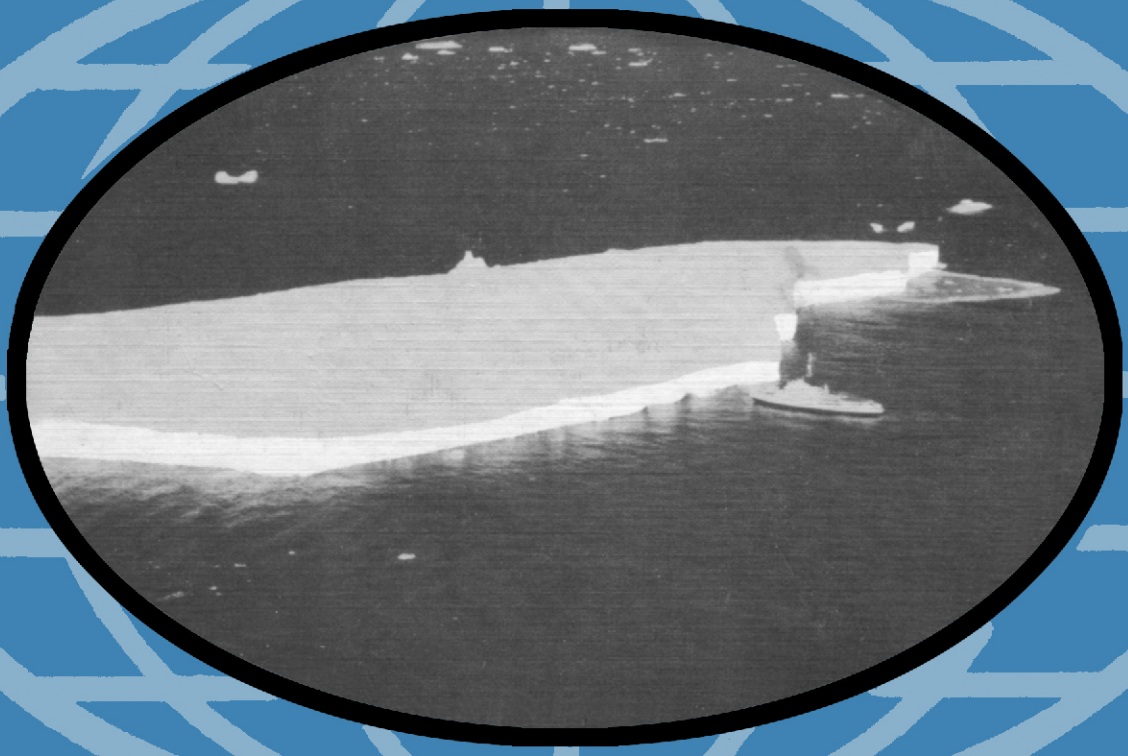
ICEBERG UTILIZATION



Proceedings of the
First International Conference
Held at Ames, Iowa

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Edited by A. A. Husseiny

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Iceberg Utilization

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Proceedings of the First International Conference and Workshops on Iceberg Utilization for Fresh Water Production, Weather Modification and Other Applications held at Iowa State University, Ames, Iowa, USA, October 2-6, 1977

Edited by
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PREFACE

In a land of plenty, people have started to realize that a time of scaracity is approaching. The earth's resources of energy, fresh water and minerals are depleting at an accelerating rate. Human consumption is doubling at an increasing rate. This is due to changes in the standard of living in many countries, to increases in population, to industrialization activites in developing economies, and to the growing interest in urban life style in place of simple nomadic or rural life style. Some regions have abundance of certain resources but have shortages of water and foodstuff. In other regions, deserts are spreading and frequent droughts have started to affect the yield of agriculture. Consequently, scientists and engineers are in active search for solutions.

The vast amount of fresh water and energy stored in icebergs have stirred the curiosity of those who like to believe that everything around has some ultimate use. Meanwhile, icebergs continue to be under close surveillance as a hazard to navigation and oil drilling rigs. Thus, a wealth of information on icebergs has accumulated. The available information has stimulated the interest in exploiting icebergs. This interest has been encouraged by the desire to utilize antarctic resources to augment the earth's depleting supply of energy, water, and minerals.

Up until recently, the efforts to explore the feasibility of using ice bergs as water resources has been limited to inventions, to appraisals and to brainstorming. The pecularity of the concept has inspired the imagination of the expert and lay person alike. The thrill of the subject matter has attract ed the comic writer and the serious investigator. The novelty of the topic has stimulated the innovative ability of many entrepreneurs.

The seriousness of the water shortage has been a greater motivation to address the concept of iceberg utilization objectively and to search for solu tions to the implementation problems This would require pooling the expertise of many experts from a variety of disciplines to evaluate the feasibility of the concept and provide technical recommendations for future studies and pro jects. One way to achieve this goal would be the establishment of a forum for research and educational institutions and industries to exchange ideas and present the results of their exploratory work.

Hence, the First International Conference and Workshop on Iceberg Utilza tion for Fresh Water Production, Weather Modification and Other Applications has been organized for discussion of the concept, and analysis of different aspects of icebergs in motion.

The conference has been planned to meet the following objectives:

1. To provide a forum for representatives of industries, research establishments and universities to exchange ideas and information relevant to iceberg utilization and potential applications.

2. To provide a comprehensive state-of-the-art assessment of iceberg utilization research and development.

3. To identify specific problem areas involved in realization of the concept including basic science, engineering and physics problems.

4. To recommend future research and development and data requirements.

5. To examine the feasibility of the overall iceberg utilization concept in regional and global perspective.

6. To evaluate the impact of iceberg utilization on the environment, ecology, climate, marine transportation, and on international law.

7. To examine the energy conservation potential of alternate water production schemes.

8. To assess the sociopolitical spects of the concept.

9. To develop a document which will provide researchers and scientists with reference material and provide technical experts and planners a basis for future decisions.

10. To transfer advanced technology of iceberg utilization from the phase of concepts and innovations to applications through industrial participation.

