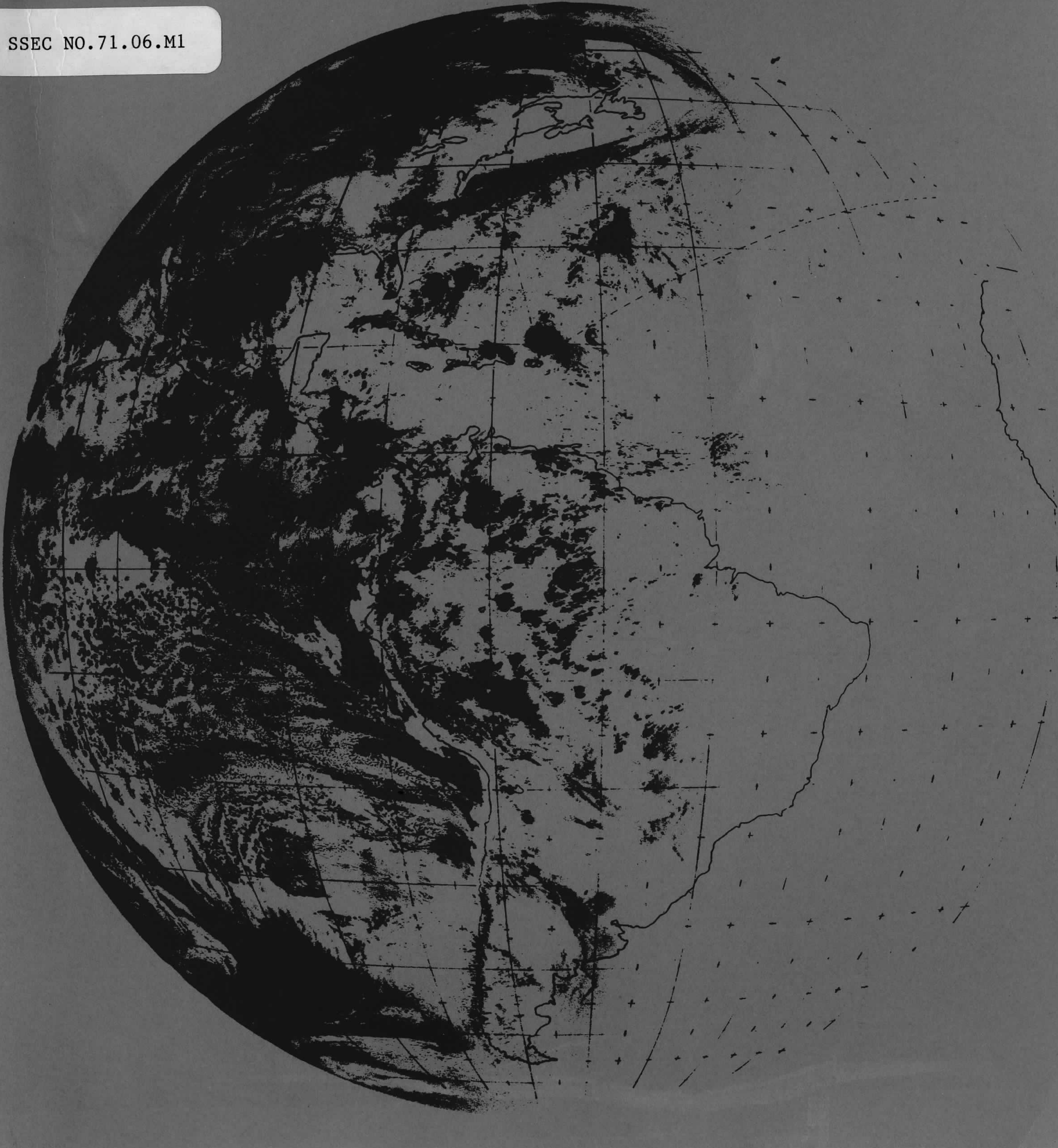
multidisciplinary studies of the social, economic, and political impact resulting from recent advances in satellite meteorology

an interim report
volume one
space science and engineering center
the university of wisconsin
madison, wisconsin



Space Science and Engineering Center
The University of Wisconsin
Madison, Wisconsin

MULTIDISCIPLINARY STUDIES OF THE SOCIAL, ECONOMIC AND POLITICAL IMPACT RESULTING FROM RECENT ADVANCES IN SATELLITE METEOROLOGY

Interim Report on

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Volume I

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PREFACE

The multidisciplinary studies undertaken under this NASA grant explore and evaluate the impact of the meteorological satellite and the concomitant impact of the data derived from it on various user groups. As expected, the primary impact related to those who would use satellite data for weather prediction and related purposes. A secondary impact was in the area of international concerns where GARP and other international meteorological activities were affected and international law was developed. A tertiary impact was exemplified by satellite photographs utilized in advertisements and related materials. However, this impact has not as yet been treated in detail given the scope of our research. The determination and analysis of these impacts are extremely significant in that this data will help guide the development of NASA meteorological satellite systems in the future. The case studies, supporting studies, and independent studies all emphasize the potential of the meteorological satellite, and from these findings it can be seen that there is a wide scope for continued research approached from the perspective of the user.

We wish to thank Nancy Bauch, Linda Mangum, Sandra Noe, Patricia Luetgert, and Harold Oxley for their help in the preparation of this report.

Additional thanks go to Professor Bruce Lusignan who was responsible for initial organization of the interdisciplinary team approach, and to

Miss Justine Dakin who served as project coordinator and was responsible for following up the initial participant contacts and preparing work assignments. A further note of thanks goes to Mr. Tom Haig for his participation in the review process on the project.

Verner E. Suomi
Delbert D. Smith

MULTIDISCIPLINARY STUDIES OF THE SOCIAL, ECONOMIC AND POLITICAL IMPACT RESULTING FROM RECENT ADVANCES IN SATELLITE METEOROLOGY

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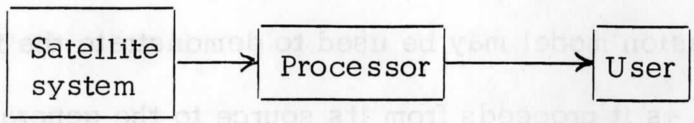
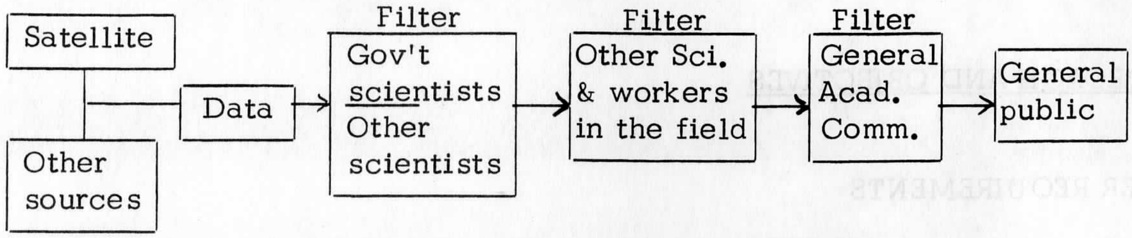
APPROACH AND OBJECTIVES

USER REQUIREMENTS



The meteorological satellite serves as a primary source for the data that is eventually put into the hands of the user. The approach of the multidisciplinary team in this project was to begin with the user and to work back in order to eventually be able to make suggestions as to the design and development of future satellite systems. It is important that the meteorological satellite system development be responsive to users' needs since ultimately it is the satisfaction of these needs that justifies the system. Such a system should possess the ability to respond to a wide variety of users who will be increasing in number. It should also be able to serve a wide variety of users who have both general and specific needs. There should be an ease of access to the data and there should be sufficient flexibility in the system to enable it to alter to meet new needs.

One difficulty in trying to develop an optimum system is that the users that might use an improved forecasting service are not ordinarily self-motivated to seek the data. The mass media have been used to somewhat increase the availability of the data, but no attempt has been made to ascertain from the media viewer whether this is what he really wants and needs.



This data/diffusion model may be used to demonstrate the fact that data is altered in form as it proceeds from its source to the general public. At the first level there are not any particular difficulties because the users are self-identifying and thus probably have a direct effect on the changes and improvements to be made in the satellite data acquisition systems. However, as we proceed through the filters towards the general public it becomes more difficult to affect or alter the data source. Along the above chain the data is also processed and the ultimate user of the raw data (e. g., a satellite picture) may not be the ultimate user of the processed data.

Thus it was one of the purposes of our study to examine the needs of the users in the general public category. Users generally are not aware of the possibilities for improving weather information and therefore they do not attempt to initiate any changes. In fact, there could even be some user resistance to change which has to be overcome by clearly presenting the opportunities that could be made available through the new satellite technology.

What we are really determining in this project is not only user needs but also user behavior. By applying the expertise available in various disciplines we are able to analyze this behavior and thus come to a truer picture of actual needs. For example, the use of agricultural specialists from the

University enable us not only to ascertain users needs but also to determine unarticulated needs which the satellite can fulfill.

The use of field studies to determine users' needs and specifically how a user goes about interrogating a weather distribution system for information is the best technique for our purposes. By using the additional techniques of oral interviews and questionnaires and bringing users together for meetings, we were able to optimize our research findings.

Therefore it is one of our research parameters that not only should the user be made aware of the best way to use satellite data but that also there should be a user input which would contribute to the best development of the system—in this case the meteorological satellite.

The values to be gained through user-oriented research include an improved use of our natural resources, a reduction of damage to people and buildings from disasters, an increase in economic gain in the agricultural and other sectors, a reduction in uncertainty and a greater ease of planning for various sectors of our society. There are many other secondary benefits which will follow from a greater user recognition of the potential of the meteorological satellite.

There is also of necessity a time factor involved in any user-oriented study. When we first made contact with various user groups we received an initial response. To a large extent this response was based on a complete lack of knowledge or understanding concerning the satellite. As we proceeded with our interviews and other forms of user contact, an education process was taking place. Users' needs were actually created. The awareness of the possibilities of the satellite created needs in areas that had not been given any prior consideration. In this sense the researchers acted as linkers between the user and the originator of the data.

This basic linking function, as described by Haas[1] and which has also been utilized in communications theory for some time provided for us a focus for the collection of data relative to users' needs. One of the ultimate goals of our research is to identify the relevant linkers with reference to the production and use of meteorological satellite data. Here again our case study experts served an educational function as they translated the technical terms associated with the satellite for the various users' communities. In the course of our research we reaffirmed our feeling that the existence of the data does not insure its utilization and that a comprehensive linking function must be present.

One of the more difficult problems to be faced by NASA and other decision-making agencies once users' needs relative to the meteorological satellite are known will be to select priorities. Which of the users' needs will be met if they are mutually exclusive. For example, is a short- or long-term

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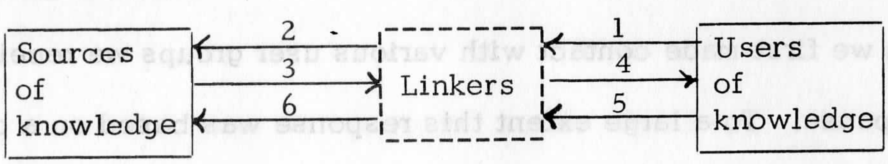
(1)



See Draft Report of Panel on Dissemination, CAS Review of Atmospheric Sciences, 1970.

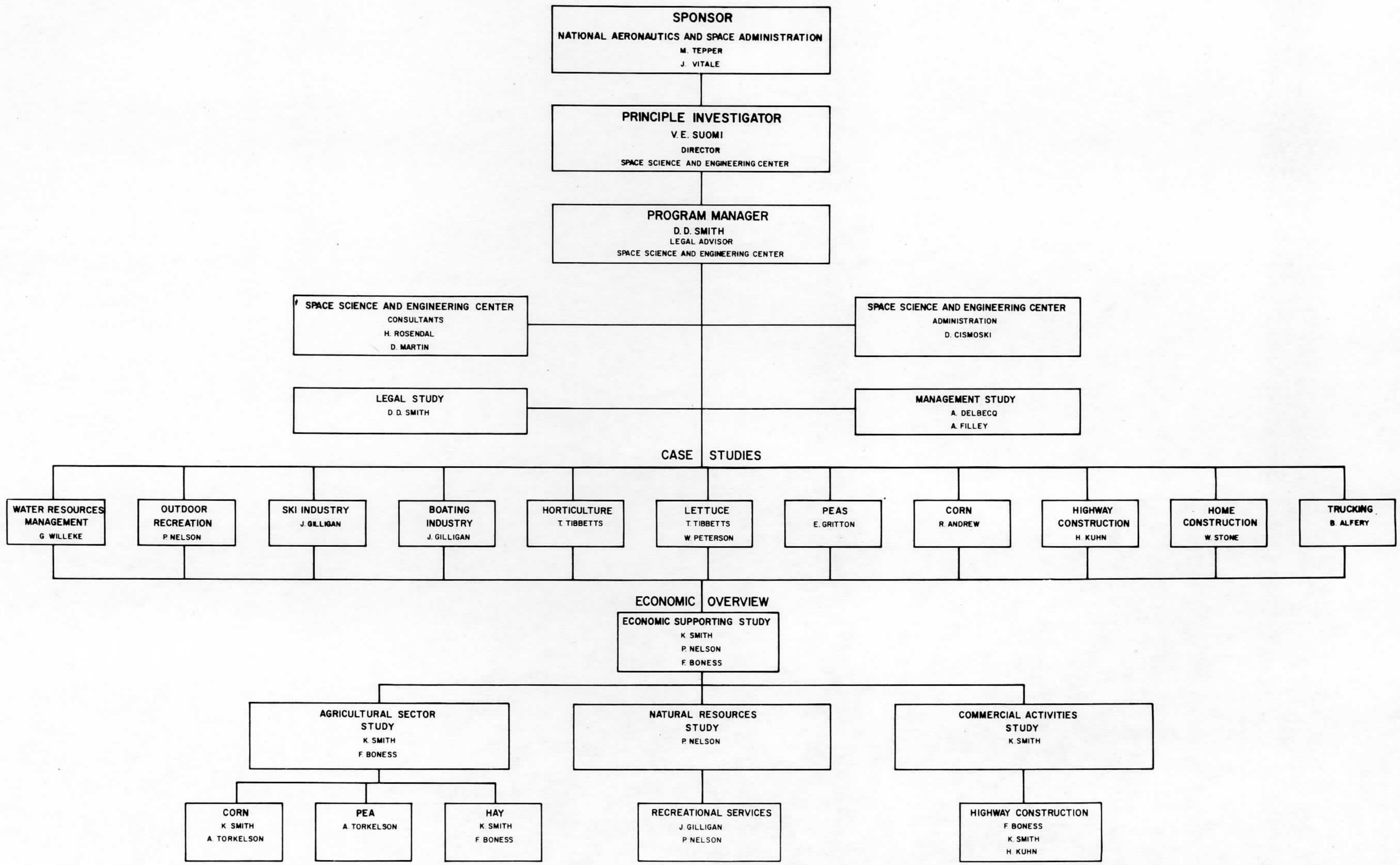
forecasting capacity of primary importance?

On asking the question, "What is the impact of the meteorological satellite program on society?" one is immediately faced with a wide number of possible choices as to how to proceed. Since ultimately this report will find its primary value in terms of its impact on NASA's mission, one objective of this study is to influence both NASA's hardware and its software activities in the meteorological satellite area.

INTRODUCTION

In a 1964 study undertaken by the Weather Bureau for the Federal Council for Service and Technology, Interdepartmental Committee on Atmospheric Sciences, it was stated that resources devoted to "systems" and "synthesis" research were "glaringly inadequate and in need of adjustment." The recommendation was that there should be "... significant increases in funds for research—to improve the link between the meteorological service and the users of weather information," and that there should be established "... immediately, a long range program of research on the economic and social impact of weather information on all segments of our society." It was also urged that this research "... should explore, quantitatively, the needs of user groups for weather information, the sensitivities of these groups to weather events, and the nature of the decision processes which are dependent on weather information."

The increasing use of meteorological satellites for providing weather information has greatly strengthened the need for user studies—synthesis research—to be conducted. Further, there has been a general recognition by the National Aeronautics and Space Administration of the need to conduct user-oriented research pertaining to the applications of meteorological satellites, and of the concomitant need to provide stable conditions for this research. As was said in a letter from NASA to the University of Wisconsin (February 26, 1969), "... the optimum return on investment for research is from that done under stable conditions which retain highly qualified investi-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gators . . . and maintain or strengthen the base of knowledge undergirding research in aeronautics and space science technology." The stable conditions necessary for research of this type were created when the Multidisciplinary Studies of the Social, Economic, and Political Impact of Recent Advances in Satellite Meteorology were undertaken by the Space Science and Engineering Center under the direction of Professor Verner Suomi in the spring of 1969.[1]

The purpose of the research was clearly stated in the original proposal: "The purpose of the proposed study is to provide a detailed analysis of the social and economic benefits of both accurate long-range weather forecasting and high-resolution weather observation, which we fully expect to attain in the next decade. These benefits are complicated by many factors. They appear in practically every sector of the economy. Many benefits appear as increased production of a commodity, but to determine the net benefit the market characteristics of that commodity must be understood. To fully exploit the potential benefits, the nation must receive timely weather information and act on it; the probability of the national response must be evaluated."[2]

[1]During the summer of 1968 a series of discussions was held with selected faculty members from the University to determine the areas within which to conduct case, supporting, and independent studies. These discussions were supplemented by an examination of national statistics to identify the most significant areas of economic activity affected by the weather.

[2]Proposal at 2-3.

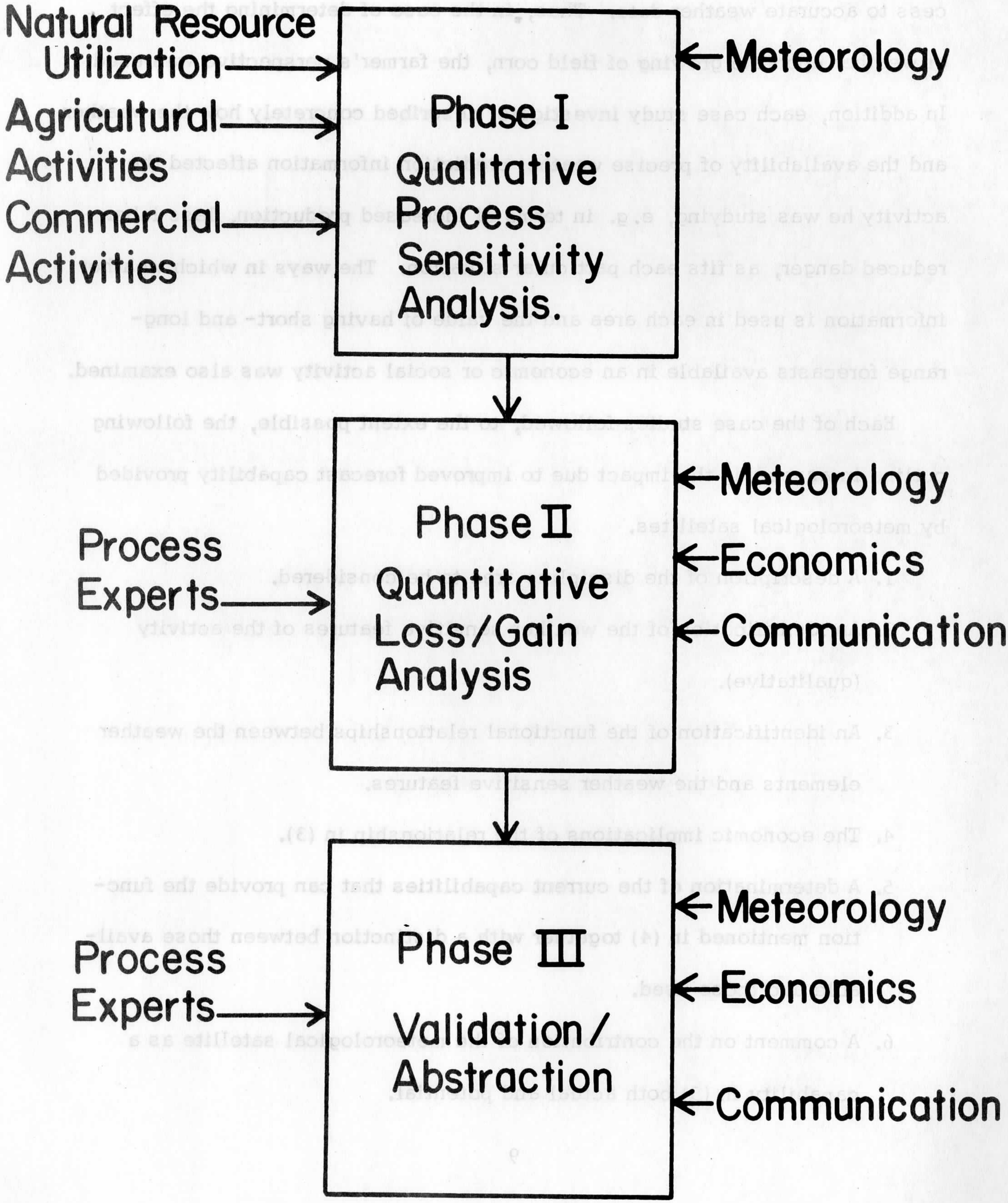
A multidisciplinary team of subject matter experts was selected from various academic departments within the University, and in addition, other specialists were selected from within the Space Science and Engineering Center to provide program management, consultative advice on meteorological matters, and independent studies. The administration of the study was also undertaken by the Center. In the areas of the case studies various professors engaged in research to determine the weather-sensitive parameters of their respective areas and the ways in which satellite meteorology could improve their situations. Existing data was analyzed and user contacts were made through the use of questionnaires and personal interviews. Meetings were held with user group representatives. Several meetings were held at which time various case study experts talked about their research techniques and findings and exchanged ideas with Space Science Center personnel.

The participating experts undertook individual case studies to determine the nature of the impact of the weather predicting capabilities provided by the meteorological satellite program upon their area of special concern and detailed where possible the annual cycle of human activity in their area and identified those times when weather affected their operations. The characteristic weather effects wrought by weather variations, the type and cost (if any) of preventive measures which must be taken as a protection against adverse weather phenomena, and the benefits derived from this protection were estimated. Each case study was described from the viewpoint of the individual most directly involved and affected by his access or lack of access to accurate weather data. Thus, in the case of determining the effect of weather upon the growing of field corn, the farmer's perspective was used. In addition, each case study investigator described concretely how the weather and the availability of precise weather prediction information affected the activity he was studying, e.g. in terms of increased production, less labor, reduced danger, as fits each particular situation. The ways in which weather information is used in each area and the value of having short- and long-range forecasts available in an economic or social activity was also examined.

Each of the case studies followed, to the extent possible, the following outline in assessing the impact due to improved forecast capability provided by meteorological satellites.

1. A description of the discipline area to be considered.
2. An identification of the weather sensitive features of the activity (qualitative).
3. An identification of the functional relationships between the weather elements and the weather sensitive features.
4. The economic implications of the relationship in (3).
5. A determination of the current capabilities that can provide the function mentioned in (4) together with a distinction between those available and those used.
6. A comment on the contribution of the meteorological satellite as a capability in (5) both actual and potential.

Interdisciplinary Approach for Case Studies



7. An estimate of the economic implications of (6).[3]

The Space Science and Engineering Center served as an information source for the studies undertaken. The Center by virtue of its specialized personnel and close association with the meteorological satellite program had the responsibility of working with project participants drawn from the many departments in the University. A number of individuals from the Center provided background information and technical information to the various members of the research teams. The Appendix contains material on the present data dissemination system. The Center also provided a library capability which was available to all researchers. By providing a central focus and coordination for the research, the Center fulfilled a necessary function.

Meetings and Seminars

In addition to the initial and early planning meetings that were held with study participants, the project manager has met with the participants and helped to maintain a coherence to the overall research design with guidelines for the preparation of the studies. Further, a seminar held at the Space Science and Engineering Center has provided an opportunity for feedback from the study participants and an interchange of ideas and suggestions to help guide the third year research. At the conclusion of the third year research, another review session will be held at the Center.

