Nazi-occupied Norway, February 27, 1943

IN A STAGGERED LINE, the nine saboteurs of Operation Gunnerside cut across the mountain slope. Instinct, more than the dim light of the moon, guided the young men. On skis, they threaded through the pine stands traversing down the uneven terrain, much of it pocked with empty hollows or buried under snowdrifts. Dressed in white camouflage snowsuits over British Army uniforms, the Norwegians looked like phantoms haunting the woods. They moved as quietly as ghosts, the silence broken only by the swooshing of their skis and the occasional slap of a pole against an unseen branch. A steady wind blowing through Vestfjord Valley, 100 miles west of Oslo, dampened even those sounds.

SABOTEURS ON

In the snowbound mountains of Norway, a band of commandos took on the Nazi A-bomb program

BY NEAL BASCOMB

SKIS

Norwegian commandos, depicted here in a 1948 dramatization, trek across the landscape laden with weapons and equipment to attack a hydroelectric plant in Nazi-occupied Norway.

The woods soon became too dense and steep for them to continue by any means except on foot. It was tough going. They clambered through the heavy, wet snow carrying rucksacks filled with 35 pounds of equipment and armed with submachine guns, pistols, grenades, explosives, and knives.

When they finally cleared the forest, the men came to the road running across the valley's northern side, westward toward the Lake Møs Dam. From here the commandos could hear the low hum of their target: the Vemork hydroelectric plant. The power station and adjacent eight-story hydrogen plant were just south of the small band, an eagle's swoop over the precipitous Måna River gorge.

In the moonlight, the Vemork plant cast the imposing silhouette of a fortress. The concrete and steel monolith occupied a defensively advantageous location on an icy ledge, 600 feet above the river. The Germans who oversaw it, however, were taking no chances. They had installed floodlights, barbed wire fences, sirens, and planted mines in the surrounding hillsides; machine-gun nests and troop barracks stood nearby; patrols frequently swept the grounds; and a single-lane suspension bridge provided workers and vehicles the only point of entry.

Now, the commandos—a heavily armed five-man covering party and four-man demolition team—planned to infiltrate the fortress. They were not the first to try. Each man was painfully aware that the last mission had met with absolute disaster: the death of an entire 41-member British force.

Although the commandos had been told that destroying Vemork would strike a significant blow against the Nazi war machine, their commitment and dedication were more personal. They had seen Nazi Germany invade their country in April 1940, curtail their rights, and humiliate, starve, and kill their family and friends. No matter the military objective, the men were there for Norway and the freedom of its people. The saboteurs refastened their skis and started down the road through the darkness.

ACROSS THE NORTH SEA, IN OXFORD, ENGLAND, the operation's mastermind, Leif Tronstad, 39, tensely awaited word of the mission. A celebrated former chemistry professor with sharp blue eyes and keen intelligence, he had once led the construction of an industrial facility at Vemork. Now he was at the center of a mission to destroy it.

The Vemork hydroelectric plant (below, in 2013) was the first industrial-sized heavy water plant in the world. By 1942 the Allies sought to put it out of action.

The commandos had seen Nazi Germany invade their country, curtail their rights, and humiliate, starve, and kill their family and friends. The men were there for Norway and the freedom of its people.

Leif Tronstad (top right, with exiled Norwegian King Haakon VII in England), masterminded the mission. The team included Brooklyn-born Knut Haukelid (left), who would go on to strike the final blow against the Nazi heavy water program, and 23-year-old Joachim Rønneberg (below, front row, right), who led the operation.

Before the war, Tronstad was a consultant for many Norwegian industrial firms. In 1933, he proposed that one such firm, Norsk Hydro, build a facility at Vemork to produce a form of water known as deuterium oxide, or heavy water. It is as rare as it is distinctive; for every 41 million molecules of ordinary water there is just one molecule of heavy water. Tronstad was not sure about the substance's utility, but, as he often told his students, "Technology first, then industry and applications!" He did know that Vemork, with its inexhaustible supply of cheap power and water, provided the perfect setup for such a facility. Through an ingenious inverse-pyramid arrangement of electrolysis chambers, Tronstad built the first—and only—industrial-sized heavy water plant in the world.

