉)

The Danish National Archives, Viborg, Denmark

for détente politics, its endless sovereignty concerns, and its desire to avoid media attention to US military activities in Greenland.

Scientific diplomacy and the role of scientific internationalism in the Cold War have received considerable attention in recent years, but the changes in international science policy brought about by emerging détente politics from the 1960s on have received comparatively little attention.¹ Events in Greenland during this period offer new insights into these transformations.

THE VIEW FROM WASHINGTON

In early 1964, a US State Department Science Office (SCI) memorandum fleshed out the possibility of an Arctic Treaty similar to the Antarctic Treaty of 1959, an idea being vigorously pursued by the influential Canadian–American geographer and Arctic expert Trevor Lloyd, who sought to increase scientific cooperation in the region.² The memo met with “uniformly negative responses,” and the Science Office was left trying to convince State’s leadership that it was not trying to “demilitarize and denuclearize the Arctic Regions.”³

Several months later, SCI—now backed by the National Science Foundation (NSF)—tried again as it renewed a call for coordinating Arctic research and international collaboration in Arctic sciences, even including scientists from both the USA and the Soviet Union. Such measures might help “lessen cold war rivalry,” SCI argued.⁴ But State’s Office of British Commonwealth and Northern European Affairs (BNA) was emphatically negative. The desk officer for Denmark and Norway, Eric Youngquist, explained, “Because of the strategic sensitivity of the Arctic area [...], BNA would have to reserve its position on any arrangement in the Arctic which involved the Soviet Union until it was clear what its impact would be on our defense posture there.” Acknowledging the presence of vital US defense installations in Canada and Greenland and DOD’s strategic interests and foreseeable opposition, Youngquist concluded that “BNA would be loathe [sic] to agree to any arrangement which might encourage Canada or Denmark to permit Soviet ‘scientists’ increased access to their territories. It is questionable whether the U.S. gain from scientific cooperation with the Soviets would be sufficient to counterbalance the possible weakening of our defense posture or hindrance to future defense activities which such cooperation might cause.”⁵ With similar arguments, BNA Director J. Harold Shullaw also opposed NSF Director Leland Haworth’s 1965 proposal to promote limited US–USSR scientific cooperation (primarily in the biosciences) in the Bering Strait.⁶ As

these two examples suggest, international scientific collaboration in the Arctic remained firmly subsumed under the priorities of the national security state.

In addition to military–strategic considerations, the BNA argued that including Soviet scientists in Arctic exchange visits might lead to the Scandinavians permitting excessive Soviet access to areas of strategic interest such as Greenland, especially if Scandinavia’s pursuit of détente resulted “in giving the Soviets unwarranted concessions.”⁷ The subsequent proposal from SCI about Arctic collaboration left out the Soviet Union and focused exclusively on cooperation with Canada and the Scandinavian countries.⁸ What these examples suggest is that the State Department saw international scientific collaboration in the Arctic as a threat to US defense posture in the northern regions and hegemonic relations with Scandinavian countries.⁹

What triggered Youngquist’s opposition? In May 1964, the Danish government had invited two Soviet geologists to Greenland, thus testing the US position on such visits. The invitation was extended on behalf of Danish geologist Henning Sørensen, who desired the help of Soviet colleagues as he explored the geology of the Ilímaussaq region in South Greenland, home of the island’s only known uranium deposits.¹⁰ The Danish Ministry of Foreign Affairs opted to support the invitation.¹¹ Conscious of the State Department’s views on Soviet visits to Greenland and its interest in being informed, and the ministry’s desire to “avoid possible misunderstandings,” the Danish Ministry of Justice informed the State Department of the decision. A Danish diplomat confirmed that the invitation had been “extended by the Danes, and not on Soviet initiative, and that the visit would take place far from any American defense areas.” He also made clear that this invitation should not “be interpreted as any sort of an opening wedge for other Soviets to travel to Greenland.” The Russians would only be admitted to the Ilímaussaq area, and they had to be accompanied by professor Sørensen or one of his associates during their entire stay in Greenland.¹²

Soviet authorities were hesitant to sanction the scheme. Nevertheless, these were early days of European détente, when Khrushchev sought a tentative rapprochement with the West, and major European nations began to explore possibilities of easing Cold War tensions.¹³ The conservative Danish newspaper *Berlingske Tidende* saw the invitation as a test of Soviet commitment to détente. Before Khrushchev embarked on his official visit to Denmark on 16–21 June 1964, the newspaper challenged him to help create a political thaw in the Arctic, and Danish officials brought

the invitation to Khrushchev's attention during the visit. Three days later, the two Soviet geologists arrived in Copenhagen.¹⁴ *Détente* was a central theme in Sørensen's agenda and his public writings about the visit echoed Khrushchev's rhetoric of peaceful coexistence.¹⁵

The invitation must be seen as a significant opening toward the Soviet Union. Less than two years before, in summer 1962, Denmark had denied the Polish Academy of Sciences' request for access to Greenland's ice cap because the expedition would have taken place not far from US defense facilities. The Danish Ministry of Defense vehemently opposed the expedition, pointing to the danger of an Eastern Bloc scientist who might intercept sensitive communications. In this case, too, Washington was kept apprised of Danish decision-making, and enthusiastically supported the position of the Danish Ministry of Defense.¹⁶

What tipped the balance, and made this first instance of East–West collaboration in Greenland possible, was the tentative thaw in the Cold War in the mid-1960s.¹⁷ Denmark and other Nordic countries were strongly committed to this development, and their neutral leanings were a principal concern in Washington. Soviet geologists made more visits to Greenland in 1968 and 1969, that time working only 150 km from the US Air Base in Sondrestrom. Not even the Soviet invasion of Czechoslovakia in 1968 disrupted these visits.¹⁸ Opening up Greenland for scientific activities was succinctly described by the Ministry of Foreign Affairs as a “way to counter balance the dominance of American activity in Greenland.”¹⁹ With a low-key effort, Denmark effectively opened up Greenland for Eastern Bloc scientists and East–West cooperation—if not on a full scale, then certainly in a very symbolic way.

DENMARK: BETWEEN DÉTENTE AND DETERRENCE

Danish historian Nikolaj Petersen has singled out five main attributes of Denmark's policy on American research in Greenland from 1951 to 1968. To avoid criticism from opponents of Denmark's association with the US strategic deterrent, Danish authorities shunned publicity about US military research in Greenland. They also insisted on respect for Denmark's authority and its *de facto* sovereignty over Greenland. In addition, Denmark banned contact and fraternization between American servicemen and the indigenous population. The objective was to keep Americans inside defense areas and away from populated coastal regions.²⁰ Denmark also aimed to assist and protect Danish research in Greenland, since these activities were key instruments used to underpin Danish sovereignty and

authority. And lastly, the Danish government sought to be as amenable as possible to American requests due to Denmark's security link with Washington.²¹ I argue that research projects in Greenland also had to be compatible with the overall aims of Danish security policy and specific Danish views on the arms race.

Danish policy toward US military research projects in Greenland underwent significant changes in the 1960s. Writing to a US Defense Department colleague in 1959, the State Department's Foy Kohler commented, "Despite occasional delays and minor modifications, I think it is fair to say that the Danish Government has been very cooperative and that we have been able to do everything we really wanted to do in Greenland."²² Speaking on the same issue in 1959, US Ambassador to Denmark Val Peterson quipped that the Danes "will give us just about anything anytime."²³ But a decade later, a much more critical attitude pervaded diplomatic interactions over American military scientific projects in Greenland. The Danish government was requesting detailed information on individual projects, and expected to be briefed thoroughly by relevant military services before approving projects. This annual briefing took place within the Kommissionen for Videnskabelige Undersøgelser i Grønland (KVUG), the Commission for Scientific Investigations in Greenland, a select governmental body consisting of scientists and administrators. In addition to keeping track of American intentions, the Greenland Ministry wanted a mechanism that could help increase participation by Danish scientists in American projects. Simultaneously, Danish scientists were raising concerns about a number of cases where American scientists working in Greenland had not limited their work to the approved military-scientific projects, but were also conducting basic scientific investigations that overlapped and competed with those of Danish scientists.²⁴

At first this approval procedure looked a lot like automatic rubber-stamping, and was described as such by Trevor Lloyd,²⁵ but gradually the Danes began to put more teeth into it. In 1967, the US Army failed to send a representative to the annual briefing. When confronted by KVUG chairman (and former Permanent Under Secretary for Greenland) Eske Brun, the US Embassy's representative "speculated that perhaps the Army had not thought it necessary to brief the commission about purely on-going projects." An obviously disgruntled Brun replied, with more than a touch of irony, that projects were "not 'on-going' until they [were] approved by the Government of Denmark." "Catastrophe was very narrowly avoided by the last minute efforts," the US Embassy noted in an

off-the-record account of the meeting.²⁶ And in summer 1968, the State Department complained that the Danish Ministry of Foreign Affairs had become “hypersensitive” regarding projects in Greenland.²⁷ The B-52 crash in January 1968 was responsible for much of this change of sentiment, but scientific–diplomatic relations had begun to deteriorate long before this accident—as we shall see.

What caused the fraying of this apparent harmony and when did it happen? Again, SCI’s aborted preparations for an Arctic treaty in 1964 offer important clues. While Denmark cooperated with the USA in Greenland, an SCI official noted, “they have shown themselves very sensitive to the Soviet menace and anxious to reduce cold-war tensions by minimizing that military cooperation and deliberately emphasizing non-military activity in Greenland.” He pointed out that following the U-2 incident in 1960 and Khrushchev’s threat of retaliation against bases supporting U-2s, Danish officials had seemed concerned over US bases in Greenland. Eske Brun had told a US official that the Danish government now wished to emphasize nonmilitary aspects of Greenland. According to Brun, “recent international events in the north had led to some Danes questioning the U.S. presence in Greenland.”²⁸ Brun was probably referring to the construction of Camp Century in 1959 (See Chap. 9), which triggered political discussions on how to increase Danish control over US military activities in Greenland, as the B-52 crash at Thule did later on.²⁹ Thus, starting in the early 1960s, the Danish government invested more effort in controlling and containing American research activities in Greenland, actively seeking to avoid both projects and publicity on projects that might provoke the Kremlin and derail détente, or arouse criticism from domestic left-wing parties. Sovereignty concerns had made Danish control of US research activities in Greenland imperative since the 1940s, but in the 1960s, broader political perspectives on the arms race and détente began to shape policy. Two large American research projects provide examples of how this worked in practice.

POLAR CIRCLING BALLOON OBSERVATORY

In the early 1960s, University of Minnesota physicist John R. Winckler developed the concept of a Polar Circling Balloon Observatory for the 1964–65 International Years of the Quiet Sun (IQSY). Known as Project POCIBO, Winckler envisioned a comprehensive investigation of the upper atmosphere at the polar cap by using balloons—extraordinarily

large Skyhook balloons containing some 42,000 cubic meters of lifting gas—circulating within the polar vortex during the Arctic winter. The primary goals were to investigate the interaction of cosmic rays and Earth's magnetic field at high latitudes and to gather data on electron precipitation, which is the cause of the aurora borealis. The balloons would also collect data on atmospheric circulation and ozone distribution. To enter the vortex, balloon launchings would have to take place as close to the geographic North Pole as feasible, for example, from Thule or Svalbard. Discovered during the IGY, the polar vortex was still not fully understood, and Winckler admitted that the path of these balloons was subject to uncertainty, writing that the balloons might drift “in a westerly wind and might cross the territory of the Scandinavian countries, the USSR, the United States and Canada.” NSF funded this civilian, basic science project, and Winckler, desiring a truly international collaboration, hoped to get Soviet scientists onboard. Soviet scientists were invited to track the balloons and receive data transmitted via radio. The balloons should “be launched from a site in the far Arctic which is accessible to scientific participants of all nationalities,” Winckler stressed in his invitation to the Soviet geophysicist Sergei Vernov.³⁰ What Winckler neglected to mention was that during the Cold War few places in the Arctic met that requirement.