Those objectives have been adequately met within the short period of time in which the conference was planned and organized. The overwhelming response to the conference invitation and call for papers of scientists and engineers working in related areas has greatly helped in achieving those objectives. In fact, including all of the outstanding papers in the conference program was not at all possible. Consequently, some of the papers have only been distributed and the authors whenever possible have made brief presentations during the discussions in the various workshops. The high quality and thoroughness of the papers presented in the conference are more than what could have been expected in a novel area of research for which practically no funds were available. In addition to the above objectives, the conference has helped in the evolution of iceberg utilization from being one person's idea into an interdisciplinary field.

A wide range of topics was covered, including locating, tracking, and selection of icebergs using remote sensing and radar techniques; studies on engineering and physical properties of icebergs; transportation; international and national implications of iceberg utilization; economical, legal, organizational and managerial aspects; weather modification; in-transit dynamics; protection; feasibility of iceberg use in different regions; and iceberg power.

The meeting was international in scope, with participants from Australia, Canada, Cayman Islands, Chile, Egypt, France, Germany, Greece, Holland, Italy, Libya, Monaco, Saudi Arabia, Sweden, Switzerland, Syria, United Kingdom, and

the United States. A total of 68 papers were formally presented. Out of these are three from Australia, five from Canada, two from Egypt, six from France, one from Holland, one from Libya, three from United Kingdom, five from Saudi Arabia and the rest are from the United States.

In order to accelerate the production of the proceedings some of the papers have been selected for publication. The detailed discussions in the workshops are not included here. The rest of the contributions will be made available at a later date.

The conference was sponsored by:

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The success of the conference and the availability of this publication are the results of hard work and sincere cooperation between the members of the program committee and the organization committee. The recommendations of the steering committee were invaluable in planning and execution of the program of the conference.

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October, 1977

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EDITORIAL NOTE

Due to the recent revived interest in iceberg utilization we have moved as rapidly as we can to make the proceedings available within a short time after the conference. To do so, we were forced to exclude some of the papers which were not submitted in the final form at the conference. This decision does not reflect on the quality of the papers not included in this volume. We hope that the rest of the papers will be published in another volume as soon as they become available.

Among the papers excluded from this publication are: 1. papers which need major revisions, whether in content or format, to assure the quality of this publication. 2. Several outstanding papers which have been submitted after the conference and were not formally presented. 3. Papers which have been presented at the conference but only submitted either as short summaries or as a copyrighted paper of earlier work. 4. Papers presented during the panel discussions in the workshops.

A.A. Husseiny
General Editor

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INTRODUCTION

Daniel J. Zaffarano, Vice President, Graduate College,
Iowa State University

Although the potability of iceberg water was recorded by Captain Cook in 1760, the economic feasibility of transporting icebergs or iceberg-derived water to drought-stricken regions has not yet been proved by demonstration. While the technical difficulties involved would seem *a priori* less demanding than for the task of placing an astronaut on the moon, other options for improving water supply, such as impoundment by dams, cloud seeding, and desalination of ocean water, have appeared to be more tractable for the present.

Recently, however, the problems associated with a growing world population, which include rising demands for food, energy and fresh water, have brought renewed awareness that conventional solutions to water shortages may not be sufficient and that the principal storehouse of the earth's fresh water -- the Antarctic glaciers eventually must be tapped.

At the same time, the advent of huge drilling platforms for oil wells beneath the Arctic and North seas has stimulated the development of large tugboats capable of towing them with forces of hundreds of tons. The feasibility of deflecting a floating iceberg from a collision course with an oil drilling platform off the coast of Newfoundland was reported last year.

One purpose of this First International Conference on the Towing of Icebergs is to assess whether or not our need for fresh water is now great enough that we are willing to pay the cost of the technical development needed to move and use icebergs to meet the demand. Economic studies published by Weeks and Campbell and by Hult and Ostrander in 1973 provided first estimates of iceberg water costs in the range of $10-$33/acre foot. Such numbers compared quite favorably to costs in 1973 of interbasin transfer or desalination and gave cautious optimism to the technological, economic, and environmental feasibility of utilizing Antarctic icebergs as a fresh water source.

At this time, Saudi Arabia finds itself in the position of being a country with continuing water shortage but fortunately having financial means derived from oil resources to pursue the innovative solution of iceberg transport. Saudi Arabia is also fortunate to have the interest and leadership of Prince M. Al-Faisal in this project. He has provided both the principal incentive and significant support for the meeting in which the technical papers reproduced here were presented.

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Overview

NEW PATTERNS OF COOPERATION IN INTERNATIONAL SCIENCE AND TECHNOLOGY

H. Guyford Stever, Scientific Consultant; Science Advisor to Presidents Nixon and Ford; Former Director, National Science Foundation; Former Persident, Carnegie-Mellon University

It is very pleasant to be here at Iowa State University with all of you experts in the sciences and technologies related to the towing of icebergs to water-short areas of the world. When I was invited to speak at this conference, and mentioned the invitation to family and friends, two questions were immediately posed. The first was, "Why Iowa?", and I disposed of that relatively easily by pointing out that Iowa State is a broadly based center of science and technology with interests ranging all over the world. The second question was a little more difficult. It was, "Why you?". I explained that I had been to Antarctic twice, and above the Arctic Circle, and my interests in science and technology were quite broad, especially in those related to resources such as energy, water, etc. One friend was not satisfied and only became so later when I showed some of my Antarctic pictures including one of Stever Ridge in Antarctic, the naming of which was the nicest honor I ever received. When he saw the great glaciers flowing down the side of the ridge, he exclaimed, "Now I see, you want to sell icebergs

It is true that I am very interested in your subject and for several reasons. It does represent a new and challenging conjunction of several sciences including oceanography, meteorology, glaciology, solid mechanics, and fluid mechanics with the technologies of ship design and operations at sea in hot and cold climes. It is a good example of "Big Science."

Your field has another feature. It requires risk-taking, not only from the science and technology standpoint, but also as an entrepreneurial venture. Now here is an area--risk-taking in technology--which is somewhat in neglect these days. There is far less technological risk-taking today than in the recent past as exemplified by the space program, or more distantly the establishment of world-wide air transportation, or building the Panama Canal. There always seems to be reasons for not being more venturesome, usually associated with the shortage of capital, but, at the same time, some fine opportunities are missed.

