CRREL's organization as of early 1962 can be briefly summarized as follows. Colonel Nungesser was the Director; W. Keith Boyd, the Technical Director; Rodney F. Poland, the Executive Assistant; Albert Taylor the Comptroller; Lillian G. Meier, the Office Services Manager; E. Earle Jewell, Chief of the Logistics and Supply Branch; Harry Page, Chief of the Plant and Equipment Branch; Frederick Kitze, Chief of the Alaska Field Station, and F.C. Gagnon, Chief of the Keweenaw Field Station.

The Research Division was headed by James Bender. The two branches in this Research Division, the Materials Research Branch and Environmental Research Branch were headed by Dr. Paul Camp and Dr. Robert Gerdel. The Experimental Engineering Division, headed by Kenneth Linell, contained the Applied Research Branch with Dr. Andrew Assur, Chief, and the Construction Engineering Branch, Edward F. Lobacz, Chief.

In the Technical Services Division (B. Lyle Hanson, Chief) was the Measurement Systems Research Branch, headed by Leonard Stanley, and the Liaison and Technical Publications Branch, headed by Wesley Floyd. In this branch were Eunice Salisbury, the CRREL Librarian and Lucybelle Bledsoe, supervisor of the publications department.

The fourth division was the Photographic Interpretation Research Division, headed by Robert Frost, who was assisted by James McLerran.

The staff at that time numbered about 170 civilians and 40 enlisted men. Of particular note at this time was the number of U.S. Army enlisted men. They were, in general, college graduates who had acquired engineering background and training and had been assigned to the laboratory through the Army's ‘‘Scientific and Engineering Assistants Program" (S&E). For many years to come, these S&E's fulfilled an important function in the overall operation of CRREL and, while doing so, probably saved the government hundreds of thousands of dollars. Serving primarily as technicians, the S&E's made substantial contributions to CRREL's technical programs both in the field as well as in the laboratory throughout the 1960's and well into the 1970's. A number of S&E's produced interim or progress reports, which often became the basis for final research or technical reports. But perhaps the most rewarding payoff of all was in the large number of S&E's who continued to work at CRREL after leaving the Armed Forces. These former army specialists became known at CRREL as "the S&E Generation."

Also in 1962 (19 November), Colonel Nungesser wrote the following letter to the Commanding General, U.S. Army Mobility Command:

> "In view of a change in research emphasis of this laboratory under certain projects, it has become evident that considerations should be given to closing the Keweenaw Field Station, reducing the scope of operation and placing the station on a stand-by basis or transferring the station to another command or Army agency..."

Within a month the Army Mobility Command sent a team of four investigators to Keweenaw and AMC General Order No. 23, dated 18 April 1963, stated

> "Effective 1 July 1963, the Keweenaw Field Station, Houghton, Michigan, a facility under the U.S. Army Cold Regions Research and Engineering Laboratory, is organized as a class II activity and placed under the jurisdiction of the Commanding General, U.S. Army Mobility Command."

When looked at in retrospect, the transfer of Keweenaw was an inevitable step toward a shift of CRREL' s research to Alaska. The investigators from the Mobility Command recommended that the Michigan College of Mining and Technology take over Keweenaw's operation. Under the college's direction the Keweenaw Field Station still functions today as a proving ground for experimental engineering equipment designed for cold regions use.

CRREL's research facilities in Hanover were still incomplete during 1962 and much of 1963, but this did not prevent research activities outside of Hanover. For example, the Photographic Interpretation Research Division (PIRD) conducted a study of aerial sensing of tropical surfaces in Puerto Rico in November of 1962. Field work consisted of obtaining aerial imagery (infrared, radar and photo) of selected flight lines covering typical geology, soils, vegetation and land use.

In Antarctica, CRREL studied temperatures at Byrd Station and, in 1963, developed a method that would substantially reduce the rate of snow tunnel deformation. A new ventilation scheme was devised, involving the use of natural convection of cold air through snow pores by means of a slight pressure reduction in the tunnels.

From January until April of 1963, CRREL participated in a joint American/Canadian project called Bold Survey. It concerned the reconnaissance of sea ice and snow-covered terrain by infrared scanners. CRREL's Photographic Interpretation Research Division obtained conventional aerial photographs and infrared imagery of areas in the Gulf of St. Lawrence, northwest Greenland, islands in the Canadian archipelago north of 75°N and of pack ice all the way to the North Pole. Concurrently, Canadian scientific teams in five locations collected surface data in the Arctic Islands and CRREL personnel on a Canadian icebreaker in the Gulf of St. Lawrence obtained additional correlatable data. This project conducted the first infrared reconnaissance mission at the Pole.

At the request of the State Department, a CRREL researcher made an on-site reconnaissance of the area around the Zoji La Pass in northeastern India. On his trip, he recommended snow removal techniques for the military supply line between Leh and Jammu, where winds sometimes exceeded 100 mph and where avalanches and landslides were frequent.

Also in 1963, the U.S. Coast Guard received help from CRREL in testing their icebreakers on perennial and seasonal sea ice in the Kennedy Channel off the north Greenland coast. The New York District, Corps of Engineers, also called on CRREL for help with problems with a BMEWS (Ballistic Missile Early Warning System) radar facility's foundation at Thule. CRREL also served in a consultant's capacity for the New England

Bridge endangered by ice jam (Lancaster, New Hampshire).

Division of the Corps in the efforts to alleviate the ice jams and floods that plagued the town of Colebrook, New Hampshire.

Bell Telephone Laboratories asked for CRREL's help in preventing snow and ice accumulation on open mesh metal panels to be used in a major system of missile defense antennas. The CRREL researchers found that electrical resistance heating was the method that proved effective under the widest variety of conditions. Interestingly, the final field tests were performed at South Georgia in the Falkland Islands because of the urgency of completing the project, when it was still summer in the Northern Hemisphere.

Throughout most of 1963 the dedication of the new building was postponed so many times that Colonel Nungesser began to think a formal dedication would appear anticlimactic. On 6 March 1963, he wrote to Major General Frank H. Britton, Director of Research and Development, Headquarters, AMC:

> "As you are aware, we have been planning a dedication ceremony for our new laboratory building for quite a while now, but each time something happens and the date slides further away. In view of the fact that a large portion of our people will be in Greenland and Alaska during the summer months,... any form of dedication ceremony should be delayed now until the fall (October–November). In fact, in view of the circumstances, I now recommend that we consider not having any formal dedication ceremonies. We will, of course, have 'Open House' for the local communities after the building is completed..."

General Britton agreed with Colonel Nungesser's recommendation but

pressed him for a definite date so that the plans could be announced. Nungesser then set the dates for CRREL's informal dedication and open house: Thursday, Friday and Saturday 21–23 November 1963.

As General Britton said before he cut the ribbon across the laboratory's doors:

> "This will open the doors to the many friends of CRREL visiting today and throughout the open house period. But more than that—it will signal, symbolically, the opening of the doors to new horizons in scientific and engineering achievements."

The dedication itself was limited to a short ribbon-cutting ceremony on Thursday after a luncheon hosted by President Dickey at Dartmouth's Alumni Hall. The open house continued on Friday morning, but on the afternoon of the 22nd, President Kennedy was assassinated and all activities at CRREL were suspended. Colonel Nungesser wrote to John F. Meck, Treasurer and Vice President of Dartmouth, on 4 December:

> "I don't believe the rain nor the sad happenings of that weekend detracted too much from our program, although we felt it appropriate to cancel the open house for Saturday morning...we had over 1700 people taking advantage of the tours through the building and I am sure an additional 600 to 700 would have participated had we been open Saturday...we plan to again have an open house for the local community around Armed Forces Day in May for those who didn't have the opportunity to attend last Saturday."