Project POCIBO was conceived as part of the IQSY program and accepted as such by the US national committee. Signs of Soviet disapproval began to surface in fall 1962 when the invitation to Vernov went unanswered for months. The Cuban Missile Crisis unfolded during October 1962, and scientific relationships became even touchier. Immediately after the crisis, leading American geophysicists wrote privately to their counterparts in the Soviet Union as they tried to assist Winckler.³¹ The key words used by these scientists to lure the Soviets into cooperation were *basic science*, *international*, and *collaborative*.

A significant setback occurred when the General Assembly of the IQSY met in Rome in March 1963. During informal conversations, Soviet cosmic ray physicist Alexandr Chudakov advised that POCIBO not be proposed officially as an IQSY-related project because the Soviet Union would oppose it. Privately, Chudakov told Winckler that a direct answer from the Soviet Union could not be given due to the complexity of the issues. He candidly pointed to “the fact that balloons had been flown over the USSR previously and that exhibits had been shown in the USSR of camera equipment carried on the balloon flights overflying Soviet territory.” Chudakov added that it would be impossible to distinguish POCIBO bal-

loons from “other balloons which might be flown at the same time by others,” that is, reconnaissance balloons. The Soviet Union suggested that that the program be implemented in the Antarctic regions instead of the Arctic, in which case Soviet cooperation might be achieved.³² Thus, Soviet scientists and their leaders feared that a scientific balloon campaign in the Arctic could disguise secret espionage missions.

Obviously, Chudakov was referring to an incident in 1956 when the Soviet Union had protested about the considerable number of Skyhook-type reconnaissance balloons overflying its territory and had shot a large number of them out of the sky. The balloons were a fraction of some 2500 that were to be launched from air bases in Norway, Scotland, West Germany, and Turkey during the clandestine Project Genetrix, which was created to collect intelligence about Soviet nuclear tests. Due to Soviet success at finding and shooting down the balloons, the plan that had been authorized—and was eventually terminated—by President Dwight Eisenhower ended after only 448 of the balloons had been launched. Eisenhower, no fan of Genetrix, was convinced that the risk was too high compared with the gains. “Time after time Eisenhower would say that if the Soviet were to do the same, the U.S. would be on the brink of war. He felt and feared the Soviets would react in a similar manner,” writes historian Curtis Peebles.³³ And besides, the balloons were on their way out as the much more efficient U-2 spy planes were coming on line. Facing international controversy, Washington for years maintained the cover story that these balloons were nothing more than weather balloons, but all it did was discredit science and become a detriment to future scientific balloon operations, especially in the politically sensitive Arctic. Chudakov’s reservations, therefore, appear justified.

Meanwhile, the State Department went ahead with plans to launch the balloons from selected Arctic sites without Soviet acceptance. Without seeking bilateral agreements from countries that might be overflown, State intended to launch them from remote outposts “and let them fly freely as long as they stay[ed] above [an altitude of] thirty kilometers.” This short cut would avoid the receipt of an official negative reply from the Soviet Union, and avoid the cumbersome process of gaining support from all Arctic nations, which “would almost require a UN type of agreement.” The State Department hoped to circumvent what they rather patronizingly termed the Soviet “allergy to balloons,”³⁴ but this unilateral shortcut made the unauthorized project problematic to host countries. Thule Air Base was Winckler’s preferred launching site, although he also considered

Svalbard and Andoya. In autumn 1963, the Americans sought permission from Denmark to launch 50 balloons from Thule beginning in January 1964. The application explicitly stated that none of the balloons would carry photographic equipment—an effort to counter suspicion that the project involved secret surveillance.³⁵ Scientific institutions in Denmark unanimously recommended the project, but did not want to participate. The Danish Meteorological Institute's director found it “regrettable that no collaboration has been established with Russia, since it can hardly be avoided that balloons will enter Russian territory.”³⁶ The Danes declined the request, expediting the response through official channels just as Danish Foreign Minister Per Hækkerup prepared to make an official visit to the Soviet Union.

The rejection was based on considerations about foreign and national security policy. The Danes were worried about Soviet disapproval and the likelihood that the balloons would enter Soviet airspace and create what officials termed a “balloon episode.” If an overflight occurred, the Ministry of Foreign Affairs assumed that the Soviet Union would (1) try to shoot down the balloons; (2) protest against the balloons, likely by “comparing the launch of balloons with U2 flights”; and (3) put forward new “charges against Denmark for having renounced its sovereignty over Greenland since the Danish-American defense areas in Greenland are utilized for war animating purposes.”³⁷ This political risk analysis reflected the cautious, non-provocative attitude that Denmark, a small state bordering the Eastern Bloc, followed throughout the Cold War, and highlighted the government's feelings of vulnerability to any charges that it had lost sovereignty over Greenland. Wider concerns about the arms race and peace policy also influenced the decision. The ministry thought it likely that the Soviets would use a “balloon episode as an excuse to reverse the détente policy, which has been a prominent feature in the East–west relations the last months.”³⁸ The ministry gave primacy to progress in its détente policy when weighed against the needs of the American research community.

Furthermore, the Danes did not accept the State Department's promise that the balloons would not carry photographic equipment: “We have no means of assessing the military significance of these balloons and consequently cannot rule out such a role or even Soviet suspicion in that direction.” The document continued: “I find the possible consequences [...] quite daunting and see in our general defense cooperation with the United States no sufficient reason that we should take any risk of this kind.”³⁹ The Danes appeared to have been worried about the possibility

of unintentionally taking part in espionage over Soviet territory—a grave issue, since spying in peacetime can be considered an act of war.⁴⁰

These confidential deliberations were not included in the official Danish reply of 18 November 1963,⁴¹ and this disapproval was not as definitive as one might think. The ministry added that its reservations would be waived if the USA secured Soviet acceptance. However, the Danes did not expect the Americans to seek such acceptance since the Soviets most likely would have demanded the right to inspect the balloons before they were launched. The ministry considered it unlikely that the Americans would tolerate the presence of Soviet scientists at Thule.⁴²

In retrospect, the early 1960s was a frictionless “golden period” in the Danish–American relationship, marked by warm relations built upon the alignment of a number of international political goals. However, compared to the Americans, the Danish government tended to emphasize the goals of détente and bridge building with the Eastern Bloc, a difference in opinion that became pronounced after the Cuban Missile Crisis.⁴³

However, the POCIBO effort did not die because US scientists renewed their efforts to secure Soviet acceptance. In December 1963, American physicist Paul Kellogg had learned from Chudakov that “the Soviets were not completely opposed to the project and that at Rome they had felt they had not had sufficient time to discuss the project so they had intended merely to delay its endorsement.” Given the nature of the Soviet political system, this makes sense. Soviet scientists had gone to a subsequent Committee on Space Research (COSPAR) meeting in Warsaw prepared to discuss the project, but project members did not attend. According to Chudakov, Soviet scientists were interested in receiving data from the balloons.⁴⁴ To exploit this opening, US IQSY Committee chairman Martin Pomerantz tried to reopen the issue by approaching the USSR Academy of the Sciences, an effort soon halted by Nikolay Pushkov. The influential doyen of Soviet geomagnetism and Communist party member confirmed in early 1964 that Soviet scientists were indeed interested and, in principle, willing to participate in the project. However, he added, “a serious obstacle to the carrying out of the planned experiment is the systematic launchings over the territory of the USSR from the West of balloons with intelligence cameras or propaganda materials of an anti-Soviet character. The appropriate agencies of our country are compelled to take the necessary measures against this.”⁴⁵

With access to Thule permanently blocked, Winckler turned to Plan B. During winter 1964, he launched three balloons from Barrow, Alaska.

All of them failed. At an early stage, the project had caught the attention of Norwegian physicist Harald Trefall of the University of Bergen. Due to his efforts, four balloons were launched from Andoya, an island off the northwestern Norway coast, during summer 1964. Summer launches were not ideal, since the altitude of the balloons would fluctuate due to the warming effect of sunlight. After all these launches failed, Winckler gave up the POCIBO project, citing the political problem of finding a suitable winter launch site. He admitted that “little or no scientific return” had come from the \$526,000 expended on the project.⁴⁶

The Danish decision created a precedent. Three years later, Martin Pomerantz and the US Air Force sought to collect data on cosmic ray intensity at the top of the atmosphere by means of balloons launched from Thule. Again, Danes reacted skeptically and pointed to the risk of unauthorized overflights of Soviet territory. The legacy of the Genetrix project and its cover story once again came back to haunt the Air Force. Unaware of the historic precedent, or perhaps just tone deaf, the persistent Danish reluctance came as a surprise to Pomerantz and his associates, who traveled to Thule in summer 1967 only to learn there that acceptance had not been granted.⁴⁷ Following a number of objections from Eske Brun, the Air Force decided to install a mechanism that would limit flight time to eight hours, which corresponded to an estimated maximum distance of 1200 miles from the base. According to the Americans, this mechanism would ensure that the balloons would remain outside of Soviet airspace in at least 99% of the flights. By late 1967, the Danish government finally approved the project, but the Americans then decided to transfer the project to Antarctica because, according to Danish sources, Denmark was demanding full liability in case of damage to people and material. The US Air Force, however, claimed that the project had been removed from Thule in order to “mollify matters”: a political move made to ease the acceptance of another project that also had come under close scrutiny within the Danish administration: Operation PCA.⁴⁸

ROCKETS OVER THULE? OPERATION PCA 1968

On US Independence Day 1968, the front page of Denmark’s premier newspaper, *Politiken*, reported the beginning of a joint Danish–American “grand rocket program” on Thule AB. The project would investigate the “splendid natural phenomena” of sunspots and solar particle emissions that affected the polar ionosphere, in particular the phenomenon of polar cap

absorption (PCA), which frequently hindered radio communication in the Arctic. Enthusiasm and national pride ran high in Denmark. Participation in the large PCA project, which *Politiken* reported would include no less than 50 rocket launches (actually 34), meant that Denmark's fledgling space research activities would reach a new level. Soviet scientists would participate in the project from a station in the Antarctic, the article claimed, leaving no doubt that this was a truly international scientific project consistent with Danish détente politics and scientific internationalism. The ink was barely dry when the next day *Politiken* reported that the Danish government had called off the American part of the effort, at least for 1968, in effect ending the entire project.⁴⁹ Despite intense public debate, the decision was not reversed. What was the nature and purpose of this project? Why ban this joint venture after announcing it? What drove the Danish government to such a dramatic decision?