When the Vemork plant shipped its first containers of heavy water in January 1935, scientists around the world heralded it as a breakthrough. Even though heavy water's application remained uncertain, Tronstad spoke passionately of its promise for chemical and biomedical research, and its use in the burgeoning field of atomic physics. By 1939, rapid advances in the latter pointed to one significant use: heavy water could be a key component—a so-called moderator, like graphite—in nuclear fission, helping to release a burst of energy on a previously unthinkable scale.

When the Nazis occupied Norway in spring 1940, they took control of the Vemork plant. And Tronstad, still ostensibly a professor and consultant, began spending most of his time on resistance activities. He established a spy network to supply the British with intelligence on German activity in Norway; one of his reports described the Nazis' efforts to rapidly increase production at Vemork.

By September 1941, the Gestapo had learned of Tronstad's underground activities and sought him for arrest. Forced to leave behind his wife and two young children, the scientist escaped to England, where the exiled Norwegian government had established headquarters. The British scientific community tried to recruit Tronstad into their fold, but he wanted an active role in freeing Norway. He maneuvered himself into a position with the Norwegian Army High Command, chiefly as a liaison with the British Special Operations Executive (SOE), which conducted espionage, sabotage, and reconnaissance in occupied Europe. With his knowledge of Norwegian industry, Tronstad had rare insight into how to undermine the German war machine.

TOP: NORGES HJEMMEFRONTMUSEUM; MIDDLE: PRIVATE COLLECTION, HAUKELID FAMILY; BOTTOM: NORSK INDUSTRIARBEIDERMUSEUM; OPPOSITE: PICTORAL PRESS LTD/ALAMY; PREVIOUS PAGE: HERO FILM/RONALD GRANT ARCHIVE/ALAMY

By early 1942, the Allies knew the Nazis were racing to harness nuclear energy. Given German interest in Vemork's heavy water, British intelligence believed the Nazis intended to build a self-sustaining reactor to produce plutonium, a highly fissile element ideal for manufacturing an atomic bomb. "Since [plutonium] is best prepared in systems involving the use of heavy water," an April 1942 statement from Churchill's War Cabinet read, "the Committee recommends that an attempt should, if possible, be made to stop the Norsk Hydro production [at Vemork]."

The Americans and British pushed to strike Vemork by air or with a major ground attack as a joint effort of the Combined Operations Headquarters—the British War Office department tasked with coordinating forces to conduct harassing raids against German forces on the continent. Tronstad feared either scenario would cost too many Norwegian lives. He advocated a small, well-planned commando attack against the facility.

Instead, in November 1942, Combined Operations Headquarters launched an airborne operation, Operation Freshman, in which a British force in two gliders would land near Vemork, destroy the plant, and escape to Sweden. But both gliders crashed before reaching their landing zones. Those the crashes did not kill, German soldiers did: altogether 41 Royal Engineers, glider pilots, and crew died on the mission. And the Nazis now knew of the Allies' interest in their heavy water production.

The SOE turned to Tronstad. He assembled a force whose Norwegian members had escaped Nazi occupation and traveled to England, where they were recruited into *Kompani Linge*, an elite group of commandos under the control of the Norwegian Army High Command and the SOE. As he had with Operation Freshman, Tronstad provided the commandos with scores of reconnaissance photographs, blueprints, equipment diagrams, and reams of intelligence reports. They even practiced using a scale mock-up of the target. On the mission they would wear standard-issue British Army uniforms to prevent Nazi reprisals against the Norwegian population. Still, Tronstad knew an unexpected event could plunge the operation into disaster. He hoped their preparation—and a little luck—would see it through to success.

"For the sake of those who have gone before and fallen, I urge you to do your best," he told the team. "Trust that your actions will live in history for a hundred years to come."