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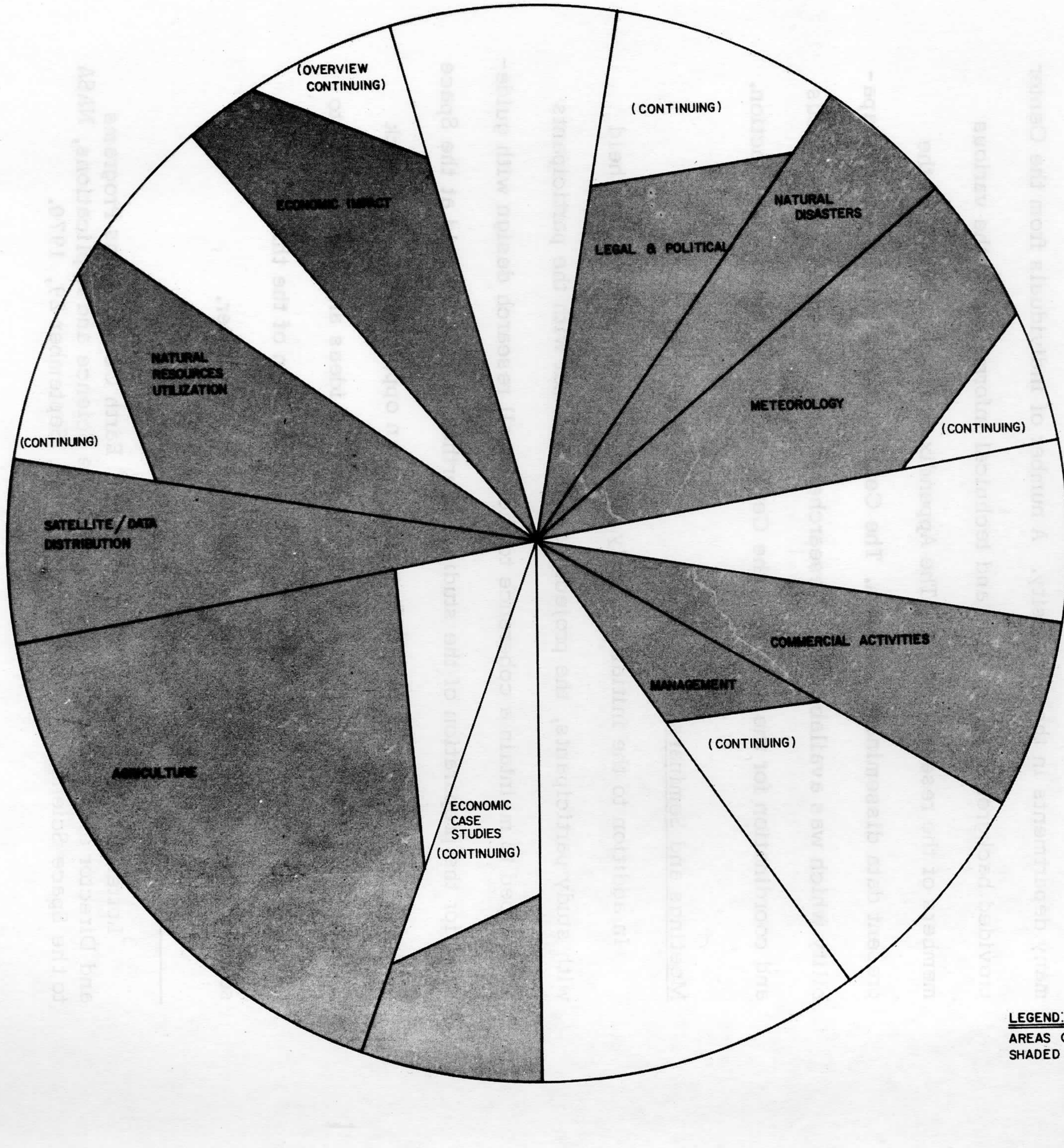
[3] Letter from M. Tepper, Deputy Director, Earth Observations Programs and Director of Meteorology, Office of Space Science and Applications, NASA to the Space Science and Engineering Center, September 29, 1970.



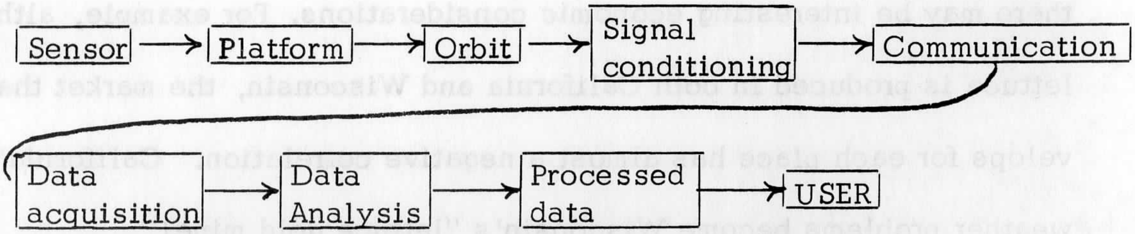
LEGEND:
AREAS COVERED BY THE MULTIDISCLIPLINARY STUDY.
SHADED AREAS REPRESENT WORK COMPLETED TO DATE

The pie chart above shows the areas which the study covered. The shaded portion of the sections which were studied is a rough indication of the magnitude and depth of the study in each area. For example, a significant number of our case studies were in the area of agriculture, and indeed some of these case studies were quite detailed since agriculture represents such a large fraction of our total economic activity. While this study covers only a fraction of the total agricultural activity of the nation it is a valid sample given the similarities of weather data uses for the various types of agriculture. However, even though this usage is similar we found that there may be interesting economic considerations. For example, although lettuce is produced in both California and Wisconsin, the market that develops for each place has almost a negative correlation. California's weather problems become Wisconsin's "lettuce gold mine!"

There were also areas of satellite impact that were not subject to quantification. For example, advertising is a form of communication and pictures of the earth obtained from geostationary meteorological satellites show up in a large number of advertisements.

The pie chart shows the area of meteorology shaded almost completely. Since weather information is the mission area of the meteorological satellite program, the emphasis is natural.

Any meteorological satellite program will have to be responsive to two considerations: the character of weather phenomena and the characteristics of the user's needs for weather information. The characteristics of weather phenomena are well documented in a number of recent studies (see, for example, Lorenz), but the characteristics of the potential users have not been studied as extensively. In this report we attempt to account for the main characteristics of weather phenomena as they might influence the user and our emphasis is user- or application-oriented rather than meteorological science-oriented. In a user-oriented approach one treats the subject in the opposite sense to that usually applied to a scientific or observational mission. In the latter instance the beginning of the hardware and software chain is usually the sensor as shown in the box diagram below:



In a user-oriented approach the output product is the first consideration. The key question is, "Does it meet the needs of the user?" The procedure we used to find the answer is the case study approach. Evidently the user, expert in his own area, ought to be best able to answer the above question.

THE RESEARCH DESIGN

The Independent and Supporting Studies

The social impact of satellite meteorology was examined in the study on the operational use of satellite data in hurricane forecasting. The detection and tracking of tropical cyclones have proven extremely valuable and definitely shows a value for meteorological satellites in averting natural disasters.

The independent study concerning the impact of satellite meteorology on political and international affairs considers the use of various sensors in a satellite system. As was stated in the original proposal: "Satellites and floating balloons do not recognize national boundaries; this means there will be legal and political questions concerning observing systems and in the decades to come, modification systems. These must be evaluated also." The use of meteorological satellites in conjunction with super-pressure balloons and ocean buoys is the subject of this study. Further work is being presently undertaken in this area which will cover liability questions regarding satellite data uses and evidentiary questions pertaining to satellite pictures.

The supporting study in economics contains an analysis of the agriculture section generally and also consists of specific economic analysis for corn and hay crops. Further, specific economic works are underway for other case study areas. These analyses attempt to gauge the economic value of improved weather data and also to determine the losses that could be averted through fuller utilization of weather forecasts.

The supporting study in communcations consists of a survey conducted in the agricultural sector to determine the ways in which the people obtain their weather information and the extent to which they understand and utilize the information that they receive.

The Case Studies

The case studies were undertaken to explore and evaluate the utilization of meteorological satellite data, the direct impact of this data on users, the national and international impact of the US. meteorological satellite program, and the potential impact of meteorological satellite data on users.

The major divisions within our case studies were (1) natural resources utilization and impact, (2) agricultural impact, and (3) commercial activities impact.

THE STUDY STATUS:

Case Studies.

Phase I	Phase II	Phase III
<u>Qualitative</u>	<u>Quantitative</u>	<u>Validation & Abstraction</u>
What is the sensitivity of process to weather?	What is value of weather losses? What is value of of perfect weather knowledge? What is value of feasible improvements?	Are results real? What are the limitations?

Supporting Studies.

Economic, Legal, and Communication.

Done ←—→ To be Done

GENERAL FINDINGS

The work conducted thus far has verified the intuitive feeling we expressed in the original proposal:

"...interdisciplinary studies like this do not come naturally despite the urgent need to have them. One one hand the scientists and engineers who design, fabricate and fly spacecraft and evaluate the data are thoroughly familiar with what space systems do for meteorology, but they are not familiar with how these new capabilities will affect the social and economic and political aspects of society...

On the other hand those who are familiar with social, economic and political aspects of society know little or next to nothing about what space systems could really do to help solve these problems. This information gap for both groups prevents one from obtaining the needed customer truth...."

WEATHER SENSITIVE PARAMETERS

While we were very surprised at the magnitude of the information gap, we found through our work that there were unarticulated needs that satellite meteorology could fulfill. Even though some users were completely unaware that meteorological satellites were even existent not to mention any familiarity with their products and how they might be useful to their needs, it was also apparent that the "two culture" separation that existed could be bridged by undertaking detailed analysis of users' needs. From these case studies we found that there are weather sensitive parameters for about 80% of the users studied and there are substantial economic benefits to be obtained from increased weather information in the majority (70%) of the cases studied. The existence of these weather sensitive parameters provided a first cut for our research and indicated to the case study researchers that further work would prove valuable. Thus, in order to evaluate user requirements in detail and to assess the impact of improved weather information whether from the present origination and distribution system or directly from a meteorological satellite without any system in between it was necessary to look into each case study area in some detail in order to extract the relevant information.

Each case study considered a specific function or task within a larger classification of types of activities such as natural resources utilization, commercial activities and agricultural activities. Case study authors met together with SSEC personnel to attempt to determine the scope and focus of their work within the bounds of the original research design. One purpose of each study was to isolate functions. In highway transportation, for example, the construction, maintenance and operation of a major highway for use by the private sector was broken down into a series of activities, operations and tasks shown in the chart below which was extracted from the highway construction case study report. It was possible from this chart and others giving a further detailed breakdown to identify the weather sensitive tasks, operations, and activities to further specify weather element or elements which were critical.

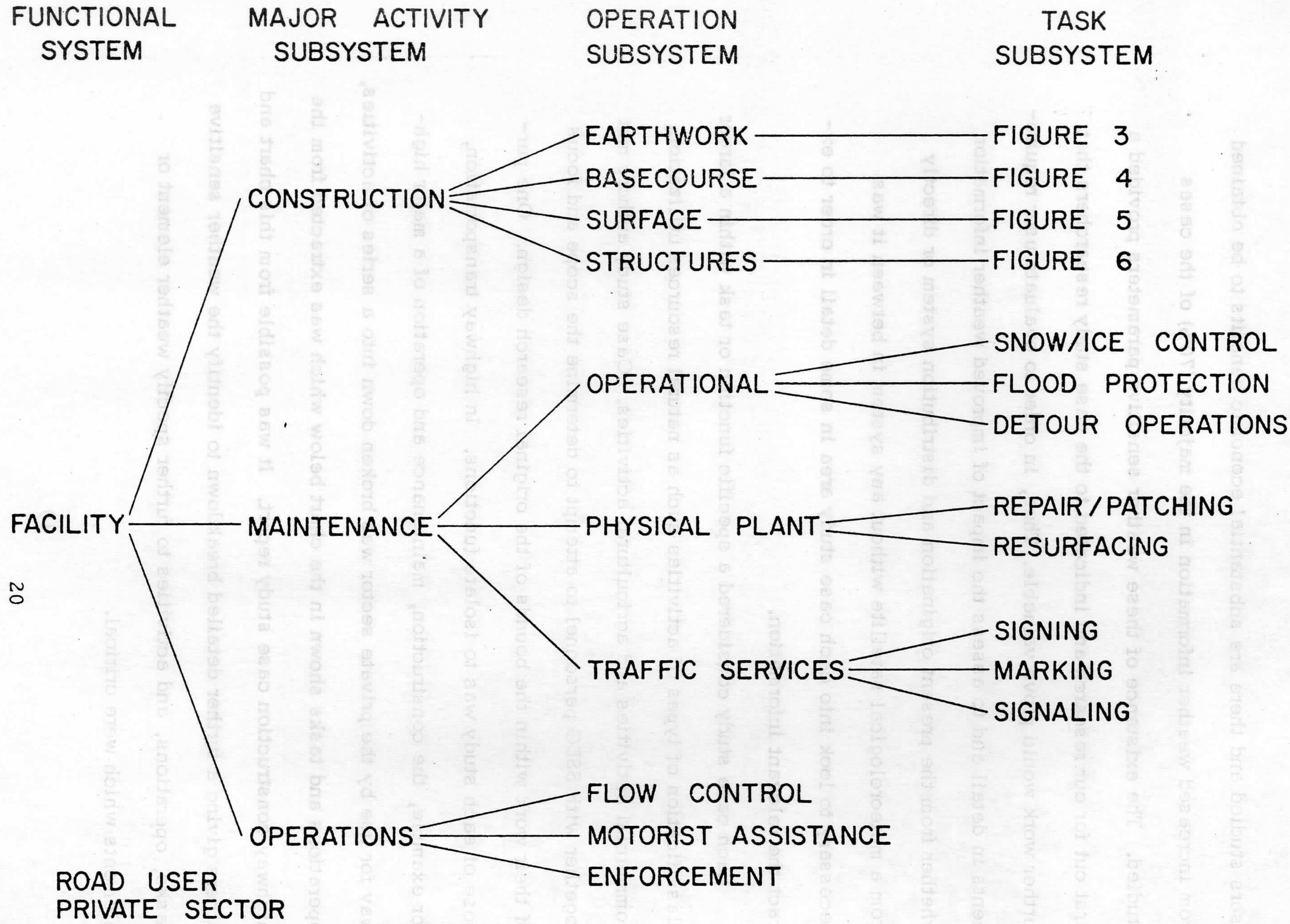


FIGURE 1
HIGHWAY TRANSPORTATION ACTIVITY SYSTEM

Not all case studies were divided in the way undertaken for the highway study but each case study used an applicable process to isolate the weather sensitive parameters. These case studies clearly showed that different weather parameters can be critical along the path from beginning to completion of the activity and also that the time scale required for the user to react in a useful way also varied over wide limits. It appears, thus, that the best way to meet user needs would not be to produce highly detailed data far in advance. To do so simply transfers the data storage and retrieval task to the user. Users' needs are specific both in time and data content. Predictions of those weather parameters which affect long lead time items are needed well in advance of the weather, but when short reaction time is possible the user would actually prefer being advised at a later date. In general, large scale weather phenomena can be predicted further in advance than can smaller scale phenomena. There is a tendency for users' needs to correspond with forecast capability, but unfortunately this is not always true. If the occurrence of smaller scale phenomena, such as hail, could be predicted sufficiently in advance, crops could be selected at planting time to avoid loss. Put another way, it may be argued that users' needs adapt to forecast capabilities only because other forecast options have not been offered. A specific finding of our work shows that even very short range information of severe weather (hours rather than days) has significant economic value. One need not provide any predictive information at all in this situation since merely communicating the present weather in some detail would be sufficient if it were received in a timely manner.

KEY INFORMATION FLOW

Still another finding of our work thus far emphasizes the great need for what Professor Eugene Haas has called the "linker." This individual must know enough about meteorology and about satellite observing systems as well as the needs of the user to be able to enhance the key information flow. We emphasize the words key information since the need for this data is obvious in the operation of a weather information service and is also critical in the design of the system. It is this latter fact that has not been widely apparent in the past and is in need of further application.

We shall illustrate this dual need for key weather information with two examples, one requiring medium-and the other short-range information:

A. The case study concerning the hay crop showed a very large potential economic benefit ($88 million on one crop, in one state, in one year) if a three-day spell of no rain could be predicted near the hay crop flowering date in early June. This crop needs a three-day no-rain period to dry after it is cut. The protein content of the crop is sharply reduced if the crop becomes wet after cutting. Upon looking at this statement in detail we learn that what is really needed is the specification of an effective drying index. Three days with no rain but extensive cloud cover may not be as effective as two days with no rain and bright sunshine. Since in summertime the satellite can easily indicate extensive clear sunny areas, it becomes apparent that satellite meteorology could have a significant impact in this sector of our agricultural economy.

B. In the case study on vegetable crops a need to predict calm wind conditions for spraying operations was identified. Except for very flat pressure gradients usually found near the center of a high pressure area near calm winds, it is almost impossible to predict calm wind conditions from gross weather features alone. In the midwest, a calm or light wind condition can exist in early evening even with fresh winds a few hundred feet above the surface provided the sky is clear. Surface cooling by strong back radiation stabilizes the atmosphere and decouples the surface layer from the windy layers above. Satellite cloud images—particularly IR images—provide the key information needed here and thus could improve the economic situation for another agricultural area.

It would be unrealistic to expect every agriculturalist to become an expert in quantitative boundary layer physics and be able to derive the key information needed himself, although he is a pretty good amateur micrometeorologist from experience. Thus a linker is needed to interpret what could be available and match this to the expressed needs in order that the agriculturalist be able to reduce his costs and maximize the benefits.

Most of the case studies show several similar specific short term information needs and this area of weather data dissemination is clearly identified as needing additional study both to establish the impact of the requirements on the design of meteorological satellite systems, and also to project the greatest benefit to the user. We expect to undertake this task and to complete the meteorological interpretation during the next work period. We will build on our current findings to proceed back along the chain from the user to the satellite system to NASA.

THE CASE STUDIES

Following is a brief description of the case study work carried out in each division, and an assessment of the relevant weather sensitive features. This latter point illustrates by implication the extent of specific users' needs for improved weather data of the type that could be provided by a meteorological satellite.

Impact of Satellite Meteorology on Natural Resource Utilization

Society is beginning to place increased emphasis on the impact that public expenditures have on the quality of the environment and the quality of life. The three case studies in this section focused on the manner in which advances in satellite meteorology will affect our utilization of natural resources. Differences in their methodologies reflect the different types of information being sought.

Water Resources. The first study examined the ways in which long range weather forecasts could be used to improve the management of our water resources. Topics addressed were hydroelectric power generation, flood control, treatment of waste effluent, urban water supply, irrigation, and navigation. Interviews with water resource managers were taken to obtain a clear picture of the different processes by which these resources are managed and to identify the particular types of weather information that would be of most value in improving resource management.

Improved Resource Management—An interesting observation noted in the study was the competing objectives of some multiple purpose reservoirs. A given reservoir might be used for flood control, irrigation, and hydroelectric power generation. A reservoir is most valuable for flood control if it is full, and the demand for irrigation releases does not necessarily coincide with the demand for power. Weather information thus can be used, and in some cases is used, to forecast the need or demand for all three functions. To the extent that these requirement forecasts can be improved, long range weather forecasts will be of significant value in improving the management of these multiple purpose facilities. Satellite meteorological data could greatly increase this capability.

Information Dissemination—An important consideration is the appropriate method of disseminating weather forecast information. The water resources study points out that some water resource managers could utilize direct telecommunication of weather data to their computers. Other managers could benefit from less rapid but more specially tailored information. Therefore meteorological satellites coupled with a satellite assisted telecommunication system could greatly affect this user area. This research is complementary to the legal research currently being done to determine the most efficient institutional process through which appropriate weather information is provided and perhaps interpreted for the many different types of users without at the same time involving the disseminator in a legal liability for incorrect forecasts.

Weather Sensitive Features—There are many uses of satellite meteorology in various areas of water resource management. In the field of power generation, long-range weather forecasting can be useful in increasing the supply of electricity, predicting demand for power, and scheduling maintenance of power generating systems. The amount of energy which can be produced depends upon the amount of water available and the head at the time of power generation. Both of these factors are dependent upon precipitation, evaporation which is closely linked to temperature, seepage, snowmelt, and other hydrolic factors. If these weather conditions can be accurately forecast, more energy can be developed from available water by reducing the amount of water spilled and by generating at higher heads.

Temperature, cloudiness, wind and precipitation affect the demand for power. Foreknowledge of these weather variables would be significant in predicting load size. This information could enable operators to reduce water wastage and the necessity for emergency measures to provide power.

Periodic maintenance of power generating systems sometimes entails shutting down a facility completely. Advance knowledge of low demand periods would aid in scheduling maintenance.

Forecasting weather information has varying effects on different kinds of hydroelectric facilities and operating systems. Accurate weather forecasts provide a basis for planning and coordinating work for a more efficient and profitable operation. For example, in the important process of predicting the amount of water flow, or resource availability, satellite meteorology could provide such pertinent information as areal snow coverage, snow depth and water content. If soil moisture measurements from satellite information were more accurate than the indexes of soil moisture content which are calculated from precipitation and evaporation data, the improved information would be worthwhile.

The aggregate potential value of a 10-14 day forecast for the amount of water, power load and maintenance is estimated at 2-3% of gross sales. When this dollar amount is applied to the gross expenditures for power generation, the dollar value which would be saved potentially is very large.

Flood damage reduction

Long-range weather forecasting could be important in reducing flood damage. If accurate predictions of flood conditions are available, flood warnings can be issued so that measures can be taken for evacuation and temporary flood-proofing. The advance warning could prevent losses of life and property. Advance knowledge of flood conditions also provides data for more efficient operation of flood control facilities. For example, if reservoir storage space is saved for a period when the flood peak will be reached, the reservoir will be more effective in minimizing flooding. Prior knowledge may also enable operators to manipulate channel facilities to reduce flood damage. An approximately 12-

hour warning is crucial to effective operations of channel controls. Advance warning of flooding would permit repair, strengthening and maintenance of levees before the onset of a flood, and materials and labor for flood fighting could be mobilized.

Satellite meteorological data on storm patterns and expected precipitation could increase the accuracy of flood prediction for small urban areas, where classical flood forecasts have not been effective. With accurate forecasts, maintenance programs could be initiated in municipal areas to reduce flood damage. A quantitative prediction of precipitation is important in projecting the runoff process which affects flooding. If the precipitation is in the form of snow, temperature forecasts are necessary for predicting snowmelt rates.

Physical, economical, institutional and legal factors may in some cases constrain the use of procedures which would minimize flood damage, but additional and more accurate forecasting information potentially could prove a major resource in reducing flood damage.

Water quality management

Forecasts of weather and streamflow are potentially significant in water quality management. Predictions of streamflow would allow regulated storage of wastes based on the varying capacities of receiving waters to accommodate waste effluents. During storm periods, waste treatment plants are often subjected to much higher flows than usual. Advance warning of storms would allow plant operators to plan for temporary storage of storm waters for later treatment. Future knowledge of waste characteristics, such as temperature, would enable operators to improve planning of waste processing. Most of the benefits listed could be achieved with forecasts currently available, but these forecasts are not being used.

Accurate 12-24 hour forecasts of precipitation would be useful for the operation of some urban storm sewer systems. In some cases, flow could be diverted to various parts of the system so that no one part overflows.

Although significant benefits could be realized from forecasts in water supply for municipal, industrial and agricultural uses, the value of such forecasts is variable depending upon the hydrological situation in a particular area. Advance weather information can be useful in irrigation planning, since water supply and irrigation demand can be predicted. Storm and precipitation forecasting would be pertinent information. If the precipitation falls as snow, significant parameters in the runoff season would be temperature and quantitative precipitation.

Satellite meteorology could provide data on areal extent of snow coverage, depth of snow and water equivalent of snow pack, which would be useful in predicting runoff.

Accurate weather forecasts would benefit navigation in the classic ways of predicting storms which might cause ship loss and providing information for estimating length of navigation seasons in waterways susceptible to freezing. Temperature is useful in predicting ice formation and breakup. Both temperature and precipitation aid in water flow forecasts, and information on wind direction and velocity is a significant factor influencing operation aspects of navigation.

Outdoor Recreation—The second study seeks a different kind of information. It attempts to predict how better weather information will affect adult participation in some twenty forms of outdoor recreation typically engaged in away from home. To make this prediction, the study uses questionnaire data from people who are known to actively engage in outdoor recreation. Information on household recreational planning horizons, vacation selection patterns, and major recreational possessions is used to delineate the boundaries within which households could be expected to change their behavior. This information, plus indications of probable increased recreational participation and information on the sensitivity of particular forms of recreation to weather, are used in a model to predict changes in recreational participation. This type of methodology avoids placing heavy reliance on respondents' opinions concerning their future behavior.