Now that it finally had a home, CRREL began playing host to many scientific symposia and meetings such as the meeting of the Glaciology Panel of the Committee on Polar Research, National Academy of Sciences, in April of 1964 and the Conference of Commanders and Directors of Independent Laboratories held the following year. And on 4 to 12 May 1964, the lab held a course in cold regions engineering for 20 Air Force officers. This course proved so successful that it became an annual event for several years. Twenty-eight CRREL staff members served as instructors, giving the Air Force students, through illustrated lectures, demonstrations and discussions, the benefits of more than 20 years' research and investigation by CRREL and its predecessor organizations. CRREL's expertise was thus applied to operations and maintenance at northern air bases and the DEW line.

Colonel William L. Nungesser's tour of duty with CRREL ended in July of 1964. The laboratory's supervisory personnel honored him at a luncheon at the Hanover Inn and later the entire CRREL staff give him a farewell reception. There it was said of him that he "brought with him not only the precision and the investigative instincts and training of the engineer, but also the much needed abilities of an able administrator." Colonel Nungesser later returned to Hanover as Commander of U.S. Army ROTC at Dartmouth College and, upon retirement from the Army, he became a Vice President of Hanover's Dartmouth Savings Bank.

Colonel Philip G. Krueger of the Army Materiel Command succeeded Colonel Nungesser at CRREL. Colonel Krueger, a West Point graduate, had been Deputy Commanding Officer of the Army Mobility Command's Engineer Research and Development Laboratories at Fort Belvoir since 1962. At the time of the command transfer, the executive function at CRREL comprised four people: the Commanding Officer (Krueger), the Technical Director (Boyd), the Scientific Advisor (Assur), and the Executive Assistant (Poland).

Colonel Krueger submitted a letter of resignation to OCE in early 1966, surprising many of the CRREL staff. On 18 April 1966, Colonel Dimitri A. Kellogg was placed on temporary duty at the laboratory for orientation, and at Krueger' s departure, he returned to Hanover as acting Commanding Officer of CRREL. He was to hold that position until a permanent commander arrived—later that summer.

Colonel Kellogg's primary duties concerned the Army Materials and Research Center (ARMC) at Natick, Massachusetts, so that his tour of duty as Acting Commander at CRREL was, for the most part, in absentia. According to Colonel Kellogg:

> "I had asked to command an Army Lab, expecting to get something like the linear accelerator and reactor lab in the Maryland complex, since I have a Ph.D. in nuclear physics. Instead I was sent to CRREL and AMRA [then called the Army Materials and Research Center or AMRC] ... to solve serious personal interface problems in the top management of CRREL and between AMRA and Watertown Arsenal. For a while I commanded both places simultaneously, commuting back and forth. At CRREL, the problem was a personality and jurisdictional clash between Phil Krueger (CO) and Keith Boyd (Technical Director). There was also some in-fighting between AMC and the Corps of Engineers over control (I was sent by AMC)... I like to think that I was at least partly responsible for getting a Corps of Engineers officer to relieve me..."

During the 8 months of his tenure at CRREL, Colonel Kellogg secured cooperation and respect from the staff. During these months CRREL received an official commendation from AMC for its "outstanding support of the AMC Cost Reduction Program." The commendation concludes: "The efforts of the U.S. Army Cold Regions Research and Engineering Laboratory contributed significantly to the excellent accomplishments of this program and reflect credibility upon the organization and the U.S. Army Materiel Command."

On 6 February 1967, Lieutenant Colonel John E. Wagner signed General Order No. 2 which designated him as Commander and Director of CRREL. Colonel Wagner was a 1950 graduate of West Point, had fought in Korea, served in Germany, and had been Military Assistant to the Director and Project Engineer of USAE Waterways Experiment Station (WES) at Vicksburg, Mississippi, among other duties and accomplishments.

But on 12 June 1968, AMC's General Order No. 45 redesignated the U.S. Army Cold Regions Research and Engineering Laboratory as the U.S.

Army Terrestrial Sciences Center (TSC), effective 30 June 1968, to the surprise of many at CRREL.

The Terrestrial Sciences Center was an ambitious undertaking. Actually, during its one-year existence, TSC was an organization on paper within which CRREL was the sole functioning laboratory. Perhaps the only indication of CRREL's expanded role as part of the TSC was the Chief Scientist's assignment for 6 months to South Vietnam to learn about difficulties in tropical areas. His mission was only observational, but after criss-crossing the country and making recommendations, he returned with a combat service medal.

Also in 1968, the same CRREL team that had drilled through the Greenland Ice Cap was the first to penetrate the Antarctic Ice Sheet, after drilling through over 7100 ft of ice. Again, a complete core was obtained, which has revealed a wealth of information about the world's past climate and about Antarctica itself.

In 1967, two CRREL researchers received Army Research and Development Awards. Lyle Hanson, who headed the drill teams in Greenland and Antarctica, was recognized for his deep drilling accomplishments, and Dr. Wilford Weeks was recognized for his research on the formation and physical properties of sea ice

In 1967, oil was discovered north of the Brooks Range in Alaska. Personnel from private oil companies as well as the government came to

Ice cores in coldroom at CRREL.

CRREL for answers to the many questions posed by this discovery. In general, the questions addressed two major problems:

1. How could they get the oil out of the frozen ground, the permafrost or from under the Beaufort Sea?
2. How could they best transport the crude oil to the continental U.S. where it could be refined and put to use?

A prominent program during this time was CRREL's participation in the two test voyages of the icebreaking oil tanker *Manhattan*. Five CRREL researchers journeyed aboard the *Manhattan* for the "Arctic Tanker Project," which was financed mainly by Humble Oil, with some assistance from Atlantic Richfield and British Petroleum. The expedition began in September 1969 with two Canadian icebreakers and one U.S. icebreaker trailing the *Manhattan*. The arrangements were for the icebreakers to carry out search and rescue operations if needed, but the main icebreaking effort was the task of the supertanker. The objective was to have the *Manhattan*, the largest U.S. commercial vessel then in service, ram itself into the thickest ice that could be found.

