New Technological Developments in Support of Arctic Research

Proceedings of a Workshop at the 40th Annual
Arctic Science Conference
Fairbanks, Alaska
16 September 1989

Arctic Division, American Association for the Advancement of Science (AAAS)
and
The Arctic Research Consortium of the United States

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December 1990

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ACKNOWLEDGEMENTS

This workshop was sponsored by the Arctic Division, American Association for the Advancement of Science (AAAS). Permission is hereby freely given for the reproduction of all or any part of these Proceedings or any previous Proceedings provided the approval of the individual author is granted and the appropriate citation is given.

When references are cited, the Arctic Division, American Association for the Advancement of Science, prefers the following citation:

New Technological Developments in Support of Arctic Research, Proc. 40th Arctic Sci. Conf., AAAS, Fairbanks, University of Alaska Fairbanks, 16 September 1989.

The information in "New Technological Developments in Support of Arctic Research" was collected directly from the workshop held during the AAAS Conference. The workshop was hosted by the University of Alaska Fairbanks and the Arctic Research Consortium of the United States (ARCUS) on 16 September 1989.

This workshop was supported in part by the National Science Foundation Division of Polar Programs Polar Ice Coring Office. The Geophysical Institute (AAAS), the Institute of Arctic Biology, the Institute of Marine Science, and the Office of the Vice Chancellor for Research and ARCUS, all at the University of Alaska Fairbanks, provided additional support.

PREFACE

The U. S. Interagency Arctic Logistics Working Group, convened under the Interagency Arctic Research Policy Committee (IARPC) and chaired by the National Science Foundation (NSF), recognized the need for a workshop on logistics and technological capabilities to support research in the Arctic. The occasion of the annual Arctic Science Conference (American Association for the Advancement of Sciences (AAAS) – Arctic Division) at the University of Alaska Fairbanks, Fairbanks, Alaska, September 1989, offered an excellent opportunity to convene such a workshop. The AAAS in conjunction with the newly formed university-based consortium, Arctic Research Consortium of the United States (ARCUS) agreed to organize and host the conference in consultation with the IARPC logistics working group.

Dr. John Kelley, Director, Polar Ice Coring Office; Dr. Luis Proenza, Vice Chancellor for Research and President of ARCUS, and Mr. Chris Shepherd, Executive Director of ARCUS, convened the workshop on behalf of the AAAS-Arctic Division and ARCUS.

This report contains presentations by participants, panel discussions and contributed papers. The workshop was attended by over sixty individuals (Appendix 1) representing universities, federal and state agencies, industry and private organizations. At the conclusion of the presentation of papers, panelists (Appendix 2) and guests discussed the following questions:

- What is the ease of access to modern technological advances to enhance arctic research operational activities?
- How can we improve the exchange of information on current logistical capabilities, not only in the U.S. Arctic but on a global basis?
- Can we realistically assess future operational requirements and plan accordingly?
- What existing capabilities are underutilized?
- What are the existing discrepancies in accomplishing planned future and long-term projects and programs?

Rear Admiral F. A. Moran, NOAA, chaired the Arctic Logistics Working Group during the organization of the workshop. A program committee based in Washington, D.C. provided suggestions and guidance for workshop topics.

NEW TECHNOLOGICAL DEVELOPMENTS IN SUPPORT OF ARCTIC RESEARCH

CONTRIBUTED PAPERS

SOME THOUGHTS FROM THE PERSPECTIVE OF ALASKA'S NORTH SLOPE BOROUGH REGARDING THE CONDUCT OF SCIENCE IN THE U.S. ARCTIC

Thomas F. Albert

These comments are restricted to a brief consideration of the following three topics:

- The need for quality in arctic science.
- Some concerns of arctic residents regarding the conduct of arctic science.
- North Slope Borough support for arctic science.

NEED FOR QUALITY IN ARCTIC SCIENCE

Steady or declining research budgets should force us to get as much for existing science dollars as possible. An obvious way to increase efficiency is to make sure that what science is done, is done correctly. An obvious area in need of improvement is in studies related to the assessment of industrial impacts. The U.S. Arctic Research Commission is now considering this need and, hopefully, will make specific recommendations regarding ways to enhance the quality of research associated with impact assessment.

SOME CONCERNS OF ARCTIC RESIDENTS REGARDING THE CONDUCT OF ARCTIC RESEARCH

Too many of us scientists focus too closely on what *we* want. We must realize that there are people living in the U.S. Arctic. Presently, there are two boroughs which are strong regional governments (North Slope Borough, Northwest Arctic Borough). Through these strong local governments, the people of the U.S. Arctic are becoming much more involved in all matters that affect them, the wildlife and the environment. We must recognize the increasing sophistication of arctic residents and their increasing desire to know what we are doing, why we are doing it, and how our studies will affect them. It is obvious that arctic residents want more involvement in arctic research.

As an example: Suppose a group of scientists came to a remote area in the county in which you live and set up a base of operations, or made repeated trips in and out of a town, or flew up and down your rivers and took pictures or air samples, and made little or no effort to tell you what was happening. How would you feel about such behavior? Of course, you would want to know more about what the scientists were doing. It is rude to ignore (or give the appearance of ignoring) local people.

Most scientists and arctic residents feel that more arctic research is warranted and that it should be conducted in an efficient manner. For the efficient conduct of science, there should be several fixed research support facilities within the U.S. Arctic. These could range in size from a few rooms in a building which is being used for other purposes, through small dedicated structures such as quonset huts or "trailers", to a somewhat smaller version of the former Naval Arctic Research Laboratory (NARL) which could serve as a truly national arctic research laboratory. Each fixed site should serve as;

- a magnet to attract researchers,
- a focus for the long-term detailed study of a given area,
- a "hub" from which scientists can radiate outward (as the spokes of a wheel),
- a place of interaction between scientists in the field, and
- a place where there can be two-way communication between scientists and local people.

This last point is often omitted in discussions of arctic science; however, it is important to people who live in the U.S. Arctic.

Some of these fixed sites should have the designation Regional Arctic Research Center (RARC) and a commitment made to their support.

Arctic residents are becoming more aware of science and the uses of technical data. This increased sophistication is leading to the desire to participate more fully in technical matters (including design and conduct of scientific studies), particularly matters that impact the people or the wildlife upon which they depend. Coupled with this is the desire to derive educational benefits from arctic research. This can be greatly assisted if there are designated sites such as Regional Arctic Research Centers where local people and scientists can interact. Such interaction could include scientists presenting community lectures, visiting local schools and, where appropriate, involving local people (particularly students) in their research.

An example of the educational benefit of a Regional Arctic Research Center is illustrated by the beneficial impact of the former Naval Arctic Research Laboratory upon the people of the North Slope Borough. Over the years, many of the "decision makers" within the Borough have either worked at NARL or had a close relative do so. The close association with NARL and its scientists has resulted in a positive outlook toward science and how science can be used to help Native people. This heightened scientific awareness helps explain the eagerness of the North Slope Borough to utilize technical data and its own significant commitment to the support of arctic science.

The overall cause of U.S. arctic science can be best served when the people of the Arctic are both supportive and involved. Regarding the extent of popular support for science in our nation, it is well known that in most of the U.S. much of the population seems indifferent to science with some people even being hostile toward science. Reference to this unfortunate situation was noted by the incoming President of the American Association for the Advancement of Science (AAAS) when, in his speech at the conference banquet, he referred to the general lack of science knowledge in the U.S. Fortunately, the people of the North Slope Borough are not in this category, as most of the people of the Borough are very supportive of science. This is due to what I call the "NARL effect", where the long-term exposure of many people in a community to scientists and research has produced a very favorable outlook toward science and scientists. This "NARL effect" has occurred in Barrow and elsewhere on the North Slope where, for many years, people have interacted with scientists from the NARL located in Barrow. One of the clear messages here is that the prolonged interaction of scientists and local people (such as at a fixed site) results in benefits to the scientists and to the residents and there is also much good will created in the community toward science and scientists.

NORTH SLOPE BOROUGH SUPPORT FOR ARCTIC SCIENCE

The North Slope Borough is the northern 1/6 or so of the State of Alaska and forms much of the U.S. Arctic. The Borough has a well-documented record of support for arctic science. The Borough helps foster quality in arctic science through its Science Advisory Committee and through the Arctic Science Prize. The Borough's Science Advisory Committee includes approximately 20 scientists who assist us by reviewing research proposals and various technical documents that affect the Borough. The Arctic Science Prize is a $10,000 award presented by the Borough to an outstanding arctic scientist. There is a rigorous selection process. The Prize is awarded approximately every other year.

The Borough also provides direct help to some scientists. In some instances there is a direct provision of research funds. Some assistance is also provided through a cooperative agreement between the North Slope Borough and the U.S. Corporation of the Arctic Institute of North America. The purpose of the cooperative agreement is to provide logistical support and/or modest funding to "beginning" arctic scientists (graduate students, young faculty) in order to help them "get started".

The Borough has a small Arctic Research Facility (ARF) in Barrow which, in some instances, can provide lodging, two-way radios, snow machines, heavy clothing, etc., to visiting scientists. Such assistance is provided at little or no cost and is intended primarily for graduate students and young scientists who are trying to obtain basic data needed in preparation of major research proposals to be submitted to a funding agency such as the National Science Foundation.

In Barrow, there is a major site (not Borough related) that can support scientists. This is the former Naval Arctic Research Laboratory, now known as the UIC-NARL facility, which is owned and operated by the Barrow-based Ukpeagvik Inupiat Corporation (UIC). The facility is now operated as a multiuse facility, in that it provides rental office space, meals and lodging for a wide range of users, including scientists.

In conclusion, let me again ask that we all strive for quality in arctic science and that we all recognize the increasing desire by residents of the U.S. Arctic to become much better informed as to the nature of and justification for research conducted in their regions.

FUTURE NEEDS IN ARCTIC RESEARCH – A VIEW FROM THE PAST

Carl Benson

When I was growing up my grandfather from Sweden told me, "The tools that I used when I was a boy, and the tools that my father used, and that his father used are all the same. I was very familiar with them and everybody knew how to use them. But if you want to see them now you have to go to Växjö and look in the museum."

The current generation is one of rapid change, especially in the fields of communication and transportation. My grandfather saw the development of the automobile, then the telephone, radio, aircraft and satellites. As we know, progress in transportation and communication has been explosive and it has irreversibly changed the way we operate. Think back to 1945 and imagine gathering this group in Fairbanks, Alaska for a one-day meeting. The idea would be preposterous. Pan Am was the only airline flying to Fairbanks from Seattle in The States and the trip took all day with stops in Whitehorse and Juneau. Dr. Charles Bunnell was still President of the University of Alaska which had 149 students and no research institute. Also, in 1945, people in the U.S. and Canada recognized the seriousness of ignorance about the Arctic regions, ignorance which had been highlighted repeatedly during World War II. One result of this concern was the founding of the Arctic Institute of North America (AINA) in both the U.S. and Canada in 1945.

In 1971 AINA conducted a four-day meeting (1-4 November) in Hershey, Pennsylvania, to address problems of the rapidly changing logistics support technology in connection with the rapid development of oil and mineral resources in the Arctic.

The proceedings of that symposium (AINA, 1972) contain 31 papers; 12 of them dealt with transportation (over-snow vehicles, aircraft and specialized research both on the surface and beneath the surface of the oceans), 6 dealt with shelters, 6 with special instrumentation for Arctic research and 2 papers dealt with satellite applications and potentials (including communication and the use of data collection platforms at remote locations). We deal with the same problems today and many of the papers in the 1971 proceedings volume are still pertinent.

Joe Fletcher gave the keynote address. He remarked about aircraft and the trouble with aircraft engines, and how the development of the jet engine has essentially solved these problems. There is reliable transport now compared to the horror stories he related about cold weather failure of the old piston engine aircraft. Modern jet engines essentially thrive on cold weather.

The one thing that has changed the most, and the only thing that has really changed significantly, is the field of electronics.

We have electronics distance-measuring devices and geographic-positioning systems which have totally revolutionized surveying. There tends to come with this rapid development, though, a problem – NASA, as an organization, tends to focus on just the latest tool developed. Already, people (even within NASA) have a hard time applying the LANDSAT imagery, partly because the Reagan administration sold the LANDSAT system to a private company which takes data from the government and then sells it back at rates which government agencies and universities cannot afford. The net result is severe restriction on the use of this valuable tool by the U.S. research community. Also, it is partly because NASA tends to focus on the latest technology which now means microwave and satellite radar systems. These are wonderful systems, but, in our logistics, we need more of a blend of old and new technology. Also, for all of our advances, we still have the same problems of ineffective communications with small field parties in isolated places. Another problem is self-imposed clumsy budget procedures which cause people to make ridiculous statements such as "It's cheaper to operate in Antarctica than in Alaska."

I spent four years (1952-1955) working on the Greenland Ice Sheet, primarily on over-snow traverses over 1,000 miles in length, based out of Thule, Greenland. We started as early as March and ended as late as October. Today you would have a hard time funding an expedition of six or eight people with four vehicles and air support to go for 120 days without any contact with anyone – just to work. Today we want to go in, get a job done and come out. What we lose is an intimacy with the field that we are studying. And, I think, that we are moving too fast for our needs.

I want to close with a story. A good Danish friend of mine, Borge Fistrøup, who died a few years ago, spent much of his life in Greenland. He said that once they were hurrying back to get to Jakobshavn and they had some Greenlanders with them. The Danes were in a hurry to get to Jakobshavn to catch the ship to Copenhagen.

As they were rushing along, the Greenlander said, "Well, we have plenty of time to get there."

The Danes said they wanted to have some lead time and to be there early enough to pack and put their notes in order.

Then the Greenlander asked, "Why are you in such a hurry to get there?"

They said, "This ship leaves on the 10th of September."

Then the Greenlander said, "You know there is always another one next year. They come every year."

We laugh at this, but the point is that there is a difference in philosophy and a difference in attitude. I think right now we are moving so fast with our electronic capabilities that we have lost track of the fact that a human being cannot really keep up. We are all suffering from jet lag. Probably, a lot of you right here are also suffering from jet lag.

When these Danes got into Jakobshavn, they spent a couple of weeks working up their data, packing boxes, organizing things, and putting them on the ship. After two or three weeks aboard, they got back to Copenhagen. They had looked over their notes and had even started writing about what they were thinking.

Contrast that with coming out of a research area on the Greenland Ice Sheet now. We came out with a helicopter from the ice cap to the little base in Jakobshavn and went by jet aircraft to Sondrestrom Fjord. Then we got into a time machine the Air Force calls a C141. (You plug your ears because a C141 is a machine designed to turn kerosene into noise.) You put up with this until you get out at McGuire Air Force Base. You then stagger from one airport to another and soon are back in Fairbanks.

You have not had time to get your clothes washed. You come into the office, planning to look over things. There are three stacks of mail on the desk and somebody says, "There is a meeting at 10:00 and we must have you there."

You say, "But I wanted to work with these notes."

After the meeting at 10:00 the director says, "We really have to get together to discuss something else." You know it's just too important for you not to be there.

So pretty soon you are caught up in new projects. Your notes sit. They start to pile up with the mail.

I think we all know what I am talking about. E-mail and FAX have jacked up deadlines by at least three days and jet airplanes appear to make it possible to be in two places at once. Our electronic-jet age revolution has presented logistic capabilities that are boggling the mind of man.*

*Man includes Woman from whence he came.

Arctic Logistics Support Technology: Proceedings of a symposium held at Hershey, Pennsylvania on November 1-4, 1971. Beverly F. Slocum (Ed.). Arctic Institute of North America, 1972, Rasmuson Library, University of Alaska Fairbanks, Fairbanks, Alaska 99775-1000.

AN EXPLORATION ICE ISLAND

Walter T. Bugno

INTRODUCTION

In 1988, Chevron USA, Inc., as operator, with Mobil Exploration & Producing U.S., Inc., as a 50/50 joint venture partner, drilled an offshore well near Prudhoe Bay, Alaska. The well was drilled from a grounded spray ice island. Ice Construction and Engineering (ICE), a joint venture between CATCO, a division of Crowley Maritime, and Sandwell Inc., were contracted for the design and construction of the ice island.

The KARLUK ice island was located 7 miles ENE of Cape Brower in about 23 feet (7 m) of water (Fig. 1). The island was constructed by spraying sea water using large, skid mounted pumps 5000 gpm (20 m^3/min), equipped with nozzles and swivels.

DESIGN

The ice island was designed for a water depth of 24 feet (7.3 m) with 22 feet (6.7 m) of freeboard over a core (top) diameter of 650 feet (198 m). The overall diameter of the island at waterline was 890 feet (271 m).

The principal dimensions of the island were controlled by lateral stability under ice loading. Design issues included bearing integrity and creep settlement under the drill rig. A brine circulation system was designed to minimize heat transfer from the conductor casing to the island.

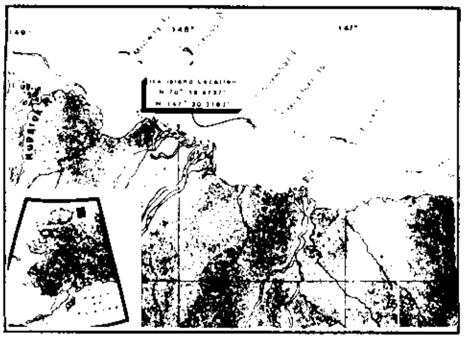

Figure 1. Location of the Karluk ice island.

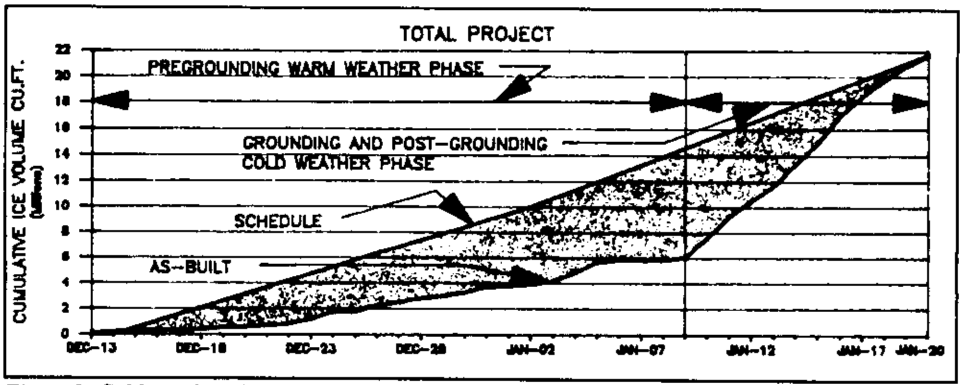

Figure 2. Cold weather phase of construction process.

CONSTRUCTION

Existing facilities at Deadhorse were used as a support base for administration and maintenance. Access to the island site was via existing roads and an ice road to the island.

At the beginning of each shift, a strategy was developed which laid out the pump locations, spray duration and cure time, if any. The strategy was based on four factors:

- existing pump positions
- existing weather conditions
- existing island thicknesses
- weather forecast

The construction progress can be divided into two phases:

- pre-grounding, warm weather phase
- grounding and post-grounding, cold weather phase (Fig. 2)

QUALITY CONTROL AND VERIFICATION

A quality control program was used to measure build-up, density, salinity, temperature and calorimetry during construction. Build-up, density and ice temperature were used to direct construction procedures.

The as-built geometry, density, temperature, and strength of the island were measured.

A comparison of design and actual parameters for the island is as follows (Fig. 3):

	Design	*Actual*
Total Ice Volume (10^6)	21.8 ft^3 (617 m^3)	24.6 ft^3 (697 m^3)
Avg. Core Thickness	46 ft (14 m)	46.8 ft (14.3 m)

The average above water (or post-grounding) density was 38.3 lbs/ft^3 (614 kg/m^3). The combination of more volume and lower density provided a net overburden pressure that was 15% greater than required for lateral stability.

Cone penetrometer tests were conducted at 20 points over the core of the island. The cone traces indicated a continuous material through the island depth. They also indicated 100% grounding of the island.

PERFORMANCE OF THE ISLAND

The temperature, horizontal and vertical movement of the ice and weather were monitored during drilling.

Ice temperatures were monitored continuously during drilling. This was to ensure that drilling operations did not undermine the thermal

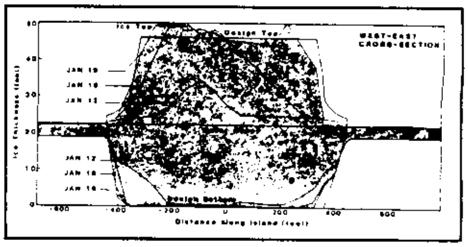

Figure 3. Comparison of ice island vs. distance during January.

integrity of the ice. Inclinometers showed that the ice bulged radially from self weight but did not translate.