An increasingly important consideration in the evaluation of public expenditures is which segments of society will benefit from the expenditure. By examining the socio-economic characteristics of those respondents predicted to increase participation most, the study infers that all classes of people who currently participate in outdoor recreation will benefit in about the same degree from better weather information. However, since some classes of people, such as the urban poor, do not currently participate in the forms of outdoor recreation considered in the study, it must be remembered that better weather information will not necessarily improve the frequency of their participation.

The section on the qualitative aspects of recreation and weather presents substantial new information. Topics addressed include the degree to which specific types of recreation are sensitive to weather, types of weather preferred for different activities, and activities spoiled by rain. It is interesting to note that different people prefer a wide variety of different types of weather for hunting, fishing, camping, and hiking. To the extent that the satellite could provide this specialized information it could increase user expenditures and thereby benefit the economy.

Of special interest is the section in crowding and congestion of recreational facilities. The study provided predictions by both managers and users of ski facilities on the effect of one-week forecasts. This ties in closely with the next study on the skiing industry.

Weather Sensitive Features—A study conducted as part of this project sought to determine the impact of accurate one-week forecasts provided by satellite on participation in outdoor recreation. Data was gathered by a mail survey to households. According to the study results, advance weather information would increase national participation in outdoor recreation by 5%.

Persons engaging in outdoor recreation generally have specific ideas about the weather they prefer for a particular activity, but individuals do not agree on weather preferences for the same sport. Over a fourth of the respondents in the survey indicated that during the past year a recreational activity had been spoiled for them by unanticipated bad weather. Rain was the major weather variable which spoiled planned outdoor recreation. The study suggests that accurate one-week forecasts would almost eliminate experiences where planned outdoor activities are ruined by unfavorable weather.

Other data from the survey indicates that the number of participants in the following sports would increase 5 to 10%: fishing, camping, outdoor games and sports (especially golf and tennis), sport flying, water skiing, hunting, horseback riding and sailing. The study predicts that advance information of ideal weather for skiing would lead to crowding and congestion in ski areas.

Many skiers, sailors, fishermen and hunters prefer special kinds of weather for their recreational activity, and the improved data would enable them to plan trips to take advantage of such weather. Accurate one-week weather forecasts would aid people in selecting recreational clothes and equipment, in driving and in locating wildlife.

A Recreation Industry—The case study on the skiing industry uses interview and questionnaire information from recreation facility managers to investigate how long-range forecasts will affect the management of this recreational facility. The study focuses on the manner in which recreational resource management and planning are currently influenced by weather information and how they might be influenced by better weather information. Specific weather information requirements and methods of dissemination are identified. Also considered are the specific types of managerial decisions which could be improved through better weather information.

Of special interest is the impact of better weather information on recreational facilities of different sizes. The ski study states that the majority of ski operators predict that there would be more skiers as a result of favorable forecasts and fewer skiers as a result of unfavorable forecasts. Thus improved weather forecasts would affect the industry. It was also found that large ski facilities were better capable of adapting to the predicted change in usage pattern than small facilities.

Taken together, these three studies provide a comprehensive analysis of how better weather information will affect the utilization of our scarce natural resources and stimulate improvements in their management. They have identified the specific weather variables which are of most importance in the areas studied. They have also noted that the response of managers and the public to the availability of better weather information will not be immediate. It will take time for people to be convinced of the reliability of the forecasts and to adjust their decision-making process and behavior accordingly. The speed and extent of the response will surely be dependent on the precise types of meteorological information which can actually be made available and the degree of confidence which can be placed in forecasts supported by this information.

Two general problems are suggested by the studies. The recreation studies have pointed out that crowding and congestion of facilities is likely during periods when the weather is ideal for such specific forms of recreation as skiing. It is noted that large facilities seem to be more capable of adapting to the predicted changes in usage patterns than do small facilities. This suggests that improvements in weather forecasting might lead to the closing of small facilities for economic reasons and bring about increased concentration in the recreation industries. On the other hand it might enable the small operator to better allocate his scarce resources to optimize his economic situation. Satellite data would enable the small user to make more specific plans regarding the need for personnel and equipment.

A second general problem involves an efficient mechanism for the development and dissemination of forecasts tailored to the requirements of different types of managers and participants in different forms of recreation. These studies identify what types of information are needed. The task remains to develop ways of getting this information to the people who want it in a form which they can understand and in a time frame in which it will be of most use. This general problem as identified in the study is precisely the one that can be solved by utilizing a "linker" who can determine the best dissemination method, the form and content of the message, and the required time frame. But in order for the linker to function, it must first be determined what use the satellite can be in providing data and also what advantages can be derived from various dissemination systems.

Impact of Satellite Meteorology on Agriculture

The case studies in this section attempted to determine the value in primarily economic terms of improved weather data. The effect of the use of forecasts on the weather sensitive features of agricultural production was detailed as was the effect of the forecasts on the decisions of the producer and the subsequent effect of the producers' reaction on the supplies of the product, the market price and the allocation of resources.

Horticultural Crops—Accurate weather information is extremely important in horticulture because the yield and quality of many horticultural crops are dependent on weather variables. In the attached study weather conditions affecting woody ornamental cultures, floriculture, fruits, fresh vegetables, and processing vegetables are discussed.

Labor procurement and scheduling are major cost factors in the production of woody ornamentals, which are trees, shrubs and vines usually sold by nurseries. Precipitation and frost can delay operations, and if a labor force has been recruited and is on hand, delay may lead to economic loss for both employers and laborers. Rain, frost and winter freeze affect digging stock for the following year. Significant variables influencing success in transplanting large trees are snow and temperature.

Weather is particularly significant in growing and selling flowers and other ornamental plants. Floricultural crops are susceptible to variable temperatures and frosts during the growing season. Advance knowledge of temperature fluctuations and frosts would permit a grower to take measures to protect his crop. Rain, temperature, frosts and cloud cover affect growing plants and consequently harvesting schedule. More accurate advance information about the weather variables listed would enable growers to take controlling and preventive measures which could lead to increased yields and better quality in floricultural products.

Temperature and frosts affect plants in shipping. Foreknowledge of such weather parameters would make it possible to provide insulating shipping facilities only when necessary, and in some cases shipments could be rescheduled to avoid harmful weather conditions. These procedures could lead to reduced costs and make it possible to avoid losses in shipment.

A significant factor in successful floricultural sales is controlling the flowering of plants immediately before holiday seasons. Temperature and cloud cover affect flowering. These variables can be controlled in a greenhouse environment, if the grower has advance weather information so he can prepare to take necessary controlling measures. Advance information about temperature and rain would aid garden supply retailers in advertising and planning for special sales.

Foreknowledge of weather data would be very helpful in the production of small fruits for fresh and processed use. Rain, wind and temperature affect germination and early growth. Prior knowledge of these weather variables would aid in establishing new beds. Flowers, new growth, buds and fruits are affected by temperature, frost and cloud cover. Advance weather data would enable a grower to plan for frost protection measures. Such procedures would help to insure consistently good yields.

Generally, the longer fruit is left on the plant, the better the quality and fruit color will be. Accurate weather predictions at harvest time would permit the grower to schedule harvesting so that fruit may be left on plants as long as possible without risking exposure to frost or other destructive weather conditions. Advance information of temperature ranges in winter would aid growers in undertaking protective measures such as flooding.

Flowers and tender new growth on fruit-bearing trees need to be protected from extreme temperatures and frost and are influenced by cloud cover. Advance information would permit some controlling measures to insure consistently good yields.

Temperature, rain and wind affect pollination and are important in determining such factors as how many bee colonies to use in the process and when to use them. Cloud cover and temperature directly influence the effectiveness of fruit thinning, which is used to produce larger fruit.

In the harvesting of tree fruits wind is an especially significant factor, since some fruits are easily bruised. Accurate predictions of winds would enable growers to pick varieties of fruits which are easily bruised or drop easily, before the onset of wind conditions which might harm fruit.

In producing fresh vegetables and vegetables for processing, rain temperature and wind are especially significant. Rain and temperature variables are important in scheduling plantings so there will be a steady supply of produce at harvest time. Plant maturity needs to be controlled to meet processing requirements. Advance information of temperature and winds can enable growers to protect seedlings from destructive weather extremes.

Table 1

Weather Information Requirements
Woody Ornamentals

Event	Type of Benefit	Critical Period	Weather Concern	Prediction Interval
*Labor procurement:	Fewer lost work days	Mid-March to April 1	Precipitation: kind, duration; Frost: duration	2 week
*Labor scheduling: digging of stock sale, planting out young stock	Most efficient use of labor	April, May	Frost: duration; Rain: amount duration	1 to 5 days
Scheduling labor for weeding	No lost work days	June, July	Rain: amount, duration	3 to 5 days
Pest control: predicting buildup of pests	Better pest control	June, July	Rain: duration Temperature: amount, duration; Wind: speed	7 to 10 days
Digging stock for following year	Efficient use of labor	Sept. - Nov.	Rain: amount duration; Frost: duration, time of winter freeze	3 day to 2 week
Transplanting large trees	Increased % of successful transplants, Better customer service	Dec. - March	Snow: amount; Very low temperatures: duration	1 to 5 days

*Most significant

Table 2

Weather Information Requirements
Floriculture

Event	Type of Benefit	Critical Period	Weather Concern	Prediction Interval
		GROWER		
Pest control: timing	Improved control: Reduced costs	Growing season	Rain: amount, duration; Temperature: amount, duration; Wind: speed	1 day to 2 week
Protection against natural hazards	Decreased loss to natural hazards	Growing season	Temperature: frosts, very high-duration	1 day to 2 week
Harvest: timing	Increased yields, better quality	Harvest period	Rain: amount, duration; temperature: frosts, very high Cloud cover: amount duration	2 to 5 day
Shipping: insulating shipments	Reduced costs; reduced losses	Harvest season, winter	Temperature: frosts-in areas shipping to and through	3 to 5 day
*Control flowering: greenhouses, 10 days before harvest	Improved quality	All year	Temperature: very high, duration; Cloud cover: amount, duration	1 to 2 weeks
		CUT FLOWER WHOLESALER		
*Contracting for and buying large volumes of flowers	Adequate steady supply of flowers to meet holiday and other demands	All year	Temperature: frosts; Rain: excess amounts;	1 to 2 weeks
		GARDEN SUPPLY RETAILER		
Advertising and planning for specials and sales	Increased sales, better customer service	April, May, September	Temperature: Rain: amount, duration	1 to 2 week

*Most significant

Table 3

Weather Information Requirements
Fruits

Event	Type of Benefit	Critical Period	Weather Concern	Prediction Interval
		SMALL FRUITS		
Establishing new beds	Fast starting plants	Spring	Rain: amount; Wind: speed; Temperature	3 to 7 days
*Frost protection: flowers, tender new growth, buds fruits	Consistently good yields	Spring, Summer Fall	Temperature: frost, time; Cloud cover: time, duration	1 to 3 days
Herbicide application	Better weed control; Prevent pollution	Spring, Summer	Rain: amount; Wind speed, direction	3 day
*Insect and disease control	More effective scheduling and application of pesticides; Prevent pollution	Growing season	Rain: amount, duration; Temperature: duration; Wind: speed, direction	3 to 10 days
Harvest	Improved fruit quality and color	October	Temperature: duration; Rain: amount, duration	1 to 7 days
Winter protection	Greater effectiveness of flooding	Late Nov. - Early Dec.	Temperature: very low, duration	1 to 2 weeks
		TREE FRUITS		
*Frost protection: flowers, tender new growth	Consistently good yields	Spring	Temperature: frost, time, duration; Cloud cover: time, duration	Hourly at night; 1 day to 2 week
Pollination: when and how many bee colonies to use	Good pollination	Spring	Temperature: Rain: duration Wind, speed	1 week
Fruit thinning: timing important	Larger fruit	Spring	Temperature: duration; Cloud cover	1 to 5 day

Table 3 (cont.)

Event	Type of Benefit	Critical Period	Weather Concern	Prediction Interval
*Disease and insect control	More effective control; Prevent pollution	Summer, spring	Rain: amount, duration; Temperature: duration; Wind speed	1 to 7 day
*Harvest	Improved quality, increased yields	Fall	Wind: speed	1 to 7 day

*Most significant

Table 4

Weather Information Requirements
Vegetables

Event	Type of Benefit	Critical Period	Weather Concern	Prediction Interval
*Scheduling of plantings	Steady supply of produce at harvest	Spring	Rain: amount, duration; Temperature: duration	1 day to 2 week
*Frost protection: seedlings very tender, irrigation	Prevents the loss of a planting	Spring	Temperature: frost; Wind: direction, velocity	1 day to 2 week
Scheduling field operations, labor	Greater efficiency	Growing period	Rain: amount, duration	1 to 5 day
Herbicide application	More effective weed control. Control pollution		Rain: amount; Wind: velocity, direction; Temperature	1 to 3 day
*Irrigating: keep crops growing vigorously	Reduced costs	Growing season	Rain: amount duration; Wind: velocity, direction	2 to 10 day
*Disease and insect control	Effective control at reduced costs. Control pollution.	Growing season	Rain: duration; Temperature: duration; Wind: velocity, direction	2 to 10 day
*Predicting yield and harvest date	Increased sales, more efficient scheduling of harvest	Summer, Fall	Temperature: duration; Temperature: frosts	1 to 4 day
Harvesting: moving of equipment and crews	Improved yield, quality	Summer, Fall	Rain: amount, duration; Temperature: frosts	1 to 4 day
*Labor procurement: timing very critical	Fewer lost work days	Summer	Rain; Temperature	1 to 2 week
Materials and supplies procurement: never run out	Less lost time	All season	Rain; Temperature	5 to 10 days
Shipping: want no sweating or excess heating	Good quality at market place	Fall, winter	Temperature: very warm, duration (at area shipping to)	1 week

*Most significant

Advance weather information would permit growers to procure laborers and schedule field operations more efficiently and at lower costs. Rain and wind affect need for irrigation, and prior weather information could lead to more efficient use of irrigation as a farming method.

Temperature is a significant factor in predicting yield and harvest date, and rain and temperature affect the harvesting process itself. Advance weather information could lead to more efficient scheduling of harvesting activities and consequently to improved yield and quality. Temperature is a vital concern in shipping fruit.

Horticultural crops are susceptible to various kinds of plant diseases and destructive insects. Survival of these diseases and insects is often dependent on weather conditions, and the effectiveness of preventive measures, such as spraying, is also influenced by the weather. Significant variables in pest survival and pest control are temperature, rain and precipitation.

More detailed weather predictions would be of great benefit in horticulture. Maximum and minimum temperatures, fluctuation in temperature and duration of certain temperature are especially significant to some crops.

Aspects of precipitation which affect crop production include amount of rain, duration, and intervals between rains. Both short and long range predictions of windiness are important in scheduling spraying, in protecting plants against wind and in scheduling harvesting to avoid having fruits exposed to windy conditions.

Predictions of the time when a cloud cover will arrive and the duration of the cloud cover are significant factors in the growing process. More accurate and timely weather forecasting could lead to more efficient and less costly production processes, more effective marketing through supply stabilization resulting in more stable prices and a potential increase in production.

Lettuce Growing—Advance knowledge of weather conditions could have considerable influence in the decision-making process in growing and marketing lettuce. Unexpected high temperatures during the last two weeks before lettuce is harvested cause overly-rapid maturity and can produce excess quantities of lettuce that cannot be sold. Accurate forecast of temperatures five to seven days in advance would enable salesmen and growers to predict daily harvests more accurately. Thus order-taking and truck reservations could be handled in advance of the anticipated increase in lettuce ready for harvest.

Unexpected rain while lettuce is being harvested can delay the harvesting process and, if harvesting is continued during the rain, may mean that the lettuce will be dirty when harvested. Both conditions can cause economic loss to the farmer. If the grower has a twenty-four hour advance forecast of rain with a reasonably accurate prediction of the time the rain will start, he can plan his operations more effectively to avoid the delay and so avoid harvesting dirty lettuce. Another condition which can cause large losses in lettuce profits is the occurrence of heavy rains which cause water to stand on the surface of the lettuce fields. The flooding can cause the loss

Table 5

The Value of Accurate Weather Forecasting to Lettuce Producers in Wisconsin

Event	Operation Affected	Average Loss per Event	Savings to be Realized with accurate Forecasts	Frequency of Event causing Loss	Annual per/A savings with accurate fcst.
High temperature at harvest	Sales and shipping	8% of total acreage at $1 per case; 550 cases per acre	100% of loss could be saved	Occurs 1 1/2 times each season	$66.00 per acre
Rain stopping harvest	Dirty lettuce; loss of goodwill	2% of total acreage at $.50 per case; 550 cases per acre	100% of loss could be saved	Occurs 3 1/2 times each season	$19.25 per acre
Standing water on fields caused by heavy rains	1) lost plantings	1) 6.6% of total acreage at $25 per acre	35% of loss could be saved	Occors once in two seasons	$12.75 per acre
	2) lost harvests	2) 3.3% of total acreage at $1 per case; 550 cases per acre			
	3) reduced quality and yield	3) 25% of total acreage; quality at $.25 per case and 450 cases per acre; yield: at $1 per case and 100 cases per acre			
Rain influencing spray schedule	Insect and fungicide spray	40% of total acreage at $2.50 per acre	100% savings	Occurs 3 times each season	$3.00 per acre

TOTAL — $101.00 per acre

of some plantings and reduced yield and quality in other plantings. A twenty-four hour forecast of heavy rains would enable the farmer to remove most standing water by lowering irrigation ditches and by digging surface ditches in the field. Although this would not prevent all losses due to heavy rain, it would reduce losses considerably. Rain can also cause economic losses by washing off recently applied insecticide and fungicide sprays. The lettuce grower could delay applying these chemicals if he could be reasonably certain of a forthcoming rain.

Other weather associated events such as high wind, frost, extreme drying conditions and high temperatures, may be dealt with more effectively if there is advance weather information, but effectiveness and costs of the various methods of dealing with the situations vary.

Growing and Processing Peas—Accurate long-range weather prediction would be of great use in the extremely weather-sensitive process of growing and processing peas. Much of the variation in yield and quality of peas is attributable to weather conditions during the growing season. Planting, growing and harvesting of peas are all highly affected by temperature.

The first peas are planted as early in the spring as the ground can be worked. Subsequent plantings are scheduled on the basis of temperatures, since development of pea plants is proportional to temperatures. Forty degrees Fahrenheit is approximately the minimum temperature at which peas will germinate and grow. Highs and lows are averaged, the base temperature of 40° is subtracted and a heat unit accumulation recorded daily. With advance weather information, field operations could be shifted to within a fifteen- to-forty-mile radius of most processing plants to avoid bad weather at planting time. Since different varieties of peas require approximately the same number of heat units to reach the processing stage, this procedure has proved successful in providing a uniform supply of peas for processing throughout the season. Predictions of temperature would aid in scheduling planting, and foreknowledge of rain which would interfere with planting would also be significant.

Precipitation and wind as well as other climatic factors affect the application of herbicides and insecticides. Atmospheric conditions sometimes contribute to air pollution which could damage peas. If advance warning of these conditions was available, preventive measures possibly could be taken at the pollution source to alleviate the situation.

Advance weather information would be helpful in scheduling labor, supplies and equipment for harvesting and processing. This information would permit more accurate estimates of the amount of peas to be harvested and processed daily, as well as more accurate estimates of total yield.

To obtain optimum quality, peas must be harvested within a narrow range of maturity. The period during which the peas are at this stage of maturity may be as short as twelve hours during hot, dry weather and as long as three to four days during cool, moist weather. Peas may develop off-flavors within two hours after harvest at 80° F weather, but more than four hours are allowable between harvest and processing at 40° F. With advance knowledge of weather conditions, harvesting operations could sometimes be shifted from areas which would probably receive rain to other areas.

Wind direction and speed, amount and duration of precipitation, hourly temperatures for each day, radiation, and cloud cover would be the most significant weather variables in the pea producing and processing activity. The attached study concludes that the greater the advance notice, the more valuable the information would be to the growers and processors.

Sweet Corn Production—A study was conducted to determine the economic impact which would result if advance weather predictions derived from meteorological satellites were available for producers and processors of sweet corn. A constant analysis of weather information is the basis for decisions affecting the scheduling of each field operation and for the sale of produce to processors and on the market. In the production of a fast-growing, highly perishable crop such as sweet corn, quality, as well as yield, is an important consideration. Weather affects both crop quality and yield.

Rainfall, temperature and wind can have significant influences on the production and processing of sweet corn in the preplanting, planting, growth, harvest, and postharvesting periods. Extreme deviations from the normal amount of rain in the corn belt during the growing period can have a significant influence on the corn yield. Generally, corn yields more as July rainfall increases. A warm, dry period just at pollination is particularly damaging to yields. Moisture supply in the soil prior to planting is significant, since sweet corn obtains about half its water needs from preseason precipitation.

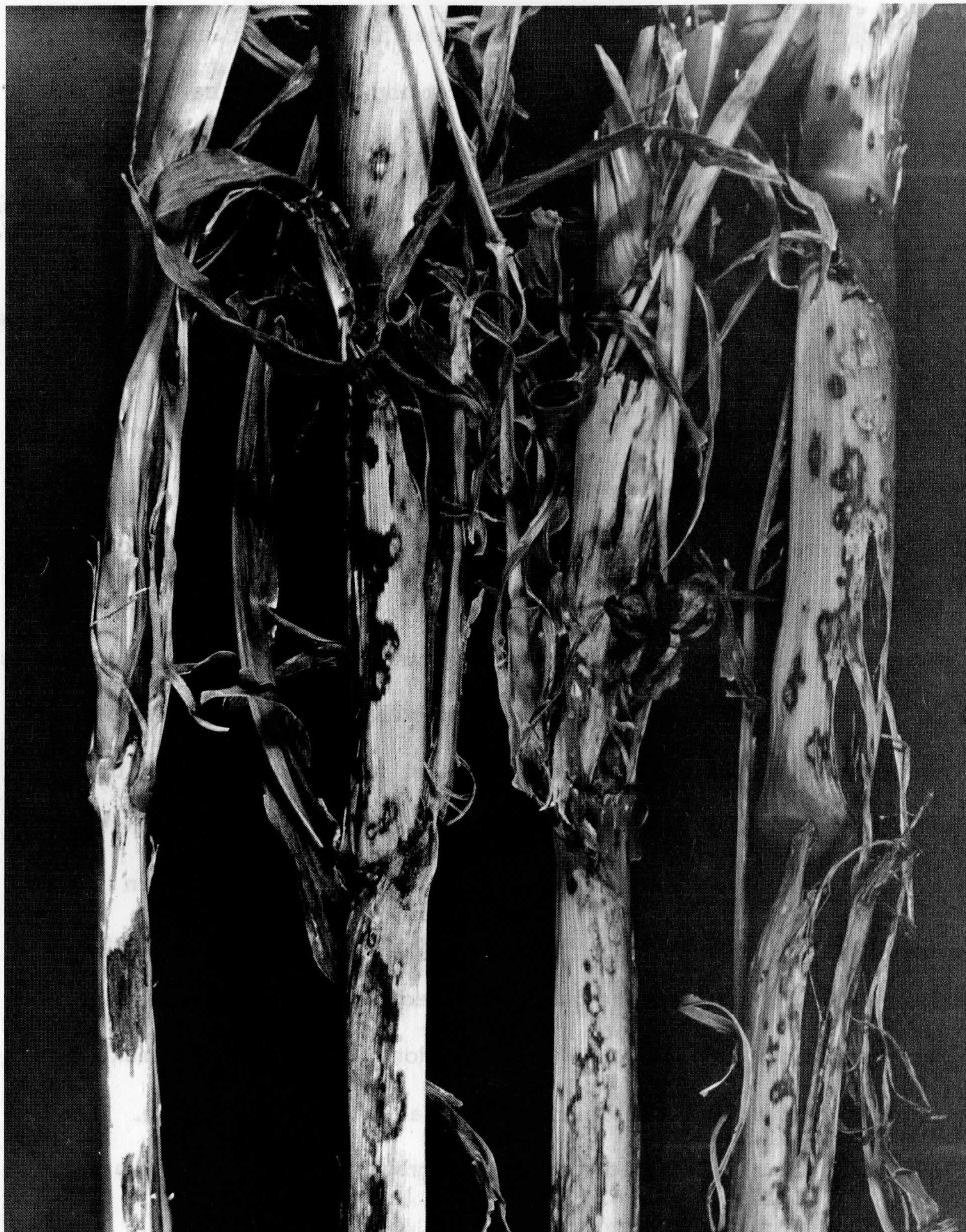
Table 6

Sweet Corn for Processing

Season growth cycle	Weather component	Production procedures and practices	Indications
Preplanting (prior to May 1)	Provides 1/2 of crop's water needs	Procurement of contract acreage	Modify each relative to developing weather components
	Temperature influences soil structure, decomposition, overwintering of insects and disease spores	Orders for kind of seed, fertilizers, pesticides in adequate volume, arrangements for labor, machinery	
Planting (May-June)	Rainfall	Soil preparation	Regulate relative to moisture
	Temperature intensity and accumulation	Date of planting	Modify relative to temperature
		Type and rate of application of pre-emergence fertilizers and pesticides	Modify time rate and frequency relative to need and weather variables
Growing season (May-September)	Rainfall	Sidedress of fertilizers	Modify time, rate and frequency relative to need and weather variations
	Temperature intensity and accumulation	Application of insecticides, fungicides, herbicides	
	Cloud cover		
	Humidity	Monitor temperature, moisture, humidity and air currents in South relative to disease and insect populations and their northward migration.	Procure emergency supply of agricultural chemicals as needed and arrange for their application
	Wind		
	Hail		
		Supplemental irrigation	Adjust based on rainfall, temperature prediction

Table 6 (Cont.)