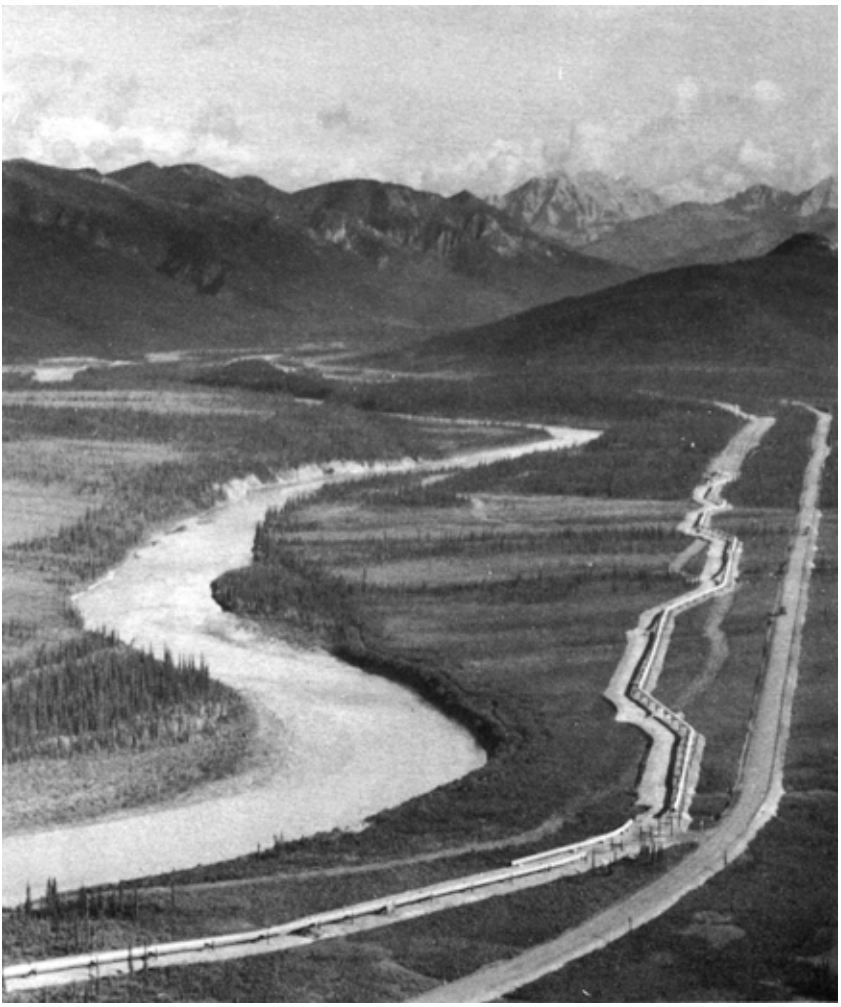
The *Manhattan* eventually succumbed to the ice of McClure Strait, where ice ridges at that time towered up to 40 ft above the water. The ship could neither budge forward nor backward, and, for the first time, called for assistance from the icebreakers. With the help of the icebreakers, the *Manhattan* was ultimately able to throw its tonnage fore and aft until, 18 hours later, it broke free. It then backtracked and rerouted its trek through the Prince of Wales Strait. Finally, 22 days and 800 miles out of port, the expedition reached clear water in the Beaufort Sea north of Alaska. The Northwest Passage had been conquered.

U.S.S. Manhattan *in Arctic pack ice.*

In April of 1970, a second voyage was begun with three CRREL scientists on board. They sailed the same route almost to Resolute Bay, and then, having secured the data they needed, returned to port. The major reasons for the second voyage were to determine power requirements (43,000 horsepower had proven to be only marginal) and to obtain additional information needed for model studies.

The two voyages had cost in excess of $50,000,000. Nevertheless, Humble abandoned its proposed project of using ice-breaking supertankers to transport oil from Alaska's North Slope to United States markets one year later, as it was about to join the other oil companies that formed the Alyeska pipeline consortium.

CRREL personnel were closely involved as consultants in the planning and building of the trans-Alaska pipeline. CRREL engineers were on the "Menlo Park Working Group" that reviewed the pipeline design and were



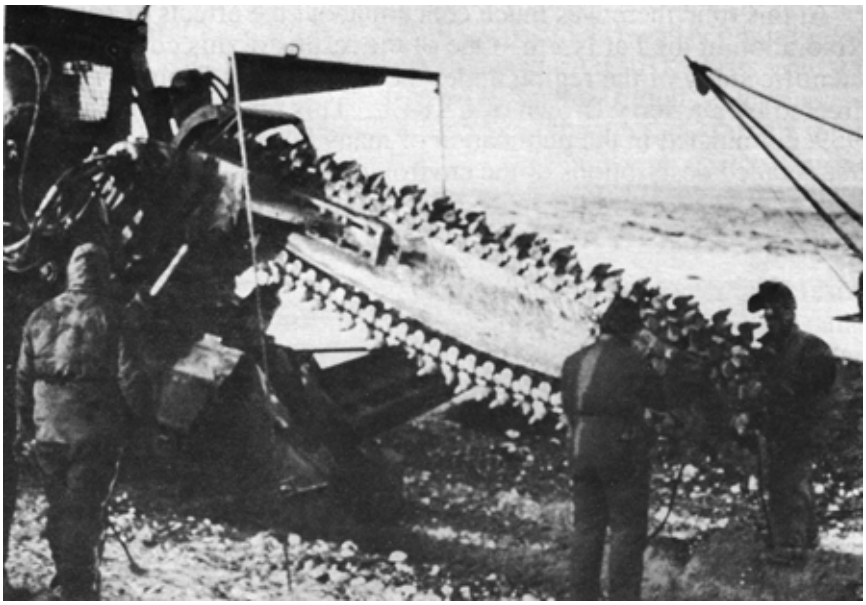
Trans-Alaska oil pipeline.

consultants to the Federal Inspector for stipulations regarding construction practices. In addition, engineers for Alyeska consulted with CRREL employees and made full use of their knowledge about construction on permafrost. In particular, advice was given on the behavior of piles in permafrost as a substantial portion of the pipeline is elevated on piles to prevent the warm oil from thawing the permafrost below.

During pipeline construction, 35 CRREL employees helped solve problems as they arose and instrumented sections of the pipeline and ad joining haul road for long-term studies that continue today. Recently, CRREL engineers have also been involved with the planning of a chilled natural gas pipeline that will eventually be built near the present oil pipeline.

At this time there was much concern about the effects of petroleum exploration in the Far North. One of the results of this concern was the

Augering holes for installation of thermocouples, trans-Alaska pipeline haul road.



Trenching equipment, trans-Alaska pipeline.

Monitoring growth of vegetation in northern Alaska.

Ice lead separating floating ice camps in Arctic Ocean.

scientific study of the region under the U.S. Tundra Biome Program,* directed by Dr. Jerry Brown of CRREL. This program, which began in 1969, culminated in the publication of many books and articles that gave the first detailed descriptions of the environment of northern Alaska.

At about the same time of the *Manhattan* voyages, a long-term program called AIDJEX (Arctic Ice Dynamics Joint Experiment) was being initiated, in which several CRREL researchers participated. AIDJEX was a voluntary collaboration of research groups from throughout the United States and Canada who were working on arctic problems. However, despite its unofficial status, the AIDJEX program had a definite plan which

*A biome is a major ecological zone or region corresponding to a climatic zone or region.

centered around deployment of an array of drift stations that would travel through the Arctic Ocean with the moving ice. Most of these stations had automatic signaling systems, but some were manned for periods of several weeks.

On 21 January 1968, a B-52 bomber carrying nuclear weapons crashed on the sea ice about 8 miles west of Thule Air Base, and CRREL was called upon to help in recovering the wreckage. An onboard fire had caused the B-52 to crash into a region of continuous sea ice, leaving a 500 by 200 ft blackened area that was strewn with rubble. Six of the seven crew members had managed to parachute to safety, but one of the crew was lost in the crash.

In charge of the CRREL on-site research was Guenther Frankenstein, who calculated the weight of equipment that the sea ice could safely hold during the round-the-clock recovery effort. At this time of year, the region was in almost continuous darkness (except for a brief period of twilight) and the temperatures were generally below –20°F; nonetheless, the recovery effort was completely successful, with the H-bombs and other important parts of the airplane safely retrieved. In addition, it should be mentioned that several other CRREL employees helped to make this mission successful.

For his work during the B-52 recovery and for his participation in the *Manhattan* voyages, Frankenstein received one of the Army's Research and Development Awards for fiscal year 1969.

CRREL IN THE 1970s AND 1980s

It was during the 1970s that CRREL was truly recognized for its scientific and engineering accomplishments. Both individual researchers and the laboratory as a whole received national awards during this decade, reflecting accomplishments that often depended on research done in previous years.