The program has another feature, perhaps its best. More fresh water is needed by many nations, rich and poor, developed and developing, all over the world. So the goal of the undertaking is clear and good. The project should bring out the best of our science and technology, and reflect our respect for human needs everywhere.

As to the technical and economic feasibility of iceberg utilization, I have no expertise or experience so it is for you people to decide. Certainly early studies have pointed to encouraging results, and you are now getting to the experimental and practical phases.

Let me turn to the subject of cooperation in international science and technology, of which the iceberg project is a good example.

In my five years as an official in the United States Government in the science and technology end of things, I discovered what I thought was an invariant in international agreements. Whenever the President or Secretary of State, or analogous officials of other countries, traveled abroad to establish brand-new relationships with another country, or cement some badly collapsing old ones, the first and sometimes only field in which agreement could be reached would be science and technology. At first I thought that I had found evidence that the experts in other fields were so cantankerous that they couldn't agree, or that other fields were so poorly defined that they couldn't be laid out neatly for exchange. More seriously, as I became better acquainted with the international negotiations, I realized how wide-spread and strong was the view that science and technology are the most powerful generating foreces for strengthening economies, solving resource and supply problems, improving food supplies and health care, as well as serving some other basic needs of people. My respect for national leaders grew as I recognized their commitment to the fundamentals on which long-term progress is based.

A strong movement of the last five years, which I noted during my government service, has been the growing interest in global issues. Scientists, engineers, and many other thinking people have been devoting more time and effort to the long-term problems besetting mankind. Perhaps some of this is due to the emergence from the unrest and revolt of the last sixties, with the positive remainder of some of the insistence on relevance by the youth of that time. Perhaps some of it results from the reaction to an unpopular war and eventual release from its burdens. Whatever the causes, interest in global problems has grown.

No doubt, progress in the understanding of global issues owes a lot to the use of the computer in global modelling. When the Club-of-Rome sponsored study, Limits to Growth, was published, there began a rapid emergence of these large-scale global model studies. There also started a wide ranging argument about the concept of limited growth. On the positive side of the argument, I think there is not doubt that the publication, which was part of the Club-of-Rome's study entitled, "Predicament of Mankind," had great shock value. It did focus attention on a few important factors and their effect on growth, change and decay in society--factors such as population, food, energy, industrialization, raw materials, etc. It also represented an interesting marriage of the thinking of a number of well-known and successful world leaders, generalists all, with that of computing and modelling experts.

Critics of the "Limits to Growth" concepts pointed out that the global situation is much too complex to model, that the mathematics used in the model were too simple, that the progressive uncertainties of technological adjustments to emerging problems was underestimated, as was the human reaction to problems. All of these made for such uncertainty in the results that global modelling could not be relied on for long-range predictions. Some even insisted that modelling and prediction on a global scale was downright dangerous because its basic conclusion that growth had to be limited was so contrary to the belief that growth and progress were synonomous.

The sentitizing of thinking to global problems received added impetus in the last five years from several other shocking events: the oil embargo of 1973; the blackouts of electric power in New York City; and the grain shortage

age brought on by one or two poor harvests in the Soviet Union and the People's Republic of China.

Whatever one believes about long-range predictions from global modelling, it does delineate the variables that are important and each of their effects on the future. Because of the use of the quantitative tools and the increased awareness of the problems, the level of debate on issues both national and international, has been vastly improved in these last five years. I think also that national decision making is improved for executive and legislative leaders do not ignore the global effects of new laws, and actions. If they do, there are many world watchers to call things to their attention.

What are some of the problem areas about which there is new attention? Here is a list:

1. Population and Its Distribution,
2. Food and Fiber - to give man sustenance, health and warmth,
3. Energy to run his technology based commerce and industry, his daily personal life and his agriculture,
4. Water to drink, to irrigate his crops, to clean, cook and warm him and his material goods, and
5. Materials such as wood, minerals, chemicals--to house him and to make things.

These are not new on the list of man s problems. They seem to have been here from the beginning. However, studies of the interplay of these factors and a relation of them to how life is lived in different countries and regions of the world, and how people would like to live it, and the strength of the world economy leads one to the belief that substantial changes in all are required from today's way of doing things. Yet the way things are going, mankind is going to run out of food for many of its growing population, and energy as well. He is already straining his water supplies and some raw material supplies are threatened. The approaching imbalances are catastrophic and only a prodigious effort by all will prevent starvation and frustration with resulting social upheavel, probably warfare as well.

To bring about the changes that are needed, science and technology must be relied on heavily. From this list of world-wide criticalities we can get out priority list for international cooperation in science and technology. It goes without saying that education is needed about the differences amongst the countries of the world in their cultures, religions, daily way of life, hopes and fears, and to make sure that changes are desired and acceptable, that the peoples throughout the world participate in decision making.

The big difference in today's vs. yesterday's way that man has looked at these global problems is in the quantification by the use of models and computers. Today we can look at the population-food-energy-water balance and tell where and approximately when starvation will set in and to what degree, given the proviso that some major controls on population are not effected. We can tell how much increased food production is needed to delay the onset of starvation in certain regions of the world. We can tell when the world's petroleum supply will not be able to keep up with demand at a reasonable price, and when we must change the mix of our fuels.

When one looks at the projections, certain conclusions stand out clearly.

No nation has the resources to stand alone. It will take the work of all in an interdependent way. So Internationalsim will be the hallmark of the coming decades. Another conclusion is that science and technology will be called upon in overwhelming proportions to tackle all of the problem areas. International cooperation in scientific and technological projects will grow. Futhermore, there will be an ever growing pressure to share scientific knowledge and technical know-how amongst the developed nations, and from developed to developing nations.

The population studies seem to indicate that mankind might get population growth under control but not before it shoots up from the current 4 billion to something like 12 billion in the next century. That's better than the exponential growth to extinction that earlier simple mathematical analysis gave. But there will be some nearly unmanageable concentrations in Latin America, in Africa, in the Asian subcontinent, mostly in the developing nations area.

Food must be grown, for the most part, where the people are, not transported entirely from a few rich agricultural nations. The international exchange in science and technology in agriculture must be aimed not at the well-watered land of the United States Midwest, but at arid land so one can use more of the desert and near-desert areas, constituting one-third of the world land; it must be aimed at the tropical jungle land, at marginal brackish wet lands as well. And the exchange will not be one way, for more of the developed nations like the United States, Canada, Australia and others which are surplus food producers have arid land, and apparently it is expanding. They, too, will benefit from the international exchanges in arid agriculture.