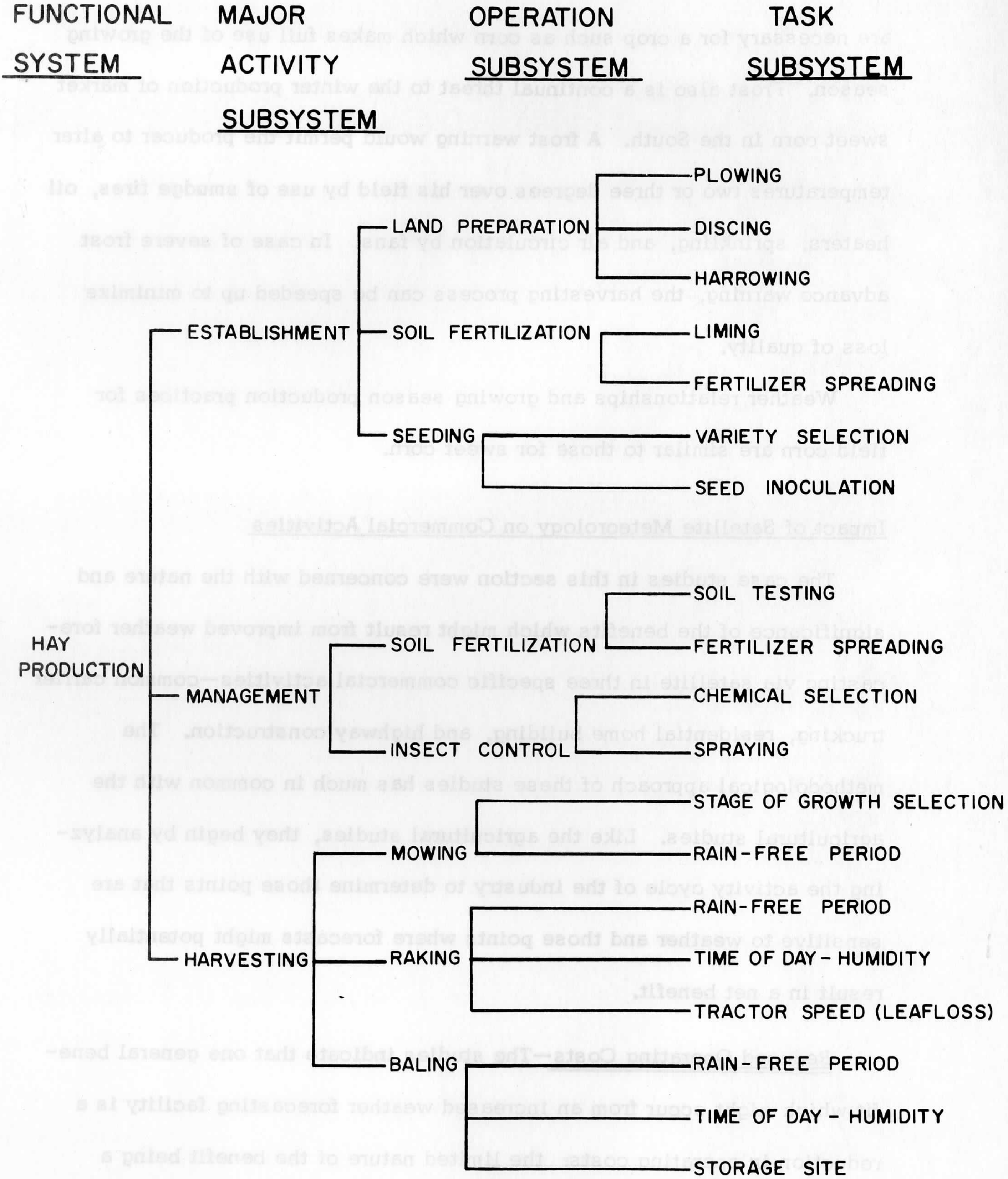
Season growth cycle	Weather component	Production procedures and practices	Indications
Harvest (August-September)	Rainfall Temperature intensity and accumulation Frost	Procure and transport harvest labor Arrange for food and lodging Lease of equipment and transport to demand site Purchase and sale of raw product to alleviate shortages and surpluses Time date of harvest for maximum quality Modify style and type of pack, compute volume of grades Arrange for sprinkling, smudge, air circulation	Adjust on basis of weather prediction
Post harvest (October-December)	Seasonal accumulation	Storage and transport of product Promotion and sales Retail outlets, shelf space Yield forecasts, pricing structure	Adjust on basis of cumulative weather prediction



Application of pre-emergence pesticides for control of insects, disease and weeds has varying effectiveness according to temperature and rainfall. Rainfall, wind, temperature and relative humidity during the growing season affect application of time and rate of herbicides, insecticides and fungicides. Accurate weather forecasting could allow time and rate application to be altered to assure maximum effectiveness. Winter and preplanting temperatures also have a profound effect on winter survival of insects and fungal spores. Humidity and cloud cover, as well as precipitation and temperature, are highly correlated with plant disease.

Temperature is also an important factor in sweet corn production. A warmer than normal spring favors high yields, since it hastens decomposition of plant residues and permits early planting. A warm spring also speeds up germination and emergence and promotes early growth. Preplanting temperatures are an important consideration, in selecting planting time, which in turn affects length of growing season. August temperature is particularly important to corn yield. Accurate temperature information is also important when thermal units are used in the corn production process. Temperature also affects the quality of sweet corn. Unseasonable hot weather during processing may force abandonment of acreage or make it transport of the product to other company factories for processing. If temperature and rainfall can be predicted accurately on a fortnightly basis, yield forecasts will be greatly improved.

Dependable frost warnings, particularly during September and October,



HAY PRODUCTION ACTIVITY SYSTEM.

are necessary for a crop such as corn which makes full use of the growing season. Frost also is a continual threat to the winter production of market sweet corn in the South. A frost warning would permit the producer to alter temperatures two or three degrees over his field by use of smudge fires, oil heaters, sprinkling, and air circulation by fans. In case of severe frost advance warning, the harvesting process can be speeded up to minimize loss of quality.

Weather relationships and growing season production practices for field corn are similar to those for sweet corn.

Impact of Satellite Meteorology on Commercial Activities

The case studies in this section were concerned with the nature and significance of the benefits which might result from improved weather forecasting via satellite in three specific commercial activities—common carrier trucking, residential home building, and highway construction. The methodological approach of these studies has much in common with the agricultural studies. Like the agricultural studies, they begin by analyzing the activity cycle of the industry to determine those points that are sensitive to weather and those points where forecasts might potentially result in a net benefit.

Reduced Operating Costs—The studies indicate that one general benefit which might occur from an increased weather forecasting facility is a reduction in operating costs: the limited nature of the benefit being a consequence of the nature of product produced in these industries. Unlike agricultural products weather does not have any direct influence on the quality or quantity of the product.

A reduction in operating costs can result for two reasons. First, losses which are currently caused by undesirable weather may be prevented. This possibility is illustrated in the trucking case study where it was reported that periodically merchandise is ruined by bad weather (usually rain). The highway construction study also points out that unexpected rain can cause damage to partially completed earthwork. Second, firms may reduce operating costs by utilizing their resources more efficiently. The most common and important example of this benefit is the improved ability of firms to allocate and schedule labor according to the weather.

As in the agricultural sector, these studies found that there are factors which can limit the firm's ability to realize the potential benefit. In fact, at the present time, in two of the three commercial activities examined these limiting factors are so significant that the firms are under the impression that they would receive almost no benefit from improved weather forecasting. For example, the common carrier trucking study found two major reasons why truckers would be unlikely to realize benefits. First, they have limited flexibility. The routes a firm may travel are regulated by government; consequently it is unlikely that if the weather is bad on one route the firm will have the option to choose a different route. Furthermore, it is uncertain whether firms would choose another route even if they could. To avoid bad weather may require them to travel so many additional miles that this cost would be greater than the delays caused by the bad weather. Inflexibility is also caused by both union agreements and company policy which limit the scheduling of drivers. A second factor limiting the firm's ability to realize benefits is the competitive nature of the industry. A firm cannot risk delay or cancellation of a run unless it is absolutely certain that a route will be impassable because if their competitor makes the run and they do not, the firm will almost certainly lose customers who feel they are undependable. This increased certainty which could be provided by the meteorological satellite could alter this situation.

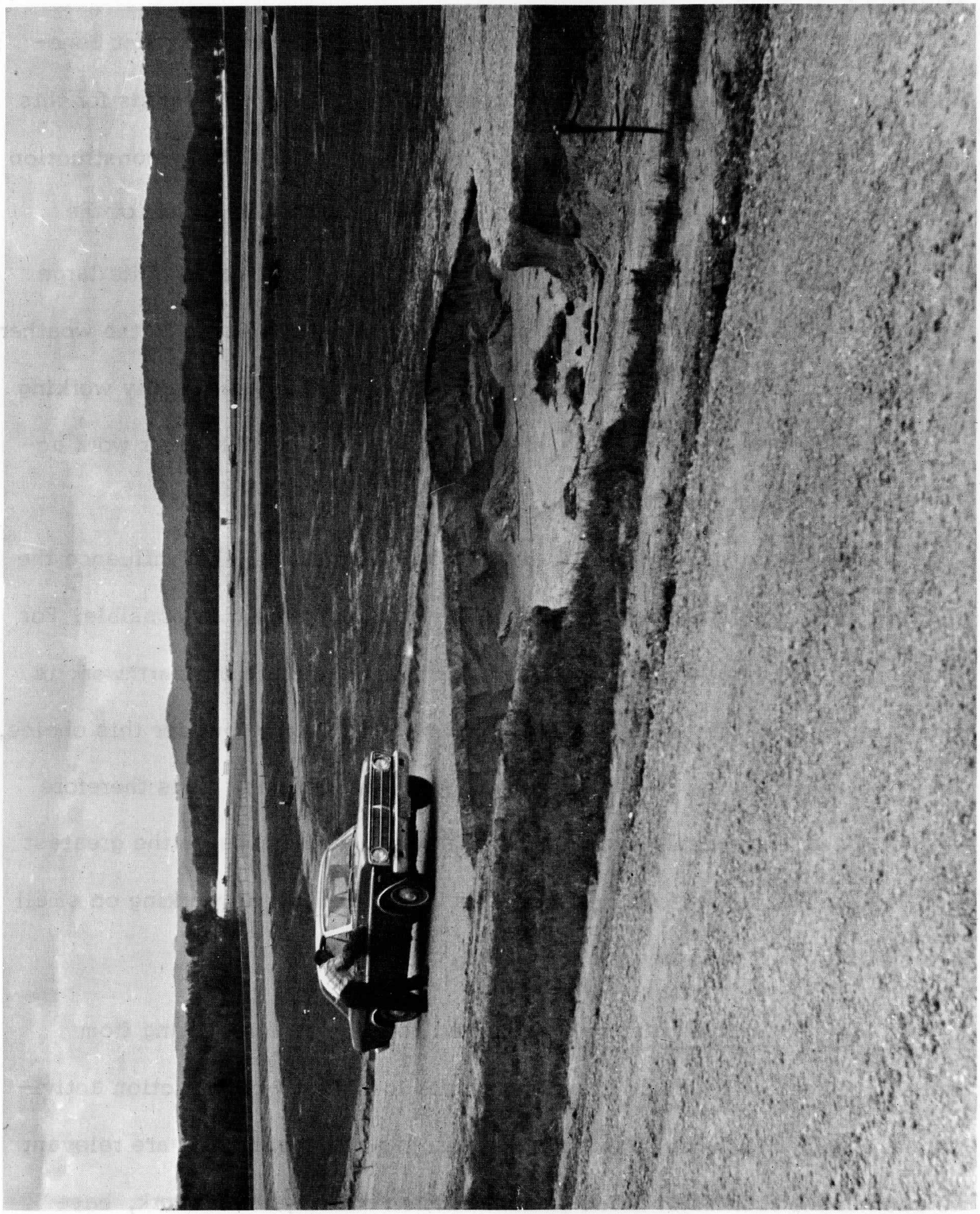
Thus, the commercial activities case studies indicate that the only perceived benefit which can be expected from improved weather forecasting is a reduction in operating costs, and that the realization of this benefit by firms is restricted by the nature and structure of the industry of which they are a part. The fact, however, that improved forecasting does have some effect points out the need for the linking function to provide an improved situation.

Thus the case studies have pointed out the need for an awareness of the meteorological satellite which requires the utilization of a linking function to improve the key information flow. One means by which the meteorological satellite can be used more effectively is if a full understanding of the dissemination of the meteorological data is obtained. To do this it is first necessary to have some idea of the development of the existing system of the National Oceanic and Atmospheric Administration.

Highway Construction—The highway study found that significant benefits from improved weather forecasting could be realized. The basis for this finding was the flexibility of firms and activities in the highway construction industry. However, this flexibility is not a general characteristic of the industry. Some of the firms in the industry are small and others quite large and it is expected that the ability of the small firms to respond to the weather forecasts would be limited. The large firms, since they are usually working on several jobs at the same time, should be able to schedule their work according to weather conditions.

The scope of the project in highway construction will also influence the extent to which a response to improved weather forecasting is possible. For example, if temperatures are too cool for pouring concrete but earthwork is possible, then if the project is large enough to permit the builder this choice, he will be able to respond to a report of cool temperatures. It is therefore expected that large firms working large projects should receive the greatest benefits from improved weather forecasts while small firms working on small projects would receive the least benefit.

Weather Sensitive Features—Improved long-range forecasting from satellite meteorology could prove beneficial to highway construction activities and winter highway maintenance work. Weather conditions are relevant to each of the four major areas of construction activity: earthwork, base course, surface course, and structures.



Earthwork

The most serious weather occurrence related to earthwork road construction is rain. Heavy rains during the grading operation can cause construction losses if work must be delayed while the grade dries out. Heavy rains may cause severe damage when the runoffs create flooding or wash out completed portions of the project. Accurate advance warning of impending rains (twenty-four to forty-eight hours notice) would permit a contractor to speed up the stage of his earth work activity to the point where the rains could only do a minimum of damage. This might include shaping the top of the grade to permit runoff instead of the capture of precipitation, accelerating work on culverts to facilitate drainage and eliminate or minimize ponding, or postponing opening up new grading areas until after the precipitation period has passed. Rain can also cause considerable damage in the final activities of a grading project, which include dressing final slopes, placing top soil on the slopes and fertilizing and seeding, and sodding when necessary. Short-term advance warning of impending rains would allow these activities to be delayed and thereby avoid the necessity of reconstructing portions that might be rain-damaged.

Typical labor contracts require that laborers be given at least twenty-four hours prior notice if there is to be no work during a normal working day. Otherwise, they must be paid two hours show-up time for reporting to work, even if work is called off for the day. Advance weather information would allow a contractor to give workers the twenty-four hour advance notice and keep him from having to pay the show-up pay.

Reliable long-range forecasts of ten days to ten weeks are most valuable since they permit better and more efficient work scheduling and, where appropriate, the shifting of crews and equipment from one project to another. Equipment mobility is great enough and costs of moving low enough that such a job shift would be to the contractor's advantage.

Base Course

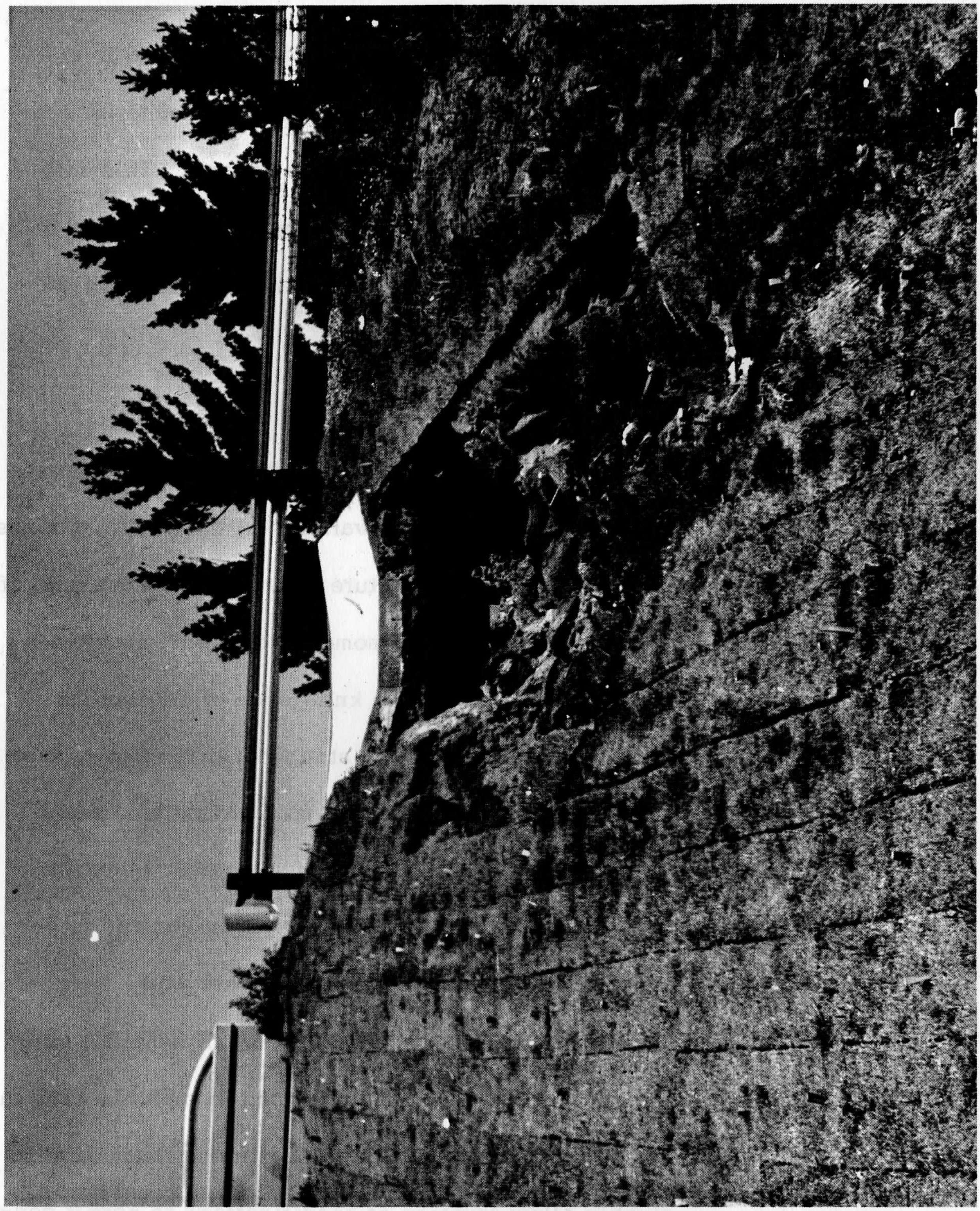
As with earth work operations, the basic impediment to construction of base course layers in road building is rain. The unstabilized materials are influenced to the extent that heavy precipitation may cause termination of work either because the material is too wet to be driven on by the equipment or too wet to permit adequate compaction. Light rain, on the other hand, may be advantageous, particularly when sandy materials are being used, since the rain may provide the water necessary for compaction. Foreknowledge of impending rains would allow a contractor to take two courses of action. He could advise his crews not to report for work, or since a base course material is less affected by rains than the native subgrade, he could accelerate work to get more base course laid before the onset of rain.

There are rigid temperature and precipitation constraints for both cement stabilized bases and bituminous stabilized bases. Asphaltic stabilized materials cannot be laid below certain minimum temperature and under certain precipitation conditions. In addition, there is a temperature related calendar date after which bituminous material cannot be placed except at the risk of the contractor himself. This date has been established on the assumption that temperature ranges at the time of year specified are generally too low to allow bituminous type work.

Surface Course Activity

Precipitation is sometimes a constraining factor affecting concrete paving, but the major prohibitive weather variable in the paving process is temperature. A severe drop in temperature necessitates some form of protection for the work in process, or in some cases low temperatures require that work be suspended. Advance knowledge of descending temperatures would allow the contractor to stop work in time to protect the concrete that had been laid, and thereby avoid having to discard work affected by falling temperatures. If freezing weather is anticipated, a minimum of twelve inches of straw or hay may be used to protect freshly laid concrete pavements and other concrete work.

Both short- and long-range weather forecasts would permit a contractor to take adequate precautionary measures and to plan his work in order to take advantage of favorable weather conditions. Such forecasts might conceivably allow revision of specifications to permit concreting activity to be planned and carried out in accord with weather



forecasts rather than by a predetermined cut-off date. There are a number of weather variables including rain and temperature which can critically affect various aspects of bituminous paving operations. Generally, the road bed must be dry at the time of bituminous laying operations. The prime coat or tack coat should not be applied before impending rains. For road mix bituminous materials, it is important that the road mix itself not be exposed to rain prior to final compaction of the mixed materials. Plant mixed bituminous concrete also should not be placed during rain or snow. Adequate advance warning of impending rains would permit a contractor, in the case of short-term occurrences, to plan his immediate work activities and his labor requirements around the bad weather.

Temperature can be a major impediment in various types of blacktopping activity. Advance information of temperatures allow a contractor to plan his operations for maximum efficiency. As with concrete paving operation, there is also a calendar date restriction on blacktopping based largely on the state highway department's experience that weather, both in terms of temperature and precipitation, is apt to be bad after a certain date. Adequate long-range weather forecasting could predict the continuence of good weather beyond this date, and the calendar constraint could be dropped to the advantage of both the contracting industry and the state highway department.

Structures Activity

Structures activities in road building, such as bridge building, are sensitive to rain and temperature parameters. Advance warning of rains and temperature would allow planning for the most economical construction activity under certain weather conditions.

There is evidence that the construction industry could realize significant economic savings by responding to improved weather forecasts from satellite meteorology. Such savings, ultimately, should lead to reduced bid prices for various construction items.

Winter Maintenance

Although the maintenance activity was not investigated in great detail in the study described, attempts are being made to use the services of a meteorological consulting firm to forecast the imminence of winter storms. Such forecasting has minimized the need for patrolling all highways and appears to be resulting in a considerable saving. Forecast information, thus, might well be an alternative to twenty-four hour patrolling of roadways during winter months in an effort to keep roads cleared of snow.

<u>Residential Home Construction</u>—The residential home building study found that the major reason why improved weather forecasting may not produce realizable benefits is that the firms are too inflexible to respond. In this industry the inflexibility stems not from regulation but rather from the very small size of many of the firms and the nature of the subcontracting

procedures of the larger firms. Frequently a firm will be working on only one (or a few) houses at a time; thus if the weather is bad there is little possibility of shifting work to a different area, even if they were forewarned of the bad weather. However, depending on the time factor, a forecast received far enough in advance might enable the industry to alter its operating procedures in order to maximize benefits for both large and small operations.