Vertical movement of the ice was detected by manually-read Sondex instruments. The Sondex instruments were installed close to the rig. The readings from the Sondex closest to the rig substructure are shown in Figure 4.

CONCLUSION

- Construction of the island was completed on schedule in a safe and efficient manner.
- Island design and construction costs were within budget.
- Verification testing after construction revealed that the island met or exceeded all design specifications.
- Monitoring during drilling showed that the island performance met or exceeded design requirements.

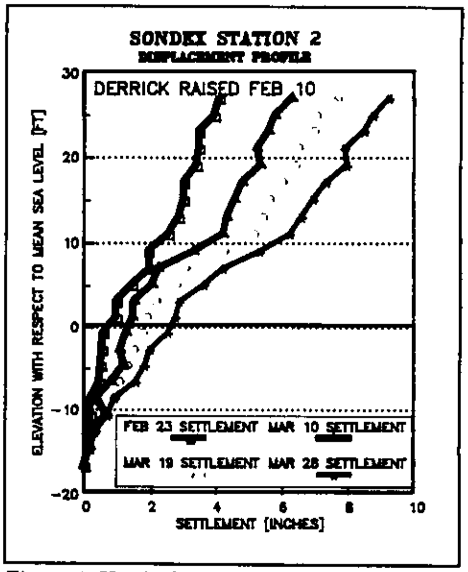

Figure 4. Vertical movement of ice.

AIRCRAFT, SPACE AND COMMUNICATION

Andy Cameron

Washington D.C. is far away from pretty much of everything. There exists what we call the beltway mentality – anything outside of the outer belt of Washington D.C. does not really exist except on paper. It is one of our responsibilities here to return to our mother agencies and let them know of our concerns and the needs of arctic operations. It has been fifteen years since I have been in the Arctic at Point Barrow and ten years since I spent time in Antarctica. Last night, looking at the full moon and the beautiful foliage and the aurora, reminded me that this is a special place and we need to deal with it with care and thoughtful planning. We need to move toward an interagency philosophy that is going to encompass this. Just before leaving Washington I was told NASA has its earth science and applications division reorganized to a degree to encompass the airborne sounding rockets and balloons under one manager. I think this is going to get us a better perspective on science and support systems throughout the world, but especially where it is critical in remote deployments such as the Arctic.

We have a fleet of aircraft operating out of two facilities. One fleet operates out of Ames Research Center. We now have a DC8, and it seems like everyone in the Arctic has a C130. We have high altitude ER2 aircraft and a separate flight facility operated through Goddard Space Flight Center. It has several aircraft including a P3 and an Electra which spends a lot of time up doing *in situ* and remote sensing research in Alaska. Also, our Sky Van and Hueys spent a fair amount of time here. Therefore, NASA has been involved in arctic operations for many years.

Recent advances in arctic geosciences are due, to a large degree, to greater access and endurance in the arctic regions in which our aircraft have played a role.

I would like to mention the most popular program of this past year – the Arctic Ozone Mission. We have both the DC8 and the ER2 flying simultaneously, which is a new trend of multi-sensor/multi-aircraft campaigns in areas operating out of Norway to the North Pole, covering Greenland and monitoring arctic atmospheric chemistry and sea ice. We started maximizing every flight opportunity possible and even went on ferry flights back and forth. We are flying over sites of interest in Greenland and Iceland. We are trying to make every flight-hour count here.

A fair area of the Arctic is being covered with each deployment. It is not just for NASA, but also for working in an interagency-interdisciplinary mode. The instruments on the DC8 are provided by NOAA, ERL and JPL. Specifically, instruments are designated for ozone research, but also to monitor other trace gases. The ER2 can be configured more like a pallet of instruments. Cooperating institutions are Harvard, NOAA, and the other university community associates such as the University of Denver.

Survival in the Arctic is a problem. There are two different types of survival. We are starting to see a financial survival in the federal government level. Continued funding at the base level shows NASA spending about $16 million dollars on arctic research in 1989. These are the flight hours requested by the scientific community. This is the $16 million dollar trend similar to what we are spending now. We are not able to take care of the entire community and are barely able to keep aircraft flying all the time. Inflation will also be a problem hitting us. With a four percent increase per year compounded in five years, we are talking about a 21 percent cut in our present funding and, in ten years, we are talking about a 48 percent cut. We need augmented funding sources just to continue our present program and, hopefully, integrate them with some new technology to offset that cut.

Another problem, in addition to ongoing funding, is that we have recently been hit with an impact from Lockheed. They have increased our overhead G&A rates for the year-two program, which is part of our high-altitude capability, by 50 percent. This is going to increase costs on the ER2 operations by 25 percent. We are struggling to come up with enough funds to maintain our FY90 capability. The Alaska high-altitude aerophotography program is going to be affected because it will be more expensive to operate the aircraft. We are concerned about the cost of supplying these platforms. We are going to maintain them, but they must be more efficient in the future. We are moving into an era of what NASA likes to call the earth-observing system. Satellites will be everywhere and there is going to be a great requirement for coordination between science and support programs. We have the programs for advanced sensing and getting higher technology in the instruments and the platforms that supply them. Nothing is going to change the requirement of having a scientist in the field for obtaining ground truth. Whether we have these satellites going up or not with support by aircraft and ships, there is still a need for someone in the field. Support programs must be designed to maintain field capability in addition to these programs.

Advances in technology sometimes are seen in different ways. We have had the NASA data architecture and data system architecture for a long time for the shuttle support. With our airborne program we are trying to improve technology and offset some of the cost of remote deployments in the Arctic. We are working for a real-time data relay system for aircraft in the field, specifically the Arctic, uplinking directly to satellites.

Scientists want to stay at their screens at their universities. That is wonderful and is more cost effective. We can relay "real-time" data to the PI. Are we going in the right direction? Do we need to modify the flight plan? What is wonderful about this "real-time" system is that you are removing some of the scientific equipment and personnel that would have to be deployed at advance sites. The recording devices would then be back at the PI's university. With less people in the field, you have a lower risk factor. We need to become more efficient and more effective in the future.

We are conscious that technological advances are not going to drive our programs. Science is the reason we are here, and yes, science is driven by how much capability we have to maintain a program in the Arctic. These programs are going to be rare. We cannot have an agency for every major program.

At NASA, we are putting together a five-year science plan to look at our science progress over the next couple of years. We are looking at actual maintenance schedules and other science programs that could be combined. In 1992 we are planning a major year with Arctic deployment and Antarctic deployment, specifically related to ozone, but also ice mapping with remote sensing with our own TSAR system, X-, C- and P-band radars.

A worldwide program that NASA would like to see from the different agencies would be some type of arctic or polar-related program schedule from everybody. Maybe some of our PIs can start sharing data directly. We do not want a duplication of effort.

We are also working with the Soviets and are trying to get a flight program going over the northern area of Kamchatka, which has some unique geology. Hopefully, that is going to allow us to do more research in the Soviet Arctic.

We also want to move into interagency and international programs. We have an airborne geoscience newsletter to which I encourage everyone to subscribe. It is free and it has some useful information on a quarterly basis. It shows interagency research aircraft typical performance characteristics and flight plans. It also shows what science projects we are planning and what instruments we are hoping to use in the future. It provides an open forum for people who would like to submit articles about the Arctic. We have an article on flights over Iceland. The Arctic shows up in almost every issue.

The Arctic is a major part of the the NASA program. NASA wants to do more than basic science in the Arctic. They want to know about engineering and ice coring projects on the polar ice cap. NASA needs your expertise.

I hope that we are able to work closer in the future with military support groups and with interagency groups. The Arctic is a very rare and beautiful place. The more we know about it the better the world is going to benefit from it.

GROUND PENETRATING RADAR

R. M. Cameron

BACKGROUND AND DEFINITION

Ground penetrating radar (GPR) is the generation, emission and reception of electromagnetic waves for the purpose of detecting subsurface objects or phenomena. Knowledge of the fundamental principles of GPR predate World War II but practical applications did not emerge until the 1950s. In recent years, GPR technology has been used to investigate a number of natural subsurface geological or physical phenomena (freeze-thaw interfaces in the Arctic and Antarctic, glacial probing and the study of ice dynamics), and the delineation of mineral veins or deposits. GPR has also been employed to detect buried metallic and non-metallic objects such as pipes or tanks, void beneath road beds and airport runways and more recently, GPR has been employed to detect and map some types of subsurface contaminants.

There are currently several ground-penetrating radar systems in commercial service, and a number of more advanced systems are under development by government agencies, universities and private industry. In application, current systems are either towed along the ground, or are flown at low altitude aboard helicopters or airplanes. At least one radar has exhibited ground penetration from a spacecraft – the JPL radar flown aboard SeaSat.

PRINCIPLE OF OPERATION

The principles and theory of operation of GPR are very similar to acoustic or seismic sounding principles. In each case, a wave or pulse is directed into the ground. As the wave progresses through the medium a portion of the signal is reflected back to a receiver whenever there is a change in the index of refraction of the material. A portion of the signal is also propagated through the material. In the case of acoustic or seismic signals, the index of refraction is a function of the density and bulk modulus of the material. For radar signals, the index of refraction results from changes in the dielectric constant (DC) magnetic permeability, and conductivity of each of the intervening materials.

The propagation velocity of a radar signal through a material is a unction of the square-root of the material's dielectric constant. By definition, the DC of air is unity. The DC of demineralized water is approximately 81. Therefore, the radar wave travels at one-ninth the velocity in water than it does in air.

Conductivity also affects the attenuation and propagation of the radar signal and becomes a significant cause of radar reflections when high conductivity substances are encountered (e.g., metal structures). In the detection of subsurface chemicals such as undissolved hydrocarbons the DC is the predominant cause of reflection.

Dielectric Constant value ranges for some typical materials are given in the table shown below. These values are for a peak frequency of 500 MHz, and a mean temperature of 20°C.

In general, current GPR systems have peak frequencies between 100 MHz and 2 GHz. Also in general, the lower the frequency the greater the depth penetration through soils. Inversely, the higher the frequency, the better the resolution of the system. However, radar antenna design and size, and spurious scatter also strongly affect resolution throughout these frequency ranges.

In the application of GPR, extreme care must be exercised to understand both surface and subsurface chemistry and geology. For example, radars operating at frequencies in the megahertz and gigahertz range cannot penetrate salt water or micaceous clays (extremely high DC and very high conductivity). Conversely, GPR performance is enhanced through frozen ground or ice. In arctic climes, for example, GPR systems can (and have) penetrated to great depths to detect permafrost, freeze-thaw zones, ice wedges, etc.

METHODS OF IMPLEMENTATION

The fundamental principle for implementing ground penetrating radar is concerned with the modulation of the radar signal. Many modulation schemes are possible, but in practice two general schemes are used: simple pulse modulation – analogous to amplitude modulation (AM) in radio and frequency modulation (FM). Both have advantages and disadvantages which

Dielectric constants of various materials

Material	Dielectric constant range
Air	1
Unsubstituted hydrocarbons	1.5 - 3.0
Ice	2.3 - 4.0
Frozen silt	4.0 - 8.0
Dry sand	4.1 - 6.0
Granite	7.0 - 9.0
Dolomite	9.0 - 9.0
Limestone	8.0 - 12.0
Micaceous clays	30.0 - >80
Sandstone	9.0 - 11.0
Schist	16.0 - 18.0
Water saturated sand	20.0 - 25.0
Pure water	81

depend on the application and performance requirements. Specialized modulation schemes may result in significant improvements for particular applications. In general, AM radar systems are technically easier and less expensive to fabricate and operate in the field. FM systems, while technically more difficult to engineer and operate, offer advantages in power throughput and data content.

DESCRIPTION OF EQUIPMENT

Two of the more widely used and commercially available ground-towed systems are pulse systems manufactured by Geophysical Survey Systems, Inc. at Hudson, New Hampshire; and Oyo, Inc. at Houston, Texas. Both companies offer GPR systems with selectable center frequencies from approximately 100 MHz to 1000 MHz. Both systems employ two transmit/receive hybrid-horn antennae, and both incorporate *in situ* data processing and real-time data display. Both also provide for external post-survey data processing. The GSSI system has also been operated from a helicopter for studies in arctic ice dynamics.

Currently, the only commercially-operated FM radar systems are designed for use aboard helicopters. These systems are operated by the Environmental Surveys Division (AES) of ERA Aviation at Santa Maria, California. The two AES systems have center frequencies of 500 MHz and 2000 MHz, respectively, and both employ high pulse compression (time-bandwidth product). They can be operated with a single transmit/receive (monostatic) antenna, or with bistatic antennae.

The ground-towed GPR systems are especially suited for detecting metallic and plastic pipes, voids and objects beneath streets and smooth ground. In general, they are not well suited for large area surveys, especially where the terrain is not smooth, since the antennae must be towed while in contact with the ground. Under ideal soil conditions (dry sand), these systems, like the airborne FM system, can penetrate to depths of the order of 20 meters. In wet soils their depth penetration is limited to a maximum of approximately 5 meters.

DATA PROCESSING AND ANALYSIS

Ground-penetrating radars generate a plethora of data. All commercially operated GPR systems employ integral data recording, processing and display systems that yield at least a "quick-look" image or graphic display of the radar responses. In the case of the two ground-towed systems, integral computers can generate real-time strip-chart recordings of radar responses. Both employ selectable gain, filtering, and averaging programs to tailor the data display to the user's needs. These displays may suffice for locating shallow buried pipes, drums, cables, or voids where the indices of refraction between media are sufficiently large to lucidly yield discrimination between the media. For more detailed analysis and interpretation, where the changes in the indices of refraction are more subtle, more sophisticated and powerful computers and software must be employed.

In the case of the airborne FM ground-penetrating radars, analog signals are first digitized within the system and recorded on magnetic tape for subsequent processing on a main-frame computer. The analyst may employ a number of software routines and algorithms that compress, average, and filter the data, apply gain versus range (depth) corrections, remove clutter, and/or generate geometrically corrected and enhanced imagery associated with particular radar responses.

It must be emphasized that in many applications of GPR, alternate means may be required to confirm the validity of the radar responses and interpretations. In confirming the presence of petroleum hydrocarbon contamination, for example, boreholes, monitoring wells, or other techniques may have to be employed to confirm the GPR findings. When used in concert with other more conventional assessment techniques, adequate ground-truth and careful application, ground-penetrating radars yield continuous streams of subsurface data (as opposed to point-source data), often in a non-intrusive and non-invasive manner. These are often very significant advantages to the user or the client.

CONCLUSION

Ground-penetrating radar is an emerging technology that offers many advantages to the detection and assessment of natural and man-made geophysical and geochemical phenomena, and is most effective when used in conjunction with other more conventional exploratory techniques. As with any remote sensing technique, great care must be exercised in the application of GPR; its limitations must be recognized along with its advantages. In geological applications, GPR is currently at a level of use and acceptance comparable to seismic technology of a decade ago. Continuing advances in engineering development, coupled with smaller, less expensive and more potent computer hardware and software, should foster the continuing growth and acceptance of ground-penetrating radar as a powerful investigative tool.

OBSIDIAN, THERMAL CELLS AND ARCHAEOLOGICAL SITE DATING IN THE ARCTIC

John P. Cook and Michael L. Kunz

At present, there is no way of addressing the significance of several thousand archaeological sites in northern and central Alaska since they have not been dated and cannot be placed in their proper contexts. These sites contain considerable information concerning subsistence patterns, prehistoric technology, cultural networks and land use, but are relatively useless without chronologic control. About half of these sites contain artifacts and waste flakes made of obsidian (volcanic glass).

As does all glass, obsidian absorbs water (atmospheric moisture) at an exponential rate from its surface inward. This water absorption (hydration) results in the growth of a thin water-impregnated rind on the obsidian artifact or waste flake. By measuring the thickness of the rind and knowing the rate at which the hydration occurred, the time that has elapsed since tool manufacture can be accurately determined. This provides the date(s) of site occupation.

The rate at which obsidian hydrates depends upon two major variables: average annual soil temperature (effective hydration temperature or EHT) at the site and the chemical composition of the obsidian. The chemical composition of obsidian varies with the source of the material and can be determined through geochemical analysis.

The Bureau of Land Management (BLM) has funded the initial phases of a multi-year research project which employs the recently developed thermal cell technology for determining the EHT at archaeological sites. Thermal cells are simple, reliable, reusable and inexpensive, making them and the *obsidian hydration technique* vastly more cost-effective and widely applicable than other dating methods. Thermal cells, which measure the EHT, must be buried in the site(s), collected after one or two years, and analyzed.

Essentially, a thermal cell acts as a piece of obsidian in an archaeological site except that it hydrates a measurable amount in one or two years while obsidian requires a millennia. A thermal cell consists of a desiccant sealed in a plastic cylinder. This cylinder is placed inside a slightly larger glass vial containing distilled water. Several glass beads are placed on top of the desiccant cylinder so that when the vial is sealed and capped the cylinder is forced to remain submerged (Fig. 1). This allows sufficient space for expansion when the water freezes so that the vial will not rupture. Several vials are then buried in the site at the same depth as the artifacts.

Prior to immersion in the vial, the desiccant cylinder is weighed. After one or two years of burial the vial is retrieved and the desiccant cylinder again weighed. The resultant weight differential represents the amount of moisture absorbed by the desiccant. The *known* hydration rate of the desiccant is affected only by the average annual temperature of the soil. Therefore, the amount of moisture absorbed by the desiccant allows the EHT of the site to be determined. This information can then be directly applied to the hydration rind measurements of the site's obsidian, thus providing an occupation date(s) for the site.

For dating, once the geochemical and EHT parameters are known, the hydration rinds on the archaeological specimens need to be measured. This requires preparing a thin section of the sample and careful measurement. Experience has shown this to be a critical step. For this study, as a means of verifying the reliability of the application of thermal cell derived EHTs, additional dates must be independently obtained for the same sites. This is done by employing the radiocarbon method at sites where both obsidian and datable organic materials are present.

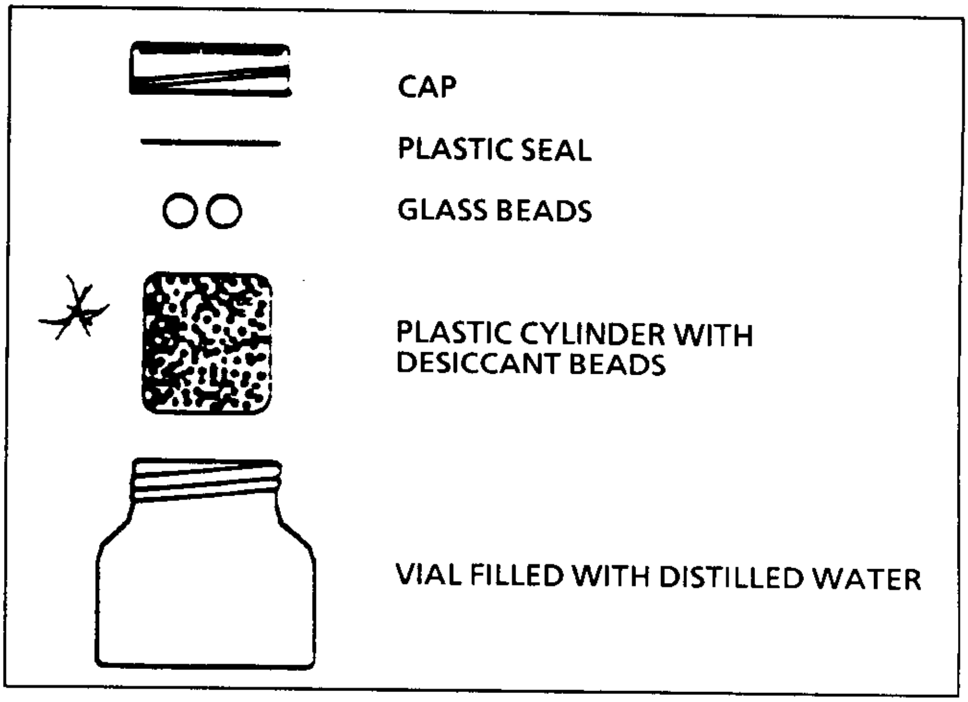

Figure 1. Thermal cell for determination of effective hydration temperature.

ENGINEERING CONSIDERATIONS IN THE DESIGN OF REMOTE POLAR FACILITIES

Kevin C. Curtis

The renewal of the Antarctic Treaty and recent advances in the area of paleoclimatic analysis of circumpolar snows have resulted in an increase in scientific research in circumpolar regions. At the same time, concern over the depletion of the ozone layer in the Earth's polar regions has resulted in an increased need for science facilities in both the Arctic and the Antarctic. Engineering support of such efforts continues to be hampered by a shortage of engineers with specific training in circumpolar design. Design efforts are further impeded by a lack of guidance in the literature regarding the selection and establishment of adequate design criteria for such facilities.