In November 1967, the US Embassy provided the Danish government with an outline of military scientific activities planned in Greenland during 1968, including two large rocket projects—later known as Operation PCA 68—to be carried out from Thule during the autumn. The embassy specifically requested early approval for these projects, the aim of which was to elucidate “problems of radar and communication systems operating through a nuclear disturbed atmosphere. Certain natural disturbances in the ionosphere can be used to study problems of a nuclear disturbed atmosphere. A polar cap absorption (PCA) event is an ideal opportunity to study the lowest part of the ionosphere.”⁵⁰ James Ulwick, of the Air Force Cambridge Research Laboratories (AFCRL), an institution with world-leading expertise in upper atmosphere physics and extensive research activities at Thule, was in charge.⁵¹ The justification for the \$10 million price tag: “To better understand nuclear weapons’ effects in the upper atmosphere, more complete knowledge is needed of the atmospheric chemistry, coupling mechanisms between the expanding fireball and the ambient air, causes of debris distribution and high altitude plasma-magnetics. Certain natural disturbances offer an ideal opportunity to gain information about the physical chemistry in the disturbed lower ionosphere. [...] These data will be used to develop a model of the disturbed ionosphere. Extrapolation can be made to higher energy levels to develop a more accurate model of the nuclear fireball and the highly disturbed ionosphere.”⁵²

The project was funded by the Defense Atomic Support Agency (DASA), a Pentagon agency dedicated to nuclear weapons research and testing to assess the effects of nuclear explosions on weapon systems.⁵³

Several spectacular high altitude nuclear tests (e.g., TEAK and STARFISH PRIME) conducted in the late 1950s and in 1962 had demonstrated severe impacts on electromagnetic systems, including the blackout of shortwave radio and the degradation of radar. Information on such effects was critical to military experts facing the delicate task of planning a thermonuclear war using intercontinental ballistic missiles (ICBM), and for assessing the feasibility of the antiballistic missile (ABM) systems under development by both superpowers in the 1960s. The military wanted a communication system that could survive a nuclear attack and continue to operate in a nuclear blackout environment jam-packed with fission fragments and ionizing radiation. The available toolkit for such R&D work was radically reduced in 1963 when the USA, UK, and Soviet Union agreed to the Limited Test Ban Treaty, which banned all except underground nuclear testing. Starting in 1962, DASA's research program gave priority to studies of natural phenomena such as aurorae and polar cap absorption (PCA), whose effect on the ionosphere resembled that of nuclear bursts. PCA is caused by energetic protons emitted from active sunspots that penetrate deep into the atmosphere in the polar regions. In lieu of actual testing, PCA can be used to gain information about nuclear effects. Researchers were interested in solar particle-induced disturbances of the lower part of the ionosphere (60–90 km above Earth's surface) and the effects of disturbances on radar and very low frequency (VLF) systems. DASA and its advisors had been developing plans for such studies since the early 1960s.⁵⁴ However, they had to wait until the late 1960s for the next peak in solar activity and they had to develop specialized probes.

Operation PCA 68 was a comprehensive cluster of interrelated projects that used rocket measurements, satellite data, flying laboratories aboard two huge Boeing KC-135 aircraft, and additional ground-based measurements—an advanced research infrastructure bearing testimony to the Pentagon's deep pockets and ability to increase the level of technological sophistication in polar science. The project made use of several Defense Department contractors who had taken part in high altitude nuclear testing in the Pacific, its organisation and structure closely resembled that of a nuclear test.⁵⁵ In fact, Operation PCA was going to be AFCRL's biggest field operation since the time of tests in the Pacific Ocean theatre. These similarities were noted by AFCRL Commander Colonel Dale J. Flinders, who pointed out that “[t]he same general types of instrumentation were involved [...] because the environmental effects of high-energy charged particles from a nuclear explosion are much the same as those from ener-

getic solar protons. A PCA event provides a kind of simulated nuclear explosion in the atmosphere.”⁵⁶ The Pentagon was preparing to use the atmosphere above Greenland as a nuclear laboratory.

Was this an international project as the Danish newspaper *Politiken* had claimed? Soviet scientists were not participating, but Danish scientists from the Ionosphere Laboratory had a limited stake in the project, albeit not one that can be meaningfully termed as scientific cooperation. During 1967, the Ionosphere Laboratory had been busily preparing its own PCA experiments to be conducted from Thule in 1968, with Danish instruments being piggybacked on the Air Weather Service’s Arcas rockets that were launched from Thule. Details about the new DASA/AFCRL project reached Danish scientists by Christmas 1967, too late to allow time for developing rocket instrumentation for inclusion in the US project or to permit coordination. What the Danes, eager to get onboard, could offer was additional ground-based measurements and support in making the applications “go fast through the official channels” in Denmark.⁵⁷ The latter translated into a public relations effort for the US project. Nevertheless, the Ionosphere Laboratory’s participation of “modest dimensions” was recognized throughout the Danish system.⁵⁸ Operation PCA 68 was an American project with a pragmatic international cover. The unclassified project’s basic data would be shared upon request—a point confirmed by project information circulated throughout international scientific bodies. At the same time, environmental effects of nuclear weapons were highly classified, so it is likely that sensitive operational knowledge gained from the project would be classified as well.⁵⁹

In early 1968, the project appeared to be on track for approval in Denmark. But then a game-changing event occurred on 21 January: a nuclear-armed Strategic Air Command B-52 bomber, secretly loitering above Thule AB on a routine Thule Monitor Mission, crashed into the ice-covered bay near the base. The impact destroyed the airplane, and detonated the high explosives in all four hydrogen bombs. Radioactive materials were scattered across a large area, and required a massive cleanup effort. Danish civilians, US servicemen, and specialists worked for months collecting more than 10,000 tons of contaminated ice and debris (See Introduction).

The crash happened less than two days before Denmark’s parliamentary elections, and spawned a serious diplomatic crisis. As explained in Chap. 9, the presence of US military forces in Greenland, nuclear weapons, and Greenland’s role in strategic deterrence had always been sensitive issues

downplayed by the Danish government. In the political atmosphere following the B-52 incident, such issues became extra sensitive, which is clear from responses to articles published in the *Washington Post* in early June 1968 by American journalist Seymour Hersh. The usually well-informed Hersh claimed that the USA had tested chemical and biological weapons in Greenland. The US government issued an official denial, but the incident was taken up when the new Danish foreign minister, Poul Hartling, met in Washington with US Secretary of State Dean Rusk for the first time.⁶⁰

Back in 1957, the Danish government had adopted a nonnuclear policy, prohibiting nuclear weapons on Danish territory, officially including Greenland and the defense areas. In a secret letter, Danish Prime Minister H. C. Hansen had sent an ambiguous message that was intended, and indeed interpreted, by the USA as a go-ahead for nuclear deployment in Greenland. Subsequent Danish governments perpetuated this tacit arrangement, while antinuclear sentiments in the population grew stronger. The B-52 accident made it obvious to the public that either the USA was not playing by the rules, or the Danish government had deliberately turned a blind eye toward US nuclear activities in Greenland. The center-right government that took office after the election was headed by the Social Liberal Party (Radikale Venstre), a party with deeply rooted antimilitaristic and neutralist opinions, which made it clear that Denmark's nonnuclear policy also applied to Greenland and its airspace.⁶¹ The new government strengthened the pursuit of détente, creating a new ministerial chair devoted to cultural issues and disarmament.⁶²

The decision to veto Operation PCA 68—made at a high level meeting between the Danish prime minister, the foreign minister, and the Minister for Greenland—was conveyed to the US government on June 27. Safety was one justification. The B-52 crash had increased risk awareness vis-à-vis Arctic military operations. What goes up must come down, which is why rocket research is usually carried out in “perceived empty spaces.”⁶³ But Thule was not an empty space. Originally the plan was to shoot rockets toward the east, but while preparing the plans, the direction was reversed 180 degrees toward the west because, a Danish source indicted, the Strategic Air Command would not risk shooting in the direction of the critically important Ballistic Missile Early Warning System (BMEWS) radar.⁶⁴ Therefore, rockets would land 5–90 km to the west of Thule AB in Baffin Bay, which was critical for winter supplies and a location where the local population hunted. It was also clear that the project could not fulfill

safety requirements established by the Danish government, since the time of launch would not be known before a PCA event was detected. (Fig. 10.1)

Worried about adverse impacts on the local Inuit population—concentrated in the settlement of Qaanaaq—the Ministry of Greenland queried local authorities. Thus the indigenous population—possibly for the first time ever—became involved in the process of approving a technological activity in Greenland. The city treasurer discussed the situation with the newly founded municipal council of Qaanaaq, which resulted in a strong protest against the rocket launches. The local population, the message ran, “had already taken a hard blow due to the accidental [B-52] crash.” According to the treasurer, “lively traffic” consisting of small whaling vessels was present. “[T]he existence of the whole population will be endangered by the planned rocket launches,” he wrote, making it “not a matter of economic consequences but a matter of losing vital catch.” Other local representatives thought differently, but the

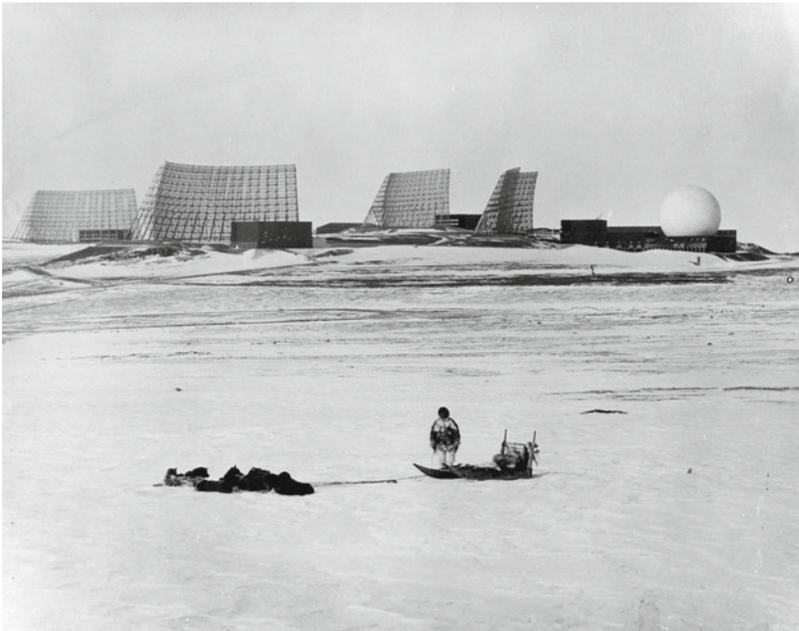


Fig. 10.1 A Greenlander with his dog sled looks at the Ballistic Early Warning System’s giant radar dishes—each longer than a football field and fifteen stories high—at the Thule Air Base in Northern Greenland in 1966. *Source/Copyright: Scanpix.*

chairman of the municipal council maintained his opposition, pointing to the possible adverse “psychological consequences” of rockets launched at Thule AB.⁶⁵ The official summary contained these risk perceptions, but it is equally apparent that the Danish administration did not see local worries as justified by objective reason. The participation and interests of Danish researchers were weighing heavily in the opposite direction. What proved decisive, according to the brief note, was the government’s desire to avoid “further anxiety about Thule,” later detailed as its “desire to avoid further unrest regarding Thule so relatively short time after the crash of the American bomber plane in January and the incorrect allegations about American tests of chemical and biological weapons.”⁶⁶ With its radical move, the new Danish government sought to stem the stream of bad news from Thule. Without doubt the decision was meant to reaffirm Danish authority in Greenland—an aspect highlighted by the prime minister’s mouthpiece newspaper, *Skive Folkeblad*.⁶⁷

What role did the military nature of the project have on the decision? The military objectives had been known to the ministry from the beginning, and as the officer in the Ministry of Foreign Affairs explained, “it is also a Danish interest, that Western defensive radar and communications systems works efficiently.”⁶⁸ On a political level, and especially among Social Liberals, these factors looked quite different. Speaking at a Pugwash conference on the “Implications of the Deployment of ABM Systems,” Danish Minister of Disarmament Kristen Helveg Petersen, a Social Liberal, greeted favorably the decision to ban the rocket project. He saw the decision grounded and justified by the widespread feeling of “mistrust and doubt that a mix-up of civil and military tasks is taking place.” Speaking more generally, Petersen rebuked scientists’ involvement in military projects and called upon them to act responsibly.⁶⁹ Despite its strong ties to the prime minister, the leading Social Liberal newspaper, *Politiken*, initially criticized the government for its handling of the project. Once it learned about the links between the project and the development of ABM systems, it immediately struck a supportive tone.