I have seen agricultural tudies which show that, given a prodigious international cooperation program of research and development, man might be able to feed, not sumptuously, almost ten times the current population or four times the eventual population--if they are all located in the right places. Given the fact they won't be, the race between population and food is still on.

International exchange in science and technology in agriculture has a couple of leg-ups over exchange in some other fields. Agriculture is an old field--it was invented over 5,000 years ago in the Fertile Crescent of the Middle East, and almost everywhere there is an agricultural infrastructure well developed. Advances coming from science and technology anywhere can often be absorbed relatively quickly and the flow of knowledge can be both ways. Also the tradition of using advanced science in agriculture is an old one; in the United States it is perhaps our biggest triumph in the application of science, and it has been for well over a century. This land grant college, Iowa State, sprang from the Morrill Act of 1802, which represented the first of the Federal Government's big pushes in the field. The record of international exchange of science and technology in agriculture is excellent, too. Look at the success of the Green Revolution, sparked in good measure by the leadership of the Rockefeller Foundation and the Ford Foundation.

In the exchange between developed nations with strong science and technology communities in action, whether it be in the government - and academic - centered fields of meteorology, oceanography, earth sciences, space, medicine and the pure sciences, or the industry-centered technologies involved in manufacturing, mining and trade in general, the methods of transfer are relatively straight forward, for the flow can be two ways between competent people and organizations within strong science and technology infrastructures. Here the problems often simply arise from considerations of national security,

industrial secrets and patents, the protection of industries and jobs, and the quid-pro-quo in the exchange. In these same fields, if the exchange is from developed to developing, there are far more difficult matters to be solved and we have a lot to learn about the process. In the first place there is the basic question of what sciences and technologies should be exchanged. Technologies sometimes have side effects in the developed countries, and they may have quite difficult ones if transplanted to other countries. Social changes brought about by technology, though often good, can also be difficult to handle, or downright undesirable in a developing country. Developing countries often don't want to end up like the developed country. They want to keep their unique culture and way of living. But they want some of the benefits of science and technology. It is clearly the responsibility of the leadership of the developing countries to be well informed about science and technology in the developed world, to be capable of making the assessments of what such science and technology will do if introduced in these countries, and to determine the areas of concentration. Those leaders may need help from the developed countries, but the responsibility should rest with the leaders of the developing countries.

By the way, from my experience with some of the leaders of the developing countries in the Middle East, in Africa, in Latin America, I judge there are many who are capable to taking the responsibility and of choosing well. On the less hopeful side, many are severely handicapped because the science and technology infrastructures of their countries are not capable of absorbing some technologies. Here the exchange process is slowed, and can never be accomplished without the needed preeducation and training as well as the forming of the institutions to manage the received technology. Herein lies the biggest rock in the shoals which threatens the passage of technology.

In the summer of 1974, the contrast between science and technology of the developed countries and that of the developing ones was brought home sharply to me. I was one of a number of visitng science and technology officials at the opening of the Atlantic Tropical Experiment of the Global Atomspheric Research Program, an international exploration of the large factors which generate the weather problems of the world. The Atlantic Tropical Experiment was to test the interchanges of energy and mass between the ocean and the atmosphere in the tropics. The site of the experiment was the Altantic, just south of the Equator, and the base site was at Dakar in Senegal at the top of the western bulge of Africa. And to this site came many superbly equipped oceanographic research ships and atmospheric research aircraft from Britain, France, Canada, the Soviet Union, the United States and others. For example, there were United States ships from the National Oceanic and Atmospheric Administration, the Coast Guard, and from universities supported by the National Science Foundation. United States aircraft were from the National Science Foundation-supported National Center for Atmospheric Research, the National Aeronautics and Space Agency, and the National Oceanic and Atmospheric Administration. And to operate the ships and aircraft, the communications and all the instruments and experiments, there were several thousand scientists, engineers and technicians, involved in what I have been told was the largest international science experiment ever conducted. It was high-powered science in an extreme form.

In contrast, we visited several developing nations in Africa. We had discussions with President Senghor of Senegal, a well-known poet, and visited Gao in Mali to see first hand the deprivation caused by drought in the Sahel, and to visit a very large refugee camp. We visited other nations. In all of

these, the contrast between the scientific activities of the Global Atmospheric Research Program, and those wanted by the developing nations was stark. They needed the elements of food, water, industrialization to exploit their mineral resources and for jobs in manufacturing.

Many of the leaders with whom we spoke understood full well the long-term goals of the Global Atmospheric Research Program which hopefully someday will give us more understanding and possibly control of the weather and climate but they had shorter range needs. They would understand much better the Iceberg Utilization Project, with its possibility of fresh water for arid lands relatively soon. Weather and climate control are much longer range projects.

The forms which international cooperation in science and technology takes are many fold: There are government-to-government, industry-to-industry, university-to-university, and person-to-person agreements as well as all permutations of these. The roles of governments, industries, universities, nonprofits, international organizations, foundations and individuals are all being studied, and we have a lot to learn. If the exchange medium is knowledge and know-how, rather than product, the effect will last longer.

In the end, however, it comes down to the individual involved--his knowledge, his know-how, and his attitude. I am reminded of the words of William Blake, "He who would do good to another must do it in minute particulars. General good is the plea of the scoundrel, the hypocrite and the flatterer, for art and science cannot exist but in minutely organized particulars."

The Iceberg Utilization Project represents a field where in doing "good to others" we help many countries, rich and poor, including ours, which are badly in need of fresh water. I look forward to listening to all of you get down to "minute particulars" in Iceberg Utilization.

THE CHALLENGES OF ICEBERG UTILIZATION

Salah Galal, Chief Science Editor, Al-Ahram Newspaper
and Editor of Youth and Science Magazine, Cairo (Egypt)

In search for raw material, energy and water, man has explored deserts, under ground, ocean waters and space. As the world resources are being rapidly drained, man will be forced to turn northward and southward to polar regions. The abundant Arctic and Antarctic resources will eventually be exploited to produce the basic needs of the earth's population. There is no doubt that the time has come for man, who desperately needs water and energy, to look forward to the use of the abundance of energy and water stored in frozen form in the polar ice. At the turn of the space age, it is likely that we are heading to the "iceberg age".