1970–75

Yet it cannot be said that the decade of the 1970s began auspiciously for CRREL. In the nation as a whole, the controversy over the Vietnam War began to assume major proportions in the late 1960s and early 1970s and CRREL was not immune from this. Despite the lab's lack of involvement in the war, a number of students from Dartmouth College, and several other individuals, including the Dartmouth chaplain, marched to CRREL in an anti-war protest in February 1970. Colonel Wagner answered many of the students' questions in an interview published in *The Dartmouth*. He met with Dartmouth's president, Dr. John Kemeny, who agreed to bring to the students' attention CRREL's environmental programs and its contributions to the local area, as in developing new frost heave criteria for local roads and in preventing ice jams on local rivers.

Nevertheless, the protests continued, culminating in sit-downs at the entrance to CRREL's parking lots on 11 and 12 May 1972, during which 31 individuals were arrested. During this and other protests, many of the CRREL employees left their offices to talk to protesters, and on 19 May about 30 war protesters and 60 CRREL employees had a picnic on the lawn in front of the main CRREL building. There were no further protests at CRREL after this informal get-together.

Interestingly, during this period of controversy, CRREL was put under the leadership of a veteran of the Vietnam war. Wagner was succeeded by Colonel Joseph F. Castro, as CRREL's Commander and Director. Castro had previously been a staff officer in the Office of the Chief, Research and Development, and a Commanding Officer of two different combat battalions in Vietnam. His experience with cold regions studies was by way of his assignments as Resident Engineer, DYE–4, Kullusuk, Greenland, and Assistant Area Engineer, Cape Dyer, Baffin Island, Canada.

Castro's tour of duty lasted 3 years, during which a number of significant research programs came to CRREL. Among these was the Advanced Research Projects Agency's Arctic Surface Effect Vehicle (SEV) Program. This study, which was carried out in concert with the National Science Foundation's Arctic Ice Deformation Joint Experiment, investigated the use of these "air cushion" vehicles in the various regions of Alaska. Included in the study were investigations of the size and number of ice ridges in the Arctic Ocean over which an SEV would need to pass, the characteristics of the tundra on Alaska's North Slope and the effect of SEV operations on the tundra itself. Dr. Kay F. Sterrett, who had succeeded James Bender as Chief of the Re-

Surface Effect Vehicle.

search Division, was Program Manager of the SEV Program throughout its 5-year duration, and various aspects of the study involved over 30 members of the CRREL staff.

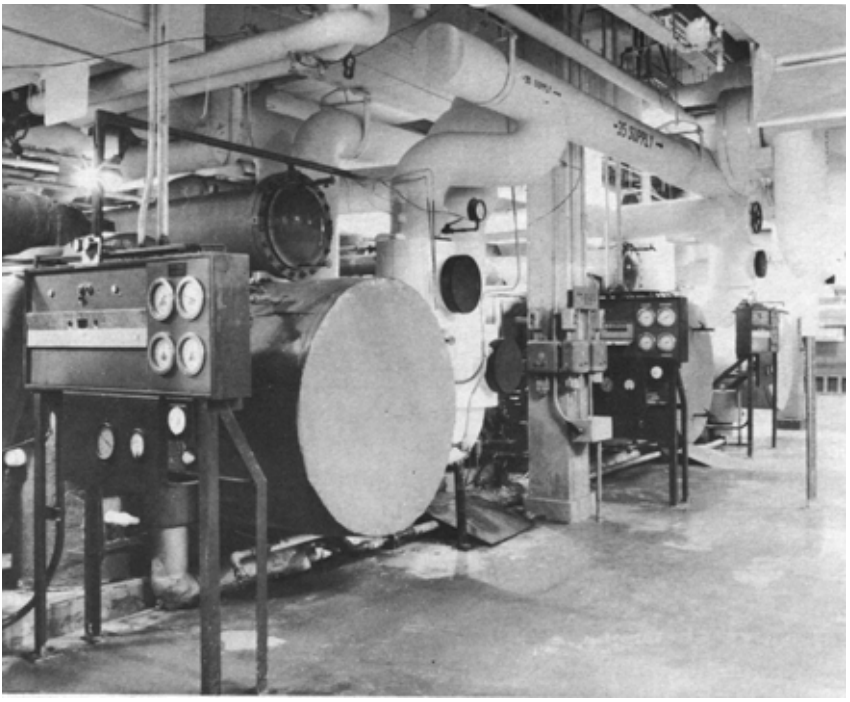
Soon after Castro took command, the Photographic Interpretation Research Division was transferred to the U.S. Army Topographic Command, thus completing the reorganization of CRREL within the Corps of Engineers that had begun the previous year. This transfer involved the loss of 5 S&E's and 20 civilian researchers and support personnel, a significant fraction of the research staff. However, CRREL soon was to gain many more staff members than were lost in the move.

In 1970, two CRREL employees, Robert Northam and Ray May, received the Army Meritorious Civilian Service Award for their lifesaving effort during an explosion of trichloroethylene vapor that occurred on 2 July 1970. They were noted for their "display of unusual courage and competence in the rescue of a fellow employee" in their award citation. On 2 July 1970, a CRREL employee, Arnold Goerke, was making repairs with a welding torch while standing on top of a 10,000-gal. tank containing trichloroethylene, when a sudden explosion blew Goerke off the tank, shattering most of the windows in the back of the main CRREL building. The quick action of Northam and May in rescuing Goerke prevented more serious or fatal injuries.

Trichloroethylene (TCE) is the refrigerant that was used in CRREL's 24 coldroom laboratories (rather than Freon or ammonia as in other systems). Prior to the explosion, TCE was generally not considered to be explosive or even flammable, and this was the major reason for the lack of precaution while welding. TCE was known to be an anesthetic that could be fatal if inhaled in a sufficient quantity for a long enough time. This was why Goerke needed to be rescued quickly. After a brief stay in the hospital, he recovered completely.

The early 1970s also were the beginnings of a long-term program headed by the Corps of Engineers to investigate ways of extending navigation on the Great Lakes–St. Lawrence Seaway throughout the winter. As part of this Great Lakes–St. Lawrence Seaway Winter Navigation Demonstration Program, begun in 1971, CRREL researchers investigated ice booms to impede the flow of ice into navigation channels, and later developed various methods of keeping locks ice-free, including the use of chemical coatings, saws for cutting ice from lock walls and bubblers for preventing ice formation.

CRREL researchers were also deeply involved in maintaining air transportation during the time. James Hicks, a CRREL meteorologist, developed a number of methods of dispersing fog in cold regions in the 1960's and early 1970's. For this work he received a Department of the Army Research and Development Award for 1971. One technique that proved to be particularly successful was the dispersal of supercooled fog with compressed propane gas. Other fog dispersal methods involved the use of heli-



Refrigeration equipment at laboratory.

copters to induce air circulation and of compressed air to cause fog nucleation and dissipation.

An important administrative development during this period was the re-establishment of the Technical Director position at CRREL. On 15 August 1972, Dr. Dean Freitag was appointed Technical Director of CRREL, a position that he was to hold for nearly a decade. Freitag was formerly the Assistant Technical Director at the Waterways Experiment Station (in Vicksburg, Mississippi), another Corps of Engineers research laboratory.

The beginning of a continuing scientific exchange between CRREL and Soviet cold regions research institutions began in 1972 with a visit from two polar researchers from the Arctic and Antarctic Research Institute in Leningrad. The following year, a delegation headed by the Director of the USSR's Permafrost Research Institute visited CRREL. These visits by the Soviet scientists were followed up by a number of visits to the USSR by CRREL engineers and scientists.

On 9 May l 973, it was announced that Colonel Robert L. Crosby would become CRREL's Commander and Director, succeeding Colonel Castro who took a position at the U.S. Army Engineer School at Fort Belvoir, Virginia. Crosby had been Secretary at the Engineer School prior to coming to CRREL. A West Point graduate, Crosby had also earned a civil engineering degree from Iowa State University. Taking command on 1 August 1973, Crosby stayed at CRREL for more than 5 years, during which the laboratory expanded greatly both in size and in national importance.