Many actors saw the withdrawal of Danish approval for the project as a game-changing decision. American diplomats complained that their Danish counterparts had become “hypersensitive” toward US projects in Greenland. Writing from Copenhagen as the press coverage unfolded, Trevor Lloyd believed he was witnessing an epic change. The days of the Danish government automatically rubber-stamping US research requests in Greenland were definitely history, and for the future he sensed a “real pos-

sibility that anything with military implications may be turned down”⁷⁰—a gross exaggeration since the Danish government had approved all other military–scientific projects proposed for 1968. The Pentagon immediately began looking for alternative high latitude launch sites. The bulk of the PCA project was transferred to Fort Churchill, Canada (a Canadian defense area), and completed the following year. For more sensitive project components, DASA hurried the swift build-up of a brand new rocket facility near Fairbanks, Alaska, which is known now as the Poker Flat Research Range.⁷¹

CONCLUSION

Legal historian Donald Rothwell concludes that the Cold War strategic constellation created “a situation not conducive to regional cooperation” in the Arctic. He points to a number of unsuccessful American attempts to enhance Arctic cooperation in the late 1960s, such as Trevor Lloyd’s proposal for an Arctic Treaty in 1965.⁷² This study has confirmed Rothwell’s general view, but it also offers additional insights and a significant corollary. What Rothwell’s account misses is a penetrating analysis of why all attempts to further true international scientific collaboration failed in the American context. First, the USA followed a strict utilitarian logic that privileged its defense posture in the strategically important region. Any proposal that would have diminished the defense posture was avoided if it did not promise significant offsetting gains. A strong American commitment to international collaboration in the Arctic, the State Department feared, would provide détente-loving Scandinavians with an excuse for inviting scores of Soviet scientists to strategically sensitive areas such as Greenland. This was how the State Department had interpreted Denmark’s invitation to two Soviet researchers to participate in scientific work in Greenland during 1964. The American approach to international cooperation in the Arctic was confined to a bipolar vision of cooperation on the Western side. American historian Walter McDougall termed scientific internationalism “one of America’s mightiest weapons” in the Cold War.⁷³ Out of concern for the more “conventional” armaments deployed in Greenland, scientific internationalism was not deployed in Greenland.

The corollary stems from the fact that Rothwell overlooked the active, independent role of small states such as Denmark. Commentators and participants on both side of the Atlantic linked the joint Danish–Soviet

expedition in 1964 to the Danish commitment to détente policy and scientific internationalism. The commitment to détente combined with the Danish desire to exercise sovereignty and authority in Greenland also led to the rejection of projects that might provoke the Kremlin and thus put détente at risk. It might be surprising that Denmark—or more precisely its small group of key decision makers—on one hand invited Soviet scientists to Greenland and promoted East–West collaboration, and on the other hand rejected several large American research projects. What we see in this case is a gradual decline of American hegemony during the 1960s: a declining ability and authority of the USA to impose its political priorities on allied nations across the Atlantic at a time when Denmark began to see scientific activities in Greenland through the lens of détente policy.

NOTES

1. See, for instance, Joseph Manzione, “‘Amusing and Amazing and Practical and Military’: The Legacy of Scientific Internationalism in American Foreign Policy, 1945–1963,” *Diplomatic History* 24 (2000): 21–56; and John Krige and Kai-Henrik Barth, eds., *Global Power Knowledge: Science and Technology in International Affairs*, *Osiris* 21 (2006).
2. Donald Rothwell, *The Polar Regions and the Development of International Law* (Cambridge: Cambridge University Press, 1996), 224.
3. Memorandum, William H. Mills, 6 May 1965 (NARA, RG 59, Entry 3008D, B36, F: Interagency Arctic Working Group) [**Hereafter Arctic Working Group**]. This short-lived initiative has not received much attention from historians.
4. Memorandum, Mills to J. Wallace Joyce, November 18, 1964 (NARA, RG 59, Entry A-1(5590) Lot#73D224, B1, F: Greenland Area Research Programs. Metrological Rocket Project) [**Hereafter Lot#73D224**].
5. Memorandum for the files, 1 December 1964 (Lot#73D224).
6. Shullaw to Mills, 25 March 1965 (NARA, RG 59, Entry A1(5602), Lot#69D527, B4, F: SCI 11–1 Research 1966, Arctic).
7. Meeting to Discuss the Arctic, 8 December 1964 (Arctic Working Group).
8. Memorandum, William H. Mills, 6 May 1965 (Arctic Working Group).
9. For the priority of national security in US Arctic policy, see, for instance, Doel et al., “Strategic Arctic science: national interests in building natural knowledge—interwar era through the Cold War,” *Journal of Historical Geography* 44 (2014): 78.
10. Henning Sørensen, “Den russiske forbindelse—en lille brik i verdenshistoriens puslespil,” *Varrv* 1 (2006): 3–32.

11. Gunnar Seidenfaden to Eske Brun, 13 September 1963 (Danish National Archives [**hereafter DNA**], Grønlandsministeriet, Journalsager 1957–1989, J.nr. 1420–106) [**Hereafter GM**].
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Cold Atoms: The Hunt for Uranium in Greenland in the Late Cold War and Beyond

Henry Nielsen and Henrik Knudsen

Thousands of recent articles now appear during Internet searches of “uranium+Greenland,” indicating that unexploited uranium deposits in the mountains of Greenland are hot news. The scale of today’s uranium projects may be larger than those in the past, but these undertakings are not new. Greenland was the focus of numerous attempts to locate, measure, and exploit uranium deposits for use in national or international nuclear power programs. Many other post-colonial states, including Brazil, Congo, and Niger, have had similar experiences.¹ However, as we have argued previously, Greenland’s strategic geopolitical role after World War II, Denmark’s exposed position and associated sovereignty concerns,² and its heavy dependence on imported fossil fuels make Danish–Greenlandic uranium history unique in the early Cold War.³ Of crucial importance, the financial and scientific backing for geologically based uranium exploration

H. Nielsen (✉)

Centre for Science Studies, Department of Mathematics, Aarhus University,
Aarhus, Denmark

H. Knudsen

The Danish National Archives, Viborg, Denmark

and extraction activities in early Cold War Greenland differed greatly from the USA's multifaceted, military-funded geophysical studies simultaneously underway there. Although the USA had a strong military presence in Greenland—and a general interest in uranium for both military and civilian purposes—it invested little money or manpower in the search for uranium in Greenland from 1945 to 1970. Thus, American hegemony within the geophysical sciences did not encompass uranium geology in Greenland.⁴

Although American and Danish states played a role in the ill-fated attempts to exploit uranium in Greenland in the second half of the Cold War, after 1970 two new actors entered the game and (through the end of the Cold War) emerged victorious: the worldwide antinuclear movement and the Greenlandic population, which was trying to create its own future by loosening its ties with Denmark. Thus, this chapter brings to the fore Greenlandic voices throughout the Cold War.⁵

THE HUNT FOR URANIUM IN GREENLAND IN THE EARLY COLD WAR—AN OVERVIEW

The hunt for uranium in Greenland has been veiled—and affected—by the Cold War. In 1946, the USA expressed its desire to buy strategically important Greenland from Denmark—an offer the Danish government immediately turned down. Because the Americans were unwilling to give up their Greenland military bases, Danish authorities lived in constant fear of receiving Soviet demands for similar bases on Denmark's Baltic island, Bornholm.⁶ They also foresaw that news about rich uranium deposits in Greenland might cause problems with either the USA or the Soviet Union. Thus, serious sovereignty concerns lay behind Denmark's political and scientific elite's lack of enthusiasm for finding uranium in Greenland immediately after World War II, when Denmark remained a weak neutral state and the Cold War became increasingly chilly.⁷ Even after Greenland became safely anchored within the North Atlantic Treaty Organization (NATO) in 1949, and Denmark signed a new post-war agreement with the USA concerning the defense of Greenland in 1951, sovereignty concerns remained important. Unlike many other countries, Denmark did not have a domestic nuclear energy program, so it would not have been able to fully exploit uranium deposits even if they had been discovered on Danish territory. Since Denmark feared pressure from powerful states desperate for uranium, no geological expeditions focused on uranium prospecting were undertaken in Greenland.

Between 1955 and 1958, an intensive hunt for uranium-containing ores in Greenland took place after nuclear scientists and engineers had succeeded

in convincing the Danish government that uranium would become the primary energy source in the near future, and that uranium from Greenland might liberate Denmark from its traditional, almost 100%, dependence on coal and oil imported from Poland and the Middle East, respectively.⁸ In the 1950s, such arguments resonated very well with the widespread Cold War fear among Danish politicians and the public of an open conflict between East and West that would disrupt fuel supplies. Scientifically, and commercially, it would have made sense to invite US experts to participate in high-profile uranium-seeking expeditions to the Ilimaussaq area (Kvanefjeld), but this did not happen. Instead, geologists—as well as journalists reporting on the expeditions—emphasized that everything was *Danish*: the money spent, the ships transporting the geological equipment, almost all the experts doing fieldwork, and the minerals in the mountains of Greenland belonged to the Kingdom of Denmark.⁹ Historian John Krige sees national identity as “the negotiated outcome of a quest for origins in the transnational [...] mobilized in a struggle for power.”¹⁰ In this particular case, Danish scientists and journalists “nationalized” their efforts, equipment, and the rocks of Greenland in their struggle to display control and exercise sovereign power over the desolate mountains and their hidden riches in faraway Greenland.

Danish efforts to exploit uranium resources in Greenland between 1955 and 1970 failed for several reasons. When Atomenergikommissionen (AEK—Atomic Energy Commission) was born in 1955, uranium explorations in Greenland were among its primary objectives.¹¹ But the government set neither clear technological goals, nor milestones—a decision that turned disastrous. Nuclear research was not considered in relation to a comprehensive energy policy, which emerged only after the 1973 oil crisis and the fierce energy debate that followed. Instead, big spending on nuclear research was made possible by a strong, but diffuse, fascination with the prospects offered by the “peaceful atom” as conceived at the 1955 Atomic Energy Conference in Geneva, along with the international prestige that would accompany a Danish nuclear energy program. Nuclear scientists and engineers became Denmark’s new heroes, and leaders in the 1950s and 1960s wanted to create a unique Danish nuclear future by developing solutions that were clear manifestations of technological nationalism.¹² As Denmark is a lowland (highest point is only 173 meters above sea level) without potential for large hydroelectric power stations, until the late 1960s the solutions preferred by the scientific as well as the political elite were focused on the development of unique heavy water reactors of Danish (DOR) or Swedish–Danish (DK-400) design. Both of these reactors were supposed to use Danish-designed fuel elements containing natural uranium recov-

ered from mines located somewhere in the cold mountains of Greenland.¹³ In hindsight, this solution was far from realistic, given the AEK's limited resources (although they appeared large from a Danish perspective), and the near absence in Denmark of large electrical manufacturing companies such as Sweden's ASEA, Germany's Siemens, or the Netherland's Philips to assist in creating a strong system of nuclear technological innovation. In fact, the two reactor projects initiated by AEK's research center Risø, situated some 40 kilometers west of Copenhagen, experienced so many difficulties that they finally had to be abandoned: the DOR project in 1963 and the DK-400 in 1967.¹⁴ Absent clear goals, the various actors—including the AEK, the Grønlands Geologiske Undersøgelse (GGU—Greenland Geological Survey), the private company Øresund, and electric utilities, to mention some of the most important—often prioritized their own interests in ways that led to destructive conflict instead of fruitful collaboration.¹⁵