Weather Sensitive Features—Of the forty-two days estimated as necessary to build a single-family home, the first twelve days, or approximately one-third of that time, is particularly weather sensitive. The initial steps in the home building process are especially vulnerable to precipitation and temperatures below 15°. The severity of the weather condition, such as a combination of rain and cold temperatures, is significant, since a small amount of precipitation may not appreciably delay progress, but rain in freezing temperatures may mean that the work must be stopped completely. Light rain may not seriously affect work, but heavy rain over an extended period could cause cessation of construction activity. Earthmoving, excavation, foundation work and closing in the house structure can all be hindered by rain or low temperatures, but such work may cease completely in freezing rain. Forewarning of freezing rain might enable the builder to speed up activities or reschedule work on the inside. There are difficulties with rescheduling work, however, since the degree of specialization in home building trades and union rules prohibit extensive reassigning of work duties. Thus, work planners having the benefit of long-term forecasts have limited alternatives in terms of reassigning manpower.

A study conducted in Milwaukee indicates that slightly more than 1% of the total value of housing units constructed was lost due to adverse weather conditions. Generally the home building industry is characterized by large numbers of small firms, local in nature and without definite, long-range planning. Usually, large home builders tend to subcontract most of the activities and subcontractors generally have the same characteristics as small home building operations. Even the bulk of weather data currently available is not being used by most home builders. The increasing trend toward prefabrication is reducing construction site losses due to adverse weather conditions. Usually adverse weather is present throughout the limited geographic area in which a home builder operates, and therefore there is little possibility of shifting manpower to another work site.

The attached report concludes that benefiting from a long-range weather forecasting system would necessitate long-range planning not generally found in the homebuilding industry. It is suggested that the major benefit from such forecasting would lie in the initiation of a long-range planning capability. Research shows that homebuilders generally planthe next day's activities about 3 o'clock in the afternoon, and the decision is reviewed the next morning in the light of observed and forecasted weather conditions. The report concludes, therefore, that the weather information most significant for homebuilders would be accurate forecasting of local conditions between 6:00 and 7:00 a.m. and 3:00 to 4:00 p.m. Long-range planning three to four months in advance for bidding purposes could utilize historical climatological information which is presently available.

Common Carrier Trucking—There are four basic trucking functions which may be affected by weather conditions: sales, pickup and delivery, dock handling of freight and line haul movement.

Sales of trucking service is an extremely competitive business. Trucking is regulated by the Interstate Commerce Commission, and uniform pricing is a result of this control. Thus, competition generally results in a quality level of service. In order to compete at set prices, a trucking company must keep its service at a high level, maintaining prompt and efficient service. Weather sometimes affects efficient service by delaying pickup and delivery and line haul movements. All trucking companies in an area, however, face the same weather conditions. Trucking companies cannot avoid loss by suspending operations during adverse weather, because their service level then drops to zero. (Basically, the report concludes that weather has very little effect on trucking company sales.)

The report suggests, however, that improved meteorological information may provide a benefit to trucking companies which they are not presently experiencing. Consistency of service is a primary measure of quality in trucking activities. When frequent, regular deliveries are made, the receiver of the goods does not have to maintain a large inventory cushion. Adverse weather can cause delays in delivery schedules. If shippers had advance warning of adverse weather conditions, they could increase the volume of shipments prior to the predicted bad weather, so that receivers would have more goods on hand during periods when deliveries might be delayed.

Although adverse weather would seem to have an obvious effect on pickup and delivery services, since snow, ice and rain seem to snarl urban traffic. Delays in pickup and deliveries lead to congestion at terminals. The study conducted shows that there is relatively little cost associated with adverse weather conditions. Improved information would only be useful if weather was expected to be especially adverse at a time when terminal operations would be congested for other reasons. Perhaps this congestion could be alleviated before the bad weather.

Temperature seems to be the major weather variable influencing dock costs, which are the costs incurred in loading and unloading freight within a terminal. The increased costs due to cold weather are usually the result of extra labor time caused by decreased labor productivity. According to the study, the effect of cold weather on terminal operations is too small to be measured. It is suggested, however, that there is a possibility of some savings with improved weather forecasting, since work load could be planned to make the best use of desirable weather.

Snow, ice and fog are obvious deterrents to efficient line haul activities. Bad weather conditions mean trucks travel at slower speeds, and extremely bad conditions may make highways impassable. Drivers are paid the same amount per trip regardless of the time the trip takes. Generally, less freight is hauled in winter, which is the season when adverse weather is more apt to affect highway conditions. Lost transit time due to adverse weather is an insignificant cost to the company.

More accurate weather forecasting would aid management in predicting impassable highway conditions, but in all but extreme cases the risk of customer dissatisfaction outweighs gains made possible by improved information.

Costs of the safety function in trucking is increased by adverse weather conditions, since rain, ice and snow make travelling more hazardous. There are some instances where weather conditions may be serious enough to cancel line haul trips, but other factors besides safety enter into such decisions. Accurate short-range predictions and information of present conditions could be useful in making such decisions.

Since claim costs due to weather only occur when the company claims policy is violated, weather related claims, therefore, are not considered a cost of adverse weather. Cost incurred in protecting freezable products is directly related to low temperatures. According to study improved weather predictions could enable the company to avoid some costs of hauling freezables, but there are some restrictions on implementing avoidance procedures.

The effect of improved weather predictions in increasing profits of a common carrier trucking company seems to be small according to the data gathered in the study described.

CONTINUING CASE STUDY RESEARCH

Corn Blight Research

The research on corn and the economic impact of satellite meteorology is being continued by Professor R. H. Andrew with emphasis on southern leaf blight. While this disease was of minor importance several years ago, during the summer of 1970 it emerged as a serious malady. The primary cause of this new development is a new race of the fungus Helminthosporium maydis called the T strain which produces a new crop of spores within a seven day period. With unusually warm, wet weather in the Midwest this year, the disease spread northward and was detected in Wisconsin in August.

Because of the close relationship of weather to development of this disease, continued research in this area is desirable. To this end, representative producers will be contacted as well as research personnel in the blighted area to document the economic impact of improved forecasting on chemical control, sanitation procedures, production plans, alternate uses and harvest of the corn crop.

Highway Construction

Prof. H. Kuhn is engaged in building econometric models with our economic research team. This modeling activity will provide a broader base for economic projections as to the dollar impact of improved weather data.

Natural Resource Utilization: Recreational Boating Operations

Following is a preliminary summary of the boating study. The field study findings will appear in the Final Report.

Questionnaires were mailed to recreational boating operators in selected areas throughout the United States. The criteria for selecting particular lakes was that they should be large and within a half-day's drive of a large urban center. The questionnaires were designed to elicit detailed information about the following:

1. Effects of present weather forecasts on recreational boating management.
2. Most important weather factors in recreational boating operations.
3. Effects that improved weather forecasts might have on present boating operations.
4. Long-term effects that improved weather forecasts might have on boating operations.

The response rate to the questionnaire was 57.5%. The distribution of respondents by state is shown in the table below.

Table 1. Percentage Distribution of Respondents by State

Lake	State	No. of Respondents	Percent of total
Dardanelle	Arkansas	5	8.6%
Lanier	Georgia	8	13.8%
Mead	Nevada	4	6.9%
Norris	Tennessee	13	22.4%
Shadow Mtn.	Colorado	5	8.6%
Tahoe	California	12	20.7%
Winnebago	Wisconsin	10	17.3%
Cachuma	California	1	1.7%
TOTAL		58	100.0%

1. Effects of Present Weather Forecasts

The majority of respondents, 85.2%, indicated that present weather forecasts do influence their planning and management decisions in the following ways:

Table 2. Influence of Weather Forecasts on Present Boating Operations

Aspect	Percent that checked
planning what employees will do	57.1%
planning number of employees	50.0%
stocking more gas and oil	38.3%
having more boats available	36.9%

Good weather forecasts mean more boat-users than normal, according to 87% of respondents, and bad forecasts mean fewer boat-users than normal, according to 64.8% of respondents.

2. Most Important Weather Factors

At the present time, local radio and television stations are the most popular sources of weather forecast information, utilized by 79.3% of respondents. Of the remainder, 13.8% use no weather forecast information whatsoever. The most important factors in weather forecasts are wind direction, rain and wind velocity. Such factors as temperature and cloud cover are not regarded as important. The most popular lengths of forecasts are five-day and one-day forecasts, respectively. Thus the type of forecast which is presently of use to boating operators is a one- or five-day forecast containing information about wind direction, rain and wind velocity, transmitted by local radio or television stations. The majority of respondents, 71.5%, regard present weather forecasts as being at least 50% accurate.

3. Effects that Improved Weather Forecasts Might Have on Present Boating Operations

If improved weather forecasts were available, 86.2% of the respondents said the following aspects of boating management and planning would be affected:

Table 3. Influence of Improved Weather Forecasts on Present Operations

Aspect	Percent who checked
season opening	70.0%
equipment and facility maintenance	62.0%
season closing	54.0%
number of employees	50.0%
number of boats	42.0%
stocking of gas and oil	34.0%
road and parking maintenance	26.0%

Improved weather forecasts would have to contain information on temperature, rainfall and wind. The most popular lengths of forecasts would be one and five-day. In contrast with present weather forecasts, these improved forecasts would have to contain information about temperature and, hope-fully, be more accurate. Respondents' opinions as to how improved weather forecasts might influence boat use are almost identical to their opinions of the effects of present weather forecasts on boat use.

4. Long-Term Effects of Improved Weather Forecasts

When questioned about the long-term effects of improved weather forecasts on their boating operations, 74.5% of respondents said they would make changes. The changes listed by this 74.5% are tabulated in Table 4. One revealing fact that emerged was that recreational boating operators in the south showed the greatest interest in making long-term changes. These results are listed in Table 5.

Table 4. Long-Term Effects of Improved Weather Forecasts

Future changes	Percent who checked
add to boating area facilities	35.3%
make week-to-week arrangements with employees more flexible	31.4%
increase number of boats	29.4%
develop alternative recreation facilities on site	19.6%

Table 5. Percentage Distribution of Respondents who Said They Would Make Long-Term Changes

Lake	Changes	No changes
Lanier (7)	100% (7)	-
Norris (11)	100% (11)	-
Dardanelle (5)	80% (4)	20% (1)
Mead (4)	75% (3)	25% (1)
Shadow (4)	75% (3)	25% (1)
Winnebago (10)	60% (6)	40% (4)
Tahoe (10)	40% (4)	60% (6)

The figures in brackets are the number of respondents to each question.

The Management Study

The purpose of the present study is to describe the management and organization system associated with the Meteorological Satellite Program, comparing it with theoretical models of organization and determining characteristics which may be applied to other organizations of a similar nature. Date are obtained from interviews, observation and document search.

Progress to Date

The present project is progressing according to its stated schedule. The steps are as follows:

1. Orientation and background review. The historical evolution of NASA and the Weather Satellite Program were reviewed in published documents. The structural configuration was identified in these documents and from interviews with members of the Space Science Center, University of Wisconsin. Of particular interest in this stage was identification of key administrators, major organization units, organization interfaces where co-ordination and interface mechanisms might be found, and historical antecedents to the present structure.

2. Comparison of organizational features with known theory and research, and

3. Identify critical issues for investigation and appropriate sources of data.

Here the research team reviewed the NASA and meteorological program experience and compared it with the experience of other project management structures. Comparisons were also made with the "Matrix Organization" model developed earlier by the present investigators and with other theory on project management.

This process identified key issues to be included in the interview schedule.

4. Preparation of interview schedules.

5. Data gathering.

Exigencies of scheduling permitted interviewing to begin earlier than expected. The first set of interviews was conducted in NASA headquarters and at the Goddard Space Flight Center from October 5-9. Eleven people were interviewed and additional information was obtained from the NASA offices of management services and the historian. The record set of interviews was conducted in NOAA (previously called ESSA) from November 2-5. Twelve people were interviewed in the headquarters and field stations. A third set of interviews may be needed but is as yet not scheduled.

The interview schedule provided detailed information on five areas of interest: organization mission, interfaces with other units or agencies, planning strategies, structural design, and position characteristics of the respondent.

Research Effort to be Completed

6. Data Analysis. Interview schedules are now being reviewed. The anticipated format of presentation will include a) Prior theory and research on project and matrix management, b) the Meteorological Satellite Program

structure and system, c) a comparison of the meteorological satellite experience with other programs or models, and d) contributions to the management field from the meteorological satellite program experience.

7. Preparation of a working paper and a review conference with key personnel. A summary draft of findings will be prepared for discussion by key personnel. The purposes are to insure accuracy of our observations, fill in mission information, and provide feedback to participants.

8. Preparation of the final case study. The final document will be prepared and submitted for approval.

The Legal Study

The legal study has examined the national and international effects and ramifications of the United States meteorological satellite program. The focus has been upon the impact of this program on political and international affairs, and the nature of the international cooperation which has stemmed from the development of the U. S. weather satellite program. Emphasis has been placed on the implications of the use of satellites together with sensors such as constant altitude super-pressure balloons and ocean data acquisition systems. The fact that the existing international law in this area is minimal has given increased significance to this work which considers both the state of the current law and the alternatives available for a future legal regime. The interactions between the law and technology have been presented and consideration has been given to an analysis of the relevant international legislation, the applicable safety regulations, the question of liability and the need for possible international agreements. The legal problems relating to the multiplicity of uses of satellites have been considered as have been the mechanisms for the dissemination of information from meteorological satellites.

Further research will stress both the need for international legal rules in the area of satellite meteorology and the need for the development of domestic law to deal with the interpretation and utilization of satellite meteorological data. Of particular concern will be an analysis of the question of legal liability for the use and applications of satellite meteorological data. Also included will be a section on the law of evidence relating to the use of meteorological photographs in courtroom proceedings. The emphasis throughout will be on finding ways that the development of the meteorological satellite program can be aided by legal research.

Economics Supporting Study

In keeping with the interdisciplinary design of the study, the case study experts have been engaged in considerations with the director of the economics supporting study. The case study experts have at their command data and information concerning the impact of the weather satellite program upon their field of activity which has been developed from the viewpoint of the user directly involved in order to provide maximum credibility. The economics study has developed economic models which incorporate the case study findings to assess the economic impact to be derived in each case study from using improved satellite-based weather prediction information.

To determine which potential benefits are realistically achievable when users have access to improved weather data, the case studies have considered whether or not there are factors which limit or prevent benefits from occurring. The objective of the economics supporting study has been to construct a model which will credibly quantify the benefits identified in the individual case studies. When the likelihood exists that a potential benefit will not materialize for reasons given above, it is dismissed. The benefit derived where the user is capable of responding to the weather forecast is counted and it is ignored when the user lacks the ability or capacity to act upon the weather information.

Finally, an effort has been made to accurately estimate those potential benefits to users of weather information based on satellite data which seem to have the greatest value. The goal is to find out where better knowledge of the weather will result in relatively large increases in the quantity and/or quality of a crop or where money saved in the production process will represent a significant percentage of the total costs involved.

Having identified the basically qualitative impacts from using forecasts incorporating weather satellite data, it has been possible to move into the actual construction of an economic behavioral model from which estimates of quantity, quality and production cost changes can be credibly estimated.

Those potential benefits which are not foreseeably attainable or which appear to be insignificant have been eliminated from consideration. This has served to reduce the number of factors the model must take into account. The specific form and details of the behavioral model employed for each case study depends upon the particular crop, recreation, or construction activity for which it has been designed.

In Smith and Boness (August, 1970), a probabilistic model of the harvesting decision was developed to provide a quantitative estimate of the benefits of weather forecasts in the Wisconsin hay industry. The expected savings derived in this study were applicable to farmers who supplement their hay in order to obtain a high level of milk output. The hay was evaluated in terms of the total digestible nutrient (TDN) and crude protein content of the hay. Poor drying conditions reduce the TDN content and necessitate a cost of bringing the hay up to a specified nutritional level. The existence of weather forecasts changes the probability that bad drying conditions will reduce the value of the hay since in these cases the farmer can leave the hay uncut until conditions improve. The expected benefit of weather forecasts was estimated to be 5-10% of the value of Wisconsin milk production. The result was particularly significant because the required forecast period was only on the order of two or three days.

The Economic Supporting Study has also been actively involved in an advisory role where the case experts themselves have undertaken to quantify benefits that they identified during the first year. Examples of this have been the contribution to the completion of the Tibbetts report on lettuce and the continuing work with Kuhn in the highway construction area. In the Tibbetts case, the initial conceptual framework was provided (also being used in the corn study) that led to some reasonable estimates of the expected benefits.

The following areas of research constitute the continuing effort in the economic area.

(a) Highway construction: A decision model from which we can obtain an estimate of the expected benefits to weather forecasts in highway construction will be developed. This is a particularly important study because the quantitative studies that have been completed to date have been in agricultural activities whereas this study is concerned with a construction activity.

(b) Pea crop: A study similar to that undertaken for corn and lettuce will be completed for the pea crop. Alan Torkelson who has worked with Professor Andrew on the corn study will work with Professor Gritton on a pea study.

(c) Recreational services: An economic supporting study will be undertaken in cooperation with Professor Gilligan.

(3) Overview: This will be a study integrating and extrapolating the results of all the individual case studies and will be undertaken during the remainder of the current academic year. Such a study should provide a unification that will allow the results to have maximum impact on the develop-

ment of meteorological satellite systems. Further, such a study can address the questions of how the benefits that have been identified and quantified relate to the satellite data and to the speed with which this data is or could be delivered, in appropriate form, to the user groups. Some general conclusions regarding the effect of weather information can be drawn by examining the common characteristics of those types of firms and industries that are able to benefit and those types that are not.

THE INTERNATIONAL LEGAL IMPACT RESULTING FROM RECENT ADVANCES IN SATELLITE METEOROLOGY

by Delbert D. Smith
J. D. Ph. D. (Cantab.)

INTRODUCTION

The mandate contained in the Proposal by the Space Science and Engineering Center of the University of Wisconsin concerning "Multi-disciplinary Studies of the Social, Economic and Political Impact Resulting from Recent Advances in Satellite Meteorology"[1] indicates that there will be an examination of the national and international effects and ramifications of the United States Meteorological Satellite Program[2] and that of great importance to a consideration of the impact of this program on political and international affairs will be an investigation into the nature of the inter-governmental agency activity and international co-operation which has stemmed from the development of a weather satellite program.[3] Further, it states:

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* Legal Advisor, The Space Science and Engineering Center, University of Wisconsin.

[1] Proposal dated Nov. 6, 1968. Grant No. NGR50-002-114.

[2] Id. at 1.

[3] Id. at 14.

> Since global weather observations are necessary to achieve accurate forecasts in the United States, sensors must orbit over and float in the air of all nations. Satellites and floating balloons do not recognize national boundaries; this means there will be legal and political questions concerning observing systems, forecasting systems and in the decades to come modification systems. These must be evaluated also.[4]

In conjunction with the use of satellites, international weather observation programs will also utilize constant altitude super-pressure balloons and buoys on the high seas which present problems in terms of international law. The international legal implications of the use of these sensors will arise whether the originating source is NASA in the United States or an international program in which the United States takes an active part. In fact, any use of sensors on an international level will involve the United States and NASA in inter-governmental activities designed to fulfill the scientific requirements for global weather observations within the framework of international law.

The above problem areas are significant in terms of the impact on NASA of the development of a weather satellite program and will affect NASA's mission and objectives, and therefore they will be the subject of this study. Consideration will first be given to the international legal problems associated with the use of sensors. The first section deals with the international legal impact of the use of meteorological

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[4] Id. at 3. The Proposal goes on to state that "Finally, these are areas in which technical decisions concerning the weather interact with political and legal decisions. These are areas of national importance; we will attempt to identify them in this study." Ibid.

satellites and includes a discussion of the relevant organizational aspects including GARP and WWW and also an analysis of the international legal implications of the United States participation in the global observation of the atmosphere via satellite.

The second section considers the international legal impact of the use of satellites with balloon data systems. The international legal context is presented and the impact of international law on the technology is treated with the aircraft safety question being given particular attention. The third section examines the international legal impact of the use of satellites and ocean data systems. Following a discussion of the technology there is an analysis of the relevant international legislation, the applicable safety regulations, the question of liability, and the need for an international agreement in this area.

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UNIT I

INTERNATIONAL LAW AND THE USE OF METEOROLOGICAL SATELLITE SYSTEMS

THE INTERNATIONAL LEGAL IMPACT OF THE USE

OF METEOROLOGICAL SATELLITES

INTRODUCTION

The objective of the science of meteorology is to pursue the search for an understanding of why the atmosphere behaves as it does and to develop the competence necessary to explain this phenomena. To a certain extent this goal would suffice in itself, but there is also a public service facet to meteorology that involves the prediction of the behavior of the atmosphere during a given period of time on the basis of information about certain characteristic features obtained prior to the beginning of that time. From these two considerations a central question emerges, and that is to what extent the successful attainment of the first goal would lead to the fulfillment of the second. In meteorology there are two problem areas that must be dealt with before an affirmative answer can be given as to whether a complete understanding of the atmosphere would enable adequate predictions to be made. The first problem is that the thesis of the structural identity of explanation and prediction[1] is valid only for deterministic systems and the complexity of the atmosphere and its fluid characteristics are such that even though the atmosphere may obey the laws of classical mechanics and

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[1] This thesis must be distinguished from prediction based on an empirical rule obtained by induction; generalizations based on a number of observed cases.

thus be considered a deterministic system, it also contains characteristics which make for unpredictability after sufficiently long periods of time based on the possible set of actual observations taken at a given time. However, generally the hypothesis is accepted that the atmosphere behaves substantially as a deterministic system and therefore it is predictable to a certain extent. The second problem is that even if the atmosphere is deterministic and every adequate explanation is potentially a prediction, there is a question as to whether the necessary observations of the atmosphere can be obtained through any feasible meteorological observing system. In other words, the practicalities involved in developing the technology of the observing system may provide the limitations upon the degree of predictability to be obtained. It is this second problem area in which the use of meteorological satellites and electronic computers can be used to best advantage. At present the useful period of validity of weather forecasts is for a period of one or two days with exceptional cases of adequacy up to five days. In order to increase predictability, to an upper limit of two or three weeks, it will be necessary to obtain special data through observational programs which would then be subjected to interpretation and analysis through the use of mathematical models which closely simulate the behavior of the actual atmosphere, the results being derived through the use of high-speed computers. There is not only concern with the adequacy of the data required for analysis but also with the geographical regions from which it is derived. Approximately 80% of the earth is inadequately observed in terms of meteorological data acquisition, and a further problem is to obtain data for these regions, a large part of which is ocean.

GLOBAL OBSERVATION OF THE ATMOSPHERE VIA SATELLITE: ORGANIZATIONAL ASPECTS

Given the necessity of data from various geographic regions, it becomes apparent that some system of global observation is needed, and to this end several attempts are being made to solve the problem. The Global Atmospheric Research Program (GARP)[2] is a combined program of the World Meteorological Organization (WMO) and the International Council of Scientific Unions (ICSU) for studying the physical processes in the troposphere and stratosphere that are essential for an understanding of

(a) The transient behavior of the atmosphere as manifested in the large-scale fluctuations which control changes of the weather; this would lead to increasing the accuracy of forecasting over periods from one day to several weeks;

(b) The factors that determine the statistical properties of the general circulation of the atmosphere which would lead to better understanding of the physical basis of climate.[3]

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[2] See "An Introduction to GARP," GARP Publication Series No. 1, International Council of Scientific Unions, World Meteorological Organization, Joint Organizing Committee (Oct. 1969).

[3] "Definition of GARP," Adopted by the Executive Committees of WMO and ICSU, Appendix II of "An Introduction to GARP," id. at 21. See also "Agreement Between the World Meteorological Organization and the International Council of Scientific Unions on the Global Atmospheric Research Programme," signed at Rome, Italy, Oct. 10, 1967, reprinted id. at 19.

The various experiments of GARP will attempt to use the available modern technology to answer the above basic questions and will also provide valuable information for the future operational system of global weather observation, the World Weather Watch (WWW) of the WMO.[4] This system will be composed of national facilities and services provided by the Members of the WMO for which the WMO will supply the needed coordination.[5] The main elements of the World Weather Watch system will be the global observing system, the global data-processing system, and the global telecommunication system.

GARP Satellite Utilization

Planning for the First GARP Global Experiment includes consideration of the use of satellites within the GARP global observing system. A satellite subsystem including (a) four geostationary satellites, (b) two or three low-altitude, nearly-polar orbiting satellites, and (c) one nearly-equatorial orbiting balloon-tracking satellite is being considered.[6]

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[4] See, "World Weather Watch: The Plan and Implementation Programme," World Meteorological Organization (May, 1967).

[5] The role of the WMO is clearly limited by the terms of the Annex to Resolution 16 (Cg-V) which states that due account is to be taken "...of the national sovereignty and security of States, in accordance with the provisions of the Charter of the United Nations and the spirit and traditions of the World Meteorological Organization." Id. at 4.