R to L: F.E. Are, Assistant Director of Permafrost Institute, U.S.S.R.; D. Freitag, G. Swinzow, J. Brown, CRREL; and P.I. Melnikov, Director of Permafrost Institute.

Also in May of 1973, Rodney Poland, Executive Assistant, announced that funds were being sought for a logistics storage building to replace the warehouse that CRREL rented in nearby Lebanon, New Hampshire. Construction of this structure, later called the Logistics and Supply Building, was begun in the fall of 1974, and the $600,000 facility was completed in 1975.

This new facility allowed the Logistics and Supply Office (Raymond May, Chief) to store all of CRREL's sophisticated devices for field exploration and other related equipment at the laboratory. It also greatly aided the shipping and receiving function, as well as providing much needed space for CRREL's purchasing agents.

A major research program that began in the early 1970s involved the use of ERTS-A satellite imagery for mapping permafrost distribution in interior Alaska and ocean current patterns in Cook Inlet, near Anchorage, Alaska. This project was primarily directed by Dr. Duwayne Anderson, who was also involved in a program concerned with developing sensors for the detection of moisture on other planets in the solar system. These sensors were carried aboard the Viking mission to Mars, and determined the amount of water present on the Martian surface.

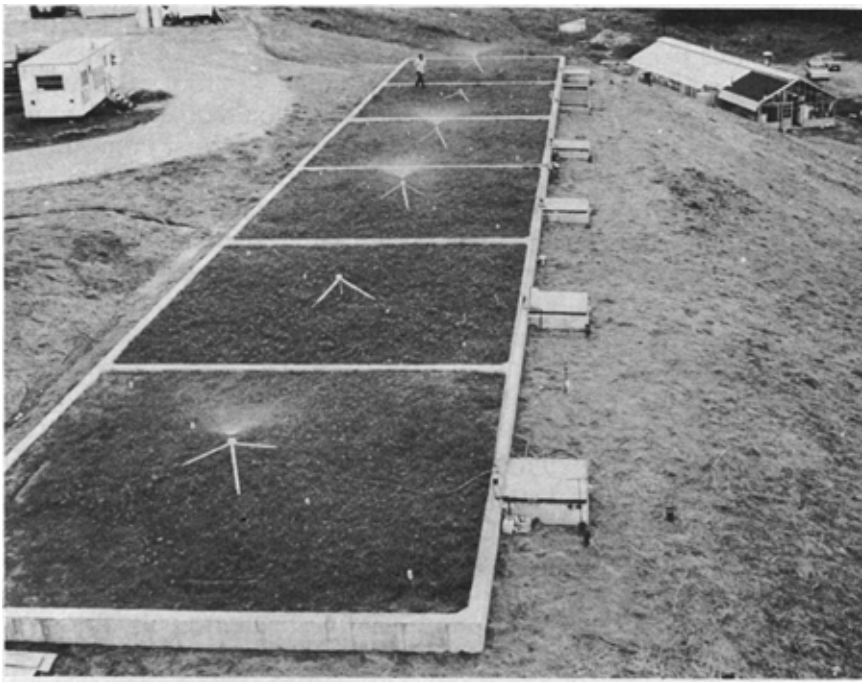
In 1974, a major Corps of Engineers program, the Land Treatment Research and Development Program, was begun with CRREL designated as the lead laboratory. Throughout the 6 years of the program, CRREL researchers made major contributions to the technology of treating wastewater by scientifically controlled application to the land, which was shown to both decrease the cost of constructing land treatment systems and to im-

Cook Inlet.

prove their effectiveness. In fact, cost savings were demonstrated to far exceed the $8 million cost of the program. The Land Treatment Research and Development Program had three program managers during the 5-year period, Sherwood Reed, Dr. Harlan McKim and Dr. Kay Sterrett.

Another project of a much smaller but significant influence was CRREL's pioneering work in detecting heat loss through building walls and roofs with infrared imagery. An early application was a survey of selected building walls at Dartmouth College, during which especially significant heat loss was detected in certain areas of some of the buildings. One inexpensive corrective measure that was taken was the installation of metal reflective panels behind the radiators in several buildings, significantly reducing heat losses from these buildings.

In addition, a method was devised for detecting wet roof insulation with the infrared scanner, since the wet insulation would conduct heat



CRREL land treatment facilities in Hanover.

Infrared roof moisture monitoring equipment.

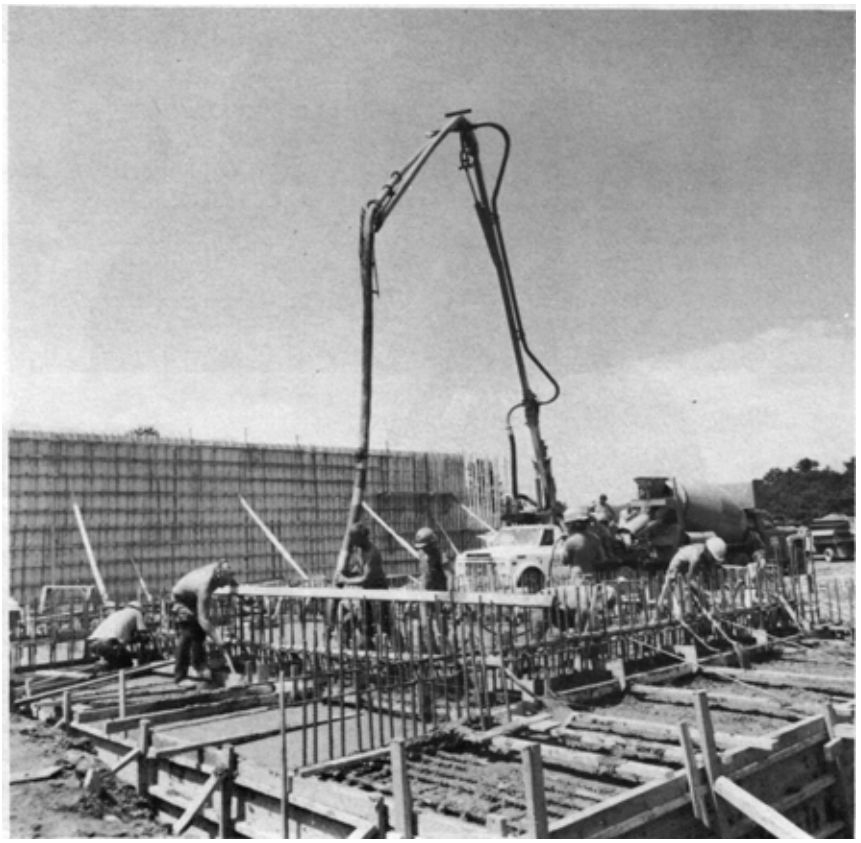
more readily. Roof moisture studies have been conducted at West Point, Pease Air Force Base, Fort Devens and Rock Island Arsenal.

In 1974, CRREL received its first Award for Excellence from the Research and Development Office of the Army. This award was presented to Colonel Crosby by the Chief of the U.S. Army Research and Development Office in July of 1975. This award was one of the first official acts of recognition by the Army of the overall excellence of CRREL's research program.

1975–80

The second half of the 1970s showed a further increase in the growth of CRREL—in staff, physical size and research budget. In fiscal year 1975, the CRREL staff numbered 240 and in 1980 this had risen to 263; CRREL's total building space in 1975 was 122,000 ft^2 and in l980 it was nearly 240,000 ft^2; in 1975 the laboratory's funding was about $7 million and in 1980 it was well over $14 million.