During the late 1950s and 1960s, the dream of rich and profitable uranium mines in the high north was very much alive among scientists and politicians in Denmark. By the late 1960s, it was evident that the Danish uranium venture in Greenland had not lived up to the high expectations raised in the mid-1950s. Uranium deposits had been found in Kvanefjeld in South Greenland, but the reserves were not large enough, concentrated enough, nor easy enough to transform into “yellowcake”—the uranium commodity for sale on the world market—to support a profitable mining and extraction industry. Estimates made in 1969, after a deep drilling program in the Kvanefjeld area, indicated proven reserves of 5800 metric tons of uranium in uranium ore containing more than 310 parts per million and probable reserves of another 10,000 tons. Reserves of thorium—a heavy element with potential as fuel in nuclear reactors of a special design—were almost three times as large as uranium.¹⁶ This seemed like relatively good news. The bad news was that uranium from Greenland was estimated to cost a good deal more than the price of uranium on the world market, which at the time was reaching the lowest level since World War II.¹⁷ Apparently, there were no good reasons to initiate commercial uranium mining in Greenland in the late 1960s.¹⁸

ATTEMPTS TO INTRODUCE NUCLEAR POWER INTO DENMARK, 1970–88

The possibility of integrating nuclear reactors into the Danish electric power network gained renewed interest in the early 1970s. After the 1967 closing of the DK-400 reactor project, Risø's reactor people were unable

to undertake new initiatives. All they could do was wait for the time when the leaders of the big electric utilities—who had always been against Risø's reactor development projects—would decide to build turnkey nuclear power plants.¹⁹ That time eventually came in August 1972, which turned out to be too late to secure a future for nuclear power in Denmark. By the time the utilities and Risø were ready to present a joint proposal for introducing nuclear power into the electric network, the global community had begun to question its feasibility. In late 1973, before Danish legislation for licensing nuclear power plants went into effect, popular opposition to nuclear power sprang up throughout the country. By early 1974, a new, efficient grassroots organization—the Organisationen til Oplysning om Atomkraft, or OOA (Organization for Disseminating Information on Nuclear Power) had been formed, capturing the mood of uncertainty over nuclear issues and playing on laymen's growing lack of confidence in nuclear experts. Over the next two to three years, Danish citizens engaged in a heated and protracted debate over nuclear power. Staff members from Risø's former Reactor Department, joining top managers from the electric utilities, argued against the fears and uncertainties expressed by the OOA and other citizens at public meetings and in newspaper articles. But they were fighting a losing battle. Popular opposition to the elite's nuclear plans continued to strengthen, nourished by the worldwide campaign against nuclear power that followed in the wake of the 1973–74 oil crises that ended the West's almost two decades of high economic growth.²⁰

In August 1976, when the nuclear issue was debated in the Danish Parliament, opinion polls showed a majority of the population to be against introducing nuclear reactors into the electric power system. The main reasons concerned reactor safety and nuclear waste. Facing a risk of splitting the party over the nuclear issue, leaders of the ruling Social Democratic Party prepared a Solomonic solution: the government simply deferred a parliamentary decision that would permit the introduction of nuclear power into Denmark until an acceptable solution to the nuclear waste problem had been found.²¹ The resulting period of uncertainty made decisions on appropriations for nuclear energy research, and uranium exploration and extraction experiments, very risky.

For eight to ten years, Risø and the electric utilities made attempts—expensive ones—to solve the nuclear waste problem, primarily focusing on the possibility of storing nuclear waste in deep underground Danish salt deposits. But they found no perfect solution.²² Consequently, in 1985, Denmark's parliament passed an act that excluded nuclear power from

energy planning, and thus brought an end to all attempts to introduce nuclear power into the Danish energy system.²³

ATTEMPTS TO LOCATE AND EXTRACT GREENLANDIC URANIUM, 1970–88

How did the fierce nuclear debate—and diverging political opinions—concerning nuclear power affect Danish attempts to find and use uranium in Greenland? Let us return to 1970, and see how the International Atomic Energy Agency (IAEA) envisioned the prospects for nuclear power and the need for uranium. At that time, the IAEA estimated that the global demand for uranium would soon outstrip the capacity of known uranium mines. This prognosis was based on the worldwide boom in commercial reactor orders following General Electric's successful bid for New Jersey's Oyster Creek power station in 1963, as well as nuclear reactors' ever-growing size.²⁴ Thus, the IAEA foresaw huge price increases for uranium. This dire prospect for the rapidly expanding international nuclear industry animated discussions at the August 1970 IAEA meeting in Vienna on "Uranium Exploration Geology." The meeting's main outcome was a petition that encouraged member states to increase uranium exploration.²⁵

In Denmark, the GGU reacted to the IAEA petition with great speed. In addition to its on-going activities at Kvanefjeld, the GGU appointed a new uranium-surveying team: it consisted of three full-time geologists, led by Bjarne Leth Nielsen, and a number of part-time specialists (electronics experts, chemists, geochemists, hydrologists, botanists, zoologists, etc.).²⁶ The group was tasked with searching for radioactive minerals in ice-free regions of Greenland, an area of approximately 400,000 square kilometers, almost the size of California, or ten times Denmark's size.²⁷ The methods employed included (1) radiometric measurements, using gamma spectrometers installed in low-flying airplanes and helicopters, which could be used to locate areas of high radioactivity; (2) geochemical prospecting based on a systematic collection of thousands of water and soil samples for laboratory analysis; and (3) detailed geological investigations of locations that looked promising. From 1971 to 1980, the group succeeded in surveying more than half the ice-free area—concluding that, as far as uranium and thorium were concerned, South Greenland held the most promise. Kvanefjeld was in this region, but additional uranium deposits were located, including uranium oxide deposits (from which uranium, in principle, was much easier to...).²⁸ But the horizontal and vertical

extent of these deposits was not known with accuracy comparable to the Kvanefjeld deposit, and further investigations were not carried out—as explained below.

One may wonder why Danish geologists were surveying for uranium after 1976, the year that the Danish Parliament deferred indefinitely a decision on nuclear power, and—almost simultaneously—changed Risø's status from being the AEK's nuclear energy research facility to a much broader institution devoted to all energy research and development.²⁹ The AEK was abolished, and its research facility was reconstituted as a national laboratory. No longer able to operate comfortably on direct funding from the Treasury, Risø had to meet an ever-growing part of its budget from grants for short-term energy projects commissioned by the Danish Ministry of Commerce (from 1979 the new Ministry of Energy) or from the European Community's research and development programs.

So why continue the search for uranium? One reason: substantial funding was available. The severity of the oil crisis in the 1970s spurred the Ministry of Commerce/Energy to increase funding for energy research with the dual aim of limiting energy consumption and pushing forward alternative means of energy production, thus helping to reduce Denmark's catastrophic dependence on imported oil.³⁰ However, for a number of years after 1976, it remained unclear whether Denmark would eventually develop nuclear power. Since only a few high-quality renewable energy projects were in the pipeline, Risø's uranium projects continued to win valuable contracts in the late 1970s and early 1980s. For example, the uranium-surveying project obtained 6.4 million DKK from the Danish Ministry of Energy and 5 million DKK from the European Common Market for energy R&D between 1976 and 1981, and about 7 million USD in 2012. Although nuclear power had become highly unpopular in Denmark, the uranium-surveying project fit well with the favored political agenda of increased self-sufficiency and use of domestic resources. That the price of uranium on the world market hit an all-time high in the late 1970s also encouraged support for extensive uranium surveys in Greenland.

The on-going Kvanefjeld project, as well as the related uranium extraction project taking place in Risø's Chemistry Department, received additional funding (more than 36 million DKK, approximately 18 million USD in 2012) from the Ministry of Trade and the Ministry of Energy between 1978 and 1983.³¹ In 1977, 27 new holes (totaling 5100 meters) were drilled near the northern edge of Kvanefjeld, and in 1979, a 960-meter horizontal shaft was blasted directly through the center of the known uranium deposit in the

mountain, 480 meters above sea level and 150 meters below the surface of the Kvanefjeld plateau. The resulting uranium ore was dumped at the foot of the mountain. In 1980, approximately 4500 tons of this material was shipped to Risø in Denmark where it was used to test a new method for extracting uranium from the ore. Designed for mass production, the new method was tested at a pilot plant, a 2300-meter-long hair-pin needle-formed tube reactor designed by Risø technicians, based on an existing Bayer-designed concept for dissolving bauxite. After optimizing the production process, the team of engineers who designed the method concluded in 1982 that if the crushed ore were mixed into a soda solution—and transported through the reactor while being subjected to high pressure (approximately 120 atmospheres) and a temperature of 260°C—more than 80% of the uranium would be released.³² In 1983, the amount of proven uranium reserves in Kvanefjeld was increased to 20,400 tons of uranium in ores containing more than 365 parts per million uranium, enough to fulfill Denmark's total energy consumption for many decades. Furthermore, plans for industrial-scale mining of uranium ores from Kvanefjeld and the subsequent extraction of its uranium in a nearby uranium factory were put in place. Quoting a new report from Risø, the bilingual Greenlandic newspaper *Atuagagdliutit/Gronlandsposten* (AG) in early 1984 was able to inform its readers that the whole enterprise would yield an annual profit of 40 million DKK (14 million USD in 2012) and add 1000 new jobs in an area of high unemployment.³³ But none of these plans were ever realized.³⁴ Why?

ENVIRONMENTALISTS AND HOME RULE ENTHUSIASTS PREVAIL

One reason for the failure of the nuclear elite's ambitious plans was the growing opposition to nuclear power in Denmark. After 1976, the future of nuclear power was still uncertain. The Three Mile Island (Harrisburg, Pennsylvania) reactor accident in 1979 and the subsequent press coverage of what was described as a near catastrophe added to the growing conviction among politicians and the population at large that nuclear power had no future in Denmark. The 1985 decision by the Danish Parliament to remove nuclear power from future energy plans formally sealed the decision that—in reality—had been decided years before.³⁵ With no nuclear power reactors in Denmark, and thus no home market for nuclear fuel, there was little interest in developing a Danish–Greenlandic nuclear fuel industry.

A second reason, intimately connected with political and social development in Greenland in the 1970s and early 1980s, was perhaps even more decisive. When Denmark was about to join the European Community (the Common Market) in 1972, Greenlanders realized that their homeland's main source of income—a small-scale fishing industry that had only just begun to expand and modernize—would be seriously threatened if large trawlers from other countries in the European Community were allowed to catch fish close to the Greenland coast. Suddenly, many Greenlanders realized that the most important decisions about their lives and livelihood were being made in faraway Copenhagen, where only two out of the 179 parliamentary seats were reserved for representatives from Greenland. In a major political turning point, opposition sprang up all over the island. In Greenland, a referendum on whether to join the European Community, held on 2 October 1972, resulted in a 71% majority voting “NO” against 29% voting “YES.” In Denmark (population 5 million), however, a large majority voted “YES,” and Greenland's less than 50,000 citizens had to follow Denmark's much larger population into the European Community.³⁶

Frustrated Greenlanders formed a number of new political parties as a result, including the Atassut (center-right), Siumut (center-left), and Inuit Ataqatigiit (left),³⁷ which, despite subscribing to different ideologies, all agreed that Greenland (1) ought to have some sort of home rule and (2) should leave the European Community, or at least have a special arrangement with it. As the 1970s progressed, the home rule movement strengthened, and in 1979, after five years of negotiations, home rule was formally established according to a detailed proposal worked out by a Danish–Greenlandic commission.³⁸

When viewing Greenland's political development during the 1970s in historical context, the question of who owned Greenland's mineral resources—not least uranium—was clearly of pivotal significance. In fact, it gave rise to many heated debates among Danes and Greenlanders, as well as within different political factions and parties in Greenland. Previously, mineral resources had never been an issue, as is amply documented in published accounts of the debates in the Greenlandic Parliament—the Landsråd—through the 1950s and 1960s.³⁹ A search using the keyword “uranium” in the leading bilingual Greenlandic newspaper *AG* confirms this assessment.⁴⁰