Until now the monstrous icebergs have been regarded as one of the useless phenomena. They are often associated with ship disasters, since they may drift unnoticed into the ship lanes. The horror of being lost on an iceberg -- lonely, in the dark, the grander commotion of clashing sounds and thundering roar of newly-born bergs -- has inspired fairy tales and science fiction writers. With deserts creeping all over the earth, and with the shrinking of the green land, NOW seems to be the high time to tame icebergs and use them for human welfare rather than let them melt away, wastefully, in the open seas.

If left untamed, drifting icebergs are hazardous to shipping lanes and oil drilling rigs. However, they also affect fish population, long-term weather changes and the life near gulf streams. Such ecological and environmental impact can be very well put to advantage if the drift is controlled. Although icebergs come in various shapes, some of them are like floating islands. If their drift is controlled, tabular icebergs can be used in military and civilian activities. During World War II, the allies seriously considered using icebergs as aircraft carriers in the Atlantic Ocean. This effort has resulted in the development of pykrete and permacrete which are formed by mixing ice with wood pulp or soil. The high resistance of pykrete and glacier ice to explosions has made icebergs very useful in military use. Although the aircraft carrier project was abandoned, due to increase in aircraft range, the idea can still be used to provide landing stations and rest areas for transoceanic flights.

Man's ingenuity has never stopped short of challenging the impossible and taming natural objects for human benefit. There are many technical problems and difficulties in making friends of ice and in navigating, breaking and disintegrating ice. However, man, under pressure of scarcity of water and other resources, is ready to cope with those difficulties. Among the challenges which will be faced in the implementation of iceberg utilization projects is the international problems which may arise when attempts will be made to tap commercially-exploitable resources, such as the fresh water tied up in icebergs. The uncertain legal status of Antartica could pose some problems regarding natural resource jurisdiction. Some sort of control and management procedures is inevitable. The passage of towed icebergs in local waters will raise some fundamental questions. Nevertheless, icebergs used as a natural resource may become a first prototype experiment for interna-

tional cooperation in which multinational human capital and finance will be made available for the common benefit of the participating countries. In fact, without such cooperation the implementation of the project may be affected.

The second challenge is that of stimulating interdisciplinary research and development (R&D) effort. The success of the R&D phase depends on the smoothness of information exchange between scientists of different training and background and the ability to participate in team work between those involved. The space program is a live example of the success of such efforts.

In the phase of transferring ideas into use, the close coordination between contractors and industries will be a major task. On a small scale, examples of industrial collaboration in large projects are the Tennessee Valley Authority (TVA) and the Colorado River basin projects. In fact, most of the large industrial enterprises have gained experience in the management of projects which require coordination of various engineering divisions of different specialities. Nevertheless, big industries are not expected to be keen to get seriously involved in the iceberg utilization plans without actual participation of the government and sponsoring agencies.

The challenges which are facing the decision-makers in the free world, and in developed countries, are embedded in a series of questions: Can the rich countries cooperate in financing a project of this sort for the welfare of humankind? Can the well-to-do countries help tow an iceberg to save a starving child in Asia, Africa or Latin America? Can the developed countries cooperate in the iceberg project for their benefit and for the benefit of other countries? Is the World Community ready to invest in a prototype experiment to tow an iceberg to Australia, Chile, Peru or any other place? Can the people of the world allow icebergs to cross national waters without starting international disputes? Can the developing countries cooperate in making the first iceberg transportation possible? Those types of questions need an answer and it is worthwhile to assess the attitude of the governments concurrently with the technical investigation.

The public attitude is also of great importance. Would people accept use of icebergs as solutions to the water problem? Would they like to see icebergs floating in their local waters? This will depend on how badly they need water. There are nature-lovers who like to enjoy the wilderness, a night in the oasis, the sparkling stars in a desert, the blue sky and the primitive life. There are others who can give up part of their life for a drop of fresh water or a piece of bread. Can both of these parties trade their life styles? If not, let us bring an iceberg for those who need it, those who drink salty water.

The attitude of the international industrial enterprises is also important. Are the big industries willing to invest time or money in this venture? Do they know all the ins and outs of iceberg utilization to make an educated decision? Would the industry anywhere be willing to actively participate in all phases of the development or would they rather stand still until someone else takes the risk?

In all of these aspects the newspapers and the public relations personnel have a duty. They need to inform the people of the facts objectively, without bias. Many of the newspapers have picked up the news about iceberg uses

out of mere excitement or for the thrill of the subject. Some science editors have done their homework and presented outstanding stories. Others have passed the news to journalists who are likely to dramatize the issues. The media have a responsibility towards the public. Science editors need to study the topic and provide the people with solutions for their daily problems. The south and north poles are parts of our world which cannot be ignored. We need to seriously review our assets and debits whenever we anticipate shortage. We need to make friends of nature, including ice, if we are to survive as a human race.

The challenges which face scientists include the need for a realistic outlook at the evolution of technology. The engineers need to provide solutions based on well developed and proven techniques, while scientists may work on development of more advanced systems. They need to realize the iceberg projects in the short term require starting with simple concepts and then applying more complex methods. However, even if the simplest method is used for locating, protecting, transporting and processing icebergs, the overall project requires a high-quality system of management and coordination. In other words, it is not a task for a small consultation firm or research center, and it cannot be done as an additional activity of a large industrial complex.

Iceberg utilization projects need people of drive and conviction who are able to put regional problems in perspective of the global picture. The realization of the concept requires stimulation of scientific interest and mobilization of investors and industries. In any case, the news media and the public attitude are expected to play a vital role in the coming Iceberg Age.

ALIEN ICE: AN EVALUATION OF SOME SUBSIDIARY EFFECTS AND CONCOMITANT PROBLEMS IN ICEBERG UTILIZATION

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ABSTRACT

Scientific uncertainty concerning some subtle environmental impacts of iceberg utilization will make plausible several types of political accusations against any who attempt such utilization. Examples are given to suggest how such accusations have been made against weather modification experiments, and how future accusations might contend that iceberg utilization experiments influence global climate.