Two major construction projects took place during this time. The first was the construction of an addition to the main building during 1976–77.



Ice Engineering Facility—concrete pouring.

The 24,000-ft^2 addition increased the main building's size by about 50% and greatly expanded CRREL's research capabilities. In the addition were several specialized laboratory rooms, including those for the study of electromagnetics, acoustics, optics, ice adhesion, heat transfer, microbiology, water and ice chemistry, sanitary engineering, thermophysics and materials testing. In addition, the soils laboratory was doubled in size, a large room with controllable humidity was added, and office space was increased significantly. New executive offices were also provided in the addition, which is now home for CRREL's Plans and Programs Office (Alan Wilson, Chief), responsible for the lab's research planning and analysis.

The addition also eventually brought about expanded space for the Administrative Services Office (William Gee, Chief), responsible for travel arrangements, duplicating services, word processing and maintaining the switchboard.

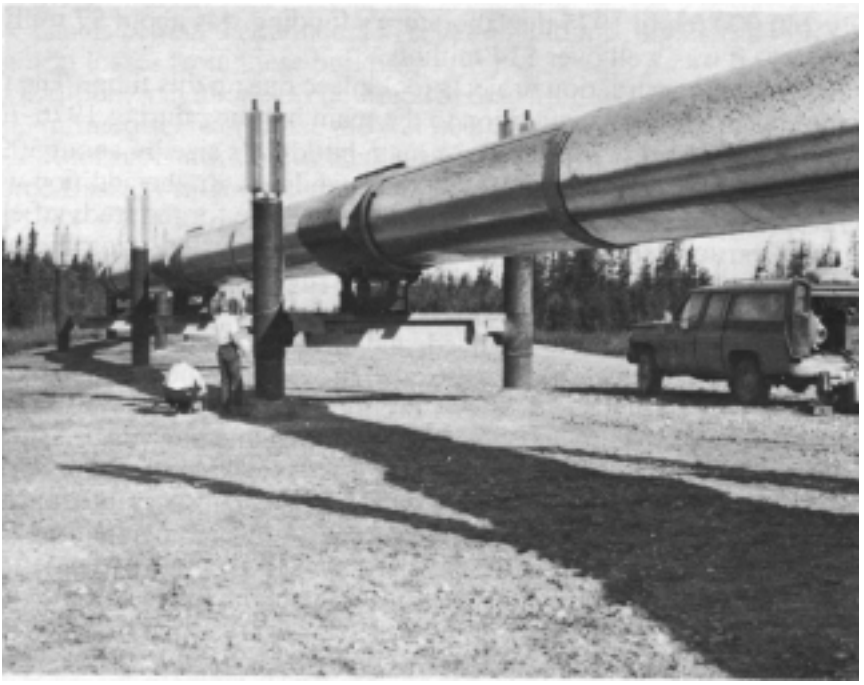
The other major addition to CRREL's research facilities was the completion of the Ice Engineering Facility in 1978. The research laboratory, the largest and most modern of its kind, was designed to enable research personnel to conduct large-scale studies of ice and its effects in a controlled refrigerated environment. The 210- by 160-ft, two story facility was constructed to contain three major refrigerated areas—an 80- by 160-ft modeling room, a flume room and a test basin.

During this period CRREL's research accomplishments were equally impressive. CRREL's expertise and technical information helped to bring the successful completion of the trans-Alaska oil pipeline in 1978, surely one of America's greatest engineering achievements. And CRREL biologists and soil scientists closely observed the pipeline's impact on the Alaskan landscape, helping to assure the preservation of Alaska' s natural environment.

Work on the trans-Alaska pipeline brought two Army Research and Development Awards to CRREL employees. In 1976, a CRREL research team consisting of Dr. Pieter Hoekstra, Paul Sellmann, Dr. Steven Arcone and Allan Delaney won the Research and Development Award for their work in developing techniques for subsurface geophysical exploration. Some of this work involved finding grounding areas for the pipeline's cathodic anticorrosion system, a project that saved the pipeline builders well over $1 million, as well as demonstrating the practicality of this experimental technique.

In 1979, Frederick Crory won an Army Research and Development Award for his advice in the construction of the pipeline. Crory, an expert on pile foundations in permafrost. was recognized in the citation as having played "a key role in the successful design and construction of this major engineering project."

In this 5-year period, CRREL researchers also received two other of the prestigious Research and Development Awards. In 1976, Dr. Malcolm Mellor received one of these awards for his years of research in the exca-



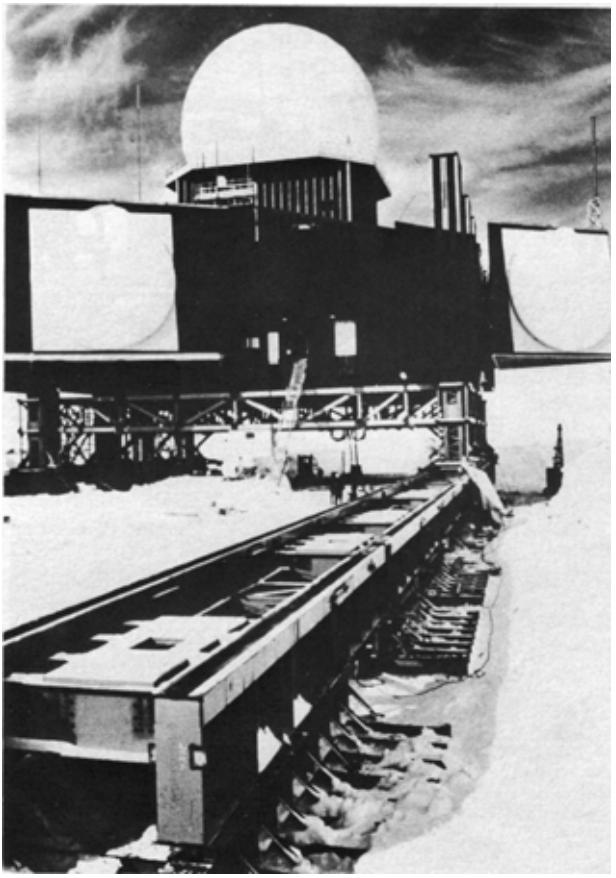
CRREL researchers monitoring temperatures of thermal piles on trans-Alaska pipeline.

Early geophysics device.

Large saw used to cut ice from lock walls at Sault Ste. Marie, Michigan.

vating and blasting of snow, ice and frozen ground. Some applications of his work were the development of machines for the rapid excavation of frozen ground and for cutting ice from lock walls, and the controlled blasting of a large ice wall in Antarctica to provide a pier for the docking of supply ships.

Wayne Tobiasson's 1977 Research and Development Award was for a single project that he conceived, designed and helped to supervise, the moving of a 10-story-high, 3300-ton Distant Early Warning (DEW) Line facility on the Greenland Ice Cap. The foundation of the radar facility had been weakened by the accumulating snow and shifting glacial ice so that it appeared that a new structure would need to be built. But by moving the existing structure onto a new foundation, the government saved an estimated $1.5 million.



DYE-3 move.

CRREL received a number of other awards during the late 1970's as well. Perhaps the most significant individual honor was the election of Dr. Wilford Weeks to the National Academy of Engineering, the highest professional distinction that can be conferred in the field of engineering. Dr. Weeks, a former president of the International Glaciological Society, was cited for the "application of research on the strength properties of sea ice to the engineering problems encountered in arctic waters." Week's work on sea ice has, of course, been extremely important to oil exploration activities in Prudhoe Bay and others areas off the coast of northern Alaska.