[6] "The Planning of the First GARP Global Experiment," GARP Publication Series No. 3, at 10, International Council of Scientific Unions, World Meteorological Organization, Joint Organizing Committee (Oct. 1969).

Concerning category (a), the ATS geostationary satellites have proved to be extremely accurate and their cloud pictures have also been of value. The four geostationary satellites do not need to be spaced equidistantly around the equator but can be located to give maximum coverage in the areas where there is little available data and leave gaps over continental areas where conventional coverage is adequate. These satellites will carry 75 kg. to 100 kg. of sensor and sensor-associated equipment including a 15 cm. to 30 cm. -diameter telescope, cooled infrared detectors, scanning mechanisms, electronic signal processing and transmission devices, a data collection capability, and sufficient electric power for this equipment.[7] Visible scanners would provide high resolution cloud observations and IR scanners would provide cloud-top temperatures. IR scanners would also give nighttime cloud pictures with less resolution than during daytime. The satellites would also contain radio circuits for data collection and relay from surface platforms such as buoys or balloons.[8] The spacecraft would be stabilized by spinning which would simplify the scanning mechanism for the radiometers and photometers. The range of coverage afforded by these satellites indicates the interest that nations will have in the sensors

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[7] "Systems Possibilities for an Early GARP Experiment," COSPAR Working Group VI Report to JOC. GARP Publication Series No. 2, International Council of Scientific Unions, World Meteorological Organization, Joint Organizing Committee (Jan. 1969).

[8] "Systems Possibilities for an Early GARP Experiment," COSPAR Working Group 6, Supplementary Report to JOC (Oct. 1969), at 1. See discussion of balloon and buoy data systems below.

that are located aboard the satellites.[9] There may also be questions as to the utilization of the infrared telescope and the analysis of the resultant data.

The two category (b) satellites which are suggested for low-altitude, near-polar orbits would have for their main functions carrying sensors for vertical temperature and water vapor soundings and equipment for balloon location. The altitude for the satellites is suggested as 1,000 km, the minimum altitude being determined by the length of time necessary to transmit the stored data to a ground station, usually once per orbit. At this height and with an orbit inclination of about 99 degrees the satellite would be sun-synchronous which means that it would cross the equator approximately at the same local time on each orbit. The sensors carried by these satellites for temperature and water vapor soundings would be IR and microwave spectroradiometers and cloud-cover imagers.

Because there may be poor coverage of low-latitude balloons, a third low-altitude satellite was proposed (category c) in an equatorial or low-inclination orbit. It would carry only balloon location equipment. Alternative configurations for the low-altitude satellites have been suggested which might make unnecessary the use of a third low-altitude satellite.[10]

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[9] See Appendix I.

[10] Systems Possibilities <u>supra</u> note 7 at 39-40.

WWW Satellite Utilization

The World Weather Watch will make use of the technological expertise developed by GARP and will utilize data from meteorolgical satellites developed by the United States and the Soviet Union. The WMO has encouraged Member States to install stations capable of receiving meteorological data directly from satellites and the global observing system will make use of the data collected by meteorological satellites launched by Member States.[11] The plan of the World Weather Watch with regard to satellites is as follows:

> Meteorological satellites already provide, on an operational basis, valuable data on the extent and character of the global cloud cover. Much improved meteorological satellites will probably be in orbit during the period 1968-1971. These satellites are expected to provide data on cloud distribution during both day and night and certain other global atmospheric parameters for operational purposes. The WMO should assist in bringing about co-ordination of the satellite programmes of individual countries (or groups of countries)."[12]

In considering the role of meteorological satellites in the World Weather Watch, the WMO realizes that "(t)he existing satellite system is only the first stage in the establishment of the ultimate operational global system which should emerge during the next few years following the

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[11] "World Weather Watch: Second Status Report on Implementation," World Meteorological Organization (July, 1969), at I-8.

[12] "World Weather Watch: The Plan and Implementation Programme," at 7. World Meteorological Organization (May, 1967).

very considerable effort which is being devoted to the refinement of existing sensors and the development of new techniques."[13] The eventual aim is to develop satellite techniques that will reduce the reliance that needs to be put on conventional surface-based observing systems.

The fact that satellite technology will be provided by the United States and the Soviet Union within the basic framework of national sovereignty is recognized by the WMO in the following statement of the basic concepts of the WWW:

> 4. The World Weather Watch is conceived as a world-wide system composed of the national facilities and services provided by individual Members, co-ordinated and in some cases supported by WMO and other international organizations.
>
> 5. The World Weather Watch shall be used only for peaceful purposes, due account being taken of the national sovereignty and security of States, in accordance with the provisions of the Charter of the United Nations and the spirit and traditions of the World Meteorological Organization.[14]

However, the above must be seen in the further context of the role that the WMO sees for itself in taking the necessary steps to see "...that the meteorological information provided by operational satellites is

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[13] "The Role of Meteorological Satellites in the World Weather Watch" at 1, World Weather Watch Planning Report No. 18, World Meteorological Organization (1967). It is further stated that "The most important feature of satellite observations is perhaps the global or near-global nature of the data output. This is of particular value in large-scale forecasting processes." Id. at 3.

[14] World Weather Watch, supra note 4 at 4.

promptly available in suitable formats and that the advantages of this means of observation are made freely available to all Members."[15] This is coupled with the following statement to the effect that "Members launching meteorological satellites should, through the WMO, ensure full co-ordination of their observational contribution with the then-current world pattern to obtain the most efficient observational output with a minimum of duplication."[16] The role of the WMO as a coordinating body would appear to be satisfactory to participating nations, but suggestions have been made to the effect that the WMO should assume a supervisory role in the World Weather Watch to ensure that the data emanating from meteorological satellites would always be available to the other participating nations in addition to the launching nations. The implication is that if there were a political controversy that the launching nations may decide to withhold data and that this would not be acceptable.[17] Since the primary responsibility for the research and development of U.S. meteorological satellites is with the National Aeronautics and Space Administration, there should be an awareness of the possible role-enlargement on the part of the WMO and consideration should be given to the extent to which

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[15] The Role of Meteorological Satellites, supra note 13 at 1.

[16] Id. at 6.

[17] Interview, the World Meteorological Organization, November, 1969, Geneva, Switzerland.

supervisory control by an international body is thought to be desirable. It is suggested that the assumption of an operational role by the WMO concerning the World Weather Watch would have a detrimental effect on the rate of scientific progress made in the global observation of the atmosphere and that the WMO functions should be maintained at the level of coordination.

As was pointed out by COSPAR Working Group 6 in reference to GARP, "...thought must be given to establishing some kind of international mechanism to discuss the coordination of appropriate national contributions and to implement the additional special GARP satellites and observing elements suggested in this document."[18] While this might take the form of a planning conference or other such meeting, it is also possible to consider the formation of a body of a more formal nature to coordinate satellite activities and to consider the need for standardization among launching countries of formats, observing schedules and related factors.

A part of the problem in developing the World Weather Watch and in contradistinction to the emphasis of the WMO on the subordination of national programs to the world plan and the distribution of data in a suitable format for all Members, is the fact that "(d)ue to the advanced

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[18] Systems Possibilities supra note 7 at 44.

nature of the developments required by the WWW and the research experiments, only a limited number of Member states are able to make substantial contributions."[19] Further, "(b)ecause international development projects are somewhat difficult to manage and execute, bilateral arrangements are favored."[20] While the example given to illustrate this point by the United States refers to the joint effort between the U.S. and France to test a satellite-horizontal sounding balloon system, this idea of bilateral or even multilateral arrangements may prove to be more viable than coordination through an international body which may attempt to define a controlling role for itself in the future. In addition, thought should be given to the implementation of an operational global atmospheric observation system that would reflect the contributions of the respective nations in much the same way that the INTELSAT consortium operates. These and other considerations should be viewed within the context of the extent of the U.S. contribution to meteorological satellite technology.

The United States Contribution to Meteorological Satellite Technology

The first TIROS (Television and Infra-red Observation Satellite) which was launched in 1960 was equipped to obtain cloud photographs

[19] "World Weather Program: Plan for Fiscal Year 1970," U.S. Departments of Commerce, Defense, Interior, State and Transportation, Atomic Energy Commission, National Aeronautics and Space Administration, and National Science Foundation at 16 (Mar. 1, 1969).

[20] Ibid.

of a portion of the earth, and this capability was expanded by the launch of NIMBUS I by NASA in 1964 and by the launch of TIROS IX in 1965, the latter two having a global capacity. The TIROS Operational Satellite System was established by the Environmental Science Services Administration (ESSA) in 1965 to provide global coverage of cloud systems on an operational basis, and eight such satellites have been launched to date. NASA has also developed the NIMBUS II and III satellites which have been used for testing new sensors in polar orbits. NIMBUS III was put into orbit on April 14, 1969 and has been considered extremely successful in terms of over-all performance.[21] The TIROS Operational Satellite System is an outgrowth of the initial meteorological satellite system developed by NASA in the 1960s, for which the TIROS-M, which was launched in 1969 was the latest in the series. This satellite contained equipment to acquire day and night-time global and local observations of cloud systems. During 1970 the initial design and fabrication work will be undertaken by NASA on an operational synchronous satellite which will contain a television camera system and infrared sensors to permit cloud photographs in day and nighttime. In addition to the NIMBUS satellite, the ATS satellite—an

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[21] Supplementary Rpt., supra note 8 at 4. The following sensors were carried by NIMBUS III: SIRS (Satellite Infrared Spectrometer); IRIS, (Infrared Interferometer Spectrometer); IRLS (Interrogation, Recording, Location System); HRIR (High Resolution Infrared Radiometer); IDCS (Image Dissecting Camera System); MUSE (Monitor of the Ultraviolet Solar Energy). The VTPR (Vertical Temperature Profile Radiometer) is being planned for use on the ITOS spacecraft in 1972.

earth synchronous satellite—is used by NASA to test advanced remote sensing and data collection devices. ATS I and ATS III provided valuable meteorological data which is being evaluated during 1970. By 1972 NASA will launch ATS F which will contain infrared sensors and an image dissector camera.

The NIMBUS D will be launched in 1970 by NASA and will test improved sensors and an advanced data collection system for the interrogation and location of remote data platforms. Design and fabrication work will be undertaken by NASA on the NIMBUS E and F which are scheduled for launching in 1972 and 1973. NIMBUS E will be used to test microwave sensor techniques and sophisticated infrared sensors, and evaluation is presently underway regarding the proposals for NIMBUS F experiments. There are also plans in 1970 for NASA to launch the Cooperative Applications Satellite (CAS) with France to develop and test a new satellite balloon technique. It will employ a French spacecraft to track 500 instrument-carrying constant altitude (37,000 ft.) balloons.[22]

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[22] For a discussion of Soviet meteorological satellite developments, see The Role of Satellites..., supra note 13 at 15. One experiment which is of particular interest in terms of the multiple uses of satellites was the Russian experiment with the MOLNIYA-1 high-orbit satellite which involved the use of television aboard the satellite—basically a communications satellite—and utilized the long-distance communications capability of the satellite. Television pictures were sent directly to reception points at ground stations and both a wide-angle and narrow-angle lens were used.

THE INTERNATIONAL LEGAL IMPLICATIONS OF UNITED STATES PARTICIPATION IN THE GLOBAL OBSERVATION OF THE ATMOSPHERE VIA SATELLITE

The launching and use of meteorological satellites by the United States both as regards participation in international programs such as GARP and WWW and as regards individual experiments raises a number of international legal questions.

The Question of Liability

The basic question here is to what extent the United States should be liable for damage caused by the meteorological satellites that it launches. Should it make a difference whether the launch was for national research purposes or was undertaken as part of an international program?

The 1967 Outer Space Treaty[23] provides basic guidance as to the assumption of liability regarding the launching of satellites. Article VI provides:

> States Parties to the Treaty shall bear international responsibility for national activities in outer space...whether such activities are carried on by governmental agencies or by non-governmental entities, and for assuring that national activities are carried out in conformity with the provisions set forth in the present Treaty.[24]

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[23] "Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon, and Other Celestial Bodies," Signed at Washington, London and Moscow Jan. 27, 1967: T.I.A.S. No. 6347, Reprinted in 61 Am. J. Int'l L. 644(1967).

[24] Id. at Art. VI.

More specifically, Article VII states:

> Each State Party to the Treaty that launches or procures the launching of an object into outer space . . . and each State Party from whose territory or facility an object is launched, is internationally liable for damage to another State Party to the Treaty or to its natural or juridicial persons by such object or its component parts on the Earth, in air space or in outer space . . .[25]

Thus it appears that not only is the State that launches an object into space liable for damage but also the State from whose territory or facility the object is launched. This would appear to create liability for the United States even though its launching facilities were used by a third State for launching a meteorological satellite. The liability would seem to be joint and some agreement as to percentages would have to be agreed upon between the parties. The situation is further complicated by Article VIII which states: "A State Party to the Treaty on whose registry an object launched into outer space is carried shall retain jurisdiction and control over such object. . ."[26] If the satellite launched by a third State using United States facilities were carried on the registry of the third State, it would appear illogical to give the third State jurisdiction and control over the satellite but make the United States jointly liable for damage caused by it because U.S. launching facilities were used.

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[25] Id. at Art. VII.

[26] Id. at Art. VIII.

The exact nature of the liability to be imposed, however, has not been finally clarified. In a proposed draft of a treaty on "Liability for Damage Caused by Objects Launched into Outer Space," the United States had suggested that the responsibility of the launching State should be absolute.[27] Another option would be to limit liability to those activities that were considered to be "unlawful." There is precedent for the position that when an immensely hazardous activity is engaged in, absolute liability is imposed.[28] To the extent that all nations of the world benefit from the meteorological data derived from satellites launched by the United States, it could be argued that absolute liability should not be imposed based on the hazardous nature of the activity, but rather that standards of fault and lawfulness should be relied upon. However, in a balancing of interests between the launching State and the national of a third State, it could be argued that the liability should rest with the launching State.[29]

[27] Draft Resolution on Liability for Damages Caused by Objects Launched into Outer Space, A/A.C./105/C.L./L.8 at Art. III.

[28] Rylands v. Fletcher (1865), 3 H. & C. 774, 159 Eng. Rep. 737; and 1868 L.R. 3 H.L. 330. The Soviet Union allows only the defenses of a force majeur or gross negligence of the victim to a charge of absolute liability. See P. Jessup and H. Taubenfeld, Controls for Outer Space 241(1959). Conventions have imposed liability upon industries such as the airlines industry without regard to fault. See Latchford, "Bearing of International Air Navigation Conventions on the Use of Outer Space," 53 Am. J. Int'l L. 405(1959), and Association of the Bar of the City of New York, Report of the Committee on Aeronautics on the Warsaw Convention as amended by the Hague Protocol, 1959.

[29] M. McDougal et al., Studies in World Public Order 761(1960).

The possibility of limiting liability or of shifting it through an assumption of liability by an international organization such as the WMO which could be used for launching meteorological satellites poses further problems. The 1967 Outer Space Treaty provides in Art. VI that

> When activities are carried on in outer space . . . by an international organization, responsibility for compliance with this Treaty shall be borne both by the international organization and by the States Parties to the Treaty participating in such organization.[30]

This raises questions as to the way in which this "sharing" of liability is to be accomplished. Is the international organization to accept "half" and the member States to divide the other "half" or is there to be an assignment based on financial contribution to the organization or active participation in the launching activity? Further, it would appear that whatever the distribution of liability between the international organization and member States, that under Article VII this liability would be further shared with the launching State or the State from whose territory the satellite was launched. Would it make any difference if this latter State were also a member of the international organization? Would it be required to accept an even larger share of the responsibility?

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[30] Outer Space Treaty _supra_ note 23 at Art. VI.

While Article VI attempts to create joint responsibility for the launching of satellites between international organizations and States, Article XIII of the Treaty asserts that it is the States that are ultimately responsible for outer space activities:

> The provisions of this Treaty shall apply to the activities of States Parties to the Treaty in the exploration and use of outer space . . . whether such activities are carried on by a single State Party to the Treaty or jointly with other states, including cases where they are carried on within the framework of international inter-governmental organizations.[31]

Here the further limiting feature is that only inter-governmental organizations are considered, and this by implication excludes international organizations with membership beyond States such as the International Council of Scientific Unions (ICSU) which is a non-governmental international organization. In Article XIII the attempt is made to make States the basic unit of responsibility even though the framework of an international organization is used. This Article continues by stating that:

> Any practical questions arising in connection with activities carried on by international inter-governmental organizations in the exploration and use of outer space . . . shall be resolved by the States Parties to the Treaty either with the appropriate international organization or with one or more states members of that international organization, which are Parties to this Treaty.[32]

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[31] Id. at Art. XIII.

[32] Ibid.

While what is meant by "any practical questions" is ambiguous, the implication is again clear that States are to be the final unit of responsibility in the Treaty and if any questions arise regarding international organizational activity that either the States Party to the Treaty will settle it with the organization or if that is not possible the States themselves will resolve the problem without consulting the organization as a separate entity.

The role to be played by international organizations is further clouded by reference in Article VIII of the Treaty only to the registry of a State when considering jurisdiction and control. No provision is made for a registry of the United Nations nor for any other international organization. Thus there would appear to be no way that an international organization could launch and maintain control over a satellite. It is interesting to note that at one time there was a suggestion that a registry be located within the United Nations Committee on the Peaceful Uses of Outer Space. In support of this position, the Draft Code of Rules on the Exploration and Use of Outer Space by the David Davies Institute provided:

> Sec. 5.2
> Every spacecraft to be launched by an international body shall be registered with the Committee on the Peaceful Uses of Outer Space, which shall issue a registration mark.
>
> Sec. 5.3
> For all purposes including that of any claim concerning the activities of a spacecraft:

a) every spacecraft to which Sec. 5.1 (registration provision) applies shall be deemed to have the nationality of the State in which it has been registered . . . and
b) throughout its life shall, with its component parts, so long as they are identifiable, be deemed, in the absence of special agreement, to be the property of the State concerned under Sec. 5.3a or of the international body registering it, as the case may be.[33]

While this Draft dealt with the ownership of a spacecraft by an international organization, it did not consider the question of nationality of the spacecraft.[34] It might be possible to separate ownership and registration in the event that an international organization were to be involved in launching a meteorological satellite.[35] Thus while it would not seem possible for international organizations to launch and be liable for spacecraft, it may be possible to use the structure of a joint operating organization or an international operating agency and apportion State liability for such an undertaking.

[33] "Draft Code of Rules on the Exploration and Uses of Outer Space," David Davies Institute (1963). See also 29 J. of Air Law and Commerce 141 (1963), and M. Cohen, Law and Politics in Space 163-4 (1964).

[34] See S. Shubber, "Jurisdiction over Crimes on Board Aircraft," Dissertation submitted for the Ph. D. degree in the University of Cambridge, at 252-53 (1968): D. P. O'Connell, I International Law 112 (1965): Jennings, "International Law of the Air," 75 Recueil des Cours de l'Academie de Droit International 560 (1949).

[35] This suggestion has been made with reference to aircraft operated by the United Nations. I, Brownlie, Principles of Public International Law 352 (1966): See also Mankiewicz, "Aircraft Operated by International Operating Agencies," 31 J. of Air Law and Commerce 319 (1965): Jennings, "International Civil Aviation and the Law," 22 Brit. Y.B. Int'l L. 208 (1945): Latchford, "Bearing of International Air Navigation Conventions on the Use of Outer Space," 53 Am. J. Int'l L. 405 (1959).

The existing analogies here are with the joint operating agencies established by States to pool their resources.[36] However, the problems of nationality and registration still arise in the existing Conventions dealing with such devices as aircraft. For example, Article 77 of the Chicago Convention provides:

> Nothing in this convention shall prevent two or more contracting States from constituting joint air transport operating organizations or international operating agencies. But such organizations . . shall be subject to all the provisions of this Convention . . . The Council shall determine in what manner the provisions of this Convention relating to nationality of aircraft shall apply to aircraft operated by international operating agencies.[37]

The implications of this provision have created some ambiguity when attempts have been made to determine its manner of application to various international operating organizations.[38]

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[36] See B. Cheng, The Law of International Air Transport 252-59(1962).

[37] Convention on International Civil Aviation (Chicago Convention, 1944) Cmd. 6614(1945): U.N.T.S. 15 at 295.

[38] "Report on Art. 77 of the Chicago Convention (Doc. LC/SC, Art 77/Rpt.(July 24, 1965) ICAO Legal Committee: Subcommittee: "Report of the Panel of Experts on Art. 77 of the Chicago Convention," 27 J. of Air. L. & Comm 292(1960): International Law Association, Helsinki Conf., Air Law Committee 246-286 (1966).

As to the question of jurisdiction, the Tokyo Convention[39] provides in Article 18 that:

> If contracting States establish joint air transport operating organizations . . . which operate aircraft not registered in any one State, those States shall, according to the circumstances of the case, designate the State among them which, for the purposes of this Convention, shall be considered as the State of registration and shall give notice . . . to the I. C. A. O. which shall communicate the notice to all States parties to this Convention.[40]

This idea of designating one State to be the State of registration could also be applied to the situation where a group of States wish to launch a meteorological satellite and one of them is willing to accept the designation as the national State of registration. However, suggestions had been made when the above provision was inserted into the Tokyo Convention to the effect that all of the Member States of such an operating organization should have the jurisdiction of the State of registration.[41] This would be in direct conflict with Article 17 of the Chicago Convention which limits registration to individual States and does not include international organizations. There is a direct parallel with the

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[39] "Convention on Offences and Certain Other Acts Committed on Board Aircraft," signed at Tokyo, Sept. 14, 1963, ICAO Doc. 8364.

[40] Id. at Art. 18. The basic grant of competency to exercise jurisdiction is found in Art. 3, para. 1 of the Convention and it refers only to the State of registration.

[41] "International Conference on Air Law," Tokyo, Aug.-Sept., 1963, I. Minutes, ICAO Doc. 8565-LC/152-1 at 68, para. 23. As to the possibility that an aircraft which is not registered in a State would be a "pirate" aircraft with no international rights see Mankiewicz, supra note 35 at 304.

provision in Article VIII of the Outer Space Treaty which refers only to registration in a State.

The difficulties that would arise if there were more than one State of registration would center around the differences in domestic laws regarding liability and compensation, these differences being detrimental to any attempt to fix liability so that the expectations of the nations would be taken into consideration. It must be remembered that the designation to be made under Article 18 of the Tokyo Convention applies only to the matter of jurisdiction,and for purposes of the Chicago Convention it may not apply at all or another set of regulations may be used. This would create further uncertainty as to the responsible State. The possible conflict between Article 77 of the Chicago Convention and Article 18 of the Tokyo Convention points out the difficulties inherent in any attempt to establish either a joint operating agency or an international operating agency and suggests that Article VIII of the 1967 Outer Space Treaty has rightly limited registration to States.

An elaboration of Article VIII could be suggested along the lines of Articles 20 and 21 of the Chicago Convention which provide that every aircraft engaged in international air navigation shall bear its appropriate nationality and registration marks (Art. 20) and that each State will supply to any other contracting State or to the International Civil Aviation organization ". . . on demand, information concerning the registration and ownership of any particular aircraft registered in that State."[42] (Art. 21). The codification of a formal duty of notification would be beneficial particularly as to meteorological satellites since observation of their registration marks when in orbit could prove extremely difficult.

Additional legal complications would arise in the event that a State leased (or chartered) a meteorological satellite to another State or to an international organization.[43] The analogies to air law are sparse and inconclusive with the subject having been omitted from the Tokyo Convention altogether. Problems of lease, charter, and the limitation of liability generally, would arise if the United States were to consider that the acceptance of strict liability for the meteorological satellites that it launches as part of the GARP experiments or the World Weather Watch would be unconscionable and that since all nations are benefitting from these activities that liability should be limited or shared. This could lead to a situation where an agreement would be reached as to the liability to be accepted among the nations participat-

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[42] Chicago Conv. supra note 37 at Art. 21.

[43] For a discussion of the various types of charter arrangements, see Shawcross and Beaumont, I Air Law 600-01 (3rd ed. 1966). See also Kean, "Interchange," 67 J. of the Royal Aeronautical Society 514 (1963): J. W. F. Sundberg Air Charter (1961): Goldklang, "Transatlantic Charter Policy—A Study in Airlines Regulations," 28 J. of Air Law and Commerce 99 (1961-62).

ing in the programs and possibly some sort of joint operating agency established.