LIEUTENANT JOACHIM RØNNEBERG, Operation Gunnerside's leader, surveyed the scene from the edge of the snowbound hillside. Intelligent and steady, with a slim, patrician countenance, Rønneberg, 23, had an innate ability to lead, and the team's complete respect. At his command, they continued toward the bottom of Vestfjord Valley, hanging onto shrubs and branches, repeatedly slipping and losing their footing in the snow, until they finally reached the Måna River. The cliffs of the gorge soared upward on either side of them.

One of the commandos, Claus Helberg, a boyish 24-year-

NAZI GERMANY AND THE BOMB

How close were they? BY MARK WALKER

ON THE EVE OF WORLD WAR II, four scientists—two Germans and two German émigrés—collectively discovered nuclear fission. Work to understand and develop the discovery began quickly thereafter. Scientists in many different countries—Leo Szilard in the United States, Frédéric Joliot-Curie in France, Rudolf Peierls in Britain, Paul Harteck in Germany, among them—saw in the discovery a potential for military applications, and some discretely contacted authorities.

During the "Blitzkrieg" phase of the war (September 1939 to November 1941), neither the United States, which remained neutral, nor Germany, which had enjoyed a string of victories without a significant defeat, needed what the Germans would later call "wonder weapons." As a result, nuclear research in both countries proceeded with surprisingly equal progress.

That changed in the winter of 1941-42. The German Blitzkrieg ground to a halt in the Soviet Union and the Japanese attack on Pearl Harbor brought the Americans into the war, with Hitler unilaterally declaring war on the United States days later. In Germany and the United States, military and political authorities asked scientists working on nuclear weapons the same question: when can we expect these weapons? Underpinning this question was another: can these weapons decide the outcome of the war?

Scientists on both sides had the same answer: yes, nuclear weapons appear possible, but developing them will take years. The contexts for that answer differed, however. In 1941-42, planners in

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The cliffs of the gorge soared upward on either side of them. Up close in the dark, the steep, 600-foot ascent looked nearly unassailable. But there could be no turning back. Rønneberg gave the hand signal: up!

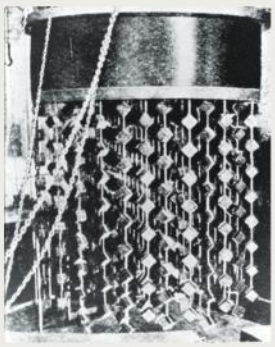
old, had grown up in the immediate area and worked as a mountain guide for a touring organization before the war. He and several other compatriots on this mission had spent the previous five months living in the mountain wilderness, surveilling Vemork and preparing for the attack against it. Up close in the dark, however, the steep, 600-foot ascent he had chosen looked nearly unassailable. But there could be no turning back. Rønneberg gave the hand signal: *up!*

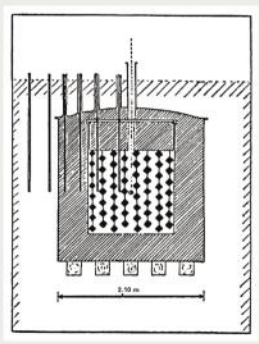
Each man took his own silent path up the rock wall. Water trickled down the cliff, freezing into tricky patches of ice and encrusted snow. On some stretches they scrambled to grab rock outcrops or tree trunks to quickly gain a few feet. When the men glanced down the way they had come, the gorge looked like a set of terrible jaws, ready to devour them. Shaking off the sight, they continued. Sweat soaked their clothes as they dug their fingers and boots into crevices and inched their bodies sideways, pressing tightly against the gorge wall to avoid gusts of wind. It took half an hour to reach the halfway point, and they were growing weary. Their fingers hurt. Their toes were numb. Their limbs ached. Any missed hold or slipped foot could prove fatal.

At last, a few minutes past 11:00 p.m., the first commando scrambled up the final bit of scree to the railway line leading to the plant. The others followed, relieved to be at the top. For a spell, nobody spoke. They rested on the tracks and looked toward the fortress at the end of the line.

Now it was time to finish the job.