In many cases, base camp facilities are located in areas remote from logistical support centers. All building materials and supplies not available at the site must be flown in at great expense to the project. Shipping weight and cube become of prime importance in the selection of building systems and materials. Additionally, base camp facilities must be founded on whatever material is available at the chosen site. In many cases, the only available foundation material is snow. The efficient utilization of snow in the construction of base camp facilities reduces the total weight and volume of building materials that must be shipped to the site.

A vital consideration in the engineering design of systems in severely cold environments is the seriousness of the failure of engineered systems and structures. The failure of elements of the engineered life-support infrastructure in extremely cold environments can result in life-threatening situations and/or death for remote station personnel. Inadequate engineering can impose burdens on personnel which range from safety and/or health and sanitation deficiencies to overall station viability.

To avoid such failures, the engineer must have access to the specialized knowledge provided by past successes and failures as well as the results of current research in cold-regions engineering. This knowledge is most effectively transmitted in the form of published design criteria. Such design criteria must adequately account for the extraordinary influences exerted on structures and facilities in the circumpolar regions of the Earth. At the current time, no such comprehensive set of design requirements in circumpolar engineering has been published in the literature.

It is quite urgent, in light of the increased scientific work that will be occurring in circumpolar regions in the near future, that a concentrated effort be expended to develop the engineering design criteria that will allow science efforts in remote facilities to proceed in a safe fashion. Engineering design criteria for remote, circumpolar science facilities need to include (but are not limited to) the following:

- *Adequate weather data collection.* These data are critical to structure and system design. It is necessary to quantify the environmental influences that must be resisted by engineered systems and structures at the site of interest. The data must include temperature, wind magnitude and direction, annual snow accumulation, etc.

- *Snow stabilization procedures.* While the strength of the snow to be used in the foundation of structures can be increased greatly through proper handling, long-term creep deflections and the resulting potential for differential settlement remain a serious problem in the design of engineered structures. In order to use the site snow as an engineered foundation material, data must be available on the snow characteristics at the site. Selection of the correct handling and stabilization techniques is dependent on these characteristics. Much research work remains to be done in this area.

- *The effects of diurnal and seasonal temperature variation in above-ground structural framing and systems.* Diurnal and seasonal temperature variations can impose significant stresses in above-ground systems and structures. Above-ground steel framing in existing facilities exhibits a high degree of diurnal temperature variation as evidenced by daily ice-up and melting. Little work has been done in quantifying these temperature variations and the resulting induced thermal stresses.

- *Fresh water supply and waste water disposal.* Techniques exist for the supply of clean water and the disposal of waste water in remote polar facilities. These concepts need to be incorporated into a systems approach to camp layout that adequately addresses sanitation safety considerations.

- *Fire protection systems for low temperature uses.* Personal injury and fire damage to structures pose a serious threat to remote stations personnel. Traditional water-based fire protection schemes are, generally, infeasible for use in remote, low temperature facilities as energy requirements to melt and maintain an adequate water supply impose an unacceptable burden on camp power facilities. Halon fire protection systems have been successfully used in cold-region structures but are expensive to operate and require recharging after use. Personal safety considerations dictate, however, that the issue of fire protection of engineered systems and structures be incorporated into the original camp design.

- *Site snow drifting.* Snow drift patterns at a site have a serious impact on the adequacy of a given camp layout. Heavy drifting can also result in additional loads imposed on systems and structures. It is generally understood that certain structure types reduce local drifting and increase wind scour but it is not known how multiple structures affect each other and the scour potential of the site. Research on snow drifting and incorporation of drift reduction schemes must be incorporated into the design criteria during the initial planning phases of the project. Inadequate guidance on this topic is available at this time to correctly formulate such design criteria.

- *Design life of camp facilities.* Depending on use, the facility's design life required by the science efforts ranges from a single season to "permanent". The project design life is an integral factor in the selection of the most cost and performance effective system for a particular camp. Camp layout, optimal structural foundation systems, sanitation facilities design, etc., are all dependent on the design life of the facility. The lack of published design criteria providing guidance to design engineers on the impact of these factors on systems design results in potentially dangerous situations for personnel as well as an inefficient use of resources.

Academics involved in cold-regions engineering research, practicing engineers working on circumpolar projects and cold-regions field logistics organizations need to combine their knowledge and formulate specific design criteria for remote science camp facilities design. This will result in more efficient use of scarce resources but, primarily, will result in increased safety for remote station personnel. The need for circumpolar design criteria is both immediate and vital from a personnel safety point of view.

TECHNOLOGIES IN SUPPORT OF REMOTELY BASED RESEARCH

Ted DeLaca

The Division of Polar Programs (DPP) is a geographically defined group within the National Science Foundation. That is, the DPP deals with the polar regions and with all sciences that relate to them. In the Antarctic we have a mandate to deal with all of the U.S. Antarctic Research Programs, while in the Arctic we deal with a relatively small amount of the U.S. research. Because of the single agency management within the Antarctic a number of interesting opportunities have been created. The Division of Polar Programs in the Antarctic funds research that ranges from molecular biology to astrophysics. There have been many new developments in recent years which have facilitated research – classical polar research – as we have known it in past years. Some of the new developments have facilitated research disciplines not previously possible to pursue in remote areas.

The broad range of technological development is extremely vast. The new technologies in polar sciences have ranged from off-the-shelf products, which clever individuals have recognized the importance of and used unmodified in their research efforts, to those that required very little modification. I use as examples not only the development of remotely-operated and satellite-related equipment, including the SAR satellite equipment that you have in this institution, but also search-and-rescue equipment for researchers working in remote areas. Animal telemetry equipment has been developed as well as ground-based sensors for the Argos satellite and thermal protection equipment for research support people and aviators. New technologies that have been modified for use in extreme conditions include automatic weather stations, some of which are air dropable so there is no need to deploy valuable resources to place them on site. Also, thermo-electric generators and other related equipment have been developed.

There are a number of mechanisms that have allowed for the development of novel equipment. NSF has, within the recent past, entered into partnerships, through its principal investigators, with industry. The University of Alaska has, in some cases, been a leader in these endeavors. We have been happy to sponsor research from NSF, with Motorola and other companies, to develop transducers for animals that can be left on year around to enable these animals to be tracked.

On research with other agencies, including NASA, we have developed data loggers that have helped us place equipment in the field to last for years. These data loggers have very low power requirements, large memory capacities and long field lifetimes. The U.S. Army has been developing new telemetry equipment, such as miniaturized materials, that have been used on various animals. NSF, on its own, has developed novel equipment which has given us a glimpse into our changing planet. Global change, of course, has been a theme during this conference. One of the issues sponsored by the DPP was the development of novel ultraviolet monitors that can look at the effects of diminishing ozone. The long range plan for the Division of Polar Programs has recently pointed out the need for continued technological development to allow researchers to pursue their interests. As a result of this uniform cry for an enhanced program of acquisition and equipment development, we are looking into a new program, or sub-element of a program, within the Division of Programs to facilitate this request.

With that background, I would like to mention a couple of interesting examples which will highlight some interesting psychological/sociological issues.

The Scott tent was the beginning for much of polar research. It has lasted and served us well. It still serves us very well in the Antarctic. But it tends to be a limitation to the full scope of research that can be conducted in polar regions. It has limited much of the research in many of the disciplines that use it in reconnaissance level research. A great deal of time is spent on survival. That is, storms and related problems shut people down, resulting in too much time spent in tents.

Recently, through the hard work of the staff of NSF and with the guidance of the scientific community, we have embarked on a new effort at McMurdo Station to develop a new station that will allow for sophisticated research. We are building a laboratory of structural steel which will be finished next year. This will allow researchers to step farther away from just the reconnaissance level of research into process oriented research.

One of the exercises that we went through (and we went through many) was to draw members of the science community together and ask them what their needs would be for a new facility. Thus, we were able to glimpse the mind set that has developed over the years. Many people still live in the heroic era of dragging a sledge and living in a Scott tent. There was a certain reluctance to make or change their future. We thought that an analytical laboratory would be desirable.

We were essentially saying whatever it is you want, within certain limitations, we will be prepared to try to acquire. The number of constraints was surprising. For example, there are certain kinds of equipment that cannot be used because they are dirty – certainly we can control that. Another example was, the ground is not solid in the Antarctic because of permafrost or floating ground – we deal with that, and so on down the list. We had quite a long and expensive list of equipment which we were going to make every effort to acquire.

We have gone through the discussion of, "Is it really sensible to put such an investment into a single location?" That is, doing research only in one location because that is where the facility is, not necessarily because it is where the interesting questions are. I maintain that it requires an effort like this to open the opportunities for researchers, but it cannot stand alone.

What kinds of field opportunities can we presently provide our researchers? A Jamesway 1950s technology is like much of the logistics support in the field. It is like a tent with a combination soft canvas outer and a wooden frame. It is quite heavy and requires a lot of air resources to deploy the equipment and the people to put it into shape. Also, it is not very fuel efficient and there are some environmental issues that instantly spring up as well as the logistical costs of delivering fuel and retrograding barrels.

An architectural engineering firm, which had previously worked for NASA, recognized the 16-foot diameter of a Jamesway and the similarity between it and what has been proposed and used for space stations. They tried to come up with some clever use of existing equipment, and it worked out relatively well. The fish hut is a hard habitat that can be used to support science. Essentially, it is a chicken coop on skis.

There have been a number of efforts by our scientists who have felt the need to take this step into process oriented research. For example, a research team is doing marine biology on the sea ice. They set up a small box and create a laboratory system. However, people are living and working in the same laboratory setting. In these situations, we have the responsibility to protect these people and to provide an opportunity to do the science.

These are examples of a combination team of university and other agency researchers, many doing work in an environmentally-sensitive area. We have to create a situation where we protect the environment and essentially allow the science to continue.

There are many examples of materials we have used such as a new helicopter deployable system that would allow for a more complete support system for logistics. Or a structure like a Jamesway that folds out. There is also a company that has recently sold a Quonset hut-like structure to the University of Colorado INSTARR for a research program. It has a rather sophisticated looking interior that would allow for habitation and science. There are many other examples of how one might go about acquiring a clean, dry, warm place that could be plumbed and would provide people with necessities. The expandable IsoVan concept is another of several different ideas that have been discussed. There are many other ideas of how we could create a modular system for research programs.

The Division of Polar Programs recognized the pressing need to provide rapidly deployable equipment that would give our researchers all of the necessary backup needed to perform their research. We went through a competition recently and let a contract out to a company from Fairbanks, GDM, Inc.

I have discussed the 1950s technology and what some creative people have tried to do about some sort of lightweight support system. What was not really considered in some of these efforts were the scientific needs. We asked the science community about what they would want if they could really make a wish list without limitations. We found some very interesting things once we could get past this barrier of their thinking that so much was just not available to them. Government agencies should also go abroad to industry and find out what systems currently exist that we might be able to modify and use to our best interest. If that was insufficient, we would either hybridize those systems or develop our own.

We decided to take a systems approach to this problem and to look at the needs for basic human habitation in a remote, isolated, cold environment and the kind of support we could provide for science. It would have to provide warmth. It would need utilities, accommodations, kitchen, etc., in addition to putting a modular system together that could be used in a number of different configurations because it would not be dedicated equipment.

Glaciologists have stated a need for clean space to do some preliminary preparations and analyses in the field. Geologists have been talking about doing in-field evaluation that would allow them to move a little faster. Many of these discussions come down to the issue of economics.

If you stop to think about the amount of money it costs to have somebody living in a Scott tent or wherever it is they are going to do research, the costs are not inconsequential. Just taking it a step further into providing a more habitable space can give us a lot more for the money.

There is a prototype box designed by Lockheed which is called an Automatic Geophysical Observatory (AGO). Its need was pointed out in a Polar Research Board report some years ago. It has a number of novel technologies using thermal electric generators controlling the heat (the vanes and the radiator are on the outside). There is a dome on the top for all sky camera observations and a variety of other sensors. Essentially this was to be an on-the-ice space station that would be an ionospheric-magnetospheric monitor. The trials went well. We re-competed the contract. Lockheed won it, and they have been in the process of designing the AGO.We will get the first one to the Antarctic this year.

We have received, within the science section of Polar Programs, proposals to look at the development of novel technologies and novel equipment that could use any number of kinds of fuel sources and that will allow deployment for at least a year at a time. Some use petroleum which allows the structure to stay on the ice for fourteen to sixteen months and generate up to a hundred watts of power with shirt-sleeve-type conditions inside. The plans for the community were to deploy such a structure in an array across the Antarctic Continent. There are also applications for all of these types of structures in the Arctic.

One of the designs allows the researchers a brief period of occupation when they come in to gather their data or to re-outfit. It provides a place to work and to live. There are ways of attaching things to the outside of it. We are very much looking forward to having such a facility in place in the Antarctic.

A collaboration study with NASA (with a group interested in Mars studies) has resulted in a data logger system. Sending probes into outer space to land and do remotely based sampling can easily be related to other types of research. Much of this technology is spilling over to our remote, unmanned research facilities that will be used in the Antarctic.

As many of these studies are bipolar, I suspect that there will be a need to work with them in the north and set up similar types of facilities.

HEAVY AIRLIFT CAPABILITY ON ICE AND SNOW

Karl Doll

Our unit is located in upstate New York. It is the 109th Tactical Airlift Group which we normally refer to as the 109th; however, our flying squadron is the 139 Tactical Airlift Squadron. We began flying C130s in 1971 with the standard tactical air drop mission and in 1975 we assumed the snow ski equipped mission from the 17th Tactical Airlift Squadron formerly in Alaska. However, prior to that mission being in Alaska, I believe it started in Tennessee, went to Texas, then to Alaska and to New York state.

We have just completed our fifteenth operating season in the Arctic. We have operated for many years on prepared ski ways on the Greenland Ice Cap. From there we have expanded our capability to operating in open field regions of Greenland, at elevations in excess of 10,000 ft, to operating on arctic sea ice north of Greenland, and north of Barrow, Alaska, on the Beaufort Sea. In late 1987, we were approached by the National Science Foundation to lend support to their operation in Antarctica. We participated with two aircraft for one week in January of 1988. We again sent two aircraft to Antarctica in December 1988 and, most recently, augmented their winter fly-in to Antarctica. We have, over the years, developed an expanded capability from that of the original mission. We are now getting into a bi-polar concept of being able to support science at both poles. Our unit has more than just LC130s, we have four C130H models with wheels. Our total arctic capability not only addresses the snow and ice but also operates in the Arctic in harsh conditions, on gravel runways. That is an important item: we do not operate snow ski aircraft on gravel runways because it tears up the bottom of the skis. When we talk about arctic capability we work both the hard surface and the snow.

The key to our success and the success of the Air National Guard is that we are run primarily by part-timers. The air crew sees this as a real diversion perhaps to their day-to-day work; to get away from the desk and fly an airplane. If we ever do any missions for you, please don't ask us to take a day off. Our crews want to go out and fly every day.

Mission pre-planning is another key to success. That is where you, the users, come in. It is important to pre-plan your mission well in advance. For instance, soon we will be putting together our 1990 arctic airlift schedule through a conference in upstate New York. That is the beginning of getting everything pre-planned; the loads you need delivered, when you need them and when you need them pulled out. Since we operate for so many users, we have to have all the users together so that we can work all of your operating windows together into one compatible season.

We support the National Science Foundation primarily through MAC-SAAM Missions, which are Special Assignment Airlift Missions. The user goes to MAC (Military Airlift Command) with a request for cargo to be carried into the Arctic which requires ski-equipped aircraft. MAC immediately sends it to our unit and we do the job and the user pays MAC.

We also support the National Science Foundation through our training missions. Our Antarctic missions largely, to date, have been air crew training so that we could develop a bipolar capability and we regard them as training missions.

I would like to describe some of our missions and some of the camps we have put in:

- a delivery to the summit of the Greenland Ice Cap at about 10,600 foot elevation. It was done several years ago. We took in a bladder and were pre-positioning some fuel for light aircraft to support a site on the ice cap.

  On the side of the aircraft, we have some gray bottles which are called JATO bottles (Jet Assisted Take Off). That is a misnomer for they are actually rocket bottles which provide about 25% more thrust for 17 seconds depending on the density of the air. We need these at high altitudes and for heavy weight takeoffs. In the summertime, which is the window scientists use to conduct their experiments in the arctic and Antarctic, the snow gets soft and it has more drag so we need this additional capability to get off the snow.

- an ice station in the north of Greenland at sea level. However, the operations are quite different. Prior to our being there, there were people who were brought in early to core the ice and make sure it had the proper thickness and to walk the length and width of the ski way to make sure there were no large ridges that could damage the aircraft. Also, equipment is flown in on typical arctic days, which can be very "white" – this is like flying inside a ping-pong ball and that is quite dangerous.

If a camp is to have extended seasonal use, a prepared ski way is often constructed. This usually requires having a bulldozer in place to assist in preparing and grooming the ski way as well as moving the cargo around for the scientists. Bore holes are made in the sea ice and the borings are taken at least at weekly intervals to insure that the ice thickness remains adequate for our operation. In one week it can go from satisfactory to unsatisfactory. It takes several passes and many days to get an adequate ski way prepared. It is labor intensive to prepare a ski way. But the result is obvious when, three days before where there was nothing, then we have what looks like a small city with a runway beside it. Consequently, we can operate for several weeks supplying the users' needs on the ice.

We have in our unit a unique resource the LC130. We also have fifteen years of successful arctic experience. In summary I would like to ask you, "What can we do for you? How can we help you do more science in the Arctic?"

SATELLITE TELEMETRY USED TO MONITOR THE MOVEMENTS AND BEHAVIORS OF LARGE MAMMALS IN ARCTIC ENVIRONMENTS

David C. Douglas, Larry F. Pank, Gerald W. Garner and Steven C. Amstrup

The United States Fish and Wildlife Service (USFWS) has used satellite telemetry for operational studies of free-ranging large mammals in Alaska since experimental testing in 1984. Biologists have deployed satellite transmitters (PTTs) on 144 polar bear (*Ursus maritimus*), 111 caribou (*Rangifer tarandus*), 25 brown bear (*U. arctos*), 16 muskoxen (*Ovibos moschatus*) and 12 walrus (*Odobenus rosmarus*), during five years of cooperative research with the Alaska Department of Fish and Game, University of Alaska Fairbanks, Canadian Wildlife Service and the University of Maine. Satellite telemetry techniques have afforded both cost-effective and logistical advantages for monitoring wildlife in arctic environments. Systematic, year-round data collection has not been constrained by hazardous weather, darkness, international borders, remoteness, or extensive animal movements (Fig. 1). The data have been used to evaluate population ranges, international status, improvements to census techniques, habitat associations, seasonal distribution and migratory behavior.

Data from PTTs were received by ARGOS Data Collection and Location System (DCLS) instruments onboard two National Oceanic and Atmospheric Administration (NOAA) polar-orbiting Tiros-N series satellites. Polar orbits enhance satellite coverage at higher latitudes, thus increasing the potential for data collection in the Arctic and Antarctic. ARGOS data were available via telephone modem two to eight hours after the satellite received original transmissions. ARGOS data were also disseminated in bulk by a variety of

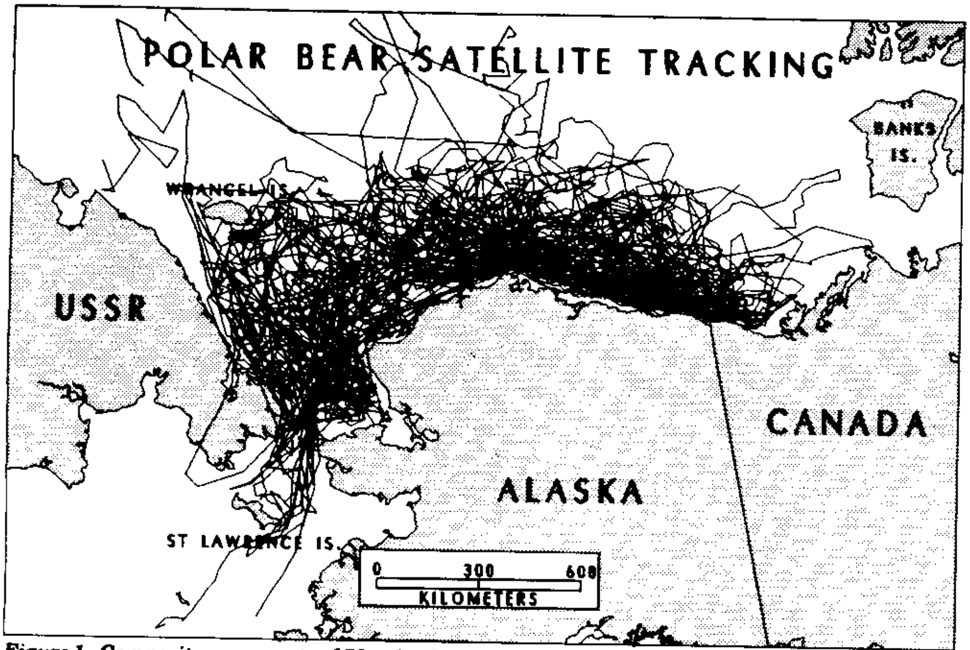

Figure 1. Composite movements of 78 polar bears instrumented with satellite transmitters during a 3-year study period.

media, such as printouts, floppy disks or 9-track tapes.