In addition, Rodney Poland, Executive Assistant at CRREL nearly from its inception, won an Army Decoration for Exceptional Civilian Service in 1978. He was cited for his exceptional accomplishments in his administrative duties at CRREL.

Yet probably the most important awards received by CRREL during this period were awarded to the laboratory as a whole. In recognition of CRREL's support of the Army and its mission in fiscal year 1978, CRREL

Coring multi-year ridge just northwest of Reindeer Island, offshore of Prudhoe Bay, Alaska

Spraying lock wall with icephobic coating developed by CRREL, Sault Ste. Marie, Michigan.

Air-transportable shelter for Arctic use

was awarded the Army Special Award for Accomplishment in a presentation by the Assistant Secretary of the Army for Research, Development and Acquisition. Among the achievements noted in the award citation were the major accomplishments of the Land Treatment Research and Development Program and the many accomplishments of the ice engineering program—in particular the development of various techniques to keep navigation locks free from ice.

In recognition of its achievements during fiscal year 1979, CRREL received the U.S. Army Award for Excellence in a presentation by Lieutenant General Bratton, Chief of Engineers. Accomplishments noted at the award ceremony included the onset of the operation of the Ice Engineering Facility, the development of a model of the ice accretion process for helicopter rotor blades, research on the properties of snow, development of nondestructive techniques for detecting moisture in roofs, and design and construction of an air-transportable shelter for Arctic use.

Yet, a number of CRREL's somewhat smaller projects also received national attention during this time. One was a proposal by Dr. Wilford Weeks for towing icebergs from Antarctica to Australia and South America to provide fresh water for irrigation. This idea eventually led to the First International Conference on Iceberg Utilization in 1977.

Also in 1977 and 1978 CRREL researchers were involved in the Ross

Ice Shelf Project which also received extensive media coverage. Although the CRREL coring drill became trapped in the shifting glacial ice, a thermal drill, developed by Browning Engineering of Hanover, New Hampshire, and tested at CRREL, succeeded in making a large hole through the 1400-ft ice shelf to reach the sea below. This allowed research scientists to lower such devices as a television camera, bait bottles, thermometers, plankton nets and coring devices. These instruments detected, for the first time, biological activity in the sunless environment beneath the Ross Ice Shelf.

However, the events of the 1975–79 period were not all positive. In 1976 occurred the only fatal accident in CRREL's history. The accident happened while a 21-year-old Northeastern University engineering student, Gordon W. Dow, was operating a coring auger to obtain pavement core samples. No-one witnessed the accident, but his arm apparently had been caught in the motorized auger, and despite rapid emergency efforts by several members of the CRREL staff, he died soon after arrival at Hanover's hospital. This accident was extensively investigated and led to greater precautions to ensure that such a tragedy would never recur.

Another problem in the 1970s was a temporary slow-down in the scientific exchanges between the USSR and the United States because of a worsening of international tensions. However, these exchanges soon were back in force, and a Soviet scientist, Igor Zotikov, spent several weeks at CRREL in cooperative research in 1979.

CRREL changed commanders in July 1978 when Lieutenant Colonel Alfred Devereaux succeeded Colonel Crosby, who had been at CRREL for 5 years. Devereaux, who held a doctorate from Ohio State University, had previously been Deputy Commander of the Engineer Topographic Laboratory at Fort Belvoir, Virginia. Crosby went to work for the North Pacific Division of the Corps of Engineers as Deputy Division Engineer.

1980–85

Some of the major accomplishments during the early 1980s were the completion of the Land Treatment Research and Development Program and the publication of the results of the U.S. Tundra Biome Research Program. In regard to the trans-Alaska pipeline, CRREL continued to monitor both the pipeline itself and the haul road next to the pipeline for their long-term performance.

CRREL also underwent some administrative changes at this time. In 1980 a new branch, the Geophysical Research Branch, was created in the Research Division, and headed for more than two years by George Aitken and then by Dr. George Ashton. At the same time, the Physical Sciences Branch was dissolved, with many of its members going to the new branch.

One of the 1981 Army Research and Development Awards was presented to Dr. George Ashton for his work on the thermal processes that determine the behavior of river and lake ice. In particular his research had

Laser beam diffraction.

developed methods to perfect the technique of using air bubbler systems to melt ice covers. He also developed a computerized technique for predicting the effect of heated water discharges on the thermal regimes of water bodies.

In July of 1981, Colonel Wayne A. Hanson succeeded Colonel Devereaux. Hanson, a registered professional engineer, previously was the material test director for the Cold Regions Test Center at Fort Greely, Alaska. He stayed at CRREL for a little less than 2 years, until May 1983.

Also in 1981, Dr. Dean Freitag, who had been CRREL's Technical Director since 1972, retired to become a professor of engineering at Tennessee Technological University. Dr. Lloyd Breslau, former director of the Coast Guard Research and Development Center, succeeded Freitag as Technical Director.

CRREL's research programs during this period continued to expand. New programs included the SNOW-ONE, SNOW-ONE-A, and SNOW-TWO projects held at Fort Ethan Allen, Vermont, and Grayling, Michigan. These three projects involved testing a number of electromagnetic and optical sensing systems in the winter environment. CRREL researchers, primarily from the Geophysical Research Branch, collected meteorological data and coordinated the various research efforts of many participating agencies during these tests. The River Ice Management (RIM) program, whose purpose is to increase the navigation period on inland waterways, also started in the mid-1980s.

On 16 September 1981, CRREL officially recognized its 20th birthday with a celebration held in the large work area of the Ice Engineering Facility. All the current CRREL employees were joined by dozens of

retired employees at a luncheon. In a short statement on the 20th birthday program, Colonel Hansen said the following:

> "CRREL, as a Corps of Engineers Laboratory, can be proud of its contributions and accomplishments over the period from 1961 to 1981. It has maintained its leadership in cold regions research despite being shifted from one major command to another and going through a period where military interest was focused on the tropical environment. It has been possible for CRREL to not only survive but grow because of the high quality people associated with the organization now and in the past. Quality products and internationally recognized professionals have established the laboratory as a mecca for cold regions researchers.
>
> "With the increased emphasis on natural resource development in the Arctic, CRREL's developed technology and research will become even more important. This provides new opportunities for service to the Corps, the Army and the Nation. Happy Birthday CRREL."

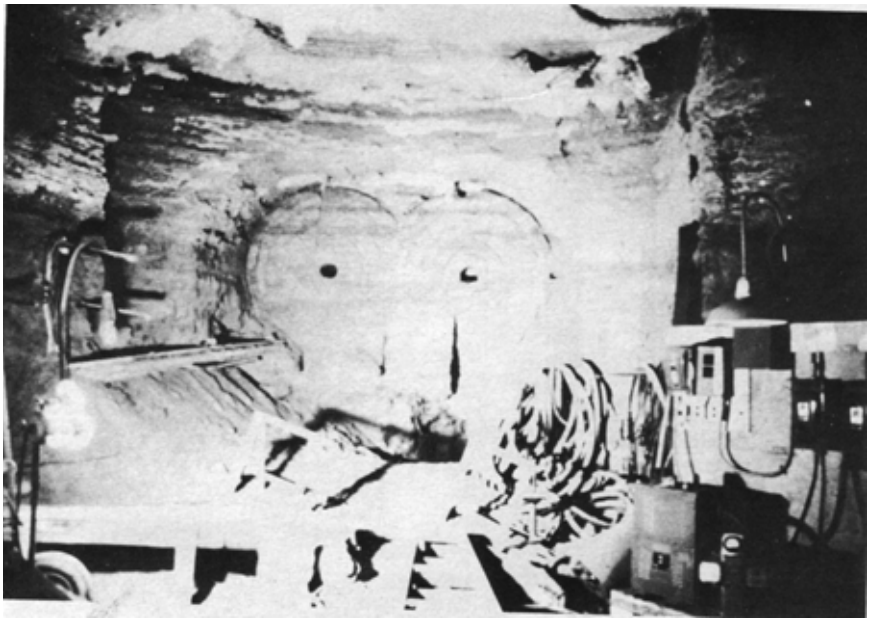
A significant development in the late 1970s and early 1980s was the opening of an exchange of scientific information between CRREL and the Institute of Glaciology and Cryopedology in the People's Republic of China. This exchange began in the fall of 1978 when two CRREL