One particularly striking case from the late-1950s illustrates the Greenlanders' attitude toward their former colonial masters at that time.⁴¹ When AEK's chairman, the world-renowned physicist Niels Bohr, visited

Kvanefjeld in connection with his grand tour to Greenland in July 1957, *AG* hailed him in a lengthy article, emphasizing that “we [...] welcome Niels Bohr because together with the population in all of Denmark we hope to see his visit as the start of a development that will bring to the surface great wealth from the mountains of Greenland for the benefit of the population of the Danish Kingdom in the future.”⁴² Four years earlier, the Danes had voted in favor of a new constitution that gave Greenland status as a county in the Kingdom of Denmark and guaranteed the island’s population two seats in the Danish Parliament, the Folketing. In 1957, Frederik Lynge, a native Greenlander from the small town of Egedesminde at Disko Bay, held one of the seats. The year Bohr visited the uranium expedition team at Kvanefjeld, Lynge gave public lectures in which he discussed the rapid social, economic, and technological development taking place in Greenland. On 9 March 1957, for example, he gave a speech on the Danish island of Bornholm that undoubtedly reveals common attitudes held by the elite segment of the indigenous Greenlandic population toward the modernization process in general and the on-going search for valuable minerals in Greenland in particular. Lynge emphasized how grateful the Greenlanders were for the new freedom to develop their culture and language. And he went on to say: “I think [...] that it will be by way of the minerals that Denmark will benefit from Greenland, and that they can help us pay back the millions of crowns Denmark has sacrificed to help us through the ages. We can only hope that the politicians and the experts will ensure that exploitation of these minerals will take place in the not too distant future.”⁴³ Greenlanders’ submissiveness to the Danes still defined relations between the two peoples in the late 1950s.

By 1975, the tone was completely different. Thue Christiansen, one of the two Greenlanders in the Danish Parliament that year, surprised his colleagues in Copenhagen when he used his first speech to warn “the Danish government [...] not [to] hand out more concessions, neither to explorations, nor to exploitations of Greenlandic resources; neither to oil, nor to uranium or other forms of solid minerals before Greenlandic home rule has become a reality.”⁴⁴ Seventeen years after Lynge had embraced Danes and Greenlanders as one big paternalistic family, a large percentage of the Inuits were now revolting against Danish political domination and its exploitation of Greenland’s natural resources. This revolt evolved over the next few years while the Home Rule committee was working, causing splits between Danes and Greenlanders, and also between Greenlanders themselves. In fact, the question of who owned Greenland’s natural resources became the main point of contention between

its three political parties. Extant legislation, passed by the Danish Parliament in 1965, simply stated that “All mineral resources in Greenland belong to the State, [and] exploration, prospecting and exploitation of these raw materials is reserved for the State.”⁴⁵ But who would be “the State” when Greenland got home rule? How much authority should be transferred to Nuuk (home of the future Greenlandic Home Rule government), and how much should remain in Copenhagen, the Kingdom of Denmark’s capital?

The center-right party, Atassut, consistently stressed the importance of maintaining a good relationship between Denmark and Greenland, arguing it would “serve the Greenlandic population the best” and because “this has characterized the relations between [the two peoples] through centuries.” Concerning the mineral resources of Greenland, Atassut’s official policy was that “[t]he Home Rule government’s authority [...] must [match] that of the Danish government,” and “revenues coming from these resources should be to the greatest possible benefit of Greenland.”⁴⁶

The center-left party, Siumut, was much more outspoken in demanding full sovereignty for Greenland’s people over its minerals. Its party program, which, like Atassut’s, dated back to 1977, stated that “the soil and the resources belong to the country’s permanent residents,” and that “exploitation of the resources must be decided by the elected representatives of the population.”⁴⁷

The last of the three parties, Inuit Ataqatigiit, advocated extreme left-wing views. In its party program, dating from 1978, leaders declared the goal of the party, “on an anti-imperialistic basis,” was to “fight colonialism and the new-colonial development in all its forms [...] and to work for recognition of the aboriginals’ common property rights to Kalaallit Nunaat (Greenland).”⁴⁸

The Danes were not unwilling to share revenues with Greenland’s permanent residents, but because the Danish government in the late 1970s annually transferred about one billion DKK (more than 600 million 2012 USD) to Greenland to keep the welfare state running, Copenhagen could not accept the demands of Siumut and Inuit Ataqatigiit. Before Danish Prime Minister Anker Jørgensen visited Greenland in September 1977, he expressed this point of view in a way that reminded his Greenlandic audience of colonial master-to-subject straight talk: “This subject is not open for discussion! If you want property rights over the subsoil of Greenland you must accept the consequences, i.e., cut the ropes to Denmark.”⁴⁹ Many Greenlanders were offended. To Jørgensen’s surprise, he was met on arriving in Greenland by demonstrators bearing signs reading:

“Stop the destruction of Greenland!” “Do Danes want to kill our identity?” and “No to uranium!”⁵⁰ Such protests had never occurred before, and the situation almost got out of control when eggs were thrown at Prime Minister Jørgensen as he was about to leave the nearby harbor. Fortunately, Jørgensen chose to be magnanimous in his last speech in Greenland: “Denmark is a small country, but we must be great in our attitude towards Greenland [...] If things are thrown against us, we will hold out our hands for friendship.”⁵¹

During the next two years, the Home Rule committee held intense discussions, accompanied by debates in political forums in Denmark and Greenland, as well as a flood of articles in Danish and Greenlandic newspapers. However, after lengthy negotiations, committee members agreed on a compromise guaranteeing that future profits from the exploitation of natural resources in Greenland would be shared, while acknowledging that permanent residents would have basic, although no legal, rights to the natural resources.⁵² The Greenlanders’ demand for self-determination stemmed not only from their wish to secure an economic outcome from commercial mining for permanent residents but also from the growing desire of the Greenlandic environmental movement to protect the extremely sensitive Arctic environment against dangers associated with large-scale mining. Since the mid-nineteenth century, the Greenlanders had seen many mining industries (e.g., coal, cryolite, lead, zinc, and gold) operate for some years during which they employed members of the local population, and then closed without any serious attempts to restore the environment to its pre-mining state.⁵³

Environmentalists in Greenland were especially concerned about the threat posed by the search for uranium in the mountains of their unique Arctic country. With huge American bases on their territory, and with geologists constantly looking for uranium everywhere in ice-free zones, uranium became the symbol of evil—on a global level (as a key element in nuclear weapons) and on a local level (because it threatened the sensitive Greenlandic flora and fauna with radioactive contamination). In his opening address to the newly elected Greenlandic Home Rule parliament (the Landsting) on 14 September 1979, chairman Jonathan Motzfeldt of the Siumut party announced that “[i]n addition to our unconditional demand that exploitation of our uranium must never serve military purposes, we have to insist that a decision to mine uranium [in Greenland] can only be taken after a thorough investigation of all environmental consequences, not least the waste problems.”⁵⁴ He received support from almost all Greenlandic politicians who were interviewed or discussed in *AG*. Lars Godtfredsen

(Siumut), for example, declared, “The explorations in Narsaq, which aim to investigate the quality of the uranium, have become much more efficient during the last few years. The recent debate, including radio broadcasts, indicates that these explorations should be stopped.”⁵⁵ Mike Sigestad (Inuit Ataqatigiit) was more outspoken: “The problems we see today with respect to the exploitation of the Kvanefjeld uranium would have been unthinkable if the question of ownership in Greenland had been properly dealt with in the Home Rule legislation [...] Have we already forgotten the unanimous decision by the Inuit Circumpolar Conference in 1977, where everybody dissociated themselves from nuclear power projects in the Arctic?”⁵⁶

News articles and radio broadcasts of these claims scared the inhabitants of Greenland’s villages, especially Narsaq, the town closest to Kvanefjeld. Henning Sørensen, the director of the uranium activities at Kvanefjeld and a devoted Danish nuclear energy proponent, regretted the environmentalists’ success. He and his team, he claimed, had “always informed the municipality in Narsaq about the aims and details of the work [...]. But then, in 1979, a representative from OOA got access to Radio Greenland and spread her terrifying message about all the evils associated with uranium mining. In one stroke many citizens panicked, and many years of objective information were forgotten.”⁵⁷

Sørensen did manage to ship 4500 tons of uranium-containing ore (lujavrite) to Risø in 1980, but the ship was met by demonstrations organized by Greenlanders, most of them living in Denmark, when it arrived in Holbæk harbor, some 30 kilometers from Risø. On 3 September, when the lujavrite was transported by truck to Risø, several hundred demonstrators marched from nearby Roskilde to the gates of Risø to listen to rock music, protest songs, and speeches. One of the speakers, Kaj Kleist, a teacher and the event’s main organizer, warned his audience that uranium exploitation in Greenland could have catastrophic consequences for Greenland’s population and environment. He used the experiences of other uranium-producing, former colonial states as frightening examples:

We have seen terrible consequences of uranium exploitation in several countries. In Namibia in Africa the uranium is stolen from the indigenous population. From the United States of America we hear alarming news about cancer illness in the original districts of the Indians where uranium is mined. Although the Greenlandic Home Rule government have said No to continued exploration for uranium in Kvanefjeld, we know now that the Danish government will continue the investigations at Risø so that in due time it has created the necessary background for a ‘legal’ decision to mine the uranium in Kvanefjeld.⁵⁸

Three years later, Risø's pilot project to extract uranium from the Kvanefjeld lujavrite was successfully concluded—at least according to the project's experts.⁵⁹ This big news landed on the front page of the *AG* in an article written by Jørgen Fleischer, executive editor of *AG*, using his pen name *Júlut*. Under the headline, “Big profit and new jobs,” he quoted the report for promising that “in ten years, it will be possible to start a mining industry that will provide a thousand new jobs and a yearly surplus of 40 million DKK” (about 20 million USD in 2012). However, this would not be easy, he continued, because “for most young people uranium is an abomination that leads to death and destruction of nature [...] But the country's economy may be so strained that we may be forced to consider the possibilities associated with the uranium.”⁶⁰ Reaction was swift. *Júlut*, in a subsequent issue of the same newspaper, was contradicted head-on by leaders of the four-year-old Committee Against Uranium Exploitation in Greenland, which claimed to have critically read the Risø report, discovered many serious mistakes and distortions, and determined that “the conclusions [of the report] are very doubtful and tend to give the reader a one-sided picture of the consequences of uranium mining.”⁶¹ In a letter to the editor, one reader commented: “The list of problems is infinite. Should we go for some millions and some jobs, and at the same time be cynical enough to close our eyes to problems we impose on other people—and our descendants? This way of thinking does not belong in our country, I think.”⁶²

Not long afterward, Jonathan Motzfeldt, chairman of the Landsstýr (the Greenlandic government), explained the political situation with respect to uranium mining. No final decision had been made, he wrote—but readers of his article could be forgiven if they concluded that the Greenlandic government was against allowing a full-scale uranium-mining operation in Kvanefjeld. Due to so many uncertainties, environmental and economic, in the project, more investigations would be needed. He added, “as long as no decisions have been taken to introduce nuclear power into Denmark, we do not see any reason to change our reluctant attitude to provide uranium from Kvanefjeld for these or other nuclear power stations.”⁶³

Motzfeldt's article in *AG* appeared at a decisive moment. Risø's pilot project (1980–84) to make commercial yellowcake from the Kvanefjeld lujavrite turned out to be the beginning of the end of uranium activities in Greenland. The penultimate nail in the coffin of nuclear power in Denmark and Greenland came in 1985, when the conservative government removed nuclear power from future Danish energy plans. In recent

years, it has been claimed that the final nail was hammered home in 1988 when the Danish–Greenlandic bilateral council, the Joint Committee on Mining in Greenland (“Fællesrådet for mineralske råstoffer”), forbade all uranium exploration and exploitation activities in Greenland.⁶⁴ Such a decision—which since 2011 has been consistently referred to as “Greenland’s zero-tolerance policy”—has never been made, however! A search through the minutes of the Fællesråd—which incidentally had no legislative authority—has shown that no such “decision” was taken in the Fællesråd, nor in the Landsting, the Greenlandic Parliament, in 1988, or in the following years. What did happen, however, was that in 1988, the Fællesråd recommended and the overwhelming majority in the Landsting decided to rule out exploration and mining activities if uranium were the main target, but they never formally excluded activities where uranium was only a by-product. It remains a mystery how sometime around 2009, when Greenland went from Home Rule to Self Rule, the myth of the so-called zero-tolerance decision in 1988 became generally accepted in Greenland as well as in other countries with interests in Greenland.⁶⁵ The fact is that in 1988 “zero tolerance” was only an extreme leftist point of view, not the declared politics of the Fællesråd, nor of the Landsting (or Inatsisartut, which is its Greenlandic name).