PTTs used by the USFWS were built by Telonics Inc., Mesa, Arizona. Transmitter components were hermetically sealed, capable of prolonged immersion in water, and designed to operate at temperatures ranging from -40 to 70°C. PTTs assembled into a "collar" configuration were also equipped with a VHF beacon for local radio-tracking. Collars weighed between 1.2 and 2.0 kg depending on battery size and degree of reinforcement. If operated continuously, a PTT powered by three size-D lithium batteries would transmit a 1-watt message, containing 32 bits of sensor data, every 60 seconds for approximately three months before expected power failure. Transmission cycles were programmed to optimize power consumption and data collection. Duty cycles were established based on the frequency of satellite overpasses for each geographic area, relevant biological or environmental events, and the desired operational life of the PTT. For example, the duty cycle of PTTs worn by caribou was 12 h/day transmission during four summer months and 6 h/2-day for remaining months. Battery life was approximately one year for the caribou PTTs. PTT performance varied with species and habitat; however, a mean of one location was acquired for every two hours of transmission from terrestrial animals. The mean locational error was 829 m (SE = 26, n = 1265, Fancy *et al.*, 1988).

All PTTs transmitted at the same nominal frequency of 401.650 MHz, allowing location to be derived from the Doppler shift in perceived frequency as the satellite moved toward and then away from the transmitter. In addition to identification data, each transmission to the satellite carried 32 or 64 bits of sensor data that allowed information about an animal's environment or behavior to be collected concurrent with location. Sensors used have included thermistors to monitor temperature, mercury tip-switches to record activity levels, conductivity switches to detect salt-water immersions, and pressure transducers to document dive profiles. Complementary location and sensor data have provided information about where and when polar bears enter and leave maternity dens, the chronology and synchrony of walrus haul-out behavior, and areas used by female caribou for calving. Patterns of habitat use by wildlife were investigated by overlaying telemetry locations onto environmental maps derived from satellite imagery data. Satellite imagery provided geographic information about sea-ice distribution, vegetation, and snow cover.

A Telonics Local User Terminal (LUT), located at the USFWS Research Field Station in Fairbanks, received D-band real-time downlinks directly from the ARGOS DCLS instruments and calculated locations for PTTs approximately 15 minutes after the satellite overpass. The quality and quantity of data received by the D-band tracking dish were superior to previous generation LUTs that used tracking yagi antennas to capture the VHF downlink. Advantages of a LUT include faster data acquisition and position fixing compared with standard ARGOS processing and cost-effectiveness for multi-year projects using several transmitters. However, LUTs acquire fewer data because both the transmitter and the LUT must be in "view" of satellite simultaneously (ARGOS accesses tape-recorded playback data), and LUTs may have a greater chance of data loss due to power or equipment failure.

Patterns of wildlife habitat use have been studied by overlaying satellite telemetry locations on base maps of snow, sea-ice, and vegetation that were derived from satellite imagery. Satellite remote sensing, both telemetry and imagery, has improved data collection logistics in the Arctic. Large volumes of archived satellite imagery for polar regions, plans for increased acquisition in the 1990s, and the multi-disciplinary scope of imagery data suggest that future arctic research programs could benefit from a coordinated, centralized archive of imagery and ground-truth data bases.

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NOTE: Trade names of commercial products were provided as specific information and do not imply endorsement by the U.S. Government.

SATELLITE REMOTE SENSING - A TOOL TO MONITOR CONDITIONS AND PROCESSES

Tom George

Satellite image data provide a synoptic view that helps integrate "point" observations. This perspective is crucial to making the step from detailed site-specific studies to an increased understanding of global processes. A few systems will be discussed that illustrate the range of capabilities, present and future.

AVHRR

NOAA Polar Orbiting Satellites contain the Advanced Very High Resolution Radiometer (AVHRR), more familiar to us as the "polar orbiting weather satellites." This sensor covers an area about 2,000 km wide, and makes several passes a day over Alaska. For years, the primary use of this low resolution (1-km pixel) data set was for the National Weather Service to observe and forecast weather. Due to advances in computer image processing, a much wider community uses this data to evaluate features such as sea surface temperature from the thermal infrared band; seasonal green-up of vegetation from an index of visible and near infrared bands; snow melt and other seasonal processes.

Telecommunication technologies allow data to be transmitted in near-real time to ships and other field parties for operational analysis and decision making.

LANDSAT

This satellite system has been with us since 1972, acquiring medium resolution data of the Earth. Each swath is 185 km wide, with pixels ranging from 30-50 m in size. The orbit of this satellite series provides coverage with a frequency of days to weeks. Since 1982, the Geophysical Institute has conducted a cooperative project with NASA and NOAA to acquire near real-time imagery from Landsat. The data are turned into high quality images used to monitor sea ice, floods, forest fires and other environmental features.

SPOT

The French operate the SPOT satellite, which offers the highest spatial resolution available outside of the defense community. Ten-meter pixel resolution begins to rival the high altitude aerial photography acquired by NASA, which is truly impressive. Another important feature of this system is the ability to point the sensor side-to-side, enabling SPOT to acquire stereo coverage. The data are detailed enough to generate topographic maps and digital terrain models over Alaska. SPOT has the potential to revolutionize updating of topographic maps, both in reduced cost and a greatly decreased production time. The potential to generate three-dimensional models for landscape studies is very exciting.

ALASKA SAR FACILITY

The satellites mentioned previously all require sunlight and clear skies to look at the Earth. In contrast, radar satellites provide their own energy, allowing us to monitor conditions at night and in the winter at high latitudes. The wave length of the radar energy is such that we can look through a cloud layer as well. Both these capabilities are important to improve our ability to look at processes on the Earth's surface. The University of Alaska Fairbanks, NASA and the Jet Propulsion Laboratory are presently engaged in building the Alaska SAR Facility. This facility will acquire data directly from a series of polar orbiting synthetic aperture radar (SAR) satellites, which will fly early in the next decade. We anticipate that radar sensors will substantially benefit studies of sea ice, ocean processes, monitoring glacier conditions and other environmental factors related to global change.

Images acquired from satellites provide a "snapshot" in time over a large area relative to ground-based observers. The repetitive nature of these systems allows time series analysis, with periods ranging from hours to years. Computer technology has advanced to the point that composite images from several sensors can be generated to enhance subtle features. In areas like the Arctic, with harsh conditions, difficult access and high cost of logistics, satellite remote sensing offers a powerful tool for observation.

COMPUTER NETWORKS - SHRINKING THE WORLD

The development of computer technology including data base software, high-density storage media and network connections have important ramifications for Arctic researchers. The area I wish to address is increased access to information.

It is already possible for a researcher located at his or her home institution to establish a network connection to a national repository and perform a search for data. In many cases, on-line catalogs are available which allow a user to order a copy of the data or document directly. This applies to literature as well as an increasing number of data collections. Where once it took a large travel budget and much time to visit data centers, your fingers can literally do the walking for you. In this fashion, investigators in distant locations can have access to the resources of larger facilities, which has been a problem for people working in the Arctic.

The "age of the computer network" even facilitates access to non-computerized information. A number of national directories are being developed that describe data collections. The user can search for different types of data, often organized by discipline. The results would be a list of collections and a point of contact with either a data center or principal investigator. This approach to listing information can apply to small data collections as well as large ones. Several of the national systems are making a concerted effort to locate and "advertise" data sets other than their own. The *Arctic Environment Data Directory* is an example of an interagency project to locate and list data of interest to the arctic research community.

As researchers, we are often producers as well as consumers of data. I would urge you to think about data sets you are in the process of generating. Should they be available to others? Are these data sets being cataloged and maintained in such a manner that they are accessible to others? Are you budgeting for the resources needed to accomplish these tasks?

In summary, computers help to make the increasing volume of data manageable. Networks are starting to provide access to data and information for scientists in remote locations. High-level directories provide listings of data collections and, in some cases, direct access to detailed catalogs. While the technologies are here now, and improving daily, their implementation requires planning, support, and sharing by the research community.

IMPROVING LOGISTICS FOR ARCTIC RESEARCH

Andreas Heiberg

Research in the Arctic is very expensive, largely because of the substantial investments required for logistics. The success of arctic field projects, and the return on these investments, depend on the cooperation of the environment as well as the performance of the scientific and support resources. Mother nature and human shortcomings upset plans and frustrate projects. We have seen how disruptive and frustrating ice breakups, frequent and prolonged periods of non-flyable weather and radio-blackouts can be. Nature's favorable influence, however, is largely a matter of luck.

Looking at the human factor, it is interesting to observe that our approaches remain unchanged. Although refined, an amazing number of support resources, techniques, and procedures in arctic logistics are basically the same today as 20 years ago, particularly in the case of ice camp operations.

This makes good sense though. In the harsh and unforgiving arctic environment mistakes can be very costly, even life-threatening. There are good reasons for sticking with approaches that have stood the test of time. Even so, progress appears possible and timely in the areas of aviation and communications.

Considering aviation, it is the range and payload of the Twin Otter that remain the limiting factors for how far from shore we deploy and support investigators. This limit falls in the 300- to 500-nautical mile range. Indeed, the records show that all our ice stations except LOREX were deployed within this distance from suitable and accessible shore staging bases. This puts two-thirds of the Arctic Ocean beyond our ready access. Today, if we want to go there, we have to do it by the leapfrog approach, establishing intermittent refueling bases. This is time consuming and leads to significant increases in cost, complexity, and risk.

One future alternative is to develop a broad cooperation with the Soviet Union which will give us access to their shore bases, ice stations, and support resources. In light of our improving relations with the Soviets, guarded optimism seems warranted.

Another alternative is a new airplane with all the essential characteristics of today's Twin Otter but none of its shortcomings of limited range, speed, and payload. The technology is available to modify existing airframes or design a new one. Adaptation of existing airframes like the Buffalo, Caribou, and C47 has been pursued. Only a three-turbine conversion of the C47 is operational. After ten seasons in the Arctic it has proven to be a nice complement to, but no replacement for, the Twin Otter. Among new developments, the Advanced Technology Tactical Transport, the AT3, being developed for the military by DARPA and presently test-flown in a 60% scale model, has some exciting characteristics. However, even if put into production and found suitable to our needs, it will be many years before it is adapted for the Arctic and made available to the research community. Regardless of which airframe is selected, the cost is going to be high and the market limited. Government will therefore have to subsidize the undertaking. I believe the lack of progress is due to a selling job of inadequate force and conviction.

Considering communications, HF transceivers are still the primary, and very frequently, the only means of communicating in high arctic field operations, even though dependable satellite communication has been around for decades. I know that I am not the only one who has raised my voice in frustration thinking that this will overcome the effects of solar activities and ionospheric disturbances. The high cost of ice camp research and the desire to maximize the return on the investment frequently lead to overcommitment of the logistics resources. This results in very ambitious objectives being stuffed into the few weeks in the spring available to carry them out. With no cushion in the schedule, prolonged periods of radio blackout cause significant waste in time, effort, and money and can jeopardize safety. It is time to eliminate this element of unpredictability in polar operations by pushing for a satellite communication system suitable for the polar regions and available to and affordable by research projects and the civilian community. Transponders should be put on polar orbiting satellites and low-cost, rugged transceivers developed. The technology certainly is available and cost could be kept in check by piggy-backing on other polar-orbiting platforms rather than launching a dedicated satellite system.

THE NATIONAL UNDERSEA RESEARCH PROGRAM: A WEST COAST CENTER

Raymond C. Highsmith

The National Undersea Research Program (NURP) is operated by the National Oceanic and Atmospheric Administration Office of Undersea Research. This program provides logistic support and modest scientific support for a variety of undersea research projects. Five regional Undersea Research Centers have been established: University of Connecticut (Avery Point), University of North Carolina (Wilmington), Farleigh Dickinson University, Caribbean Marine Research Center (Riviera Beach, Florida), and the University of Hawaii. There are no centers on the West Coast of the United States. This is clearly an untapped opportunity and NURP hopes to establish one or more West Coast centers.

A West Coast Undersea Research Center has been established at the University of Alaska Fairbanks (UAF) by NOAA's office of Undersea Research. The geographic location and size of Alaska are major attributes favoring placement of an undersea research center at UAF. Alaska's proximity to the arctic provides a major opportunity for new lines of polar research and technical development. Because of its considerable expertise in polar research and logistics, UAF also has a strong interest in developing parallel research and support programs in Antarctica, providing additional impetus and opportunities for development of an Antarctic undersea program through the West Coast Center. Alaska shares international borders with Canada and the USSR, which provide substantial opportunities for international collaboration. Over 50% of the U.S. coastline and 74% of the U.S. continental shelf occur in Alaska. Alaska represents approximately 85% of the West Coast coastline. Nearly half of the U.S. commercial fisheries catch and about 90% of the West Coast catch occur in Alaskan waters. The strategic and economic importance to the U.S. of Alaska's offshore oil and mineral deposits is well documented, providing potential linkages to federal agencies and petroleum and mining industries. Marine mammals, all of which are protected or managed by the United States Government, abound in Alaskan waters.

At first glance, Alaska may seem a great distance from parts of the West Coast, but the distance is the same in both directions. Regardless of where a single West Coast NURP Center is established, it will face the same challenges and costs of developing a major program over a large geographic area. Because of the established research program in Alaska (more proposals are currently being submitted and funded for work in Alaska than for Washington, Oregon or California) and the numerous additional opportunities of national interest mentioned above, there is ample justification for establishment of a Northwest or West Coast Center in Alaska.

UNDERSEA RESEARCH PROGRAMMATIC OPPORTUNITIES

Several programmatic areas of special opportunity for a West Coast Center have been identified by scientists of the region. The following areas offer priority opportunities for the advancement of our understanding of marine systems and processes and of our knowledge of valuable marine resources in the region.

- *Fisheries research.* Half of the fish harvested from the U.S. exclusive economic zone (EEZ), including 85% of that allocated to foreign nations, are taken within the northern portion of the West Coast region. To ensure the continued wise management of this valuable resource, it is important that we increase our understanding of the relationship of finfish and shellfish to particular habitats and improve population estimates. Recently, fisheries scientists have begun to address these tasks on a multi-species basis. Submersible research vehicles provide new means to investigate fish habitats, community relationships, life histories, and recruitment processes. By viewing fishing gear performance we can better understand the effects of fishing on target and non-target species as well as the effect of various types of gear on the habitat.
- *Shelf and slope ecology.* The broad and rich continental shelves along the western U.S. margin provide a special opportunity to study important biological processes and the physical and biogeochemical processes which accompany them. Studies of the allocation, flux, and fate of carbon in the marine environment are fundamental to our understanding of shelf processes. The scientific and economic importance of these continental shelves warrants extension of these studies to important benthic processes. Because the effects of short and long-term climate changes are expected to be especially prominent at high latitudes, the northwest provides a major opportunity for this research in the U.S. EEZ. Because research on the slope and shelves in this region is relatively new, the investigation of

faunal associations and habitats provides abundant opportunities for new understanding. This research will also complement and enhance the research proposed above on "Fisheries research."

• *Ridge crest processes.* Modern tectonic theory of ocean crust formation and evolution is only two decades old. Our understanding of ridge crest processes is advancing rapidly, thanks to the parallel advancement of undersea technology. Because the full range of tectonic environments, such as hot spot effects, fracture zones, and propagating rifts, occur in the northeast Pacific Ocean, the northwest ocean region of the U.S. provides a unique opportunity to study these submarine processes.

Ridge crests provide a further opportunity to study a wide range of ecological processes since the ecology of hydrothermal systems is both different and relatively isolated from the broader biological environment of the ocean. The rock/water chemical processes at ridge crests are not fossil but are occurring in real time. These processes are the same as those that have produced economically important mineral deposits. Studying the geology/geophysics of the region will help us understand the process of sea floor generation, a process responsible for formation of 70% of the earth's surface and continuous recycling of the ocean's water.

Many of these studies will involve the deployment and operation of instrumentation for monitoring these processes on a decadal time scale, and will be heavy users of submersibles, ROVs, and remote sensing instrumentation.

• *Subduction zone processes.* Underwater technology provides a unique opportunity to study subduction zone processes. The physical, chemical, and biological processes associated with the dewatering of sediments during subduction of the ocean floor is of particular interest and importance. Study of these processes can be done rather rapidly by moving across the subduction zone and sampling appropriately. The submersible vehicle provides a unique platform for precisely taking the sequential samples. In addition to studying the biogeochemical processes associated with subduction, information on the deformation of sediments and on earthquakes can be gained. Alaska has been the site of many large and destructive subduction earthquakes. The Oregon-Washington margin could also be the site of future great earthquakes. Although the effects of the earthquakes are largely felt in onshore communities, they are caused by faulting beneath the shelf and slope of the margins. Historical evidence for these earthquakes and predictive evidence for future events may well exist on the sea floor. Submersible technology will play a major role in studying these phenomena and deploying instrumentation for monitoring deformation.

• *Sea mounts.* Sea mount formation is a major geological process on the ocean floor. The sea mounts in the eastern Pacific Ocean are relatively unstudied, and provide a valuable location to study the geology of the sea floor and some of the fisheries and ecological problems already mentioned. The fishery potential of these sea mounts deserves particular attention. Due to a combination of isolation, bathymetry and ocean current regime, sea mounts have unique biological communities. Investigation of the physical and biological processes occurring on sea mounts may yield clues to causes of intra- and interannual variability of fish stocks. Geological and geochemical studies of the active sea mounts in the area will enhance our understanding of submarine volcanism and impact on ocean waters and associated biological communities.

• *Polar research.* Marine scientists working in both the Arctic and Antarctic are severely limited by vessel capability and other logistical problems. Only the Arctic is included in the West Coast region, but similar challenges and opportunities faced by high-latitude marine scientists suggest that the West Coast Center should handle Antarctic as well as arctic undersea research. Development of submersible technology, especially unmanned vehicles, may significantly improve our ability to study and understand the physical and biological processes of the polar seas. The United States Arctic Research Commission, in its draft report on logistical needs, anticipates the development and use of submersible technology and submarines. The increased U.S. policy interest in the arctic and the accumulating related biological and physical data challenge undersea technology. The physical oceanography of the arctic is particularly interesting. Research using acoustic propagation under the ice where few internal waves seem to exist provides a unique location for physical oceanographic studies. Increasing evidence suggests much higher levels of biological activity under the ice in both the arctic and Antarctic than previously thought. Light and chlorophyll studies, coupled with studies of the biological communities and ecosystem dynamics under ice and in areas covered seasonally by ice, are topics of urgent interest.

• *International cooperation.* The University of Alaska Fairbanks is a leading institution in high-latitude research. Consequently, there are frequent opportunities for international collaboration. The rapid improvement in relations with the USSR, in particular, may present opportunities for extension of ongoing U.S. studies in the Bering and Chukchi Seas into Soviet waters. The West Coast region brackets the Canadian west coast and adjoins the Canadian Beaufort Sea. There are numerous fisheries and oceanographic research problems of mutual interest and potential collaboration. The International Arctic Polynya Project is a new initiative of the Arctic Ocean Sciences Board that will involve scientists from approximately six countries in the coordinated study of polynyas in the Bering Sea, Canadian Arctic and Greenland.

In summary, the programmatic themes listed above are not intended to be all inclusive of the possible research opportunities in the eastern Pacific bordering the West Coast of the United State. They are, however, areas of current priority interest. Because of productive and cooperative research which is already underway, these areas provide special opportunities for submersible technology to enhance our knowledge of marine resources in the region and to increase our understanding of important oceanographic and biological processes.

LOGISTIC SUPPORT AVAILABLE THROUGH NURP

Several types of logistic support are available to the scientific community through the National Undersea Research Program. The plan for the West Coast Center is to lease most items provided to researchers by the Program. In this way, underwater vehicles, particularly those with the latest technological capability, can be closely matched to research needs.

Manned submersibles, with support vessels, are available through NURP. Typically, submersibles have space for a professional pilot and one or two scientists. Shallow diving submersibles usually have a maximum depth capability of about 300 to 330 m. NURP is also a co-sponsor, along with the National Science Foundation and the Office of Naval Research, of the deep submersible *ALVIN*, which is capable of working to depths of 4000 m. Hopefully, it will soon become possible to gain access to manned submersibles operated by the U.S. Navy, such as *NR-1* and *Sea Cliff*, through NURP.