The Multiplicity of Uses Problem

As technology develops the number and complexity of sensors put on meteorological satellites will increase, and to the extent that these sensors utilize television and other pictorial devices and are able to photograph clouds and also the earth's surface, they raise problems of unauthorized emplacement and use. There would appear to be only slight differences between meteorological satellites and the reconnaissance satellites which have been the subject of much controversy.[44] The 1967 Outer Space Treaty provides some guidelines for resolving problems as to the extent of the use of sensors on meteorological satellites. Article XI provides:

> In order to promote international co-operation in the peaceful exploration and use of outer space, States Parties to the Treaty conducting activities in outer space . . . agree to inform the

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[44] See Lipson and Katzenbach, "Report to the National Aeronautics and Space Administration on the Law of Outer Space," at 30-31, American Bar Foundation (1961): Morenoff, World Peace Through Space Law (1967): Kraus, "Legal Aspects of Space Communications and Space Surveillance," 29 J. of Air Law and Commerce 230(1963): A consideration of reconnaissance satellites raises the further problem of the utilization of fractional orbital bombardment systems which are put in orbit and fired by remote control at ground targets before completing its first orbit. This in turn leads to consideration of plans to use reconnaissance satellites as part of an arms control inspection system which is beyond the scope of this work.

> Secretary General of the United Nations as well as the public and the international scientific community, to the greatest extent feasible and practicable, of the nature, conduct, locations and results of such activities. On receiving the said information, the Secretary General of the United Nations should be prepared to disseminate it immediately and effectively.[45]

The limitation of the effectiveness of this provision lies in the phrase "to the greatest extent feasible and practicable," but if a problem as to the real nature of the use of a meteorological satellite arises, such information furnished by the launching State would do much to allay unfounded suspicions.

Another possibility would be to have representatives of interested States present at the launching of a meteorological satellite or immediately prior to the launching to inspect the electronic payload and determine the type of sensors being sent into outer space. This type of plan can be inferred from Article X of the Outer Space Treaty which states:

> In order to promote international co-operation in the exploration and use of outer space, . . . in conformity with the purposes of this Treaty, the States Parties to the Treaty shall consider on a basis of equality any requests by other States Parties to the Treaty to be afforded an opportunity to observe the flight of space objects launched by those states.
>
> The nature of such an opportunity for observation and the conditions under which it could be afforded shall be determined by agreement between the states concerned.[46]

This provision only calls for consideration by the launching State of requests to observe the flight of its satellites and does not refer specifically to the launching procedure, but it might be possible, in light

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[45] Outer Space Treaty, supra note 23 at Art. XI.

[46] Id. at Art. X.

of the goal of promoting international co-operation, to devise some system for reciprocal inspection.

While it is probable that all of the problems relative to inspection found in the arms control and disarmament field would arise here, there is always the possibility of success if national security interests were not involved. The type of visit contemplated by State representatives would be similar to that mentioned in Article XII of the Outer Space Treaty with reference to installations on celestial bodies:

> All stations, installations, equipment and space vehicles on the moon and other celestial bodies shall be open to representatives of other States Parties to the Treaty on a basis of reciprocity. Such representatives shall give reasonable advance notice of a projected visit, in order that appropriate consultations may be held and that maximum precautions may be taken to assure safety and to avoid interference with normal operations in the facility to be visited.[47]

The key phrase here is "on a basis of reciprocity" since it is unlikely that the United States would be willing to undertake such an operation if the Soviet Union did not also provide a similar opportunity. The fact that maximum precautions to avoid interference with the normal operation of the facility would be taken would minimize the possibility of any breach of security. Additional guidelines as to the type of arrangements that could be made can be found in the recent seabed treaty proposed by the United States and the Soviet Union in Geneva in October of

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[47] _Id._ at Art. XII.

1969.[48] While the Outer Space Treaty does not have any articles dealing with violations of treaty provisions nor any sanctioning provisions, it is valuable as a formal indication of the intentions of the major nations and as such can serve as the basis for further international agreement on the problems dealing with meteorological satellites.

Since the WMO does not play an operative role in either GARP or the WWW it is unlikely that a system of liability for satellite use should involve this organization. If some form of consortium such as used by INTELSAT were established it might be possible to consider a primary claim against the international organization and secondary claims against the Member States. The lack of central control would seem to preclude any assertion of centralized responsibility. The question remains open as to whether all participating States should share equally or proportionally in any loss experienced. One alternative would be to consider joint liability with a secondary claim against the launching

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[48] Details of the provisions of this Treaty will be added when available. The Treaty bans nuclear weapons and other means of mass destruction—chemical and biological weapons—from the ocean floor not more than twelve miles offshore. The Treaty leaves to the "super powers" the difficult task of inspection. The success of this Treaty will be in direct proportion to the success of the U.S./U.S.S.R. strategic arms limitations talks (SALT).

State only if willful neglect were shown as to its particular activities.[49] Practical considerations involving the ability of an international organization to meet any damage claims would preclude most attempts in this direction. A further consideration would be that if liability were apportioned among participating nations, this might prove to diminish the propensity of some nations to participate in a program since they could not meet their share of a possible damage claim. This would particularly apply to developing nations that are encouraged to participate in programs such as GARP and WWW and are even assisted in doing so.[50]

It is suggested that a one year limitation be placed on any claims for liability against a launching nation, and that claims be made only by States through the proper diplomatic channels. Individual claims should be made only through the responsible government, and if an agreement is drafted dealing with governmental liability, provision should be made for the submission of any disputes regarding claims to arbitration or to the International Court of Justice.

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[49] Fitzgerald, "The Participation of International Organizations in the Proposed International Agreement on Liability for Damage Caused by Objects Launched into Outer Space," 3 Can. Y.B. Int'l L. 265 (1965).

[50] "Consolidated List of Voluntary Assistance Programme Projects Approved for Circulation in 1969: World Weather Watch," World Meteorological Organization (July, 1969). This program provides for assistance to be given to Member countries at their request either in the form of equipment and services contributed on a voluntary basis by Member countries or by direct financing, using financial contributions obtained on the same basis.

The Dissemination of Information from Meteorological Satellites

While generally there is no question as to whether or not all information obtained from meteorological satellites should be freely disseminated to all nations, the problem has been raised[51] and merits consideration. There may be the need for a formal agreement between all participating nations regarding the continued availability of meteorological satellite data, or it may prove desirable to install duplicate facilities to ensure a continued flow of data. At the present time, United States meteorological satellites carry an Automatic Picture Transmission (APT) system which transmits automatically to receiving stations within visual range. Some forty-two countries operate one or more APT receivers and by 1971 it is expected that about one hundred countries will be using them. While the output of these satellites will be constantly improved and this will require continued sophistication of the receiving devices in order to make full use of the data, a basic source of information will always be available to those nations operating

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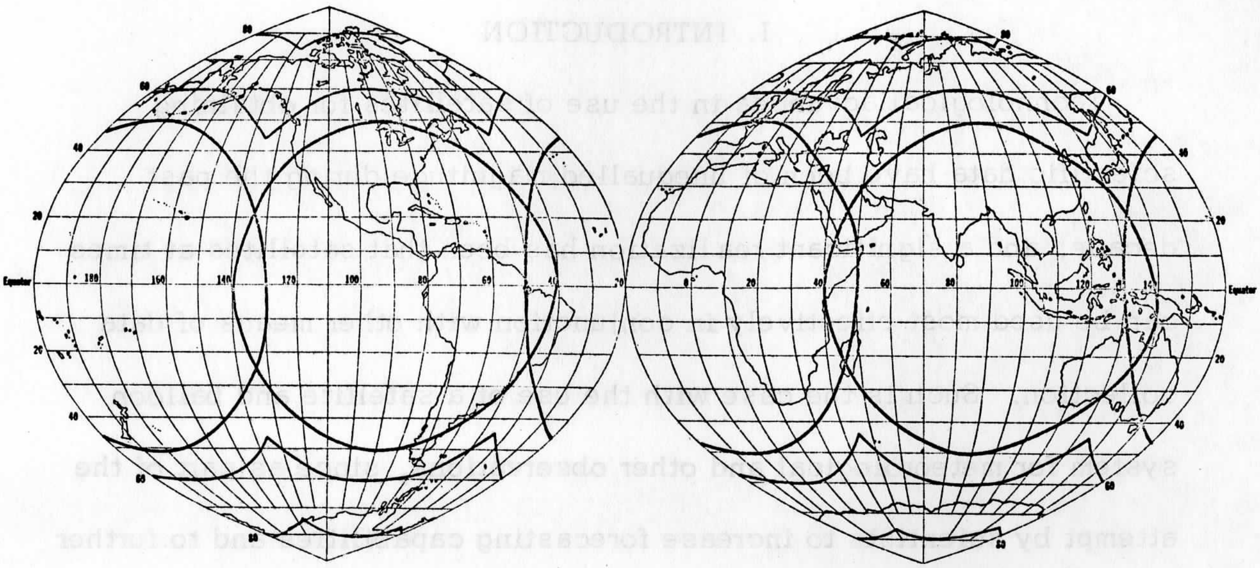
[51] Lipson and Katzenbach, supra note 44 at 30. The problem is raised to the effect that if foreign national satellites are used that there may be some question of the free and accurate dissemination of information. This same question has been raised by the WMO with regard to the availability of information from both the U. S. and U. S. S. R. satellites and the likelihood that political circumstances might cause a curtailment of the data. Interview, the World Meteorological Organization, November, 1969, Geneva, Switzerland.

receivers. The Soviet Union has also indicated that their satellites will use the APT system in the near future and that reception details will be provided to the WMO for the use of all its Members. Plans are also being made for the use of satellites in transmitting coded weather data by direct relay to remote areas where conventional telecommunications channels are lacking. Thus there is no immediate need for concern over the possible restriction of data, but the possibility and means of averting it should be considered in any formal document relating to satellite meteorology on a global basis.

APPENDIX I

Global Viewing Area from Geostationary Satellite Altitude



The above figure represents the viewing area from geostationary altitude. The angular distances cited are measured from the subsatellite point along any great circle arc. The fields of view shown on this equal-area map projections are:

80° — the limit of the useful viewing field.

60° — the probable practical limit for reliable meteorological observations such as wind determination (and probably limited to high level clouds under some circumstances).

50° — the field of view conservatively estimated for reliable meteorological determinations of winds under most circumstances.

Note particularly the limit of the useful viewing field and the respective countries that are included within even the most precise 50° range.

THE INTERNATIONAL LEGAL IMPACT OF THE USE OF SATELLITES AND BALLOON DATA SYSTEMS

I. INTRODUCTION

Technological advances in the use of satellites for obtaining scientific data have been of unequalled magnitude during the past decade, and a significant realization has been that satellites at times can be used most effectively in conjunction with other means of data collection. Such is the case with the use of a satellite and balloon system for meteorological and other observations, since as part of the attempt by scientists to increase forecasting capabilities and to further the accuracy of meteorological research, it has been found that balloons of various sorts have a utility.

The familiar expandable unvented balloon can be used to carry aloft radiosondes to take measurements in the upper atmosphere. It is made of rubber or synthetic rubber and is designed to ascend until the expanding gas stretches the balloon wall to the breaking point. There are also zero pressure balloons made of plastic film which permit the expanding gas to escape once the balloon envelope has been filled to its full volume, the result being that the internal gas pressure equals the pressure of the outside atmosphere. The venting of this gas allows neutral buoyancy to be attained and the balloon floats at a reasonably constant altitude. These balloons are used for carrying heavy scientific instruments to high altitudes.

Finally, there is the superpressure balloon which is used in the NASA Nimbus D/IRLS Program, the GHOST (Global Horizontal Sounding Technique) system and the French EOLE system among others. These balloons do not vent a predetermined amount of excess gas once they have filled out to their full volume but rather they rise until the mass of the displaced air equals the mass of the balloon and its instrument package, where, unable to expand, the gas sealed within the balloon exerts an increasing pressure on the walls of the balloon. The internal pressure becomes approximately 20% greater than the ambient atmospheric pressure (superpressure), and the balloon volume and mass remain essentially constant so that the balloon continues to float at a constant density altitude with the prevailing wind. These superpressure balloons are of particular interest concerning their overflight over national territory and their effect (along with their electronic payloads) on aircraft safety.

Superpressure balloons usually carry temperature, humidity, and pressure sensors, a radio transponder for the transmission of data to interrogating satellites and for providing signals by which to determine the balloon's location, and a radio altimeter to determine altitude. One of the operational problems with these balloons is that the solar cells used for prime power function only during daylight, and so further research is necessary to develop low density batteries, such as those developed in France, to extend operation into nighttime and to provide a functional power source in the polar regions. Thus scientific research in this area is attempting to find ways to extend balloon lifetime and to develop a fully effective low density battery. The balloons are used in the stratosphere but not generally in the mid-troposphere; the following Chart describes the technical results of GHOST and EOLE balloon tests as of January 1969. Note the figures for the average life, the maximum life, and the outlook for the average life of the balloons.

BALLOON LIFETIMES AT DIFFERENT LEVELS[1]

Level (mb)	Number	Average Life (days)	Maximum Life (days)	Outlook for Average Life (days)
30	10 U.S.	50	116	≈ 365
100	22 U.S. 10 French	> 100	> 439 and still aloft	≈ 365
200	60 U.S. 20 French	90	351	170-200 except in tropics
300	50 French 5 U.S.	12 43	102 88	50 15 in tropics
500	20 U.S.	7	22	
700	3 U.S.	14	21	20
850	10 French	11	20	20

[1] "Plan for U.S. Participation in the Global Atmospheric Research Program" at 23. U.S. Committee for the Global Atmospheric Research Program, Division of Physical Sciences, National Research Council (National Academy of Sciences, Wash. D.D. 1969). As of October, 1969 there were no new figures as to balloon lifetimes. "Systems Possibilities for an Early GARP Experiment" at 18. Supplementary Report to JOC by COSPAR Working Group VI (Oct. 1969). The following descriptions are supplied for the four primary altitude zones: (1) Below Freezing Level (1000 to 600 mb) where balloon lifetime is limited by topography to two to three weeks; (2) Region of Occurrence of Super-Cooled Water (700 to 250 mb) where balloon lifetime is limited by ice accretion on the balloon; (3) Tropopause Level (200 mb) where with careful factory test and packing techniques lifetimes of six months or more can be expected; and (4) Stratosphere (100 to 10 mb) where at the higher altitude ultra-violet deterioration may restrict flights unless increased film thicknesses are used. Appendix 3 "The Feasibility of an Operational Superpressure Balloon System for the Southern Hemisphere" at 3-4 of Report, World Meteorological Organization, Informal Planning Meeting on Constant-Level Balloon Program in the Southern Hemisphere, Melbourne, Australia, 24-28 Mar. 1969.

It should be remembered that the word "level" in this context refers to density level and not altitude level. It has been suggested that by 1971 improved materials used in the balloon construction will make it possible to employ a limited network of low-altitude (850 mb) balloons in the tropics.[2]

At the present time it is probable that balloons will not be used in the Northern Hemisphere but will be restricted to use in the Southern Hemisphere.[3] However, the fact that balloons can be used with satellites to provide an increased scientific observing system for meteorological or other purposes makes a consideration of the international legal

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[2] "Systems Possibilities for an Early GARP Experiment" at 13 (COSPAR Working Group VI Report to JOC) GARP Publication Series No. 2, International Council of Scientific Unions, World Meteorological Organization, Jan. 1969. It had been suggested that 1,000 balloons would be used for the early GARP experiment with 600 balloons at one high level (150 or 200 mb) distributed over the entire earth carrying location equipment, temperature sensors, pressure sensors, and radio altimeters. Since the balloons might not have maintained a uniform distribution, it was also thought necessary to consider additional balloons at this level. There were to be approximately 300 balloons at low-altitude level (about 850 mb) which would carry instrumentation for wind field determination, temperature, pressure and possibly relative humidity. Finally, about 100 balloons could be used for special limited experiments at other levels. Balloons were not proposed for the polar regions but it was thought that some balloons would ". . . drift into the polar regions, of course, and at times of the year when there is sunlight, will give some additional data." Id. at pp. 34-5.

[3] Interview, Joint Planning Staff, November, 1969, Geneva, Switzerland.

implications of the use of balloons in national airspace of practical importance. This fact was recognized by the COSPAR Working Group VI which considered as an essential prerequisite for the worldwide constant-level balloon system "international agreement regarding balloons overflying all of the countries of the world, and aspects of aircraft safety"[4] and recognized that "(t)here is no international agreement now as to what constitutes a hazardous balloon package, nor are there any agreed-upon specifications for flight packages that set any design limit for mass distribution or configuration."[5]

II. THE INTERNATIONAL LEGAL CONTEXT

A number of international legal problems arise in connection with the overflight of balloons which raise questions of national sovereignty. When the balloons overfly national territory, the subjacent State would have control over their safe passage in conformance with Article 1 of the Convention on International Civil Aviation (Chicago Convention, 1944) which provides that "the contracting States recognize that every State has complete and exclusive sovereignty over the air space above

[4] Systems Possibilities. . . . supra note 2 at 44.

[5] Ibid. The report continues by stating that "However, the results of EOLE and GHOST hazard tests to date provide at least some important design criteria within which the flight packages can realistically be kept to insure negligible damage upon impact at jet airplane speed." Ibid. The validity of this contention will be examined below.

its territory."[6] This exercise of sovereignty extends to the airspace above territorial waters as well as the land.[7] Thus there is no real question as to the source of authority for control regarding the national overflight of balloons.

If one considers balloons to be aircraft within the definition found in the Chicago Convention which defines aircraft as being any machine which can derive support in the atmosphere from reactions to air[8] then the provisions of this Convention could be applied. There are some significant differences with the standard conception of aircraft in that the constant-level balloons are not under manned-control as to their exact flight path since they drift with the prevailing winds, and further their flight path cannot be determined to any precise degree. While there had been a general freedom of innocent passage through a State's air-space provided for in Article 2 of the Paris Convention of 1919 for the Regulation of Aerial Navigation, this right was circumscribed by the Chicago Convention which required the consent of the subjacent State

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[6] Cmd. 6614(1945); U.N.T.S. 15 at 295: text and commentary also available in D. Johnson, Rights in Air Space, Appendix II at 88(1965); 23 Brit. Y. B. Int'l L. 460(1946).

[7] Id. at Art. 2.

[8] The constant-level balloon floats on an isopycnic surface and is employed primarily at the present time in the stratosphere.

for the overflight of scheduled international air services.[9]

The closest analogy for observational balloons would probably be with unscheduled aircraft which, under the terms of the Chicago Convention ". . . have the right, subject to the observance of the terms of this Convention, to make flights into or in transit non-stop across its territory and to make stops for non-traffic purposes without the necessity of obtaining prior permission, and subject to the right of the State flown over to require landing."[10] Observational balloons would be making, in effect, non-stop flights across a nation's territory, but there would be obvious technical difficulties involved in complying with the clause which requires landing at the order of the State flown over. In effect, this amounts to a right of inspection of the aircraft which would be denied the State in the case of observational balloons. Since there might very easily be some question concerning the purpose of the sensor devices on the balloon, this requirement of landing might be used to void the analogy. However, the Convention also calls upon the contracting nations in Article 4 not to use civil aviation for any purpose inconsistent with the aims of the

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[9] A scheduled international air service operates under a published timetable, passes through the airspace of several States, and transports passengers, mail, or cargo for remuneration. It is unlikely that observational balloons would fall into this category.

[10] Chicago Conv. supra note 6 at Art. 5.

Convention, which are found in the Preamble and admonish the States to avoid friction and to promote cooperation between nations. Thus, to the extent that the balloons did not cause any practical harm either to aircraft safety or to some other activity, the desirability of international cooperation might outweigh the arbitrary prohibition of such endeavors particularly if the doctrine of reciprocity were considered.

There is a relevant distinction in international law made between state and civil flight craft. State flight craft are those used by the military, customs, and police services while all other flight craft are designated as "civil." State flight craft require express permission for overflights while civil flight craft require only tacit or implied permission.[11] To the extent that meteorological balloons are launched by governments and are the responsibility of governments, they could be considered as civil flight craft. The interpretation depends on whether one considers the major purpose of the flight or the entity responsible for claims against it in terms of liability for damages.

With respect to the high seas, the question would appear much simpler since Article 2 of the Geneva Convention on the High Seas[12]

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[11] Cheng, "International Law and High Altitude Flights: Balloons, Rockets, and Man-Made Satellites," Int. & Comp. L. Q. 488(1957).

[12] Geneva Convention on the High Seas (1958); UN Doc. No. A/CONF. 13/53(1958) reprinted in 2 Off. Rec. 135. The adoption by States of the provisions of this Convention is declared in the Preamble to be "generally declaratory of established principles of international law."

provides in paragraph (4) for the freedom to fly over the high seas, and also for other freedoms which are recognized by general principles of international law, provided that they are exercised with reasonable regard to the interests of other States. The question, here, is one of interpretation since the listing of freedoms may be considered to be open-ended and therefore not restrictive so that overflight by a scientific balloon may be included. Support for this position is found in the awareness of the International Law Commission of the legitimacy of the freedom to undertake scientific research on the high seas.[13] Thus, by considering the freedom to fly over the high seas and considering it together with the general freedom to conduct scientific research, it may be possible to conclude that there should be a freedom recognized by the general principles of international law as to the overflight by scientific observational balloons.

The International Law Commission specifically did not mention particular freedoms for the reason that some of them may not have assumed sufficient practical importance to justify special regulation. The scope of limitation recognized by the Commission was that "States are bound to refrain from any acts which might adversely affect the

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[13] Commentary on the Report of the International Law Commission to the General Assembly (1956 I. L. C. YB. (II) at 278).

use of the high seas by nationals of other States."[14] Put another way, the test to be developed should reflect the "reasonableness" of the use or activity since this would aid in the promotion of minimum order on the high seas.[15] To the extent that the overflight of balloons did not interfere with the activities of the nationals of other States, it would probably be permitted under the general rules of international law pertaining to the high seas.

There are several possible responses on the part of a State that does not grant the privilege of overflight to scientific observational balloons. The most obvious is to destroy the balloon. The precedent for this can be found in the destruction of aircraft by the Soviet Union when they were claimed to be within the area of sovereign protection of that country.[16] While ostensibly the scientific observations carried

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[14] Ibid.

[15] M. McDougal and W. Burke, The Public Order of the Oceans 763(1962).

[16] In 1952 the Soviet Union shot down a Swedish military plane over the Baltic Sea claiming that the plane was within their airspace since their territorial waters were asserted to extend twelve miles from the shoreline. The major claim by Sweden, in addition to a disputation of the relevant facts, was that they did not recognize the extension of Soviet territorial waters and airspace. That same year the Soviet Union also shot down an American aircraft that it claimed was within their territorial airspace. While this latter case was referred by the U. S. to the International Court of Justice, it was removed from the Court's list subsequent to a finding that the USSR had not accepted the jurisdiction of the Court. See Johnson, supra note 6 at 71-2.

out by meteorological balloons would not have the same political impact as the presence of foreign aircraft in a nation's airspace, it is possible that the sensors employed in these balloons could be such that they could be used for intelligence gathering and observations of military establishments within the subjacent State and thus would generate substantial hostility. A less final response would be to lodge a diplomatic protest where either the launching State was requested to destroy the balloon or permission was received by the subjacent State to destroy it after notice was given to the launching State. Another form of diplomatic protest would merely refer to the violation of national sovereignty such as was done by Albania, Bulgaria, Communist China, Czechoslovakia, East Germany, Hungary, Mongolia, Poland, Rumania, and the Soviet Union.[17] If there were distribution of the scientific findings of the balloons to all nations overflown, the likelihood of formal protest would be lessened.

III. THE IMPACT OF INTERNATIONAL LAW ON THE TECHNOLOGY

In order to more fully understand the application of international law to the flight of meteorological and other balloons, it is necessary to consider the existing programs utilizing these devices and the extent to which technological changes may bring about a situation that

[17] Cheng, supra note 11 at 488.

will require new legal rules. Essentially there are two types of payloads that are attached to the various forms of meteorological balloons which can be differentiated by the implications of their collision with aircraft or other airborne devices. The first is the non-frangible payload which must be jettisoned in case of a malfunction or the likelihood of collision. It is of a substantial size and may or may not consist of a balloon interrogation package for use with a satellite system. The second is a frangible payload which is theoretically safe in terms of the effect it has on a jet aircraft engine when it is ingested. It is usually of a very small size and light-weight. One of the scientific decisions presently being made is whether to employ one type or the other in various meteorological experiments where atmospheric data must be obtained. The National Aeronautics and Space Administration in its series of experiments with observational satellites uses balloons as a part of its data-gathering system, which can be expected to expand in the future. The following sections consider the current programs utilizing balloons in terms of the problems of national overflight and sovereignty and also in terms of the need for aircraft safety.