INTRODUCTION

Iceberg utilization has, until now, been an attractive idea to many ecologists. When compared with the widely discussed potential hazards of atmospheric ozone erosion from the chlorofluorocarbons in spray deodorants, of lethal plagues brewed from recombinant DNA molecules, of terrorists running amok with nuclear reactor wastes, or of thousands of other risks, great and small, we have assumed because of changes humankind has introduced into the environment, the use of icebergs appears to wear a white hat -- to be benign at worst, greatly beneficial at best. People who point with alarm to the possibility of a nuclear reactor "core melt" have expressed few concerns about the melting cores of transplanted icebergs near their homes.

But questions about the environmental impact of iceberg utilization are beginning to be raised, and how they are answered may determine the *political* feasibility of iceberg use.

AREAS OF CONCERN

Weather Modification

Would the towing of an iceberg from Antarctica to, e.g., Saudi Arabia result in altered weather patterns? Inevitably, yes, for any iceberg will be both a solid mass, somewhat like a small island, and a heat sink. Thus it will influence wind and ocean currents to some degree. How extensive will such effects be? About this, judgments vary. Hult (1) assumes that a large iceberg's major impact on weather will be limited to within a few

kilometers distance from the ice itself. H.R.H. Prince Mohamed Al-Faisal has been quoted as saying, on the basis of private data available to him, that the anchoring of icebergs near Saudi Arabia might influence its weather: "Over a period, we would hope to change the vegetation and climate in some coastal areas." (2) Scientists generally agree that even a heavily insulated iceberg, brought to lands like Saudi Arabia or Southern California where such ice is alien, would cause more condensation of water vapor from the air than it would give off in evaporation. Simpson (3) calculates that in the region of the Red Sea an iceberg could produce significant amounts of fog, and that if anchored off the east coast of Florida an iceberg might reduce storm damage by reducing the evaporative energy available to nearpassing hurricanes. How such effects might change with different utilization techniques remains uncertain -- in part because no such iceberg has been transported, and in part because the private interests busy developing iceberg utilization techniques have kept much of their research data private and proprietary.

Uncertainty in this instance can be expected to breed suspicion and discord, for the possibility exists that an iceberg anchored off the coast of one nation could subtly influence weather over another nation hundreds or thousands of kilometers distant. Scientific evidence of such influence may be sparse or questionable, but scientists, often unable to predict accurately changes in weather more than a few days in advance, would be first to admit that our understanding and measurement of the complex interacting forces in Earth's "weather machine" are as yet primitive.

In light of these primitive tools for determination of cause, the leader of a nation whose people are dying from famine caused by drought or flood can be forgiven for an angry resort to the *post hoc* reasoning typical of witchdoctors: e.g., "The bad weather came soon after you moved the iceberg. You are responsible!" At our present level of scientific knowledge, such a charge is difficult to prove, but it is also difficult to refute with absolute certainty.

In 1973 two Central American nations, Honduras and El Salvador, accused the United States of "stealing" their rain. This had been done, the drought-stricken nations said, by Project Stormfury, a joint undertaking of the U.S. Department of Defense and Department of Commerce to research ways to weaken or redirect Atlantic hurricanes. Flying aircraft off the coast of Miami in Florida, Stormfury had employed cloud seeding to weaken many of the giant storms. But, said Honduras and El Salvador, these hurricanes customarily spawned smaller storms that brought rain to Central America -- hence the accusation of rain theft. Project Stormfury officials replied that no hurricanes had been experimentally seeded by its operations since 1971.

Similar accusations of rain theft have been made against Israel and Rhodesia by neighboring countries and, within the United States, by the Attorney General of the State of Idaho against the seeding of overpassing clouds by the neighboring State of Washington. These cases tend to invoke a cloudy but linear ex-

tension of the idea of water rights, arguing that wind currents are merely "invisible rivers in the sky" that carry water in rainclouds. The use of seeding to harvest these clouds is thus likened to the siphoning off of an unfair share of river water by one state before the alloted water can flow into another (4).

But in the Honduras-El Salvador accusation we see a more elaborate claim of causality -- that the United States altered a natural energy system that, prior to such tampering, for thousands of years had begotten storms which in turn spawned rainfall in Central America. Because there is no substantial international law governing concepts of weather modification or weather rights, the case these nations set forth received little response from the world community. In May 1977 the United States and Soviet Union began to gain co-signers for a jointly-proposed treaty to ban all "hostile" use of environmental modification. Although this treaty has been called "more loophole than treaty," it will likely become a springboard for the development of global weather law. At present, all such attempts at international regulation remain intentionally vague, and the abovementioned treaty excludes from control all research, experiments, and actions that have intent that is "peaceful. Elsewhere I have suggested that its weak provisions would not even have forbidden the military uses of cloud-seeding the United States employed in Southeast Asia from 1967 until 1972. (5)

As such international law evolves, the resolution of cases could devolve to the International Court or United Nations General Assembly's 149 members, wherefrom the same emotions might govern judgment as now sometimes are found in paternity suits -- i.e., a poor victim in need of help accusing a rich defendant; a poor nation suffering famine accusing a rich and technologically advanced nation. In such cases, hard evidence of guilt might be less of a consideration than the victim's need and the accused's ability to pay. The analogy is useful, for law in many nation's once held that weather calamities were "Acts of God" whereby weather was conceived in the sky by an immaculate Mother Nature. This conception has been made obsolete, for evidence clearly shows that clouds can be inseminated, and weather altered, both by the inadvertent seeding of pollution from factories and other sources and by the deliberate use of chemicals like silver iodide in efforts to alter rain and hail patterns. If God is not responsible for a nation's bad weather, who is...or might be?