Unmanned vehicles are another form of logistic support available through NURP. Unmanned vehicles are usually not provided with support vessels but scientists can apply for funds to charter a vessel. Unmanned vehicles have certain advantages over manned vehicles. Risks associated with an underwater accident are limited to equipment loss. Also, the cost of operating an unmanned vehicle is only a fraction of that for a manned vehicle. It should also be noted that unmanned vehicle technology is advancing rapidly. Instrumentation typically available for attachment to unmanned vehicles includes video and still cameras, side-scan sonar, pressure (depth) sensor, CTD (conductivity, temperature, density) and oxygen probes. There are three general categories of unmanned vehicles (Kolf, 1989). Towed vehicles do not have power systems of their own and are pulled through the water column by a surface support vessel. The second type, known as a remotely operated vehicle (ROV), is attached to a stationary surface vessel by a tether through which it receives power and control signals for small thrusters. A video camera mounted on the ROV allows a shipboard operator with a monitor to maneuver the vehicle. The third type is an autonomous vehicle (AV), which operates independently (no tether) of a surface vessel, utilizing its own power and preprogrammed instructions. The latter type may be particularly useful in ice-covered seas.

Side-scan sonar can also be supplied by NURP. This type of sonar is useful in locating objects on the bottom, sediment profiling, and bottom mapping. Recently the Program has provided specially engineered side-scan sonar capable of working at depths greater than 1000 m and equipped with still and video cameras.

DISCUSSION

Access

One of the major functions of the proposed Center will be to facilitate communication between suppliers and users. In this way, researchers will be kept up to date on technological advances and vendors will be informed of research needs.

The operational plan for the Center is to lease underwater vehicles on a seasonal or project basis. In this way, the Program can keep pace with technical advances in the field and provide the most modern equipment to researchers.

Information Exchange

The proposed Center will actively acquire and accumulate information on equipment availability and capability. This information will be available to the research community upon request. In addition, mailing lists will be developed in order to disseminate information on new advances, research initiatives and funding opportunities.

Operational Requirements

The Center, if established, will have staff that regularly attend scientific meetings and symposia in order to hear and discuss the latest research developments. The Center may also sponsor symposia and workshops to bring researchers together for discussion of recent accomplishments and to project future needs. Again, the leasing mode of operation will allow the Center to respond to rapidly changing needs as well as to plan successfully for long-term requirements.

Logistic Capabilities

The National Undersea Research Program is underutilized, particularly on the West Coast and at high latitudes. The establishment of a West Coast Center, dedicated to publicizing facilities available through the program and encouraging and helping scientists to participate, will be a major step in achieving full utilization of NURP capabilities.

Deficiencies

The most obvious deficiency is the topic of this paper, a West Coast Undersea Research Center. Limited funding is another deficiency. All programs can use more money but, in the present context, the establishment of a Center should result in greater research funding for the West Coast and the polar regions. The Center Director would represent these regions in negotiations with managers of the national program for an increased portion of the NURP budget. At present, the West Coast is unrepresented at budget meetings. Further, the Center staff would work with Senators and Representatives of western states to increase the overall NURP budget.

With regard to undersea vehicles, unmanned vehicles have typically lacked the capability of manned submersibles. Because of reduced risks and lower costs associated with unmanned vehicles, a great deal of effort is now being expended on development of advanced models closer in capability to manned vehicles. The development and availability of light, efficient manned submersibles would also be an improvement. Such submersibles are more easily launched and recovered than heavier vehicles, requiring less specialized and expensive support vessels, i.e., more dive days can be purchased for a given sum. In addition, lighter vehicles can usually be launched during a somewhat greater sea state, reducing "weather" days and increasing dive days. Finally, the United States needs a deep-diving manned submersible capable of working to a depth of approximately 10,000 m. Such a submersible is needed, for example, to explore the Aleutian Trench, which in places is deeper than 8000 m, well beyond the capability of vehicles presently available.

The above is a brief listing and there are undoubtedly other deficiencies. Of those mentioned here, the most significant is the need for a West Coast Undersea Research Center, the establishment of which will result in a professional staff working toward resolution of these and other challenges.

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NEW NATIONAL WEATHER SERVICE TECHNOLOGICAL DEVELOPMENTS IN SUPPORT OF ARCTIC RESEARCH

Gary L. Hufford

The National Weather Service is just beginning a national process of modernization that will result in the implementation of new observational equipment and an interactive processing system in the mid 90s. The goal of modernization is to improve forecasts and products.

In Alaska, the new equipment will range from automated surface weather observation systems (ASOS), new generation doppler radars (NEXRAD), wind profilers, advanced polar orbiting satellites, and a state-of-the-art computer system (AWIPS). The ASOS units should number about 110, located state-wide. If necessary, this equipment is able to produce automatically a weather observation every minute. The new doppler radars will have a range of about 250 km with a resolution to observe mesoscale phenomena in the atmosphere. The total number of radars to be placed in Alaska is still under study but should be around seven. The automated wind profilers will provide vertical profiles from near ground up to 18 km high. The next generation of polar orbitor satellites will be of higher resolution (1/2 km) with broader sensor capabilities (IR, Microwave, Vis, near IR, Water Vapor). This suite of surface observations and satellite imagery will be processed on an interactive computer system resulting in computer assisted forecasts.

The new technologies of the 90s will allow a completely new and more detailed "look" at arctic atmospheric processes. Research opportunities will be many. Synoptic and mesoscale phenomena never before documented or even observed will be detected by the new observational network. Analysis of this new database will help the researcher (and ultimately the forecaster) understand generation physics. From this understanding will develop early detection capabilities, better initialization of parameters in the numerical models, and predictive techniques. In addition this new database will support research in those projects where weather is a factor.

At present, most of the efforts to create an effective communications system to access this new database involve activity within the National Weather Service locally, regionally, and nationally. Now is the time to insure rapid access to the research community not only in the United States, but globally. Any solution to the communications network should be built around satellite up-link and down-link systems. At this stage, enough is known about the new technologies of the National Weather Service to "size" computer and communications needs. To incorporate National Weather Service technological developments with developments of other organizations is an area requiring coordination and planning.

SHALLOW AND DEEP ICE CORING TECHNOLOGIES DEVELOPED BY THE POLAR ICE CORING OFFICE (PICO)

John J. Kelley and Jay Sonderup

The Polar Ice Coring Office (PICO) is operated by the University of Alaska Fairbanks for the National Science Foundation, Division of Polar Programs. It has two major tasks:

- Provide logistical support for National Science Foundation projects in Greenland.
- Provide engineering and technical support services for National Science Foundation-supported glaciological projects.

The acquisition of good quality ice cores for paleoclimatological investigations worldwide has created a need for a variety of ice coring drills. Ice coring drills must handle a variety of ice types from 0° to -57°C, various pressure and physical characteristics of the ice. Associated with the ice coring drills are the design and construction of support systems.

Numerous ice coring systems have been developed over the past 30 years. Each project has a unique requirement and requires an initial decision as to the most effective drilling system to be used. Figure 1 schematically illustrates a decision tree for choice of a drilling or coring system.

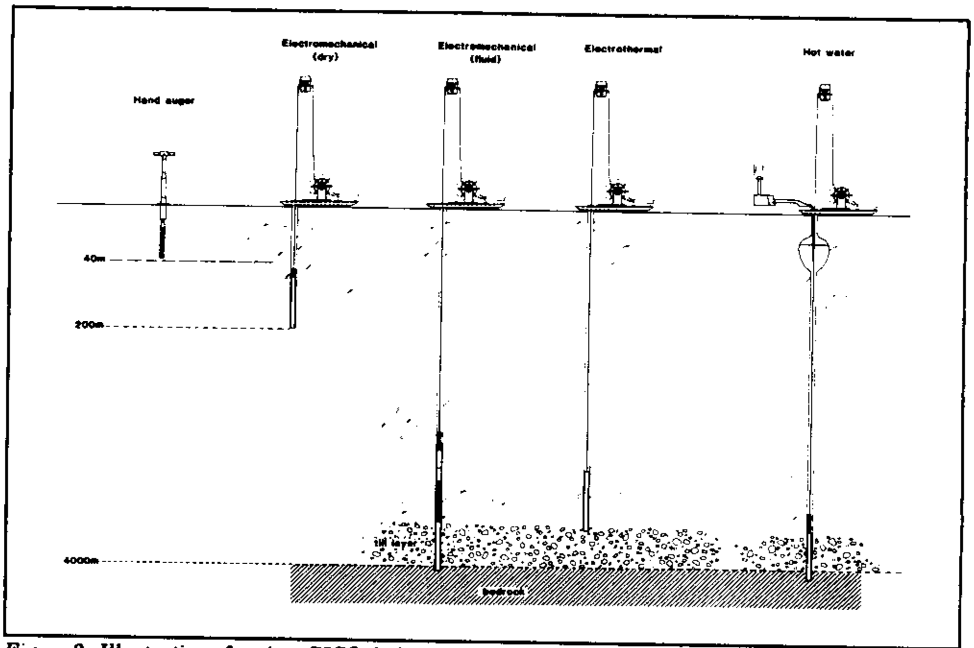

Figure 2. Illustration of various PICO drilling systems and their capabilities.

Figure 2 illustrates several types of ice drilling systems from a lightweight hand auger to the much more complicated electromechanical deep ice coring system for use in fluid-filled holes.

Since many field investigations require operations on glaciers in remote regions of the world, lightweight state-of-the-art materials are used to enhance design flexibility and minimize weight. Composites and composite fibers are incorporated in most PICO drills from the lightweight hand auger to the deep-ice coring drill. High strength-to-weight ratios and high tolerance to damage are among the reasons for the selection of composite materials. Kevlar, rather than steel, is used in drill system cables which allows for an eight-fold weight reduction.

All PICO drill systems use a variety of power sources. A 2-Kw array of Solarex, Inc., HE-60 panels have been used successfully.

Core quality rather than hole closure limits maximum drilling depth in a dry hole. Addition of a fluid not only compensates for the overburden pressure, but aids the drilling process by enhancing ice chip removal and damping vibration in the drill. The practical limit to open-hole drilling is in the 200-300-m range. Beyond that depth the ice becomes brittle due primarily to high bubble pressure in the ice.

PICO designed and built a drill capable of extracting high quality core through the Greenland Ice Cap (3200 m). Development of this 13-cm drill is an expansion of the standard 10-cm PICO drill. The deep drill design is based on the incorporation of pumping and filtering mechanisms for operation in a fluid-filled (butyl acetate) hole.

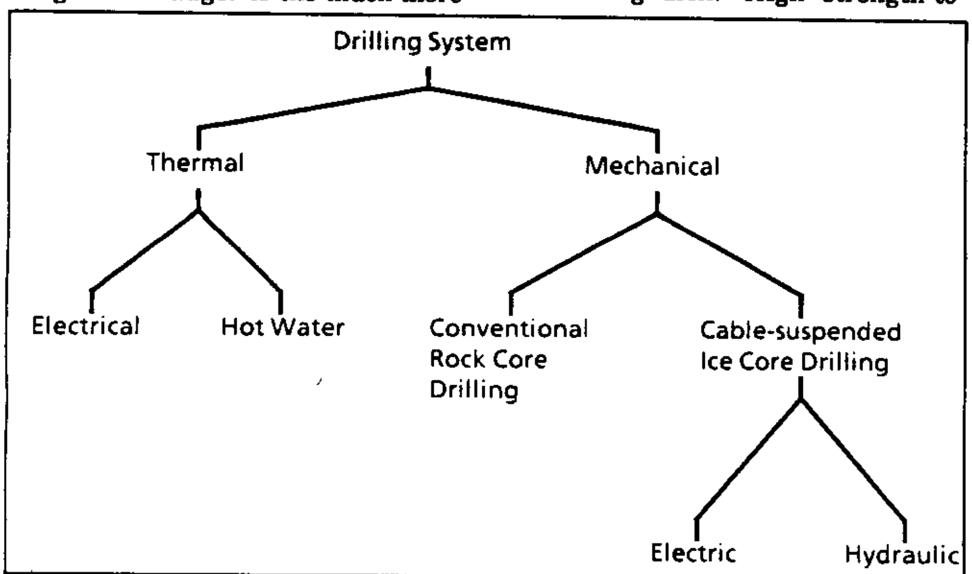

Figure 1. Drilling system categories.

A carousel drill handling system was designed and constructed to support the approximately 22- to 29-m long deep-ice coring drill string on the Greenland Ice Cap. An illustration of the system is shown in Figure 3. The carousel is used to break the drill string into 6-m sections.

Construction of the drill handling system utilizes aluminum and composite materials. Drill components are stored in fiberglass-epoxy (AMERON) pipes. These pipes also contain the butyl acetate wash system used in the removal of the chips from the well screen sections in the drill. The chip slurry mixture is collected in a drain pan located under the carousel. An auger removes the chips to a holding tank when the butyl acetate drilling fluid is removed by a centrifuge and recovered.

Handling of the drill core barrels is accomplished by use of a tilt-table made of an aluminum beam. Once the core barrel is in a horizontal position, the cutter head can be serviced and the core removed. The core is immediately logged and cut into 2-m sections and placed in a polyethylene tube in 2-m trays.

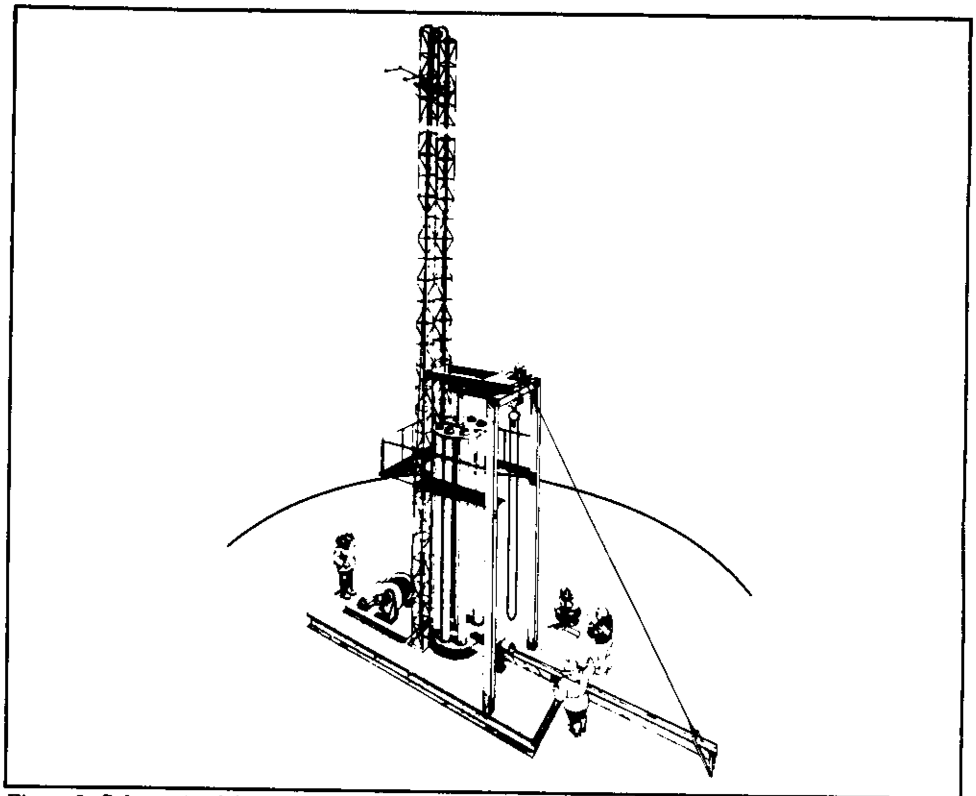

Figure 3. Schematic of the carousel-type ice coring drill support system for use on the GISP-2 project on the Greenland Ice Cap. This system will be housed inside a 52-foot diameter geodesic dome.

The Polar Ice Coring Office is working on improvements and investigating alternatives to current ice drilling systems. For example, PICO is investigating a hybrid hot water mechanical drill with deep-ice coring capability. PICO is also investigating new technologies useful to the support of its field projects including air-deliverable structures.

INTERAGENCY PLANNING AND COOPERATION

*Rear Admiral F. D. Moran**

Along with George Lapiene, I have been involved in support of arctic logistics for a number of years. Others in NOAA, such as Joe Fletcher, have been pioneers in arctic research. Interagency cooperation and coordination has been shown time and again to work for everyone's benefit. NOAA achieved noteworthy success in managing a multi-agency, multi-university, and multi-discipline project in the Arctic – the OCSEAP program. We have all known for years that working together is the best way, and often the *only* way to get things done, particularly in the Arctic. Shrinking fiscal resources provide a new impetus for working together. During the past year, as I have served as chairman of the Arctic Logistics Working Group, the extent of concern over interagency cooperation to support arctic research appears to have hit critical mass. Mr. Erich Bloch, the Director of the National Science Foundation and Chairman of the Interagency Arctic Research Policy Committee has accurately stated that the success of research proposed in the Arctic depends on cooperation in planning and implementation among the federal agencies and others. The three ambitious interagency programs proposed in the 1989 revision to the U.S. Arctic Research Plan can not survive intact without that spirit of cooperation. Progress of science in the Arctic demands it.

My principal concern, both as a member of the Logistics Working Group and as director of NOAA's manned research and support platforms, is that the support be provided in response to clearly articulated scientific need. The Arctic is a harsh and unforgiving environment. The scientists in the field had better exploit every source of expertise and have support for their field effort lined up well in advance. They must plan for every possible contingency. Murphy's Law applies in the Arctic; the consequences for the unprepared

**Presented by Richard Permenter, NOAA Corps.*

are drastic. When things go wrong the lives of people, as well as the data and scientific mission are placed in jeopardy. We are all faced with tight and diminishing budgets. This budgetary restraint must not be permitted to translate into ill-conceived and inadequate support for field research in the arctic. The risks are simply too great.

We all know how expensive high-latitude research is. The lion's share of money for such research is spent on logistic support. This is an absolute fact, as our friends in NSF and others working in the Antarctic can testify and it must be recognized as such. It is our responsibility to acquaint the taxpayers and the decision makers in the legislative and executive branches with this fact. The scientific program managers must also recognize and accept this and include logistics planning and platform support in their thinking. We are all in this together and we simply cannot afford to address the science and its supporting platforms and logistics separately. The best way to do this is with a unified and cooperative approach. As important as our own agency missions, or our separate concerns within our own agencies are to us, it is essential that we avoid separate efforts in both planning and implementation of arctic research. Not only is it wasteful, but the folks who control the purse strings simply should not allow it. If we ignore these facts and go merrily on our separate ways we risk quickly reaching a point where the science is driven by the limited available logistics rather than the other way around. None of us want that.

The revision to the Arctic Research Plan recognizes the need for science and logistics in the Arctic to go hand-in-hand and devotes an entire section to operational support. The section provides for some solid first steps to support the Plan and shows the commitment for interagency support. As an interagency body, we have come out in support of the need to upgrade, maintain, and add to existing ships, aircraft, and land-based facilities. This type of interagency support lends credence to what could otherwise be viewed as a single-agency effort. We have gone beyond the step of providing this moral support and the working group is actively involved in improving coordination of vessel and aircraft scheduling. We have produced a Federal Arctic Logistics Support Directory accessible on an electronic bulletin board (AMNET, Arctic Logistics) that is available to all.

This is the first comprehensive directory of federal arctic logistics facilities since 1972. Any interested researcher can use it to locate a source of support for the actual science or a source of arctic expertise. It includes aircraft, ships, field facilities, and engineering and test facilities. Among other things, every entry provides a brief description of the support available, scheduling requirements when known, and the all-important phone number for more information. More important, the directory is not intended to be a static document; we welcome and encourage additions and updates. This directory represents a major success in cooperation among the various federal agencies and provides a particularly good mechanism for coordination to everyone involved in arctic research and support.

The first biennial revision to the U.S. Arctic Research Plan represents a major step on the part of the federal agencies to work together for a common cause. The science and its supporting logistics are spelled out in the Plan, and coordination efforts are well underway. The work continues. We *can* cooperate to the detriment of none and for the benefit of all.

ELECTRONIC COMMUNICATIONS FOR THE ARCTIC ENVIRONMENT

Lloyd V. Morris

Engineering of communications networks for support of groups performing research in arctic areas is often complicated by various factors such as lack of public interconnect facilities, distance to be spanned and climatic conditions. Moreover, the remoteness of operations and the potentially hazardous climatic factors make it extremely important to personnel safety that the communications channels provided be reliable. In most cases, the communications equipment for the research team must be transportable and also be relatively energy efficient. A well-engineered network will, wherever practical, employ redundance in the primary communications channel to protect against equipment failure. Usually, one or more backup channels employing alternate transmission modes is advisable to enhance service probability within a variable electromagnetic continuum.