J. Brown and Y.-C. Yen at Chinese Permafrost Conference.

researchers participated in a $2^1/_2$-week seminar tour on cold regions engineering and construction, just before the official recognition of China by the United States. In 1981, CRREL participated in the Second National Chinese Conference on Permafrost, and the following year a Chinese researcher began a 2-year sabbatical at CRREL to learn about new techniques for analyzing frozen ground. This exchange opened a much wider participation by Chinese scientists in international exchanges of information on cold regions science.

At almost the same time as the Chinese Permafrost Conference, two other CRREL scientists participated in a joint American-Soviet expedition into the ice-covered Weddell Sea of Antarctica aboard the *Mikhail Somov,* a Soviet ice-breaking transport ship. Along with 22 other American and Soviet scientists, the CRREL researchers spent nearly $3^1/_2$ weeks within the frozen sea. One of the purposes of the voyage was to study the polyna, a large area of open water surrounded by ice, which often forms in the Weddell Sea. Although no polyna formed during the time of the voyage,

Launching meteorological balloon from Mikail Somov.



Permafrost tunnel, Fox, Alaska.

the researchers onboard the *Mikhail Somov* obtained a wealth of new data about Antarctic sea ice, ice pack extent and meteorological conditions.

CRREL personnel also played a key role in the Fourth International Conference on Permafrost, held in Fairbanks, Alaska, in 1983. In addition, a number of major symposia have been held at CRREL (in Hanover) in recent years. These include the Eastern Snow Conference, the SNOW Symposia, the Third International Symposium on Ground Freezing, a conference on icing, and a workshop on ice penetration. These have all been coordinated by CRREL's Public Affairs Office.

Among CRREL's more notable projects during this time was an extensive study of sea ice off the northern coast of Alaska funded primarily by the Shell Development Company. This study was primarily concerned with the mechanical properties of ice samples from the large pressure ridges (mounds of sea ice fragments that result from crushing of interacting plates).

Another important project was in predicting the amount of ice that would form on the tank containing the supercooled fuel for the launcher of the Air Force Space Shuttle. This new shuttle is to be launched from Vandenberg Air Force Base, in a climate significantly colder. than that of Cape Canaveral, Florida. The CRREL study predicted the amounts of icing to be expected and suggested ways of minimizing the icing. The research approach used by CRREL researchers to study this icing problem was estimated to have saved the Air Force at least $500,000 over the costs of a more conventional approach. For this work Michael Ferrick received an Army Research and Development Award in 1983.

Testing cryogenic panel (for the Space Shuttle) at CRREL.

The CRREL activity to gain the most attention during this time was not a research activity but an application of this research. When an Air Florida airliner crashed into the Potomac River on 14 January 1982, CRREL researchers Arnold Dean and Carl Martinson were able to locate the "black boxes" (containing the flight and voice recorders) beneath the ice-clogged river by using a broadband subsurface radar that they had developed to profile frozen rivers. They also were able to locate bodies and parts of the wreckage and thus to help with the effort to determine the cause of the crash. Again CRREL researchers succeeded in rapidly solving a cold regions problem beyond the capabilities of other organizations.

In 1982, the Technical Services Division (Ronald Atkins, Chief), was reorganized, being divided into the Technical Information Branch, the Engineering and Measurement Services Branch and Facilities Engineering. The Technical Information Branch (Wesley Pietkiewicz, Chief), has been responsible for editing and publishing over a thousand CRREL technical reports and information bulletins since CRREL was founded. Also, this branch contains the CRREL library and one of the largest cold

CRREL machine shop.

regions collections in the world. It maintains the *Bibliography on Cold Regions Science and Technology*, with more than 100,000 publications accessioned to date.

The Engineering and Measurement Services Branch (Donald Garfield, Chief), is responsible for developing and maintaining much of the specialized equipment used by the laboratory. Engineers and instrument makers from this branch developed the drills used in Greenland, Antarctica and Alaska for geological investigations. Sophisticated computer-operated meteorological sensors are some of the other instruments made here The branch also maintains CRREL's central computer and provides programming services for the research staff. Facilities Engineering (David Gaskin, Chief) maintains the physical plant of CRREL. This includes not only care of the five major buildings and CRREL's vehicles but also of the sophisticated refrigeration systems in the main coldroom complex, the Ice Engineering Facility and the new Frost Effects Research Facility.

In 1983, Colonel Morton Roth, from the Defense Mapping Agency, Inter-American Geodetic Survey, Fort Sam Houston, Texas, took command, and CRREL has continued to prosper. In a period when the Corps is enlarging its National role as the Federal Engineer, CRREL has sought to broaden its activities into new areas of cold regions research and development.

In 1983, CRREL's personnel office was consolidated with that of the New England Division of the Corps of Engineers. The greatly enlarged Personnel Office (David Wilber, Chief), now is responsible for recruitment, training and appraisal of more than 900 employees. At the same

CRREL site selection team locating new radar stations along Labrador coast, July 1984.

time, the Resource Management Office (Peter Swart, Chief), responsible for accounting and budget analysis, moved into new offices.

A research team of Yoshisuke Nakano, Joseph Oliphant and Allan Tice won a 1983 Army Research and Development award for their research in the use of nuclear magnetic resonance (NMR) techniques for investigating water content and transport in frozen soils, and David Deck received an Army Research and Development award for designing a frazil ice control structure for a town plagued by recurrent flooding. And, in 1984, Edgar Andreas, Richard Berg, Edwin Chamberlain, David Cole, Thaddeus Johnson and Walter Tucker all received Army Research and Development awards for their research accomplishments.

Also in 1984, CRREL personnel completed their survey reports for 31 sites of the new North Warning System, to replace the aging DEW line. The new radar system will have greatly improved radar coverage, and will be able to detect low-flying cruise missiles as well as ICBM's and bombers. CRREL personnel evaluated the construction and access problems of each site, while Air Force personnel evaluated the range of the radar equipment.

In 1985, CRREL's new Frost Effects Research Facility was completed and officially dedicated. As with the addition of other research facilities, the specialized laboratory greatly expanded CRREL's research capabilities. In the $6 million, 29,000-$ft^2$ building, CRREL scientists and engineers are able to study frost heave and permafrost problems in a controlled setting. This research facility is the only one of its type in the United States, and is

considered to be superior in its capabilities to similar frost research laboratories in other countries.

Construction of a new coldroom complex for CRREL also began in 1985. When completed, the new coldrooms will offer researchers state-of-the-art refrigeration capabilities and the system will no longer use the dangerous TCE refrigerant.

The replacement can be seen as symbolic of CRREL's continuing commitment to excellence in cold regions research and development. CRREL has helped to pioneer this Nation's expansion into northern Alaska and the study of the cold regions, and now CRREL is helping to improve on this earlier scientific and engineering work. Undoubtedly the next 25 years will bring forth an even greater advancement in CRREL's involvement with research and development in the areas of the world affected by snow, ice and frozen ground.