AT 12:30 ON THE MORNING OF FEBRUARY 28, a half hour after Vemork's guards had changed shift, Knut Haukelid, 31, cut the chain on the gate to the railway line. The team maverick, he had been born in Brooklyn to Norwegian parents. Now Haukelid—who bore a striking resemblance to American actor Humphrey Bogart—was second-in-command of Gunnerside and leader of the covering party. The men moved onto the grounds, Haukelid's eyes sweeping for any signs of alarm. They would be ready to act if German guards approached or an alarm sounded. The demolition party followed, heading for the eight-story hydrogen plant. To double their





American soldiers dismantle the Nazis' experimental research reactor (left) at Haigerloch, Germany, in April 1945. The reactor featured a lattice design of metal uranium cubes (below). It was not until late in the war that the Allies were able to reliably assess just how close the Germans were to developing an atomic bomb.

LEFT: NATIONAL ARCHIVES; CENTER: AIP EMILIO SEGRE VISUAL ARCHIVES; RIGHT: MARK WALKER

chances they split into two pairs—Rønneberg with Fredrik Kayser and Birger Strømsheim with Kasper Idland.

Rønneberg and Kayser edged around the eastern side of the building. Their goals, a steel basement door and adjacent first-floor door, were locked and inaccessible. Rønneberg remembered discussing alternate entry points with Tronstad, who had suggested a narrow utility tunnel running between the basement ceiling and first floor, with an access hole in the exterior wall. Rønneberg led Kayser around the building and searched through the snowbank until they found a steel ladder leading to the tunnel. The two climbed 15 feet to the entrance. It was unbarred. Rønneberg swept snow out of the opening and crawled inside. His body barely fit, so he dragged his rucksack of explosives behind him. Kayser squirreled after him. Meanwhile, Strømsheim and Idland—who had not seen the pair climb into the tunnel—sought another way inside.

After crawling dozens of yards through the maze of pipes, Rønneberg arrived at a large opening revealing a cavernous hall. He checked the room and dropped to the floor.

Vemork began shipping heavy water (above) in January 1935. Rapid advances in atomic physics soon suggested its utility as a key component of nuclear fission.

Kayser followed.

They quickly reached their objective—the basement room housing 18 high-concentration cells, where the final stage of heavy water production occurred. In the tens of thousands of electrolysis cells on the floors above, the ratio of heavy water to ordinary water flowing through the system had steadily increased. Now these 18 cells brought the concentration to nearly pure deuterium oxide. A sign on the double doors read: NO ADMITTANCE EXCEPT ON BUSINESS.

Rønneberg and Kayser drew their Colt .45 pistols and entered. The night-shift worker overseeing the plant, a portly, gray-haired Norwegian, swung around in his seat. Kayser was beside him in an instant, his pistol leveled at the man's chest. "Put your hands up," Kayser barked in Norwegian. "Nothing will happen to you if you do what you're told. We're British soldiers."

NAZI GERMANY AND THE BOMB

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the United States assumed it would take years to defeat Germany and Japan, meaning nuclear weapons might decide the outcome. At that same time, Germany remained optimistic about winning the war—if it could be won quickly, which ruled out the need for nuclear weapons.

Both sides knew that creating such weapons would take immense manpower and resources. The United States quickly boosted uranium research to the industrial level for the Manhattan Project with massive isotope separation plants in Oak Ridge, Tennessee; plutonium plants in Hanford, Washington; and, of course, the weapons lab in Los Alamos, New Mexico. German research, which concentrated on finding a method to separate uranium isotopes and on building nuclear reactors relying on a substance called heavy water as a moderator, did not expand. Nevertheless, German political and military authorities considered uranium research important enough to continue during wartime, exempting its scientists from frontline military service and providing them relatively generous support in materials and funds.

Throughout 1942, German scientists worked hard and made progress, but unknowingly fell far behind the Americans. Following the German collapse at Stalingrad in 1943, propagandist Joseph Goebbels's calls for "total war" and "wonder weapons" to stave off defeat did not directly affect the German nuclear weapons project. Instead, the Third Reich put its faith in rockets, jet aircraft, and other apparently more promising high-tech weaponry.