Since research work is frequently performed under relatively strict budget constraints, systems assembled from off-the-shelf components should be employed wherever possible. Various techniques are currently being implemented or could be adapted for use in the arctic for voice and data transmission. Innovative use of this available technology can yield reliable, yet cost-effective, communications.

HF RADIO COMMUNICATION SYSTEMS

In the past five years, there has been a renewed interest in the use of HF for voice and digital communication systems. Advances in computer technology and digital signal processing are being integrated with HF communication product lines to increase the functionality of HF communication systems. For example:

- Data modems are available from several companies that offer up to 2400-baud data transmissions over HF paths. Special signal coding and digital signal processing permit transmission over paths that suffer from severe multipath fades and rapid channel fading and flutter, typical of conditions often found in the Arctic. Such techniques can raise net daily data throughput far above the capabilities of traditional low speed data equipment commonly employed.

- Intelligent data modems operating at 100 baud, combined with microprocessor controlled/frequency agile HF radios, are available that can be configured into packet HF data networks. Low data rate experiments could automatically feed intracontinental data back to a central collection point on such a network.
- Modern frequency management and signaling techniques can make HF channels appear more like conventional VHF links. Microprocessor based HF radios are available that keep track of propagation characteristics between different stations in a network on the available frequencies and automatically select the best frequency for transmission. Digital selective calling between stations in the network automatically notifies operators of incoming traffic on a specific channel.

SATELLITE COMMUNICATIONS SYSTEMS

Satellite communications technology has been available for many years, but has continued to evolve. Increases have been made in usable system gain through higher power satellite transmission, use of spot beams to enhance coverage in specific areas, lower noise receive amplifiers and adaptive control of earth station transmitter power. In particular, improvements in earth station peripheral equipment permit highly efficient utilization of the available transmission bandwidth, enabling cost-effective tradeoffs of message throughput against equipment size and power consumption.

- Depending on location of the area of operation and mobilization factors, earth stations may be suitable for establishing direct satellite links between the research camp and support facilities. These links could be used for 24-hour real-time data and multiple full term telephone trunks. Current multiplexers can combine 9.6 kBit data and up to eight voice telephone trunks into a single 56 kBit bandwidth carrier. Employment of such techniques maximizes the utilization of available bandwidth.
- Terrestrial INMARSAT stations offer an easily deployed, economical alternative when traffic requirements are minimal. In particular, antenna gain requirements for this approach are typically substantially less than for other available satellite services. Recent strides in technology have resulted in lighter weight, more reliable and less costly Earth station units.
- A variety of analog and digital satellites have been constructed and launched in non-geosynchronous orbits on very low budgets and may be accessed by inexpensive Earth station equipment. This technology could be applied to meeting intermittent or non real-time data transmission requirements where access to geostationary satellites is not appropriate or is deemed too expensive.

ADVANCED VHF/UHF COMMUNICATION SYSTEMS

Ingenious means have been developed to extend VHF and UHF communications ranges far past the radio horizon. These techniques are capable of supporting low bit rate data or single channel voice communications.

- Meteor burst communication uses the momentary ionization trails from random incoming meteors to reflect VHF signals over the horizon. Suitably adapted transportable equipment can gather near real-time data from low data rate experiments and serve as a basic communication link between field parties and their base camps. Useful range is from 200 to 500 miles.
- The Syledis system, originally developed for use in over-the-horizon electronic survey systems at VHF/UHF frequencies, can also be used for data and voice communications at distances up to 200 miles. This system uses tropospheric reflection of the radio wave to bounce signals over the horizon. System gain is increased by 25 dB through the use of spread spectrum modulation techniques and correlating receivers, allowing the use of low power transmitters and simple antennae. The equipment is very portable and requires only small power sources such as thermoelectric generators. Such a system could serve as a basic data and voice communication link between field parties or telemetering stations and the base camp.

To summarize, two primary considerations must be borne uppermost in mind when designing and implementing communications for the arctic environment:

- The system must be reliable.
- The system must be cost-effective.

Only with innovative, apt engineering approaches, with due consideration given to the extreme climatic and difficult logistic factors involved, can we successfully meet the challenge offered by these two criteria. Our experience shows that reliability is best enhanced by providing redundancy either in the primary communications channel or by implementing backup channels employing alternate transmission media. Where the ability to communicate is critical, utilization of both approaches should be investigated.

Finally, in accepting the latest technological advances in electronics, we should not overlook the potential to develop cost-effective and reliable systems by marrying components of both evolving and relatively static technologies. Current trends in communications stress ever higher speeds of information interchange, necessitating large bandwidths and higher transmission frequencies. But much of the digital and microprocessor control componentry that falls out from such research can be adapted to mature radio technologies to enhance the performance of thin route systems.

INDUSTRIAL RESEARCH AND DEVELOPMENT IN THE ARCTIC

David Pritchard

I will briefly cover three points:

- Our involvement so far in Arctic R & D.
- Permits, because that's perhaps a logistical element that can be overlooked.
- Industry's logistical capabilities.

INVOLVEMENT

BP Exploration and the oil industry have made significant contributions to arctic research. We have conducted, commissioned and published research on a variety of topics dealing with terrestrial and marine environments. Terrestrial studies have included work on *Arctophila*, a hydrophilic tundra plant, caribou, snow geese, brant and other birds. Recent marine research has included laboratory and *in situ* studies on anadromous fish, the physical oceanography of the Beaufort Sea, including ice dynamics, and biological community structure and the growth strategy of the kelp, *Laminaria solidungula*, in the Stephanson Sound Boulder Patch. This work is published in journals such as *Biological Papers of the University of Alaska, Arctic, Ecology* and *Marine Biology*, a book – *The Birds of the Beaufort Sea*, and elsewhere. We have at our disposal in Anchorage a capable, dedicated and professional staff of environmental specialists leading this work. A wealth of knowledge and data are available within the industry.*

Previous extensive industrial research constitutes a resource that is under-utilized. This, perhaps, has not had much exposure because of the diversity of forums in which it is presented. For example, we are presenting four papers at the upcoming convention in San Antonio of the Society of Petroleum Engineers. I doubt that many in this audience will be attending the Society of Petroleum Engineers Annual Convention, so that work will not be exposed to this community. The converse is also true; there is arctic research that industry does not hear about because the forum in which it is presented does not include industry. That is not deliberate, it is just the way these things happen.

PERMITS

The permitting process is intricate, time-consuming and complex (Fig. 1). For just about any activity such as traveling on the tundra, collecting biological specimens, banding birds, or erecting any kind of a structure, a permit is required. It can take a long time to get these permits, and, since arctic research by its very nature is seasonal, you need to allow for that in the planning process to make sure that when you want to do your project, you have the permits in hand.

INDUSTRY LOGISTICS CAPABILITIES

In terms of the industry's logistical capabilities, at any one time we probably have around 1440 people living and working on the North Slope, which means that we need a formidable logistical capability for accommodations, food and transportation. Each weekday there are four to five round trips made by a Boeing 727 from the south of Alaska to the North Slope. We have approximately 1,000 vehicles including trucks, tractor trailers, cranes and other heavy equipment. We also operate and maintain boats. These logistical facilities have been made available to academic and government agencies for research purposes. Among these are the University of Alaska Fairbanks researchers studying the under-ice behavior of ringed seals, and the U.S. Fish and Wildlife Service researchers studying polar bear movements and reproduction. Our scientific staff is available for consultation and cooperative studies, as is our data base. If members of the scientific community think that we might be able to provide logistical support, consultation or data, it would be worth their while to contact us or other industry members. While we cannot promise anything, there is nothing to lose by getting in touch with us. It can only help.

In conclusion, I would like to reiterate the three points. First, there is much information available. Let's use it as efficiently as possible. Second, in planning any program, do not forget about permits. And third, a cooperative partnership among industry, academia and government agencies will inevitably enhance both basic and applied research in the Arctic.

NOTE: Copies of noted research, including a 30-page bibliography of industry-sponsored research can be obtained by contacting Ray Jakubczak. See address on page 44.

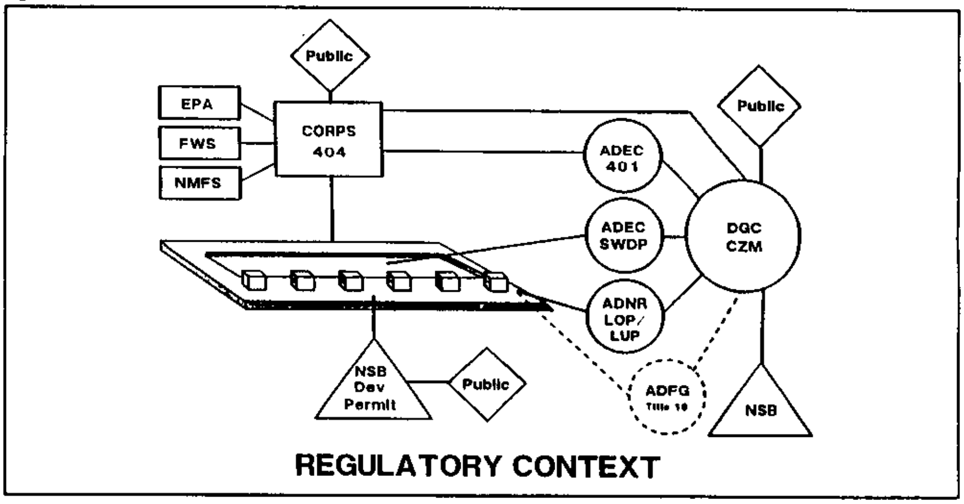

Figure 1. Illustration of the complexity of the permitting process.

NEW TECHNOLOGIES IN THE FUTURE OF ACADEMIC ARCTIC RESEARCH

Luis Proenza

We are entering the Age of the Arctic. The Age of the Arctic is that time where economic, strategic and scientific interest in the Arctic is peaking. This is after so many years in which prophetic words were echoed back to the time of Billy Mitchell, back to the time when so many people in Alaska, Washington and other countries called attention to the vast resources and vast interesting issues to be addressed in this region of the globe.

Over the last twenty years we have seen substantial happenings. In particular, throughout the Nordic countries we have seen people move in, join the native communities and begin to enhance the economic development of this area. It already seems that we are approaching this age of the Arctic with a somewhat disarrayed infrastructure and with an arctic research community that is only now beginning to think about what it means to come together and draft common goals for common benefits. One avenue of approaching getting together in matters of arctic research has been the formation of the Arctic Research Consortium of the United States (ARCUS).

A consortium is created to conceive, energize and support activities of vital interest to arctic research. Its mission is to strengthen and advance arctic research to meet national needs. There are three principal goals:

- Produce improvements in U.S. arctic science.
- Build communities of scientists for arctic research.
- Open avenues for interdisciplinary approaches.

A fourth goal is cooperation among institutions as well as agencies and the private sector.

Now, a word of background. I understand, being relatively new to arctic and polar matters, that discussions about a consortium have occupied individuals attentions and minds for well over thirty years.

You might ask why has it taken so long for us to get to this point. I certainly do not have the answer to give you. Perhaps some individuals with historical knowledge can speculate about some of the reasons it has taken so long for us to come together. It is certainly a remote region of the world and early in our nation's approach to arctic science a conscious decision was made to "let excellence grow wherever it may." And indeed it did, throughout the United States. There are very important and very significant research endeavors at many institutions from the far northwest in Alaska to the far southeast, from the west to the east and the southwest to the northeast directions. Many institutions are involved. But, a coordinated effort has emerged in only a select few institutions where critical masses of researchers have emerged. I think all of us know pretty much what those institutions are. During the 1970s and early 1980s additional interest occurred and just about three years ago, Jerry Brown of the National Science Foundation circulated the question – if you will – "Is there a need for this?" Mark Myer, Norbert Steiner and others poled their colleagues throughout the country. The word came back, somewhat nervously, "Yes, there is a need. But no, we don't want it to be bricks and mortar. We want it to be some sort of cooperative endeavor to bring something of the critical mass beyond that founded select institution into place".

A group of institutions met in early 1988 in Boulder, Colorado, to decide what to do about a consortium. In the fall of 1988 in Fairbanks, at the Fall Meeting of the AAAS, the meeting which we are also participating in this week, the consortium was formally inaugurated. It was inaugurated by the attendance of thirty to forty institutions and the consortium created an executive committee. I serve as president and Chris Shepherd has been brought on board to act as executive director for the officer/executive consortium. We are up and running. But there is much to be done.

Specifically, we must first bring other institutions into the fold. As of about two months ago seventeen institutions joined. More are expected in the coming year. Internationally, several critical institutions have written and asked to be admitted as international members cooperating with us. This is very important because what we develop in this country has to be linked with the efforts that are present and continuing to emerge in other countries so that we can have a reciprocal relationship that will allow access to other regions of the circumpolar Arctic.

The consortium views itself as having several functions including contributing to efficient, cost-effective logistics, providing linkages with Antarctic research efforts, maintaining awareness of needs, improving educational opportunity, encouraging the participation of native residents, developing and maintaining formal as well as informal partnerships, identifying and focusing the concerns of member institutions, maintain communication among the members, and providing information to federal agencies, legislatures, and policy makers.

Of course, critical to this effort is improving the public supported funding for arctic science and promoting the cooperation involving data exchange. The consortium is in the midst of developing and will issue a program plan very soon.

There are key elements of the program plan. The educational opportunities will be very critical. Why is this of interest to this group? It is because the community is diverse and dispersed throughout the country. It is a small community. Although there are about 100 institutions, only a handful of institutions include a critical mass of scientists. Many research institutions have, at best, one or two institutions include a critical mass of scientists. Many research institutions have, at best, one or two scientists who are interested in the Arctic. Therefore, for us to create a continuing cadre of scientific expertise will require development of educational opportunities and educational exchange programs among these institutions and agencies in the private sector.

One element of the program plan involves the evolution of specific scientific program planning efforts. One such effort is that of arctic-interactions/arctic-systems science. I know that most of us are keenly aware of this particular issue. The issue of global change and the impending possibility of a greenhouse effect and ozone hole are important issues. For the Arctic, this is important because it is right here in our own backyard that the first and largest signs of global change are expected to be seen. And it follows that if our country or the world enacts polar policies to try and counteract these growing changes, there could be potentially deleterious effects. It would be here where the first effectiveness of those policies could be tested, so the Arctic is not only a bellwether for global change and the understanding of global change, but it becomes a natural test-bed for policies. The consortium is involved in planning and assisting the National Science Foundation in planning its arctic-interactions/arctic-systems science program.

The third element of the program plan has to do with communication and information systems. There are dramatic improvements in many aspects of technology; communications being one of the critical ones. We in the scientific research arena must make available to ourselves state-of-the-art technologies. Our community is dispersed and the growing amounts of data require the appropriate mechanisms to deal with it. We must link ourselves directly to the private sector and be aware of how those communications systems could impact not only our science, but in terms of the logistics of reaching out to remote camps with the appropriate communications to maintain data flows, to maintain safety and communications in general. We would hope that one thing we could contribute to, and one thing at this conference that we could come away with, is a decision that a clearinghouse for arctic logistics support is needed. There are certainly too many things going on for us to go at it individually.

Arctic engineering and technology transfer is another thing that is very critical. We cannot operate as a community of research scientists and research agencies without moving from what we discover to what we transfer to the private sector, and what the private sector can transfer back to us in terms of capabilities. There is a vast network of private sector concerns with a high degree of capability. The problem is that because it has grown up largely in association with specific industries in Alaska, we as researchers or as agency representatives, are largely unaware of those capabilities.

The ARCUS program plan is an initial three-year effort intended to begin to address these various issues. Finally, of course, is the process of beginning these efforts which must be involved in a continuing dialogue to revise, to improve the program plan and the organization of the consortium. I certainly welcome your input about how we can better marry the university community with agencies and the private sector.

Finally, we must discuss a strategy that involves an increase in public awareness about the Arctic. The Soviet Union has a superb ice breaker fleet. The Soviet Union now derives fully 60% of all of its oil and gas from the arctic region. The Scandinavian countries have substantial interest in their arctic regions. The Canadians have substantial interests and endeavors in their arctic regions. The United States, at the present time, has two ice breakers – a very marginal ability to support its government activities in the far northern regions. I hasten to add, sadly, that it has been my impression that in certain areas there is a growing reluctance to address these regions of the world at a time when they are so vastly important.

In the United States, we presently derive 25% of our oil from the North Slope of Alaska. But we are not utilizing gas. We are not utilizing the trillions of tons of coal that are stored there. The importance will only continue to increase. Communications, science programs, logistics, technology, and education - we need to bring them to bear in this particular region of our U.S. Arctic.

The Canadian infrastructure is good: the Polar Continental Shelf program is one that we may wish to emulate. The Scandinavian infrastructure in Svalbard through the North Polar Institute is good. There is no question that our private sector infrastructure is superb. We have a few available options. Here we are in Fairbanks. Airports exist in Alaska from southeast to the far corners of the Aleutian Chain and all the way up into Barrow, Alaska. There are opportunities for a network of support as envisioned by the National Science Board in their report to the National Science Foundation. I would certainly suggest that we consider that Juneau, Anchorage and Fairbanks can serve as hubs of that support network with additional arrays going to airports in the remote regions of Alaska. This network could include communication capabilities that are already in place in many of the agencies and certainly in the private sector, and cooperative endeavors are also possible.

We need to address the possibility that the submarines that are currently dedicated to research purposes can gain under-ice capabilities and/or at the very least, that we can begin to cooperate in an appropriate way compatible with our national security interests to undertake a joint effort of realizing data from the many missions that the Navy undertakes in the Arctic Ocean.

In some ways, I think we have the capability – if only we can come together with the will to use it. Underlying all of this is the fact that our resources are scattered. I would suggest that if you think about one concept, and one concept alone, we can leave here with substantially more than we came in with. The concept is leveraged integration. Our resources are there; if we integrate them we will have leveraged far more than we could have by going at it alone.

OPERATIONAL CAPABILITIES IN SUPPORT OF ARCTIC RESOURCE DEVELOPMENT AND ENVIRONMENTAL PROTECTION

John Schaeffer

I work for Governor Steve Cowper and he is very much concerned with Arctic Research. Dr. Henry Cole is here and he will have an opportunity to tell you what the State is trying to do in support of your operations. Governor Cowper has asked his cabinet to support arctic research in any way possible. This is not something new. I suppose we should have supported arctic research back in the old days when practically all the research agencies pulled out of Alaska. They left us with no capabilities and we had to go to the east coast and to the south and everywhere there were those with concern for the Arctic. That is not a very good feeling for us who live up here. We would like to support any effort to increase your capability to conduct research in Alaska.

The next message I would like to deliver is from myself. The Alaska National Guard (ANG) has supported some of your operations and we do not have a problem doing that. We like to support you. You have learned that we have a great capability such as the ski-equipped C130s.

I brought both a representative from the Army and the Air National Guard because we do have some equipment that may be of assistance to you. We have the only Twin Otters in the military inventory in Alaska. We have Hueys and Black Hawk helicopters. We, of course, also have C130s that are not ski equipped. So all of that capability is here. Whether or not we can support you on a particular mission, we will not know until you ask. I would like to suggest to you that if you need us, let us know well ahead of time.

Other potential research support capabilities of the Alaska National Guard are:

- ANG units are operated in 104 communities with 8 more communities to be added in 1990
- 8 C-130 aircraft (9 aircraft in 1990)
- 4 KC-135 tanker aircraft (8 aircraft by 1992)
- Airborne Search and Rescue capability
- C12 (King Air), 4 CH54s (Sky Crane), 4 UH60s (Black Hawk), 30 Huey helicopters and 7 Twin Otters.
- 6 LCM8 landing barges, 17 18-ft aluminum boats, 12 over-snow articulated vehicles, and 200 snow machines

The Guard is still a part-time force. We have very few crews for our aircraft that are full time. We run out of those in a hurry when we conduct operations and we are always conducting operations.

I like to think that since I have come on board as Adjutant General we have been busier. We have had one disaster after another, but we are in the disaster response business. In fact, we are trying to figure out how we can better utilize our people. We are running out of part timers to fly our aircraft as well.

Fortunately, this year about the time we were running out of pilots and crews, we ran out of money and flying hours but it is working out. Give us time to look at it because we have to go back to Washington for approval on any support outside the military directly. In some cases, we have to go back to Washington whether or not it is military. It takes a little time, but we can accomplish anything.

Recently, we flew the first military flight into the Soviet Union. It took three months of hard work on some people's part to get through ourb ureaucracy. Even then, we did not quite get through it; we did not have visas for the second trip. When you know the right people you can get almost anything done.