Even in the absence of any evidence of weather modification, politicians in one nation might find advantages in making accusations against another nation. Nor can we assume that no scientists will join in such cases. In 1974 Hurricane FiFi struck Honduras and killed 10,000 people. A year later Dr. Jorge Vivo, director of the Geographic Research Center at the University of Mexico, charged that the United States' Project Stormfury had used seeding to "artificially detour" the storm away from Florida and that thus the U.S. was responsible for the deaths and damage in Central America. The United States replied that Stormfury had done no seeding of hurricanes since 1971 but said nothing of other known experiments for altering hurricanes -- such as coating sea

surfaces with anti-evaporation chemicals like hexadecanol. Dr. Vivo presented little evidence to support his charges, yet his accusations were widely reported in Latin America and no credible scientific explanation or refutation followed. Because cloud seeding, whether from aircraft, shipboard, or burners on land, is difficult to detect, it could be carried out in virtual secrecy -- as it was for five years in Southeast Asia. Such accusations thus are likely to gain much public attention and to be taken as true.

Climate Modification

Had an international tribunal heard the charges by Honduras and El Salvador, the United States might in its own defense have pointed across the Atlantic Ocean to the African Sahel. In 1973 Ethiopia and the nations along the southern edge of the Sahara Desert were suffering in a drought that would, before its end a year later, cause the deaths of an estimated 400,000 people. The Sahel is at the same north latitude as Central America. Perhaps these droughts had a common cause in some global environmental distortion.

Weather has been anomalous throughout the world in recent decades. In addition to droughts in Africa and in the Caribbean region, North America has experienced record drought in the West, record cold in the East. In January 1977 snow fell for the first time humanly observed in Miami and in the Bahamas. England in 1975 suffered the worst dry period in 400 years. The extremes of weather elsewhere -- too numerous to mention here -- are too large in magnitidue and too widespread to be dismissed as routine variations.

These extremes, some scientists suggest, may be symptoms of what could prove to be a rapid change now underway in global climate. A few scientists conclude that they are the chills and fevers of a planet catching cold. A report by the U.S. Central Intelligence Agency made public in 1976 shares this view. Measurements taken in the Northern Hemisphere show that between 1940 and 1970 the average annual temperature fell 1^{o} Celsius. Crudely speaking, this average represents the balance between winter and summer on our planet, and the balance has been tipping in favor of winter. The heavy mass of cold air above the Arctic has expanded, and this has squeezed various distortions into the jet stream and other world-circling wind currents -- and thereby caused huge hot and cold, wet and dry, weather anomalies in many regions.

If this cooling trend were to continue unabated, a report by the U.S. National Academy of Sciences said in 1975, a new ice age could theoretically be upon us in as little as 100 years -- arriving not with slow-moving glaciers, but with snowfall that would begin earlier in winter, end later in spring, and eventually would linger on the land yearround. We already live in an Ice Epoch -- a period when the polar regions of the planet are locked in ice. An Ice Age merely involves an expansion of

area thus covered yearround with ice and snow.

On the other side of the planet, however, measurements indicate a warming trend, although not enough of one to offset a falling global average. The Southern Hemisphere, according to data from relatively few monitoring stations, may have warmed 0.5° Celsius during the period 1940-1970.

Why has the Northern Hemisphere cooled? Dr. Reid A. Bryson, director of the Institute for Environmental Studies at the University of Wisconsin, has suggested (6) that the particulate pollution from factories, automobiles, and other sources has blocked sunlight that otherwise would have passed through our atmosphere to warm the Earth. Measurements made in the United States and Soviet Union confirm that the amount of sunlight reaching the ground in both countries has diminished by 5 percent between 1950 and 1970. This loss, equivalent to 10 minutes of solar energy per day, could help explain the rapid cooling phenomenon -- and could explain why this cooling seems centered high in the Northern Hemisphere, where the major industrial centers of the planet, and hence their pollution, are located.

Other scientists noted in the N.A.S. report that the cooling may simply be a return to normal conditions on this planet. The weather of this century, which we tend to think of as normal, is instead shown by fossil records and isotopic studies of ice cores to be the warmest period of the past 7000 years. The cycle patterns in fossil records also show that warm episodes like the one in which we live tend to be infrequent, being typical of global temperature averages during only 2 percent of the past 450,000 years, five percent of the past 700,000 years; they tend to be short, lasting typically only a century or two at most; and they tend to end abruptly, with temperatures falling with the kind of rapidity evidenced in the cooling trend since 1940.

A vocal minority of scientists discounts the cooling trend as a temporary aberration in what they say will be a continuation of a Northern Hemisphere warming trend in evidence from 1890 until 1940, the peak of which marked the Dust Bowl years of the mid-1930s in the United States. In the view of these scientists, natural systems of slow to tip unless human activity influences them. Human activity since 1890, they contend, has had a strong influence in favor of planetary warming. Human activity obeys the Second Law of Thermodynamics, whereby all use of energy is eventually degraded to heat. As we have used increasing amounts of energy, the amount of heat pollution added to Earth's environment has increased and is already tipping natural balances. A far bigger factor than heat is our use of fossil fuels, a by-product of which is the release into our atmosphere of CO_2. Carbon dioxide is assumed to enhance the atmosphere's so-called "Greenhouse Effect," the ability to retain heat in the biosphere by retarding its escape back into space. Soviet climatologist Dr. Mikhail Budyko (7) has produced computer models of planetary energy systems that suggest our most severe concern with climatic change should be the increase in atmospheric carbon dioxide. In 1900, CO_2 made up 290 parts per million in our atmosphere; it had

increased to 330 ppm by 1971 and is estimated to be 379 ppm by year 2000. (8) Budyko anticipates that soon the polar icecaps will begin a hasty retreat, and that within 100 years seacoast cities will be threatened as water now locked up in its solid form on masses of land like Antarctica begins to rush back into the oceans.

It would seem that either Bryson or Budyko must be wrong, but this is not necessarily so. As Dr. Stephen H. Schneider of the U.S. National Center for Atmospheric Research has said (9), particulate matter thrown into the atmosphere tends to remain in the general latitude of its source. Carbon dioxide, on the other hand, tends to mix evenly with atmosphere throughout the planet. Thus the CO_2 added to our atmosphere may be adding to the Greenhouse Effect of the entire world, but in the Northern Hemisphere its resulting warming has been more than offset by the loss of solar energy caused by dust in the atmosphere.

Knowing this, we now can consider some new problems in how iceberg utilization can be perceived as influencing environment.