During the last, desperate 18 months of the war in Europe, the German scientists struggled hard to achieve their goals—not an atomic bomb, but successful uranium isotope separation and the construction of a nuclear reactor that could control a self-sustaining fission chain reaction. In the end they were able to significantly enrich uranium 235 and came close to creating a self-sustaining chain reaction. Thus, by May 1945, the Germans had achieved almost,

HYDRO ARCHIVES

At any moment, a German sentry could raise the alarm, bringing on searchlights, sirens, and machine guns. The likelihood of something going wrong increased with each passing minute.

As Kayser guarded the worker, Rønneberg unpacked the explosives and fuses from his rucksack. The heavy water cells stood in two rows, looking exactly like the replicas with which they had trained. Each stainless-steel cell tank was 50 inches tall and 10 inches in diameter, with a cluster of rubber tubes, electrical wires, and iron pipes snaking out the top. Rønneberg had 18 charges of one-foot-long Nobel 808 plastic explosives to destroy them. Donning rubber gloves to avoid electrical shock from the metal containers, Rønneberg moved from one cell to the next, adhering a daisy-chained series of plastic explosives to their bases. The night-shift worker, his hands still held high, became increasingly nervous as he watched Rønneberg work.

"Watch out," he blurted. "Otherwise it might explode!"

"That's pretty much our intention," Kayser replied drily.

Rønneberg had just finished fastening a band of explosives to the ninth cell when the window behind him shattered. He grabbed his pistol and he and Kayser swung around to face the threat—but it was Strømsheim.

Like Rønneberg and Kayser, Strømsheim and Idland had been unable to find any accessible doors and decided to force their way into the room—only narrowly avoiding being shot by their comrades. Now working together, Rønneberg and Strømsheim positioned the remaining explosives. Idland remained outside to block the light emanating through the shattered window.

OUTSIDE WITH THE COVERING PARTY, Knut Haukelid felt as though hours had passed since they had snuck through the railway gate. He glanced at his watch: it had been only 20 minutes. He wondered if the demolition team had made it inside the building and if all was going according to plan. At any moment, a German sentry could raise the alarm, bringing on searchlights, sirens, and machine guns. Haukelid's eyes searched for guards patrolling the grounds. If any walked past, he had chloroform-soaked pads ready to take them down—or several grenades, if it came to that. So far they had encountered no one, but the likelihood of something going wrong increased with each passing

but not quite, what the Americans—including émigrés who had fled Nazi Germany and Fascist Italy—had accomplished by December 1942.

Ironically, the Germans believed they were ahead of the Americans. After the end of the war in Europe, an American intelligence unit housed ten German scientists—nine of whom had worked directly in uranium research—at Farm Hall, an English country house near Cambridge wired for eavesdropping. When the Germans heard a radio announcement about the bombing of Hiroshima, their world shattered. Instead of having done important and valuable work under difficult conditions, they had been second-class. Moreover, postwar revelations of Nazi atrocities made very clear the sort of regime they had been working for.

WERE THE GERMANS TRYING TO make nuclear weapons? This might seem like a simple question, but it is not, and helps explain why the Nazi regime never came close to building an atomic bomb. If by "trying," one means doing what was necessary—investing massive resources—then the Germans did not try. But if one means using available resources to work hard under adverse conditions to achieve the first necessary steps toward an atomic bomb—uranium isotope separation and a self-sustaining nuclear reactor—then, yes, the Germans were trying.

By February 1943, when Norwegian commandos attacked the Vemork hydroelectric plant producing heavy water for German uranium research, there was no chance of Germany coming close to an atomic bomb. Despite that attack and the February 1944 sinking of a Norwegian ferry loaded with heavy water, the Germans had enough heavy water for their model nuclear reactor experiments. Many war-related factors slowed the German work. A shortage of heavy water was not one of them.

This should not call into question the honorable and daring efforts of the Norwegians, Britons, and Americans seeking to stop the Germans' heavy water production. At the time, the Allies had good reason to believe that the Nazi nuclear program was a threat, and the heavy water plant at Vemork was one of the few targets they could attack. The Allied men involved were told that this was necessary, and they risked everything to carry it out. ✯

German General Nikolaus von Falkenhorst (above, in white) visits Vemork. He planned the April 1940 invasion of Norway and commanded Wehrmacht forces there.

minute. Fear gnawed at his mind.