With that I would like to let you know how thrilled I was to be able to travel in the Soviet far east. Some of you have been doing it for some time. You have an international network that kind of bypasses our political framework. Some of us now are getting the opportunity. Because I work for the Governor I was able to go and I thought it was great. Our customs in the United States is much more strict than theirs. If we could continue the relationship that many of you are already building with the Soviets there is a lot of capability over there that we can use.

Their Navy would probably like to have more of their ships working on our side of the Polar Ice Cap. It may be hard to get our people to give you permission to use them. Even if we are successful in getting a couple of new ice breakers, we are still going to be limited in our capability to support your operations in both the Arctic and the Antarctic. The Russians have the capability and we should utilize their logistics to whatever degree we can. I think it will take just your imagination and the amount of work you want to do to get through the bureaucracies on both sides. There is no limit.

SCIENCE INSTITUTE OF THE NORTHWEST TERRITORIES: APPROPRIATE TECHNOLOGY FOR THE SUPPORT OF NORTHERN REGIONS

David A. Sherstone

I would like to present a portion of the Northwest Territories and the Science Institute's viewpoints on the support of arctic science and argue for the use of *appropriate* technology for the support of northern research. When Mr. Andy Cameron spoke of NASA's commitment to spend almost $15,000,000 on the DC-8 remote sensing program it made me somewhat weak in the knees!

If we look at the Canadian situation, the two agencies providing arctic logistic support are: the Science Institute of the Northwest Territories, through its three research centers at Inuvik, Igloolik and Iqaluit and the Polar Continental Shelf Project through its main bases at Tuktoyaktuk and Resolute Bay. Together these might represent about $5,000,000 in expenditures each year. Despite this "low" level of funding the Science Institute supports 80 projects and 200 investigators per year and provides over 10,000 person-days of assistance. David Forsyth, the Polar Shelf representative, estimates that his organization will help 230 projects and supply field assistance to more than 1,000 researchers in the current year.

The biggest logistical problem facing my Research Centre managers right now is small camp stoves! Those familiar green stoves which every field researcher comes in contact with have undergone a number of design changes in their Canadian versions which make them unsuited for arctic winter use. The plungers used to pressurize the fuel tanks are now made of plastic and these either snap in extreme temperatures or shrink enough that only partial pressure is achieved.

In another area, I am reminded of a major study undertaken by Environment Canada in the mid-1970s to determine the possibility of navigation of the St. Lawrence River in winter ice conditions. NASA provided Convair 990 radar overflights of the ice. I was the technician on a helicopter-based radar profilometer flight and there were several dozen direct-reading ice gauges in the ice. All this came to naught, however, when a Russian freighter proceeded upstream through the gauge network, thus proving the hypothesis at a much lower level of technology and at much lower cost!

Thus, I would urge those responsible for developing Alaska's logistical capabilities to recognize that the success of arctic research support is often most dependent on simply having the sufficient technology to do the job – and having it work right.

Secondly, I would like to address the theme of the Conference, Global Change, in light of the remarks and requests of one of the other participants at this session. A lady asked what plans could be developed to deal with climate change. Similarly, the tone of many of the speakers in the plenary sessions seemed to imply that this is a national or international problem and that solutions must be reached on this level.

There was an excellent article by Michael H. Glantz in the January 1989 issue of *The World & I* in which he looked at responses to events defined as having been caused by regional climate change. These included such events as the expansion of the Great Salt Lake in Utah since 1962 and the persistent freezing of the Florida orange growing districts. In all, ten regional climate change case histories were examined. In these cases the response was *regional*, not national. It would appear that the perception of climate change-induced events provoked action at the political or organizational level most affected and that national interests were not heavily involved in decision making leading up to remedial efforts. As scientists and research managers we should thus be wary of establishing studies which view climate change solely in the national or international context. The practical aspects of dealing with a global climate change are most likely to be dealt with in the smaller political and geographic units, at least in the earlier years of change.

Finally, there is the problem of pricing ourselves out of the market. In providing support facilities we must keep the costs to the research community to the lowest level possible, even if this means utilizing less than the most sophisticated technology available. Dr. Jim Ritchie, a noted Canadian paleo-biologist, stated that all the facilities (in Canada) were wasted if no one could afford to use them. David Silverberg, speaking yesterday at the session on Interdisciplinary Science and Global Change, stated that his study of NIH grants showed that the major universities in the United States took 71% of every researcher's grant for overhead costs. This leaves little for the scientist and is a doubly crippling blow if the work is being performed in a high cost area like the Arctic. Under these conditions it may be best if the scientist does his field work in the shortest possible time and returns to the lower-cost southern-based laboratory facility for analysis and report writing. This approach does not, however, do anything to develop a resident expertise in the North. At present, the Science Institute of the Northwest Territories provides almost all of its logistic support to both domestic and foreign researchers at no cost, as our contribution to the development of northern science and as a cost-effective way of increasing the body of northern scientific knowledge. I would urge the Alaskan proponents of new research facilities to strive for similar low cost, high benefit methods to promote your science initiatives.

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STAGING AREAS FOR DEPLOYMENT TO THE ARCTIC SEA ICE

Imants Virsnieks

Primary staging bases currently in use by the U.S. are Deadhorse (Prudhoe Bay) Alaska, Alert Canada, Thule AB Greenland, Nord Greenland and Longyearbyen Svalbard. Last spring (1989) all the aforementioned bases, except Deadhorse, were utilized at close to their maximum capacity for supporting arctic logistics. The following topics will be addressed in this context:

- Maximized capacity of these staging bases ("land-based logistics centers").
- Existing and potential baseline support for these and other support bases.

COORDINATION OF U.S. PRESENCE IN THE ARCTIC

There are strategic, scientific and safety aspects that need to be articulated in the context of U.S. presence in the Arctic.

CENTRALIZED COORDINATION FOR ARCTIC SEA-ICE CAMPS

The obvious benefits, such as cost-effectiveness and efficiency in utilizing the arctic sea-ice logistics dollar, illustrate the need for an arctic logistics clearing house that will also help match ice research platforms and researchers. To avoid duplication, all U.S. participants involved in arctic endeavors should have a single Point of Contact (POC).

The issue of limited capacity at staging areas for deployments to arctic sea-ice is best addressed through more efficient and better coordinated use of existing capabilities. Better coordination can be obtained by an arctic logistics clearing house or a single point of contact for arctic logistics. Safety, research, strategic, tactical and funding issues will also benefit from a clearing house for deployments to the arctic sea-ice.

Safety will be enhanced by drawing from a pool of experienced personnel. Safety will also be enhanced by the sharing of logistics costs, where the program with the limited budget might otherwise compromise safety by attempting to cut corners. Sharing of equipment, experience and costs are obvious contributors to safety. Safety is further enhanced by all camps being aware of each others presence and capabilities. The presence of aircraft needs to be disseminated and coordinated for flight following and for use in emergencies.

SCIENTIFIC, STRATEGIC AND TACTICAL NEEDS

Better communication and coordination between the scientific, strategic and tactical communities regarding data to be collected and the availability of berths at ice camps will give us more for our science and logistics dollars. By filling up unoccupied berths at ice stations, we optimize the positioning costs of aircraft which usually are the most expensive line items when deploying camps on arctic sea-ice. In a modest way ICEX-89 successfully demonstrated the feasibility of sharing positioning costs of C-130 aircraft between NORDA (Outpost Iceshelf) and AREA-89 (SPAWAR). *Ad hoc* coordination and sharing of resources was achieved on an interagency level between AREA-89, APLIS, NORDA (all ICEX-89 participants) and CEAREX. This example, which came about in a serendipitous manner, illustrates the potential for a policy of cooperation and coordination.

Standardized automated data sets of meteorological, oceanographic and ice dynamics are ways to optimize the science dollar. We need to devise and agree on a basic data suite to be obtained at all ice camps. Even today we forego the recording of basic meteorological, oceanographic and ice data at some sea-ice camps. Such data very often can be obtained for a pittance relative to the cost of deploying an ice-camp in a hard-to-access data-scarce region. Even though we have made some advances since Fridjof Nansen's 1893-96 exploration on the ship, *Fram*, and the U.S. sponsored, *AIDJEX* 1975-76, our understanding of the arctic sea-ice can still benefit from manned stations. A clearinghouse for the logistics of buoy deployments and other arctic instrumentation would also enhance the needs of the arctic sea-ice community.

BASELINE ARCTIC LOGISTICS COSTS

More by accident than design we have an arctic sea-ice logistics capability that is being maintained at a "baseline" level. This base line consists of APL/UW, NORDA, Polar Associates, PSC/UW. So far these organizations, in various configurations, have met our needs. If we make the above improvements in coordination via a logistics clearinghouse or POC we can make more efficient use of our existing capabilities and thus increase our capabilities with no significant increase in cost. Baseline maintenance of our arctic logistics capability should consist of refurbishing, replacing and depreciating existing equipment and retaining a pool of key experienced personnel. A primary function of the arctic logistics clearinghouse would be to advise the various funding agencies on how to employ and allocate projects to the various logistics facilities.

In summation, we need to inventory what we have in the way of equipment for arctic sea ice deployment. A summary of their capabilities from each of APL University of Washington, NORDA, Polar Associates and Polar Science Center, University of Washington would be a useful first step. Proposed/funded and wished-for research in 1991 and 1992 would be an excellent second step. Finally, it would be helpful to reach a consensus on a low-cost easy-to-acquire basic data suite that will be provided, and later pooled in a data bank, by all ice-camps on a not-to-interfere basis with the primary objectives for the ice camp.

NEW TECHNICAL DEVELOPMENTS IN SUPPORT OF ARCTIC RESEARCH: THE ALASKA SAR FACILITY

Gunter Weller, Wilford F. Weeks, John Miller

INTRODUCTION

With funding from NASA, the Jet Propulsion Laboratory (JPL) at Pasadena and the University of Alaska Fairbanks (UAF) are developing a ground receiving, processing, archiving and distribution facility for synthetic aperture radar (SAR) data. In the 1990s the Alaska SAR Facility (ASF), located at UAF's Geophysical Institute, will process radar data from three satellites: the European Space Agency's ERS-1, the National Space Development Agency of Japan's (NASDA) JERS-1 and Canada's RADARSAT. The characteristics of these satellites are presented in Table 1. Thus, from 1990 until at least 1999, these systems will provide the continuous flow of radar data necessary for a wide variety of studies on air-sea-ice interactions of the Arctic Ocean and Alaskan waters, glaciers, geological and hydrological processes and seasonal vegetation changes.

DATA ACQUISITION

Acquisition and recording of signal data are the primary functions of the Receiving Ground Station (RGS) (Fig. 1), which consists of a 10-m parabolic antenna, an attendant control computer, and X-band (8000-8400 MHz) and S-band (2200-2300 MHz) receivers and data recorders. The system components are integrated from existing technology of the Landsat type. To maximize coverage poleward, the antenna is located atop the eight-story Elvey building on the UAF campus (Fig. 2), which has an unobstructed view to the horizon. The station will be able to receive real-time SAR data from satellites located within a 3,000-km radius of ASF thus covering a large area of the arctic. In fact, the combined coverage of ASF with stations located at Kiruna, Sweden, Prince Albert, Saskatchewan and near Ottawa, Canada, will give almost complete arctic coverage.

Table 1. ASF missions.

Mission Descriptions				
		ERS-1 ESA	JERS-1 Japan	RADARSAT Canada
SAR	Frequency	C-band 5.3 GHZ	L-band 1.275 GHZ	C-band 5.3 GHz
	Polarization	VV	HH	HH
	Swath Width	60 km	75 km	100 to 500 km
	Resolution/looks	30 m/4	20 m/4	30 m/4 - 100 m/8
	Incidence	23/35° (Roll Tilt)	35°	20-50°
	Orientation	Right	Right	Right/Left
	Onboard Storage	none	20 minutes	10 minutes
	Data Rate	105 Mbs	60 Mbs	85 Mbs
Orbit	Inclination	97.5°	97.7°	98.5°
	Altitude	777 km	568 km	797 km
	Repeat Cycle	3 day/35 day/176 day	44 days	24, 3 day subcycle
	Type	sun-synchronous	sun-synchronous	sun-synchronous
Mission	Launch	2Q/1991	3Q/1992	4Q/1994
	Lifetime	2-3 years	2 years	5 years
	Status	Approved	Approved	Approved
	Planned Follow-On	ERS-2	ADEOS	Pending
Other Instruments		Radar Altimeter, Wind/Wave Scatterometer, Along-Track Scanning Radiometer (not downlinked to ASF)	Optical Sensor (Downlinked to ASF but no processing capability)	none

Also, because JERS-1 and RADARSAT will both carry tape recorders, SAR coverage will become world-wide in 1992, constrained only by the power limitations of the satellites.

DATA PROCESSING

In the SAR Processing System (SPS), signal data will be played back and correlated in a custom pipeline processor that operates at 1/10 real time. Output from the SPS consists of a 1-look complex, 4-look full resolution and low resolution images. Frame sizes of images are about 100 x 100 km. The spatial resolution of 1-look image is about 10 m, that of 4-look image about 30 m, and for low resolution image about 240 m. The number of looks indicates the number of independent pixels that are averaged together to reduce speckle intensity. All images will be georeferenced (i.e., each pixel is earth located). Post-processing, consisting of geocoding, will be performed on request. Geocoding is a process whereby an image is resampled to a map projection and rotated to true north. Some geocoding procedures will also correct images for terrain induced distortions.

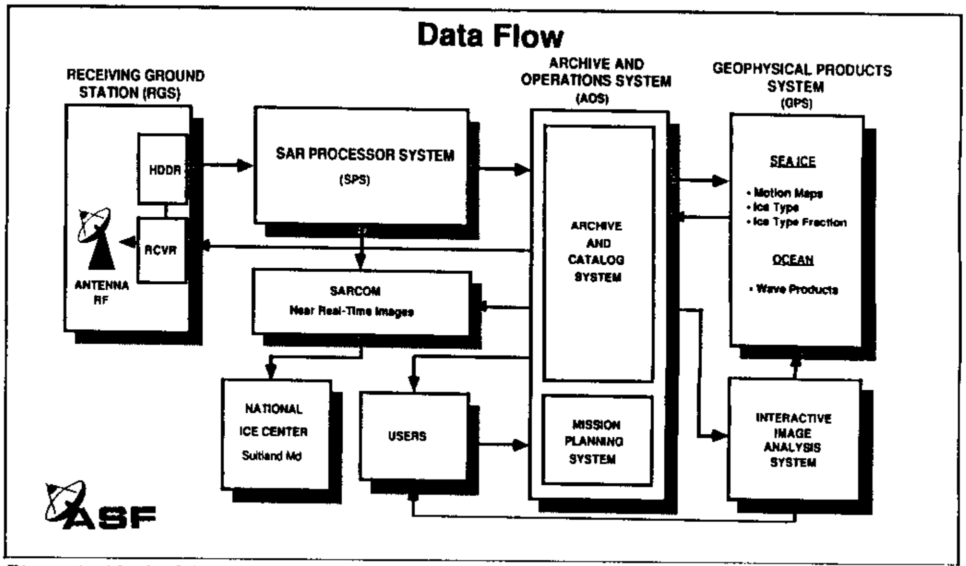

Figure 1. Alaska SAR facility functional block diagram.

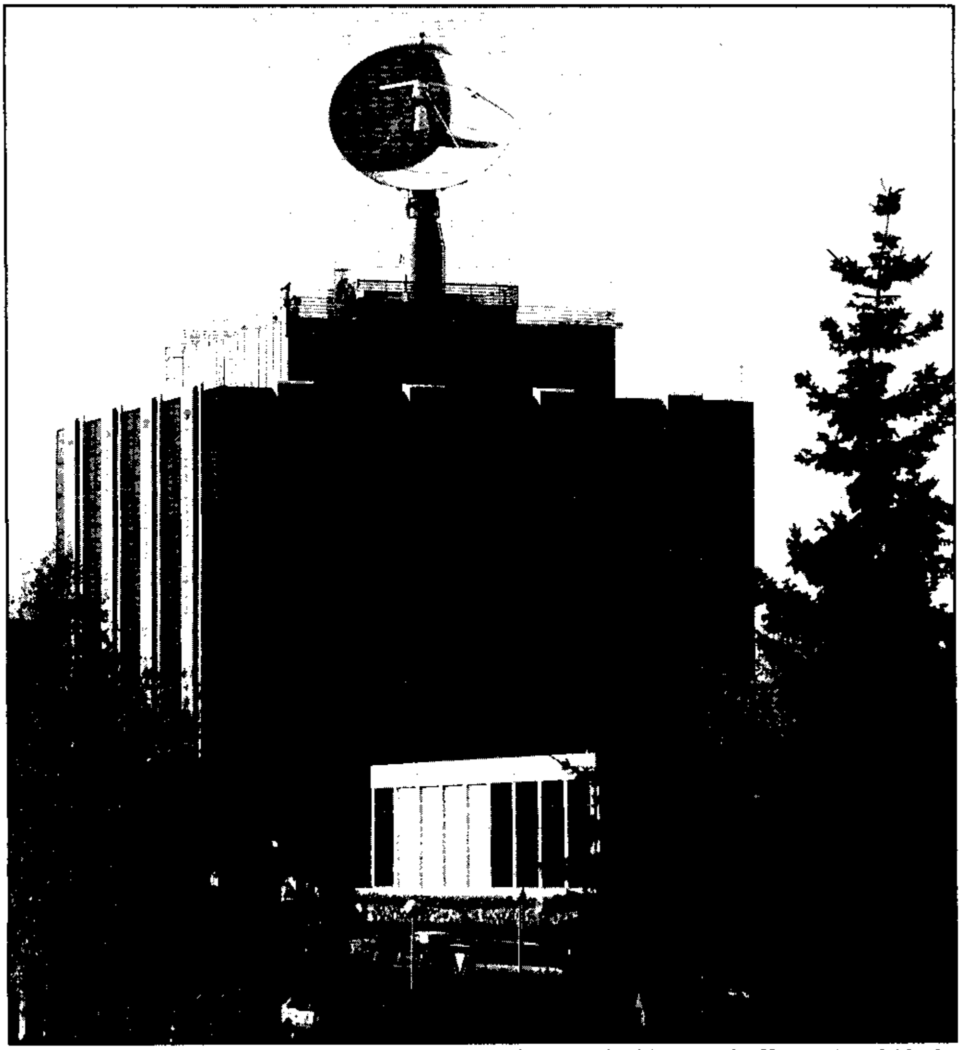

Figure 2. The 10-m diameter antenna on top of the Elvey building on the University of Alaska Fairbanks campus.

In addition to producing digital images on magnetic media, 20% of the full resolution and 100% of the low resolution images will be recorded on film. Distribution of data (Table 2) will be through digital optical disks (DOD). All products produced in the RGS and SPS will be permanently stored in the Archive and Operations System (AOS), for archiving, duplication and dissemination to investigators.

GEOPHYSICAL PRODUCTS SYSTEM

One unique aspect of the ASFis its geophysical data analysis capability. Although SAR images contain a great deal of information, this information is commonly not in a form that is directly useful to the general scientific community. In some cases the extraction of this information from the SARdata set via the use of image analysis techniques is non-routine involving hundreds of hours of expert investigator time. Such studies will be carried out on the Interactive Image Analysis System (IIAS). In other cases, the analysis is highly repetitive and in principle can be carried out with minimal human supervision through the use of automated procedures even if the procedures themselves are computationally very intensive. This last task is the function of the Geophysical Products System (GPS) under development at JPL.

The need for such a system has been clear since the SEASAT experience when several types of analyses with obvious scientific and operational potential were only possible months after the fact. GPS capabilities are expected to include procedures for obtaining ice movement vectors and mean velocities via the automated tracking of identifiable ice features, and for providing topographically corrected SARimages. It is also planned to implement procedures for classifying ice types and characterizing ocean surface wave fields. The continual expansion, improvement and verification of this line of derived products will be an important ASF activity during its initial period of operation, with routine procedures that are developed and tested on the IIAS gradually being automated and transferred to the GPS.

DATA DISTRIBUTION

The AOS consists of two subsystems: an Archive and Catalogue Subsystem and a Mission Planning Subsystem. The Mission Planning Subsystem will provide the ASF station scientist and manager with tools for predicting ground swath coverage of the satellite and site viewing opportunities. It will also be used in investigator data requests. A daily plan for ASF data acquisition will be conveyed to ASFoperators and will also be reviewable from the on-line catalogue.

Management of SAR data and information about data is the Archive Catalog Subsystem's primary function. An on-line catalog and inventory will provide investigators with the opportunity to interactively select and order data products. High-density digital tapes (HDDTs) containing signal, 1-look and full-resolution data and computer compatible tapes (CCT) containing low resolution data will be stored in the off-line archive. Film products and digital optical disks will also be managed by the permanent archive.