POSTSCRIPT: THE URANIUM GHOST RETURNS—A BRIEF FOLLOW-UP, SINCE 1988

In its struggle to become economically independent of Denmark, since 1988 the Greenlandic Parliament, Inatsisartut, has gradually given up its restrictive attitude toward the exploitation of the country’s mineral resources. It has granted oil companies exploratory licenses to search for oil on Greenlandic territory in offshore waters, but so far with limited success. Mineral explorations were few until the new millennium, but since then companies mining gold, iron, zinc, lead, and several other metals have shown great interest in Greenland, which is amply documented by the rapid increase in mineral licenses applied for or granted by the Greenlandic authorities. On 31 December 2011, the number of such licenses was 142 (up from 20 in 2002), including 25 preliminary investigation licenses, 87 exploration licenses, and four exploitation licenses (for gold, olivine, molybdenum, and lead/zinc respectively).⁶⁶ One really big project in the pipeline in 2012 was the Chinese-dominated London Mining Company’s

plans for a huge iron mine at Isukasia/Isua some 70 kilometers north of Nuuk, Greenland's capital. "It is estimated that a possible mine will produce 15 million [metric] tons of ore annually for many years, and the company expects to employ as many as 2,100 people in the construction phase and 700 in the production phase" stated the 2012 official government report on the mineral resources of Greenland.⁶⁷ An unsolved problem, however, was that London Mining wanted to import some 2000 Chinese workers to Greenland, to install them in some sort of "Chinese" town isolated from the Greenlandic population and to let them construct the mine with all its facilities for Chinese wages, these being only a small fraction of corresponding Greenlandic wages. That idea was far from popular among labor organizations in Greenland and in Denmark. However, in its eagerness to get large-scale mining businesses rolling in Greenland—and corresponding revenues rolling into the treasury—the former Greenlandic Inuit Ataqatigiit government prepared an act to that effect. It was passed in the Greenlandic Parliament on 7 December 2012, but a new Siumut-dominated government—in power since March 2013—announced its intention to roll back the so-called Large-Scale Act. The situation was confused. On 24 October 2013, London Mining obtained an exploitation license from the Greenlandic government, but problems with the Large-Scale Act remained unsolved. The fact that the Danish Parliament in Copenhagen had to consent to decisions by the Inatsisartut that could have international implications did not make the problems easier to solve.

As of spring 2015, the continued economic slowdown is a serious challenge to Greenland's attempts to attract large foreign investments. Mining is an ultra-cyclical industry, notoriously undergoing boom-bust cycles as metal prices fluctuate up and down. Since the onset of the global financial crises, the prices of most industrial metals have decreased significantly. Recently, gold and silver prices have declined as well, and the price of uranium has slumped by more than 50% since it peaked in the mid-2007. Mining companies are adapting to the slowdown by slashing capital expenditure and by delaying and curtailing new projects. In fact, London Mining, the company that planned to invest 14 billion DKK (more than 2 billion USD) in an iron mine in Isukasia, has been hit so hard by falling prices and the Ebola epidemic in western Africa (where the company had its only productive mine), that it was forced to declare bankruptcy in January 2015.

Of even more relevance to the uranium story, however, is the dramatic rise in the demand for rare earth elements (REEs), for example, lanthanum, cerium, neodymium, gadolinium, holmium, and ytterbium after

the turn of the millennium. Some REEs are essential materials in modern technologies such as batteries, LCD displays, cell phones, computers, and windmills, but since China currently controls about 95% of the world's productive REE mines, it has a virtual monopoly for the time being.⁶⁸ Since 2007, the Australian-based company Greenland Minerals and Energy Limited (GMEL) has been granted a license to explore the rocks for REE in a specific area near Kvanefjeld. In 2008, GMEL notified the Greenlandic government that it had discovered REE reserves of more than 2.5 million metric tons and uranium reserves of more than 100,000 metric tons in the area.⁶⁹ If granted a license to extract the REE and the uranium with which most of it is associated, the company expected to invest approximately two billion Australian dollars in mines and production facilities in the Kvanefjeld–Narsaq area.⁷⁰ Without a license to mine the uranium—worth more than ten billion Australian dollars, according to GMEL's own estimate—the project would not be viable.

The message from GMEL started a heated and protracted debate in Inatsisartut as well as among Greenlandic citizens. A large fraction of the Greenlanders—also among the inhabitants of Narsaq—appear to hold a dim view of the Kvanefjeld Uranium Project, but in the absence of much needed information about the project, reliable opinion polls do not exist.⁷¹ In spring 2012, GMEL announced substantially increased estimates of rare earth and uranium resources in the Kvanefjeld (now more than 10 million tons of REE and 260,000 tons of uranium).⁷² In addition, GMEL announced that a formal application for a license to mine uranium and REE in its Kvanefjeld concession area would be forwarded soon after the Inatsisartut had removed Greenland's zero-tolerance policy. This has indeed happened. On 24 October 2013, Greenland's Parliament voted 15 to 14 to abolish the nonexistent, but nevertheless generally accepted, 25-year-old ban on uranium exploration and mining in Greenland. But this does not mean that all obstacles for companies like GMEL have been removed and that large-scale mining in the Kvanefjeld district is just around the corner. The close decision in the Inatsisartut and a new election on 28 November 2014 resulting in a weakened Siumut government almost guarantee internal problems if and when this government decides to hand out exploitation licenses to foreign-mining companies. In addition, the consent of the Danish Parliament, which regards uranium mining and export as a security issue, will be needed before any foreign company, whether dominated by American, Australian, or Chinese economic interests, can start exploiting the uranium resources of Greenland.⁷³ GMEL,



Fig. 11.1 *Naamik* = No! Demonstrators protest against uranium mining in the streets of Nuuk on 24 October 2013—the very day when the Greenlandic parliament decided to put an end to “zero-tolerance,” the imaginary (yet widely accepted) 25 year old ban on uranium mining. *Source/Copyright: Scanpix.*

for example, is trying to find investors willing to invest nearly 750 million USD in this very risky business (Fig. 11.1).

The uranium ghost has made a dramatic comeback in Greenland, a quarter of a century after it was sentenced to death in Greenland and Denmark.

CONCLUSION

The history of repeated attempts to find and exploit uranium deposits in Greenland’s huge, inhospitable landscape over a period spanning four decades is filled with failed political and commercial expectations. It is a story of failed economic investments totaling millions of Danish crowns, lost in a chimerical hunt for a heavy metal, which, before World War II, was almost worthless. In the absence of strong political guidance, frequent power struggles among the different actors involved in the uranium hunt seriously damaged the project in the first half of the Cold War. In the Cold War’s second half—despite considerable scientific and technological progress in locating

uranium deposits and developing efficient methods to extract it from ores in Kvanefjeld—the uranium hunters’ efforts remained in vain as they became victims of the native population’s demand for Home Rule and the budding environmental movement’s ability to turn public opinion against the nuclear establishment’s vision for the future. Indeed, by following the Greenlandic debate about uranium exploitation, it becomes clear that such debates were virtually nonexistent before the mid-1970s, exploded in the late 1970s, and then in the 1980s united the permanent residents to support a successful zero-tolerance policy with respect to uranium exploration.

Concerns of the political and scientific elites about Danish sovereignty over Greenland underlaid their lack of enthusiasm for finding uranium in Greenland in the immediate postwar years when Denmark remained a weak neutral state and the Cold War grew colder. Although this anxiety gradually disappeared in the years following Denmark’s entry into NATO, sovereignty concerns and techno-scientific nationalism continued to play an important role in the late 1950s and early 1960s when the Danish government initiated a series of national uranium expeditions to Greenland, carried out by AEK, GGU, FFR, and the Cryolite Company Øresund. One may even view the Danish position in the negotiations over natural resources of the 1970s and 1980s with the Greenlanders as a third kind of defense of Danish sovereignty. No matter which party has been in power, the Danish government has consistently held that as long as Greenland remains attached to Denmark and continues to receive substantial subsidies from the Danish state, Denmark and Greenland must share the revenues resulting from the exploitation of the island’s natural resources. Since Home Rule was established in Greenland in 1979, Greenlandic authorities have gradually taken over the responsibility for a large part of public service and administration, but revenue-sharing remains part of the political deal. The transition from Home Rule to Self Rule in June 2009 and the recent dramatic increase in mineral prospecting activities in Greenland—especially for REE and uranium—suggest Denmark’s days of having sovereignty rights to defend in Greenland may soon be gone.

NOTES

1. The story of the USA’s and the UK’s attempts to control the production of uranium from 1943 to the mid-1950s is treated in Jonathan E. Helmreich, *Gather Rare Ores: The Diplomacy of Uranium Acquisition* (Princeton, NJ: Princeton University Press, 1986). For details on uranium exploration and exploitation in individual countries, see Richard G. Hewlett and Oscar

- E. Anderson, *The New World, 1939–1946. Volume I, A History of the United States Atomic Energy Commission* (University Park: Pennsylvania State University Press, 1962); Margaret Gowing, *Britain and Atomic Energy, 1939–1945* (London: Macmillan and Co., Ltd, 1964); Gunnar Skogmar, *Nuclear Triangle: Relations Between the United States, Great Britain and France in the Atomic Energy Fields 1939–1950* (Copenhagen: Copenhagen Political Studies Press, 1993); Alice Cawte, *Atomic Australia, 1944–1990* (Kensington: New South Wales University Press, 1992); Roy MacLeod, “The Atom Comes to Australia: Reflections on the Australian Nuclear Programme, 1953 and 1993,” *History and Technology* 11 (1994): 299–315; Gabrielle Hecht, *The Radiance of France: Nuclear Power and National Identity after World War II* (Cambridge, MA: MIT Press, 1998), and *Being Nuclear: Africans and the Global Uranium Trade* (Cambridge, MA: MIT Press, 2012); Valerie Kuletz, *The Tainted Desert: Environmental Ruin in the American West* (New York: Routledge, 1998); and Eric William Mogren, *Warm Sands: Uranium Mill Tailings Policy in the Atomic West* (Albuquerque: University of New Mexico Press, 2002).
2. We are using sovereignty to mean the modern notion of political authority. See, for example, Shelagh D. Grant, *Polar Imperative: A History of Arctic Sovereignty in North America* (Vancouver, BC: Douglas and McIntyre, 2010) for further discussion of sovereignty issues in the Arctic context.
 3. See Henry Nielsen and Henrik Knudsen, “Too Hot to Handle: The Controversial Hunt for Uranium in Greenland in the Early Cold War,” *Centaurus* 55 (2013): 319–343, for more details on the discussion in this section.
 4. See, for example, John Krige, *American Hegemony and the Postwar Reconstruction of Science in Europe* (Cambridge, MA: MIT Press, 2006); Ronald E. Doel, “Constituting the Postwar Earth Sciences: The Military’s Influence on the Environmental Sciences in the USA after 1945,” *Social Studies of Science* 33 (2006): 635–666; Matthias Heymann et al., “Exploring Greenland: Science and Technology in Cold War Settings,” *Scientia Canadensis* 33 (2010): 11–42; and Janet Martin-Nielsen, “The other cold war: The United States and Greenland’s ice sheet environment, 1948–1966,” *Journal of Historical Geography* 38 (2011): 69–88.
 5. See Hecht, *Being Nuclear*, for a recent take on the exploration for and exploitation of uranium in Africa, and the attitudes of aboriginals toward uranium.
 6. Nielsen and Knudsen, “Too Hot to Handle,” 319–343. See also, for example, Bo Lidegaard, *I Kongens navn: Henrik Kauffmann i dansk diplomati 1919–58* (Copenhagen: Samleren, 1996); DUPI, *Grønland under den kolde krig. Dansk og amerikansk sikkerhedspolitik 1945–68* (Copenhagen: DUPI, 1997); Thorsten B. Olesen and Poul Villaume, *I blokopdelingens tegn 1945–1972*, Vol. 5 in *Dansk udenrigspolitik historie* (Copenhagen: Gyldendal, 2005).
 7. Max Sørensen, the Danish government’s legal expert, in “Udvalget til Koordination af Forskellige Opgaver i Grønland,” 3. Meeting, 28