Once the explosives were in place, Rønneberg secured fuses to the charges. He sent Strømsheim to open the exterior basement door while Kayser moved the night-shift worker to the hall. Footfalls suddenly echoed in an interior stairwell. Expecting a guard, Kayser and Strømsheim aimed their pistols and waited. But it was the Norwegian night foreman, who whelped in surprise and flung up his hands. As Kayser guarded his two hostages, Strømsheim unlocked and opened the steel door leading outside.

In the high-concentration room, Rønneberg carefully checked the explosives one last time before lighting the fuses. He barked at Idland, who was still outside the window, to get clear and dashed into the hall, counting down seconds in his head. He told the two hostages to go upstairs, lie down, and keep their mouths open to avoid having their eardrums blown out when the explosives detonated.

As the Vemork workers raced up the stairs, the three commandos pushed through the basement door. Kayser slammed it shut behind them and the men sprinted away from the plant. Idland joined them on their run. The commandos were 20 yards away when they heard a muffled explosion and saw a flash of light as the high-concentration room windows shattered. To Haukelid, who was still in position covering the demolition party, the explosion seemed like an anticlimax: an insignificant pop. Nevertheless, German sirens across the facility eventually began to blare and Haukelid and the rest of the covering party joined their comrades in their flight back toward the railway line. They would have to move fast.

The commandos pushed through the door and sprinted away from the plant. They heard a muffled explosion and saw a flash of light through the windows of the high-concentration room.

American heavy bombing raids in November 1943 caused extensive damage to the Vemork plant (above), but failed to decisively knock it out of action.

WITHIN AN HOUR, VEMORK'S CHIEF engineer, accompanied by a host of Germans, inspected the high-concentration room. Everything lay in ruins. Pumps were broken, walls scorched, the network of tubes a twisted wreck. Shrapnel had sliced through the cooling system's copper pipes and water sprayed the room. The 18 steel-jacketed cells had been shredded, and all their precious heavy water had swirled down the room's drains. Whoever the saboteurs were, the chief engineer concluded, they knew exactly what to destroy and did their job well.

"The most splendid coup," remarked the commander of German forces in Norway, General Nikolaus von Falkenhorst, when he visited Vemork after the sabotage. His admiration for the work did not dull his wrath toward his men guarding the plant.

The Germans staged a massive manhunt, sending more than 3,000 soldiers to comb the area in search of the fleeing saboteurs. The commando team split up; some of the men, including Haukelid and Helberg, escaped into the mountains to wait out the hunt and continue further operations against the Nazis. Rønneberg and four others made their way on a long, looping trek toward Sweden—an arduous, 18-day journey that covered more than 280 miles, and an epic feat in its own right.

IN LONDON, LEIF Tronstad received a long-awaited confirmation from one of his operatives in Norway: "OPERATION CARRIED OUT WITH 100 PERCENT SUCCESS. HIGH-CONCENTRATION PLANT COMPLETELY DESTROYED. SHOTS NOT EXCHANGED SINCE GERMANS DID NOT REALIZE ANYTHING. GERMANS DO NOT APPEAR TO KNOW WHENCE THE PARTY CAME OR WHITHER THEY DISAPPEARED."

Tronstad estimated that Operation Gunnerside had cost the Germans up to 700 kilograms of heavy water, and that the damage to the plant's equipment would delay production by at least 10 to 14 months.

His estimate proved optimistic: Within five months, the Germans rebuilt the hydroelectric plant and returned it to production. Only the combination of American air raids on the plant that November and a last-minute sabotage raid by Knut Haukelid on a ferry carrying the plant's heavy water supplies the following February would put the fortress at Vemork out of play for good. But the first major blow against the Nazi atomic bomb program had come at the hands of the saboteurs on skis. ✯

NORSK INDUSTRIARBEIDERMUSEUM; OPPOSITE: NORGES HJEMMEFRONTMUSEUM