The ASF catalog will be accessible via the Space Physics Analysis Network (SPAN). Requests for digital images will be filled on CCts and DODs.

The 5.25 in write-once-read-many (WORM) DOD is envisioned as a major medium for data distribution

Table 2. ASF Data Products

Product Type	Distribution Media	Data Characteristics
Standard Products:		
Computer Compatible Signal Data	CCT, DOD	12 second segment
Complex Image Data	CCT, DOD	8 m pixel spacing 30 x 50 Km Area 10 m Resolution
Full-Resolution Images	CCT, DOD, Film	12.5 m pixel spacing 30 m resolution 8K x 8K pixels
Low-Resolution Images	CCT, DOD, Film	100 m pixel spacing 240 m resolution 1K x 1K pixels
Geo-Coded Products:		
Geo-Coded Full Res.	CCT, DOD, Film	12.5 m pixel spacing 30 m resolution 8K x 8K pixels
Geo-Coded Low Res.	CCT, DOD, Film	100 m pixel spacing 240 m resolution 1K x 1K pixels
Geophysical Products:		
Ice Motion Vectors	CCT, DOD	Ice Displacement Vectors 5 km grid 100 km x 100 km (nominal)
Ice Type Classification	CCT, DOD	Ice Type Image 100 m pixels 100 km x 100 km (nominal)
Ice Type Fraction	CCT, DOD	Fraction of Ice Classes 5 km grid 100 km x 100 km (nominal)
Wave Product	CCT, DOD	Wave Direction & Wavelength 6 km x 6 km subsections From Full-Res Image
Other Geophysical Products	CCT, DOD	TBD

CCT: Computer Compatible Tape
DOD: 5.25" Digital Optical Disks
Film: 8" x 10" Format
TBD: To Be Determined

in the 1990s. Furthermore, distribution of images via telecommunication networks may be feasible for browse purposes by using a data compression scheme before transmission. A decoding algorithm resident on a receiving computer would then restore images to approximately the original fidelity.

SCIENCE AND APPLICATIONS PROGRAMS

A preliminary Science Working Group has been established by NASA to assist in the development of the ASF and to prepare for the use of ASF SAR data in scientific and applications research. This working group has developed an ASF Science and Applications Plan.The oceanographic/ice portion of the report identifies a number of primary scientific thrusts to which SAR data will be able to make significant contributions. These include the circulation of ice in the Arctic Ocean and its peripheral seas, the fluxes of heat and mass in the arctic and their role in the global climate system, the effect of change in ice pack morphology on air/ice/ocean momentum transfer, air/sea/ice interactions in the marginal sea ice zone, and the study of ice kinematics.

In the open ocean, studies include the occurrence and evolution of mesoscale circulation features, the interaction of gravity waves and currents with bottom topography, the fine scale wind field and surface fluxes for inputs into oceanographic models, the surface wave climatology of Alaskan waters, and examining the effectiveness of SAR data in initializing, updating and verifying ocean wave and circulation models.

In land processes opportunities exist in a variety of fields, including glaciers, ice sheet and ice shelf research, geomorphology and quaternary geology, hydrology, structural geology, volcanology and ecosystems studies.

Applications research is often difficult to distinguish from related basic research. A few examples of possible SAR applications that are of interest include the support of offshore operations and ship routing around and through ice infested waters, monitoring changes in sea ice characteristics in near-shore areas in support of over-ice traffic and marine mammal habitat studies, assisting in locating suitable ice floes for offshore camps, landing strips, and experimental areas, monitoring natural revegetation sequences that develop following forest fires, land clearings and vehicular activity, and utilizing SARin monitoring natural catastrophic events and in search and rescue missions.

The Alaska SAR Facility presents a sophisticated new technical development in support of arctic studies. SAR, with its high resolution, all-weather view of the Earth's surface, has a very important role to play in future arctic research.

CONCLUDING REMARKS

Juan G. Roederer

I would like to make my concluding remarks from the perspective of, and on behalf of the Arctic Research Commission. We are very pleased and encouraged that this workshop took place and that it was so well attended by such a diversity of individuals with arctic responsibilities. This will be not just one more meeting, but a very important meeting and it will be remembered as such.

Changes are in the air - global climate change. I am not talking about the climate outside, I am talking about the climate here - in this room - among ourselves. We are beginning to talk to each other and talk business when it comes to arctic logistics. I am very encouraged. I did not attend the entire meeting but from the portions I did attend, I think we are finally on a good track.

The Arctic Research Commission has many goals and objectives. Perhaps the ultimate goal can be summarized in the simple words, "To help the United States to achieve excellence in all matters related to the Arctic." And our contribution, by definition, would be in terms of arctic research.

In a more mundane fashion the duties of the commission are prescribed. They are prescribed in the Arctic Research and Policy Act of 1984. You can read them in our colorful brochure. I want to stress two of them. This is written into the Arctic Research and Policy Act. This is a very serious business for us: to recommend, improve logistics planning and support and also improve sharing and dissemination of data and information. I want to find out that the two are totally intertwined.

Of course, we have paid attention to logistics in this meeting. It is connected to data and information systems in the Arctic and the bridge is communications. We cannot really discuss one without the other. The commission has addressed, initially, these two. There were two related publications produced last year, *Logistics Support of Arctic Research* with findings and recommendations on the subject and, more recently, *Arctic Data and Information: Issues and Goals*, a findings and recommendations volume.

Very briefly, I will discuss the principal recommendations on logistics.

The first one is difficult to implement and we are doing what we can from our perspective and our framework to try to help acquire an adequate research vessel. We are also strongly supporting the acquisition of an ice breaker for arctic endeavors. The second one has been repeatedly addressed at this meeting. The third one relates to upper atmosphere research and has a good chance of being implemented. The fourth one, the Central Office for Logistics Coordination, or clearinghouse, is the most pressing one.

I would like to find out that not everything is money. Of course, the first and the third recommendations imply considerable amounts of additional federal support. The fourth really requires very little support from a comparative view with respect to the others. It can, in itself, do much for the improvement of arctic research. We not only have to put money into logistics, we have to put order into logistics. Putting order into logistics should improve the cost effectiveness of the financial support of arctic research.

Let me link this to Antarctica by devising a national bipolar plan in which Arctic and Antarctic research operations are carefully coordinated, and in which we can devise a mechanism of the transport or transfer of know-how, including engineering, operation and people. This is knowledge about living in the cold. From the north to the south we will have achieved a great improvement, and, in this way, may indirectly be able to obtain and free more financial support for the actual science.

We have heard about new approaches concerning the psychological and sociological issues regarding arctic scientists. The heroic explorer before the computer age was mentioned. Now we have many arm chair, computer monitor, explorers. We need both. We also need something else in view of the tremendous demands for large networks, long monitoring observations, especially in light of the proposals for the International Geosphere/Biosphere program, a global change program. We have to think more and more about automatic observatories in the Arctic and Antarctic. We have to somehow trace a similarity with the space program. We have manned and unmanned missions. Both are necessary but the unmanned space and ground-based programs are essential.

Finally, it was mentioned repeatedly, but I want to emphasize once more, that international cooperation in arctic logistics is essential. We are eight arctic nations, and there is only one Arctic to share. We have to work together, deliberately and officially through agreements. This must be done government to government and institute to institute. Agreements must be made to share the equipment, the transportation, the communication systems and the knowledge in the Arctic.

We will be walking out of this meeting with more than we came in with. Certainly not with more money, but with more and clearer ideas on how to achieve the leverage of integration. This type of meeting and sharing of ideas should become a regular feature.

DISCUSSION

John J. Kelley

The workshop concluded by asking a group of panelists (Appendix 2) and the audience to reflect and comment on five questions:

- What is the ease of access to modern technological advances to enhance arctic research operational activities?
- How can we improve the exchange of information on current logistical capabilities not only in the U.S. Arctic, but on a global basis?
- Can we realistically assess future operational requirements and plan accordingly?
- What existing capabilities are underutilized?
- What are the existing deficiencies in accomplishing planned future and long-term projects and programs?

- **Solutions to communications problems in the Arctic is clearly a concern to most participants with respect to the enhancement of arctic research operational activities.**

Peter Wilkniss commented that we are working with outdated military systems, and that they are not available to the general public.

Meteor burst communications is becoming increasingly useful for high arctic field camp locations (I. Virsnieks, D. Witt), but it has its limitations with respect to distance. Reliability is high to distances up to perhaps 2000 miles. Lloyd Morris feeels that a combination of systems is necessary. A combination HF packet and INMARSAT (Telex) will be used to support the GISP-2 project on the Greenland Ice Cap during the summer of 1990 (J. Kelley).

Peter Wilkniss stated that a dedicated polar orbiting satellite is needed for search and rescue, science use such as data transmission and automatic weather stations, and general communications. Wilkniss feels that with the cooperation of all potential users a greatly improved satellite communication system is possible in the foreseeable future for the polar regions.

Peter Wilkniss further emphasized that there is little of modern technology applied to logistical needs in the polar regions. Furthermore, the driving force in the polar regions is one of the strategic concerns of the U.S. and USSR. That got us the Lockheed LC-130 aircraft, making it possible for heavy airlift deep into the polar regions. We may, however, be entering a period of decreasing funding for the new technologies which would allow for the increased use of high technologies for science and science support in the polar regions. We need improvement in the development of science-configured aircraft which can meet the needs of contemporary problems such as studies related to the ozone hole in both hemispheres.

Wilkniss also stated that perhaps programs such as studies of global climate change may be of such large magnitude that they will be a source of additional money for research. Increased funding for research support, however, may still be an open question.

National Undersea Research Program - Ray Highsmith stated that the operational plan for the Center is to lease underwater vehicles on a seasonal or project basis. In this way, the Program can keep pace with technical advances in the field and can provide the most modern equipment to researchers.

One of the major functions of the Center will be to facilitate communication between suppliers and users. In this way, researchers will be kept up-to-date on technological advances and vendors will be informed of research needs.

- **Exchange of information on current logistic capabilities not only in the U.S. but on a global basis is of concern to the participants.**

Henry Cole addressed the Governor's concern with education, engineering, and especially research programs, many of which have national goals. The State of Alaska has been generating reports and proceedings from various symposia on engineering, fisheries, rare earths and logistics. One such document, the Arctic Research Sites Compilation, is a very important compilation of land-based logistics in Alaska. It is based on George Hopson's Canada's Northern Field Stations and includes research site descriptions and maps. These research sites are split into federal sites, state sites and university sites (University of Alaska or the University of Washington). There is a full outline of port facilities, airstrips, radio communication frequencies, emergency services; basically anything that would be of use to people who are trying to carry out research in the bush. This document can be obtained from the governor's office in Juneau.

Tom Albert stressed the desirability of a directory similar to that which the State of Alaska publishes which states where the logistic capability exists and where to get information. Kelley emphasized the need for formal publication of such a directory, since informal publications such as flyers tend to get lost. Jerry Brown reminded the participants that there is regular communication among the agencies regarding logistic support. Directories are important, but the value is maintained in updating them.

Luis Proenza thinks that a directory alone does not address the question of what is going on and where. He suggested the establishment of a single point of contact or arctic logistics clearinghouse.

Peter Wilkniss strongly urged the Arctic Division of the AAAS to make workshops such as this one a regular feature. Many people with a wide range of interests can make effective use of such exchanges through sharing of information and experience.

William Gibbs, speaking as an industry observer, reminded the group that industry responds to demand. There is surely a demonstrated demand for new technologies for the support of scientific research. However, some group must be the lead agency to ensure better coordination than we now have if industry is to be more actively involved.

George Martin of the Coast Guard commented that the Federal Oceanographic Coordination Council is developing a real-time program for the exchange of information on ship schedules.

Ray Highsmith pointed out that the new NOAA-sponsored National Undersea Research Program (NURP) Center at the School of Fisheries and Ocean Sciences (SFOS), University of Alaska Fairbanks (UAF), will actively acquire and accumulate information on equipment capability and availability. This information will be available to the research community upon request. In addition, mailing lists will be developed in order to disseminate information on new advances, research initiatives and funding opportunities.

Both Carl Benson and Luis Proenza mentioned that the Arctic Institute of North America (Canadian and U.S. corporations and ARCUS) are potential focal point organizations for coordination at national and international levels.

- **Another topic of interest relates to whether we can realistically assess future operational requirements and plan accordingly.**

Andy Cameron stated that NASA has a five-year science plan. He emphasized that it is highly desirable to know what are the science and support capabilities in other agencies. He suggested the development of an interagency five-year plan. Kelley feels that this interagency five-year plan justifies another single-purpose workshop.

Ray Highsmith commented that the UAF/SFOS NURP Center will have staff that regularly attend scientific meetings and symposia in order to hear and discuss the latest research developments. The Center may also sponsor symposia and workshops to bring researchers together for discussion of recent accomplishments and to project future needs. Again, the leasing mode of operation will allow the Center to respond to rapidly changing needs as well as to plan successfully for long-term requirements.

- **The question of what existing logistics capabilities are underutilized brought varied responses.**

Tom Albert's response was related to the excellent facilities and availability of the UIC/NARL at Barrow for the support of scientific research. Imants Virsnieks described the availability of services at Prudhoe Bay for the support of programs on Arctic Ocean sea ice.

The National Undersea Research Program is underutilized, particularly on the West Coast and at high latitudes (R. Highsmith). The establishment of a West Coast Center, dedicated to publicizing facilities available through the program and encouraging and helping scientists to participate, will be a major step in achieving full utilization of NURP capabilities.

- **The discussion period ended by addressing what deficiencies exist to accomplish planned long-term projects and programs.**

The expression "long term" is itself not clearly defined. Luis Proenza responded that we do have a sense of what is coming, e.g., global change studies. There is a need to develop a more effective scientific coordination and infrastructure. We need to generate new interest in arctic problems among our graduate students. A single point of contact is desirable to get students into the field with the least frustration and maximum guidance.

Tom Albert mentioned that the North Slope Borough's Department of Wildlife Management could accommodate almost 20 students year around at the UIC/NARL facility at very low cost. Students could study a wide variety of arctic-related problems.

Rex Okakok emphasized that there are many knowledgeable residents of the Alaskan Arctic who are willing to assist research projects. Okakok also emphasized that we need to improve opportunities for science and mathematics education for school children.

Ray Highsmith observed that there are some major deficiencies that interfere with long-term planning. One of these has to do with funding cycles and the intense competition for support. It is hard to complete a project in two or three years. Some biological systems require much more time. Another major deficiency is the lack of an ice-breaking vessel dedicated to scientific research and adequate budgets to support the scientific research associated with it.

EPILOGUE

Richard T. Porter

"A burgeoning array of big-ticket science programs, such as the space station and missions to the moon, threatens to crowd out a much larger number of less expensive but valuable efforts." This was stated in a recent Associated Press report on the Federal Science Budget, which also included a study of global climate changes, estimated to cost at least $20B over twenty years. The arctic research community will no doubt be involved to some degree in that program: after all, no fewer than twelve federal agencies are members of the IARPC. Even so, federal R&D spending is meager relative to the rest of the budget. Moreover, not all arctic research programs will deal with global change. Adjusted for inflation, the science budget is barely larger than in the late 1960s; yet, the cost of science is escalating. Arctic research is especially expensive. Advances in technology are proceeding at a pace that defies anyone to keep up. Our particular problem in the Arctic is continuing to carry out quality research in the face of rising costs and shrinking budgets.

The single thread that ran through almost every speaker's remarks was the quest for more information; needed were details on new technology, logistics assets, other arctic plans and programs, new funding opportunities, and so forth. The biennial revision of the U.S. Arctic Research Plan addresses this shortfall, as did Dr. Roederer in his closing remarks, by calling for the establishment of a central coordination and logistics information clearinghouse and identifying the need for an Arctic Information Network.

How do we go about getting more for less? By exchanging information about our plans and programs, combining logistics support capabilities when possible, and carefully utilizing our limited logistics resources. We need to do this on both a national and on an international scale.

The first step in accomplishing these objectives is to establish a truly coordinated national arctic research *program* which encompasses both the private and federal sectors, and which is predicated on the unbiased sharing of information and most efficient utilization of existing assets. As I see it, such a *program* would incorporate the following factors:

- **Logistics staging areas.** There are a number of remote sites at which arctic logistics support equipment should be pre-positioned and stored during off-season. This procedure would significantly reduce follow-on logistics support transportation costs. Sites to be considered for this purpose include, but are not limited to:

  Nord, Greenland – Thule, Greenland – Sondrestrom, Greenland
  Alert, NWT, Canada
  Barrow, Alaska – Prudhoe Bay, Alaska
  Svalbard, Norway

Some of these sites are already being used for that purpose; others are not. Staging areas in the Soviet Union might be considered as well. International agreements are necessary in some cases, containing *quid pro quo* compensation for use of these facilities.

• **Logistics transportation platforms.** Comments have been made regarding the design and acquisition of new arctic-capable vessels and aircraft. These are noble long-range goals which, while noteworthy, will unfortunately not get us to the Arctic in the near term. It was correctly pointed out during the meeting that the workhorse of the Arctic, the DH-6 Twin Otter, does not always have the required range or payload capabilities. We can take a lesson from the Soviets in this regard: use what we have to the maximum extent possible, and modify existing platforms such as the turboprop C-47s. We must also continue to refine the already impressive operational capabilities of our LC-130H aircraft to land in remote areas of the Arctic, including the sea ice.

• **Federal Arctic Logistics Coordination Clearinghouse.** A structured series of programmatic planning meetings need to be instituted similar to those currently conducted by DOD, at which researchers from *all* federal agencies reveal the scope of their arctic science programs, their plans for the upcoming season, and funding that is available and/or needed. Representatives from the private sector would be invited to participate. Since arctic science cannot be discussed without including logistics, these meetings would also be attended by logistics coordinators from the various agencies who, as the plans and funding profiles become more sharply defined, could accurately ascertain the logistics costs associated with the envisioned efforts, and work together to reduce expenditures by recommending the combining of certain science efforts while working out the most efficient and cost-effective utilization of scarce arctic logistic support assets. The U.S. Navy's 6.2 and 6.3 R&D program managers currently plan and execute their annual arctic ICEX programs in this fashion.

• **Arctic Information Network.** The Clearinghouse, in addition to providing the mechanism by which information on private sector and federally-funded arctic research programs and logistics support could be exchanged, would also be tasked to investigate and advertise new developments in arctic technology, including military advances, if appropriate – in short, to set up and manage an Arctic Information Network. An electronic bulletin board might prove to be an effective means by which to disseminate this information. The Clearinghouse would also compile bibliographic information on past, present and planned polar research programs in order that prospective investigators might build upon rather than duplicate previous work, and perhaps combine their ventures with other ongoing projects.

The critical issue is: who should host the meetings, take notes, put out the minutes, broker the dollars, provide overall coordination and, in general, lead the pack? In other words, who is going to run this Clearinghouse and Arctic Information Network? In my judgment, no one associated with any of the federal agencies currently involved in arctic research can execute these duties in an impartial manner.

This Clearinghouse, at which programmatic and logistics support information would be exchanged and ways to reduce costs derived, would have to be operated by an agent appointed and salaried by the U.S. Arctic Research Commission. This individual, and staff, in order to remain strictly objective, should be entirely independent of any other arctic-related federal agency or organization. The missions of this Office of the Arctic Research Commission should be to coordinate logistics support for federal arctic research programs, disseminate information, and resolve scheduling conflicts between agencies. Efforts to achieve these ends by other *ad hoc* means, such as appointing someone already on the payroll of an organization with existing arctic interests, is ultimately doomed to failure, if for no other reasons than conflicts of time or interests.

The second step in the process of improving the cost-effectiveness of arctic research is to skillfully negotiate cooperative science and logistics support agreements with our arctic neighbors. We must be careful about embarking on piecemeal agreements with other arctic nations until we can speak with one national voice. U.S. arctic research has a history of fragmentation, driven at least in part by budget adjustments, lack of interagency cooperation, shifting national priorities, and a reluctance to reveal the details of one's research until the results are published and properly accredited.

Initial development of a national arctic research program, then, as an outgrowth of the U.S. Arctic Research Plan, with attendant level funding and coordinated by the U.S. Arctic Research Commission, followed closely by international cooperation with other polar nations, will ultimately enable us to represent American interests most effectively in the international arctic community.

Participants in the logistics meeting pointed out that the need for interagency cooperation in arctic research exists *now*. Shrinking budgets, limited assets, and geopolitics demand it. If we continue our separate ways, we will do the arctic research community, and the nation, an outrageous disservice. It is up to the U.S. Arctic Research Commission to make it happen.

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