- February 1947, p. 23, Box 73, Niels Erik Nørlund papers (07322), Danish National Archive.
8. Nielsen and Knudsen, "Too Hot to Handle," 337–338.
 9. Kjeld Rask Therkilsen, "Uranbyen paa den gamle nordbomark," *Berlingske Tidende*, 8 June 1958, 13–14.
 10. John Krige, "Hybrid Knowledge: the Transnational Co-production of the Gas Centrifuge for Uranium Enrichment in the 1960s," *The British Journal for the History of Science* 45, no. 3 (2012): 335.
 11. Except for Bornholm, a small Danish island in the Baltic Sea, the geological formations that constitute the topsoil of Denmark are mainly remnants from the last ice age (moraine tills). They contain few radioactive minerals.
 12. Henry Nielsen and Henrik Knudsen, "The Troublesome Life of Peaceful Atoms in Denmark," *History and Technology* 26, no. 2 (2010): 91–118.
 13. DOR stands for "Deuterium moderated, organic cooled reactor." DK-400 refers to a 400-megawatt boiling heavy water reactor, a scaled-up version of the 200-megawatt Swedish reactor built near the town of Marviken. Closed in 1968, it was never loaded with nuclear fuel. For details on the Marviken reactor, see Arne Kaijser, "Redirecting Power: Swedish Nuclear Power Policies in Historical Perspective," *Annual Review of Energy and Environment* 17 (1992): 437–462.
 14. Henry Nielsen et al., *Til samfundets tarv. Forskningscenter Risø's historie* (Roskilde, Denmark: Forskningscenter Risø, 1998): 113–123, 168–182. See also Nielsen and Knudsen, "The Troublesome Life," 92, 104.
 15. Nielsen and Knudsen, "Too Hot to Handle," 319–343; Knud Ellitsgaard-Rasmussen, "En stjerne fødes. Beretning om GGU's tilblivelse," *Danmarks og Grønlands Geologiske undersøgelse, Rapport 1996/112*: 27–46.
 16. Henning Sørensen, "Grønlands uran og thorium," *Tidsskriftet Grønland* 4–5 (2008): 198.
 17. 1948–1967: Data from US Department of Energy Publication GJO—100(82); 1968–2007: Data from Trade Tech (Denver, Colorado). <http://static.seekingalpha.com/wp-content/seekingalpha/images/UraniumPriceHistory.gif>, Last accessed 14 June 2013.
 18. Henning Sørensen, "På spor af sjældne metaller i Sydgrønland: III Ilimaussaq-intrusionen—rosinen i pølseenden," *Tidsskriftet Grønland* 6 (1966): 197; Bjarne Leth Nielsen, "På spor af sjældne metaller i Sydgrønland: VIII Man har atter boret på Kvanefjeldet—kan uranmalmen brydes," *Tidsskriftet Grønland* 5 (1970): 136.
 19. Nielsen et al., *Til samfundets tarv*, 285–289.
 20. On the Danish nuclear power debate, see Søren Hein Rasmussen, *Sære alliancer: Politiske bevægelser i efterkrigstidens Danmark* (Odense, Denmark: Odense Universitetsforlag, 1997), 123–164; and Oluf Danielsen, *Atomkraften under pres: Dansk debat om atomkraft 1974–85* (Roskilde, Denmark: Roskilde Universitetscenter, 2006).

21. "Beretning over forslag til lov om anvendelse af kernekraft som energikilde i Danmark, afgivet af energipolitisk udvalg den 30.9.1976." *Folketingstidende* 1976. *Tillæg B*, columns 2409–2416 (Copenhagen: Folketinget).
22. Miljøstyrelsen, *Vurdering af elværkernes salthorstundersøgelse: rapport* (Copenhagen: Miljøstyrelsen, 1984).
23. "2. behandling af forslag til beslutning om offentlig energiplanlægning uden atomkraft," *Folketingstidende* 1985. *Forhandlingerne*, 29 March 1985, columns 8254–8262 (Copenhagen: Folketinget).
24. New Jersey Power and Light Company, *Report on the Economic Analysis for Oyster Creek Nuclear Electric Generating Station* (Morristown, NJ: New Jersey Power and Light Co., 1964), 1–46.
25. Bjarne Leth Nielsen, "Uraneftersøgning og uranforekomster i Grønland," *Tidsskriftet Grønland* 5 (1974), 143–153, and "Ti års regional uraneftersøgning i Grønland," *Tidsskriftet Grønland* 2 (1981), 33–40.
26. The presence of botanists and zoologists in the team reflects a growing interest, starting in the late 1960s, in the evaluation of the environmental effects of mineral prospecting and mining activities. See *Danmarks Miljøundersøgelser* 38 (2001).
27. Hans P. Steenfos and Jørgen Taagholt, *Grønlands teknologihistorie* (Copenhagen: Forlaget Gyldendal, 2012), 59.
28. Nielsen, "Uraneftersøgning og uranforekomster," 33–40.
29. See Nielsen et al., *Til samfundets tarv*, 281–410.
30. In the mid-1970s, about 90 % of Denmark's energy consumption was met by oil, mainly from the Middle East. See Bent Elbek, *Energi, Energi, Energifikrise* (Copenhagen: Munksgaard, 1974).
31. The figures are from Sørensen, "Grønlands uran og thorium," 198.
32. Emil Sørensen and H. Jensen, "Uranium Extraction by Continuous Carbon Leaching in a Pipe Autoclave," in *Proceedings of the Advances of Uranium Ore Processing and Recovery from Non-Conventional Resources* (Vienna: IAEA, 1985): 41–52.
33. "Stort overskud og nye arbejdspladser," *Atuagagdlitit/Grønlandsposten* 4 (1984): 6.
34. Sørensen, "Grønlands uran og thorium," 198–199; I. Rasmussen, "Udvindingsforsøg med malm fra Kvanefjeld," in *Uran Efterforskning i Grønland*, ed. Gunnar Larsen (Copenhagen: Akademiet for de Tekniske Videnskaber, 1981), 43–50. See also Per Kalvig, Karsten Secher, and Gert Asmund, *Uran: Information og fakta om udvinning af uran i Grønland* (Copenhagen: GEUS, 2010).
35. Danielsen, *Atomkraften*, 505–554.
36. Keld Hansen, "Grønland sagde ja til hjemmestyre," *Tidsskriftet Grønland* 1 (1979): 1–4.
37. Tupaarnaq Rosing Olsen, *I skyggen af kajakkerne: Grønlands politiske historie, 1939–1979* (Nuuk, Greenland: Forlaget Atuagkat, 2005), 277–289,

lists the parties' programs at the time of their formation. It gives a very useful account of the political history of Greenland during the Cold War from a Greenlander's perspective.

38. A brief account of these events is given in Mads Lidegaard, *Grønlands historie* (Copenhagen: Nyt Nordisk Forlag, 1991): 217–226. See also Nikolaj Petersen, *Dansk Udenrigspolitisk Historie. Vol. 6: Europeisk og globalt engagement 1973–2003* (Copenhagen: Gyldendal, 2004): 334–340, 372–377.
39. *Grønlands Landsråds Forhandlinger*, 1955–1970.
40. Electronic versions of all issues of *AG* since its start in 1942 can be seen at: <http://timarit.is/>.
41. Greenland remained a colony until 1953, when it gained status as a county of Denmark. On the transition, see Erik Beukel, Frede P. Jensen, and Jens Ole Rytter, *Phasing out the Colonial Status of Greenland, 1945–1954: A Historical Study* (Copenhagen: Museum Tusulanum Press, 2010).
42. “Niels Bohr i Grønland,” *Atuagagdliutit/Grønlandsposten* 15 (1957): 15.
43. “Ligger der en fremtid i Grønlands mineraler?” *Bornholms Tidende*, 16 March 1957.
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45. Olsen, *I skyggen af kajakkerne*, 215.
46. *Ibid.*, 283–84.
47. *Ibid.*, 282.
48. *Ibid.*, 288.
49. *Ibid.*, 229.
50. “Befolkningens ønske skal være afgørende,” *Atuagagdliutit/Grønlandsposten* 35 (1977): 12.
51. *Ibid.*
52. Olsen, *I skyggen af kajakkerne*, 231.
53. Examples of this kind of exploitation (cryolite, lead, zinc, and gold) are given in: Danmarks Miljøundersøgelser, “Minedrift og miljø i Grønland,” *DMU Tema rapport* 38 (2001). See also Karsten Secher, *Det hvide guld og det ægte guld—minedrift og råstoffer i Grønlands 20. århundrede* (Copenhagen: GEUS, 2004); and Dawn Alexandra Berry, “Cryolite, the Canadian aluminium industry and the American occupation of Greenland during the Second World War,” *Polar Journal* 2, no. 2 (2012): 219–235.
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57. Sørensen, “Grønlands uran og thorium,” 200.
58. “Ca. 300 i protestmarch mod grønlandsk uran,” *Atuagagdliutit/Grønlandsposten* 37 (1980): 17.

59. Per Kalvig, "Preliminary mining assessment of the uranium resource at Kvanefjeld, the Ilimaussaq intrusion, South Greenland" (Risø National Laboratory, Kvanefjeld Uranium Project, 1983); E. Sørensen, S. Kofoed, L. Lundsgaard, and J. L. Paulsen, "Uranudvinding ved udludning med natriumcarbonat under højt tryk og temperature" (Risø National Laboratory: Kvanefjeld Uranium Project, 1983).
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63. "Der er endnu ikke taget politisk stilling," *Atuagagdliutit/Gronlandsposten* 40 (1984): 32.
64. Sørensen, "Grønlands uran og thorium," 193. In November 2008, Greenland's Parliament (the Landsting) renewed the 1979 decision in "Fællesrådet for mineralske råstoffer" that forbade uranium mining in Greenland. However, since 2009, the Landsting has permitted exploration activities to find desirable rare earth elements (REE) in Kvanefjeld, even if uranium and thorium exist in the same region. It remains uncertain if a majority in the Landsting will grant licenses to actually extract the REE if radioactive elements will unavoidably be extracted as a by-product.
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