Dr. John L. Hult and others have repeatedly referred to icebergs as a renewable resource, rather like the icecubes in the family refrigerator. Until recently, when questions have arisen about the stability of this planet's climate, this assumption seemed self-evidently true. The ice mass of Antarctica is vast, and each year only 1/10,000th of the mass is calved into icebergs which drift slowly away to melt in warmer seas.

But even if none are towed away for use, Antarctic ice may be diminishing. Whillans (10) has calculated that for at least part of Antarctica -- the West Inland Ice Sheet -- ice is flowing out to sea 15 percent faster than it is being replenished by precipitation. As we meet here in conference in the Northern Hemisphere at summer's end, 1977, Antarctica has been experienced the warmest winter ever monitored.

In our eagerness to bring water to a thirsty world where, as U.N. investigators say, deserts are growing, we may have forgotten a simple fact: *much of Antarctica is also a desert*, for it receives very little precipitation to replenish its snow and ice cover, which it took millions of years to acquire.

In other words, *we are talking about taking ice from a desert as well as bringing it to deserts.*

We have forgotten, too, that although ice seems commonplace on our planet, the solid form of H_2O is -- over the longer geologic timespan, one of the *rarest* resources on our world. Out of every 200 million years during the past billion, only 5 million have featured ice overlaying the North and South Polar regions. Scientists are uncertain why this is so. One theory holds that ice formed only when the poles lay over a landmass or enclosed sea like the Arctic Ocean. Whenever the poles have reversed or shifted (as they have at least 171 times in Earth's history) and have settled with open oceans above them, warm waters circulating from tropical

regions could reach them and prevent ice from forming.

Thus in times when dinosaurs roamed the world, our planet probably had no ice on it whatsoever. Sea level was as much as 120 meters higher than it is today, and a short way from Ames, Iowa, where we sit today, dinosaurs with fins splashed in the inland seas of Kansas and Nebraska. Tropical plants and animals laid down their bodies to make oil, which we find today in a far different world: in non tropical environments like Saudi Arabia and north Alaska. Those living things of 100 million years ago were breathing an atmosphere far different from ours, an atmosphere richer in carbon dioxide...a bit more like the atmosphere found today on our hot sister planet Venus. Thus their warmer planet may have been warmer because of the enhanced greenhouse effect of this CO_2-rich atmosphere.

The carbon dioxide was devoured in two ways. The seas spawned a kind of plankton that converted the gas into limestone, from which it fashioned protective shells. These plankton depleted CO_2 from the atmosphere. Climate consequently cooled, and the creatures diminished in numbers in the cold. On land, plants and animals incorporated carbon dioxide into their bodies. Just as CO_2 remains locked up to this day in vast sedimentary deposits of limestone, so too, much remains imprisoned in fossil fuels like oil and coal.

What this means is simple: *when we burn fossil fuels, we are to some degree recreating the atmosphere of millions of years ago, when the planet was tropical and ice-free.*

As industrialization continues on our planet, both CO_2 and heat pollution are likely to increase. If warming continues in the Southern Hemisphere, consideration will have to be given to the idea that Antarctic ice will no longer be replenished naturally. It is conceivable, if improbable, that ice could itself become a scarce resource, that ocean levels will rise by more than 100 meters, that many cities and places -- e.g., Florida, the Netherlands -- will be submerged and that latter-day Noah's will be carrying on a brisk trade in small icebergs towed behind floating cities.

If Southern Hemispheric warming continues, then its *ice must be viewed as a diminishing, not an incessantly renewed, resource.*

On the other hand, if the Northern Hemispheric cooling trend of recent decades continues, the towing of icebergs to climates where weather is deteriorating may be viewed as giving aid and comfort to Jack Frost. Any activity which diminished heat in a region or caused increased precipitation might be viewed unfavorably.

Dr. Joanne Simpson has presented good evidence that icebergs off the coastline of Florida could potentially cool ocean surfaces enough to weaken hurricanes. I would go a step farther and warn that such icebergs could also slightly weaken the heat transport of the Gulf Stream. During America's Revolutionary War against

Great Britain, colonial scientist Benjamin Franklin proposed damming the Gulf Stream as a way to victory. This ocean current travels north along the East Coast of North America, bends across the North Atlantic, and splashes its remaining warmth against Western Europe. Were that current blocked, or even weakened, Europe would be severely colder, argued Franklin, and modern science confirms his accuracy. But this gives European nations a stake in any towing of icebergs to Florida, and a similar dependence on existing ocean currents by dozens of nations could involve any utilizer of icebergs if these nations saw hazard in small modifications of ocean currents. This could include small redirections of a current -- such as prompted a "cod war" between Great Britain and Iceland during the past 15 years as cooling global climate pushed equatorwards the center of the Gulf Stream's North Atlantic Drift south of Iceland. It could also include changes in upwelling currents, like the El Niño off Peru...a change in which in 1973 devastated the anchoveta harvest and hence the Peruvian economy.

Could the transport of one or a few icebergs have such effects? Probably not, but a more important issue is that this could be *perceived* as a cause of environmental changes. That such an iceberg project will cause some tiny, subtle changes is undeniable, so the argument becomes one of degree, and this is important to keep in mind, for tiny changes can be significant. Simpson has estimated that a sea surface temperature change of as little as one-half degree Celsius can transform a hurricane under some conditions into a mere tropical storm. In climatic terms, in the region here of Ames, Iowa, the average summer temperature at the height of the last Great Ice Age 23,000 years ago was perhaps only 3°-4° Celsius colder than it is today. Budyko's calculations suggest that a new ice age could be initiated by a hemispheric temperature drop of only 2° Celsius -- merely twice what has been seen since 1940.

As you can now see, huge environmental changes can be matters of degree -- and small degree at that. Thus, to limit international hostility, some form of international oversight and environmental evaluation should be involved in all efforts at iceberg utilization. Such international involvement need not entail ownership or control, but it should provide a comprehensive ability for nations to collect data concerning the environmental impact of iceberg use. Among the things to be monitored: (A) any utilized iceberg's impact on wind currents, precipitation, and evaporation patterns; (B) its impact on ocean currents, their heat transport and upwelling patterns; and (C) its impact on the total polar ice mass. Ways and means might be discussed and evaluated of augmenting precipitation in Antarctica to alter its ice equilibrium.

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