The Nimbus D/IRLS Program

The U.S. National Aeronautics and Space Administration (NASA) and the National Center for Atmospheric Research (NCAR) are jointly conducting an experiment which employs the Nimbus D satellite and an

IRLS which is an interrogation, recording and location system, both of which were developed by NASA's Goddard Space Flight Center. The IRLS will be able to determine wind speeds and directions by identifying and tracking constant level balloons and then storing this information for subsequent relay to a central data processing center. The satellite itself is in low orbit and receives a command from a ground station to interrogate a series of balloons which it does by calling the address of the balloon, making two range measurements, and receiving the necessary information from the balloon. Each balloon will have a receiver and decoder so that it will be able to recognize its address when it is called. Since the transmitter on the balloon will only be on for a short time there will be low power consumption which will permit the use of thin-film non-hazardous batteries for night operations. During daylight hours the battery cells can be recharged by thin-film solar cells.

The IRLS is designed to collect data of various sorts from remote unmanned platforms such as the balloons to be employed in meteorological research along with ocean buoys and possibly other platforms. The system is composed of the satellite, a Ground Acquisition and Command Station, and the remote data platforms. Equipment at the platforms converts the raw data to digital form and transmits these data to the satellite. The Nimbus D satellite memory is capable of storing data measured during each orbit for up to 370 different interrogations with the range measurement between the satellite and the platforms being accurate to within ± 500 meters. The resultant accuracy of the location measurements can come within 2 km. of the actual position.

The equipment carried by the balloon—its interrogation package—consists of self-contained transponding devices capable of sustained operation at high altitudes. It is composed of a lightweight directional antenna constructed of polystyrene foam with aluminum foil conductors, a panel of Clevite solar cells to recharge the electronic batteries and to supply heat for thermal control, and a small, low power, insulated electronic unit composed of a thermal capacitance section, electronics section, power supply section, and a receiver and transmitter. A radar target is also attached to the balloon package, which while not sufficient for long-range tracking at float altitudes, is used for tracking during ascent. On the balloons launched for testing purposes from Ascension Island, a conventional GHOST electronics package was attached to the balloon beneath the interrogation package. Finally, a cutdown device is attached to all balloons which terminates balloon life after 180 days or below 18 km.[18]

Inasmuch as the Nimbus D/IRLS is scheduled for launching during 1970, it is important to consider the legal implications of the balloons

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[18] "GHOST: A Technical Summary," at 6, 17, 25-28. National Center for Atmospheric Research, Boulder, Colorado, U.S.A. (May, 1969). See also Supplementary Report _supra_ note 1 at 8-9.

that have been designed and are currently being tested for the system prior to the operational establishment of the system.

The SPARMO Experiment

The Solar Particles and Radiation Monitoring Organization (SPARMO) which is the Permanent Service of F. A. G. S. (I. U. GG-IAU) has planned to launch three 10,000m^3 balloons at 24 hour intervals between July 30 and August 5, 1970 from Finland. The payload for each balloon will weigh 10 kg. and will be made up of a particle-detector, a transponder, electrical batteries, two telemetering instruments, and safety devices to ensure release of the load by parachute and destruction of the balloon.

The balloons will drift towards the West at an altitude of 8 mb. passing over Finland, Sweden, Norway, Iceland and Greenland. The flight will last for a week during which the balloons will cover a distance of 4,000 km. to 5,000 km. Because of possible problems regarding overflight, the Organization requested the WMO, within the framework of the general policy of cooperation between WMO and ICSU to correspond with their Permanent Representatives in the affected countries and to obtain the approval of the governments for this overflight.

These letters were sent by the WMO to the Permanent Representatives of Finland, Denmark, Sweden, Norway and Iceland with copies being sent to Canada, the U.S.A. and the U.S.S.R.[19] The possibility of an erratic flight path was the reason for the distribution of the copies.

There was unanimous consent on the part of the directly affected States, and there was no objection from the other States with the exception of the Soviet Union whose response—when, in fact one was not specifically requested—was that the flight of any device and particularly of a free flying balloon should be made in agreement with the country organizing the flight and the country overflown. The response then stated, rather ambiguously that "[C]onsidering that the flights of the aforementioned trial balloons represent a danger to aviation, as well as the lack of any agreement on these flights or of a guarantee that they will not intrude into the airspace of the Soviet Union, we regret that we cannot contribute to the implementation of the free flying balloon flights over our territory."[20] What the lack of contribution to the implementation of the flight means is open for future interpretation if the circumstance arises that one of the balloons goes off course and enters Soviet airspace before being destroyed. The full significance of this response is not yet known, since in the future it is likely that the Soviet Union will wish to engage in similar experimentation which

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[19] The letters were sent out on July 18, 1969 and were signed by the Secretary-General of the WMO. (Ref. No. 17.428/T/OSM) along with an annex which generally explained the scope of the experiment.

[20] Letter to the WMO from G. I. Golўsev, Assistant Chief, Hydrometeorological Services of the U.S.S.R. dated August 21, 1969. [Translation]

would require international cooperation. The fact that the response did not threaten the destruction of the balloon or some similar action is in itself encouraging.[21]

An immediate problem is that of aircraft safety. In an effort to overcome this difficulty the SPARMO experiment relies on the fact that the balloons will be launched in agreement with the Finnish air traffic authorities in the same fashion as was done in 1956, 1966 and 1967, and that they will contain a number of safety devices. The receiving stations to be set up in each of the overflown States will contain telecommand facilities (on 108 m/cs) for measuring the balloon's location and if necessary for destroying the balloon and jettisoning the payload by parachute. There will be two additional receivers for listening on the 15m/cs band to follow the balloons in the event that their flight-path differs considerably from the one foreseen and they are lost by the regular tracking stations. When the balloons reach the height of 150 mb, it is stated that the airspace "will be completely free" by which it is presumably meant that there will be no aircraft flying at this altitude. The safety devices aboard the balloon will permit:

(a) Separation of the load and automatic destruction of the balloon if, after two hours' flight, the balloon is still below 50 mb;

(b) Separation of the load and automatic destruction of the balloon when the electricity supply to the experimental elements runs out;

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[21] Interview, the World Meteorological Organization, Nov. 1969, Geneva, Switzerland.

(c) Separation of the load and automatic destruction of the balloon should it descend to a level of lower than 50 mb.[22]

There will be two methods of destruction of the balloons: lateral and polar. Finally, two radar reflectors are to be attached after the balloons are fitted out to enable their location to be checked by radar.

Questions arise as to what safety precautions are to be taken during the two hours maximum time when the balloon is obtaining its approved altitude? What is the degree of effectiveness and reliability of the devices that are to be used for the destruction of the balloon? Further, what is the effective range of the signal that will be used to destroy the balloon, and what is the reliability factor of the automatic destruction device that will destroy the balloon when the electrical supply terminates? One factor that would seem to be in need of further study is whether the radar reflectors attached to the balloons can be used by aircraft in flight to discover the existence of the balloons in sufficient time to allow for evasive action to be taken. When it is said that there will be no conflict with aircraft flight paths, does this take into account both military planes and nonscheduled private aircraft which might be in the vicinity. Also, nothing is said about the frangibility of these balloons. Is it to be concluded that they

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[22] Annex to letter sent July 18, 1969 to involved countries by the Secretary-General of the WMO. (Ref. No. 17.428/T/OSM). See text at footnote 19.

do pose a danger to aircraft but that their flight path is to be such that they will not come into contact with them?

Plans for an Operational System in the Southern Hemisphere: WWW and GARP

Despite the many available data sources for obtaining meteorological information, the tropics remains as the area where the least data is available. This situation is to be remedied with the development of the WMO World Weather Watch[23] and the experiments planned for inclusion in the Global Atmospheric Research Programme.[24] While the use of the satellite to obtain data is the most outstanding of the technological innovations to be employed in these systems, there are still some measurements that for reasons of accuracy and economy, can at the present time still be accomplished better by the use of balloons. The balloons to be employed in such a data-gathering capacity are constant-level superpressure balloons utilized by GHOST (Global HOrizontal Sounding Technique) developed in the United States and the French EOLE system.

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[23] See "World Weather Watch: The Plan and Implementation Programme," World Meteorological Organization, Secretariat (May, 1967).

[24] See "An Introduction to GARP," Global Atmospheric Research Programme, Joint Organizing Committee, GARP Publication Series No. 1 (Oct. 1969). GARP is jointly sponsored by the WMO and the International Council of Scientific Unions.

An early WMO Executive Committee Resolution on the subject of horizontal sounding techniques for the Southern Hemisphere and also for the desert regions of the Northern Hemisphere contained, among others, the following two recommendations:

> (1) That research in the creation and development of horizontal sounding techniques should be encouraged and should be directed toward the development of equipment which would not present any hazard whatsoever to aviation;
>
> (2) That before any horizontal sounding techniques are introduced in any region there should be full agreement between all the countries concerned to ensure that there will be no possibility of infringement of national sovereignty.[25]

While this Resolution is no longer in force, it represents an early recognition of the desirability of a system that presented no hazard to aircraft and did not violate national sovereignty, and thus it is with these two considerations in mind that the EOLE and GHOST balloon systems are analyzed.

The French EOLE Project

The constant level balloon flight program in France, called EOLE involves the development of plastic, superpressure balloons to trace air circulation patterns by drifting with the wind at constant density altitudes. The payload on these balloons consists of a solar powered

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[25] "Horizontal Sounding Techniques," Res. 20 (EC IX) (1957) WMO-No. 67. RC. 14 at 60.

15 MHz radio beacon keyed on and off by suitable switching circuits to transmit Morse code signals. The beacon is composed of a solar generator, sensors and associated circuits, switching logics, and a radio transmitter. The over-all assembly in the shape of an open box weighs 300 grammes. The French have accepted the results of tests conducted in the United States concerning the ingestion of a payload in a running jet engine,[26] and they have also conducted their own tests regarding the effect of the payload impact on the front windshield of a commercial jet aircraft. Direct impact tests have been conducted at nominal 600 mph speeds on standard Boeing 707 windshields, the results of which are that the specifications for a completely safe balloon payload is a maximum mean weight per unit cross section area (for all horizontal directions) of $3g/cm^2$ and a maximum weight of individual (dense) components of 3 g.[27]

As a further justification for the use of such a balloon payload, statistical studies are cited showing the probability of a commercial aircraft hitting a balloon payload which consider the scheduled commercial flights for 1968, and fifty constant level balloons at 200 mb

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[26] See discussion below of GHOST ingestion tests.

[27] Morel, "Constant Level Balloon Flight Program in France," unpublished paper dated Mar. 17, 1969 at 22. [Laboratoire De Météorologie Dynamique, Centre National de la Recherche Scientifique, 1 Place Aristede-Briand, 92-Meridon-Bellevue.]

distributed randomly in the Southern Hemisphere; they conclude that the probability of one aircraft/payload collision per 100,000 hours of flight is r = 0.0005. This is then compared with the current flight incident statistic which is r = 0.27 per 100,000 hours (world average).[28] The statistical validity of these results depends partially on whether the use of only the figures for scheduled commercial flights is sufficient without consideration of military and nonscheduled aircraft. Further, even preliminary studies indicate that from fifty to 100 balloons will be launched as an "operational experiment in the Southern Hemisphere"[29] and many more are contemplated for an operational system. This would appear to necessitate a study of the possibility of multiple collisions. Also, consideration should be given to the use of balloons at various levels and the resultant collision percentage.

French plans for the future may include the development of a balloon tracking system using an improved version of the EOLE satellite for balloon tracking and data collection. The spacecraft could be launched in a low-altitude (1,000 km) nearly equatorial orbit. This system would eventually become the part of the GARP Global Experiment provided by the French meteorological space program.

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[28] Id. at 21. See Appendix I.

[29] See discussion below of WMO Informal Meeting concerning constant-level balloons in the Southern Hemisphere.

The American GHOST Project

The use of constant level balloons was first shown to be practical in the United States when in 1957-59 U.S. Navy scientists used 100 balloons in the Transosonde Project which were flown at 300 mb and were tracked with radio direction finders. These were extremely heavy balloons and with the coming of transatlantic jet aircraft the experiments were discontinued. To circumvent the problem created by the jet aircraft, attempts were made to utilize strong high-modulus plastic films and micro-miniature electronics to develop a nonhazardous system. In 1958 a proposal was made by two scientists at the Air Force Cambridge Research Laboratories to establish the GHOST system, and in 1961 the National Center for Atmospheric Research in Boulder, Colorado became the headquarters for the GHOST system development. Subsequently, in March of 1966 a southern hemisphere test program of GHOST balloons was begun in Christchurch, New Zealand.[30] The first two phases of the test flights were completed between March 1966 and June 1968 during which 152 flights were made at pressure altitudes ranging from 900 mb to 10 mb, the results of which have shown that the GHOST balloon is capable of providing a useful description of the global atmosphere from

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[30] "GHOST: A Technical Summary," at 4. National Center for Atmospheric Research, Boulder, Colorado, U.S.A. (May, 1969). The test program is a joint research undertaking of the New Zealand Meteorological Service and the National Center for Atmospheric Research [NCAR] and the Environmental Science Services Administration [ESSA]. The flight program is managed by NCAR.

200 mb. to 10 mb, that the balloons fly stably at a constant density level with maximum deviations of less than 50 m., and that the electronics systems are able to locate the balloons anywhere in mid-latitudes during daylight hours within about 100 kilometers.[31] Part three of the southern hemisphere test program which was begun in October of 1968 is composed of approximately 130 flights within the two year test period with the balloon payloads consisting of either one or two GHOST electronics packages each weighing no more than 150 grams. The scientific goals of this phase will be to attempt to solve the flight failure problems at low levels down to 900 mb, to improve the current location systems, and to test a non-satellite balloon location system for possible application in some of the projected GARP sub-programs. Flights will also be made to high levels (80 mb) to measure secondary radiation from solar flares which is considered to be a potential hazard for supersonic transports during active solar years. The scientific payloads for these flights will not exceed 600 grams. There will also be additional flights at 10 mb and some at 30 mb to complement flights over equatorial regions at 30 mb, all of which will carry scientific payloads. Northern hemisphere stations

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[31] Id. at 5. Tracking stations were operated on a full-time basis at Christchurch, Melbourne, Buenos Aires, Lima, and Pretoria, and on a part-time basis at Tahiti, Brazil, Zambia, Angola, Mauretius, and Antarctica.

have been established in Israel, the Philippines, Hawaii, and Colorado to provide location information on balloons that come within radio range. There are also stations at Santiago, Ascension Island, and Mauritius to assist in balloon tracking operations. Finally, there will be a group of flights that will test an electronics system which will function both day and night with battery power.

Pertaining to aircraft safety, it has been found that the balloon itself should be constructed of polyethylene terephthalate (Dupont Mylar) which is plastic at room temperature but is brittle at cold temperatures so that it will shatter if struck by an aircraft. The GHOST electronics package consists of a sun-angle sensor which aids in determining the balloon's location, and telemetry equipment to relay the sun-angle data and other measured parameters to ground stations. Experimental electronics packages powered by solar cells, with miniature electronic circuits built on very thin epoxy circuit boards make the package light weight, spread out, and of fragile construction. The weight of the entire package, including the solar cell power supply is about 150 grams. A black plastic cover houses the package to maintain warmth at high altitudes. The package itself hangs below the balloon on the antenna of the 15-megahertz transmitter.[32] Provision is made for the

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[32] Id. at 18. The antenna is a center-bed dipole consisting of a quarter-wave section above the package and an equal section trailing freely below the package.

conversion of the basic electronics package to a more comprehensive one by the addition of more circuit boards. In aircraft safety tests conducted in cooperation with the U.S. Federal Aviation Administration, two GHOST electronic packages were ingested into jet engines of the kind used on commercial jet aircraft.

> No engine performance changes were noted, either visually or audibly, nor did the monitoring gauges show any indication of abnormal behavior. Upon inspection of the engines, minor damage to fan blades was found; however, this damage was of the type that normally occurs in routine operation of jet engines, for example from ingestion of runway debris.[33]

The conclusion was that the GHOST package does not present an operational hazard to jet engines. It is assumed that when additional circuit boards are attached to the basic package that these tests will again be run. It would also seem desirable for tests to be run using the GHOST basic and augmented packages in impact simulations with the windscreens of the type used by aircraft that would be in all of the altitude occupied by the balloons.[34] A further safety test was conducted which involved a balloon at room temperature being impacted on a jet engine, with the result of this "worst-case" test being that the impaction did not interfere with the operation of the engine.

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[33] Id. at 22.

[34] The tests in France, mentioned above, are cited as providing ". . . rigorous specifications to eliminate all hazard to aircraft windshields." Ibid.

While it is logical to expect that future technological developments will bring the weight and bulk of the electronics package down even more,[35] it is also logical to expect that new sensors will be developed and there will be pressure for their inclusion in the electronics packages. For example, the Cannibal-loon system which consists of an unpressured helium balloon enclosed in a larger superpressure balloon contains a motor, pump, and humidity sensor which may necessitate the addition of a cutdown device if they prove to cause significant damage to aircraft engines or windshields. These balloons are to be launched during the third phase of the GHOST test program in an attempt to solve icing problems by allowing the balloon to change its altitude.

The IRLS system which will be flown in conjunction with the Nimbus D launch will weigh between 4 kg. and 5 kg. and as such would definitely constitute a hazard. To eliminate this problem the flight will take place at 50 mb and 30 mb which is above the flight paths of most aircraft. On test flights for the IRLS a 180 day cutdown timer has been used in addition to a pressure-switch which is activated if the balloon descends below 60,000 feet. The actual cutdown is

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[35] Advances are suggested as to ultra-thin resistors, capacitors, semiconduction devices, and solar cells. Resonant circuits for the higher frequencies can be made as a strip transmission line and foam plastic can serve as a dielectric material. <u>Ibid.</u>

accomplished by a small squib which blows a hole in the balloon after which the entire system descends at 5 m/s to 10 m/s, the balloon acting as a parachute. On the Nimbus D/IRLS flights the 180 day timer will be replaced by a command cutdown operated from the ground through the Nimbus D satellite; the primary concern here being to destroy balloons which move into the Northern Hemisphere rather than solely aircraft safety.[36]

At present the American F. A. A. is considering specifications for electronic packages, including radiosondes, and it is important that NASA consider what the realistic limitations on these packages ought to be so that there will be no unnecessary hinderances to progress in this area.

The WMO Informal Planning Meeting on a Constant Level Balloon Programme in the Southern Hemisphere

In March, 1969 an informal planning meeting concerning the constant-level balloon program in the Southern Hemisphere was organized by the WMO in Melbourne, Australia.[37] In the report of this meeting the statement was made that "the balloon packages under consideration are non-hazardous to aircraft operations and comply with the specifica-

[36] Letter from V. E. Lally, Project Head, Global Atmospheric Measurements Program, to the author dated December 8, 1969.

[37] Report, "World Meteorological Organization Informal Planning Meeting on Constant-Level Balloon Program in the Southern Hemisphere," Melbourne, Australia, 24-28 March 1969.

tions given in the report 'Constant Level Balloon Flight Programs in France,' 17 March 1969 by Prof. P. Morel, University of Paris."[38] At a later point in the report, under the heading "Navigational and Political Questions," it is again stated that ingestion and impact tests on aircraft have been made with experimental flight packages and components and that these tests have indicated that the system proposed is non-hazardous to jet aircraft. It continues: "Any change to operational balloon systems will be tested to ensure that the non-hazardous nature is maintained."[39] It is not apparent whether any specific study has been given to maintaining effective contact with the balloons so that any variation in course could be immediately notified to any affected aircraft, or whether the tests take into consideration the variation in aircraft models that might be in the airspace occupied by the balloons either during ascension or during any part of their lifetime.

The question of permission for overflight has apparently been solved inasmuch as it was reported that "continuing consent has been obtained from the Southern Hemisphere nations for experimental flights. It is assumed that no objections will be raised for the proposed experimental operational flights in the Southern Hemisphere."[40] The

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[38] Id. at 5. This report is discussed above under the heading "The French EOLE Experiment."

[39] Id. at 10.

[40] Ibid.

designation of "experimental operational" flight is slightly confusing but apparently indicates an experimental launch of a large number of balloons to test the feasibility of the operational system. Reference is made in the Report to the "operational experiment" in Region V which would be conducted prior to any operational system using constant level balloons for the entire Southern Hemisphere. For this operational experiment fifty to 100 balloons would be used in flight at one time with the majority of the balloons flying at 200 mb. and a small proportion at 50 mb. In order to maintain fifty to 100 balloons in the air in mid-latitudes at one time it would be necessary to have between 150 and 250 launchings per year.[41]

The suggestion was made that twelve direction find stations would be necessary for Southern Hemisphere coverage with a nominal range of 2500 KM. The question then arises as to what means will be available to track the balloons if their flight path causes them to leave the Southern Hemisphere. Will they be equipped with an effective cutdown timer and pressure switch? The statement is made in the Report that "It should be recognized that there is a small, but real possibility that some balloons may cross into the Northern Hemisphere."[42] If so, what

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[41] Id. at 6-7. There is some question as to whether these figures refer only to Region V or to the entire Southern Hemisphere.

[42] Id. at 10.

practical means will there be to determine the location of the balloon, to establish whether a hazard to aircraft is present, and to effectively destroy the balloon without a substantial time delay? Further, given the tendency of the balloons to cluster in the Southern Hemisphere, have tests been conducted to examine the results after several payload packages have been ingested by a jet aircraft engine or directly hit the windshield of such an aircraft? Considering that the "recommendations for the future" suggested the possibility of changing eventually from a ground-based to a satellite balloon system and the expansion of the Southern Hemisphere system into a global one,[43] much more serious thought should be given to the possible international legal implications and specifically to the question of aircraft safety.

Reference is made in Appendix 3 of the Report of the Melbourne meeting to the ingestion tests carried on with GHOST electronic packages on two occasions.[44] It was stated that the electronic package had been designed to minimize the cross-sectional density, that its mass is less than one hundred grams, and that it is distributed to reduce

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[43] Id. at 14.

[44] Appendix 3, "The Feasibility of an Operational Superpressure Balloon System for the Southern Hemisphere" of Report, World Meteorological Organization, Informal Planning Meeting on Constant-Level Balloon Program in the Southern Hemisphere," Melbourne, Australia, 24-28 March 1969.

impact hazard. It does not, however, state that any impact tests have been conducted. It only refers to the balloon itself in this respect by stating that the balloon ". . . is unlikely to present an impact hazard or to foul aircraft surfaces. At stratospheric altitude, the balloon material acts like a brittle glass which should shatter on impact."[45] The use of the world "should" raises some doubt as to the certainty of this conclusion.

As to locating the balloons, it is stated that simple direction finding techniques are feasible for determining the direction of the balloon from the tracking station when the balloon is within 3,000 kilometers. It is further stated that the National Center for Atmospheric Research in the United States has under consideration a system (estimated cost $5,000) which would be able to determine the azimuth of a balloon within one degree. This would correspond to a theoretical error of 17 kilometers at a range of 1,000 kilometers and 52 kilometers at a range of 3,000 kilometers, although propagation conditions on some occasions may degrade this performance considerably.[46]

An additional limiting factor in determining how many balloons can be used for any experimental or operational system will be the available frequency bands and the workload of the tracking stations. Care will

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[45] <u>Id.</u> at 6.

[46] <u>Id.</u> at 8.

have to be taken to see that only the number of balloons are launched that will be capable of being effectively tracked at all times.

OWNERSHIP AND OPERATION OF BALLOON DATA SYSTEMS BY INTERNATIONAL ORGANIZATIONS

One of the international legal problems concerned with the development of the technology of advanced balloon data systems is that there is the possibility of the United Nations or one of its specialized agencies assuming an operational role which might involve the ownership and operation of the technical devices needed to carry out the appropriate research within the scope and functions of the organization. In fact, it has been suggested informally that the WMO might assume a supervisory function in relation to some aspects of the World Weather Watch and this function might involve the exercise of control over some of the necessary equipment to ensure that complete data reports were received by all nations.[47] To the extent that such a role is contemplated, national organizations such as the National Aeronautics and Space Administration should be aware of the international legal consequences of such an occurrence.

Since balloons may be considered aircraft within the meaning of the Chicago Convention,[48] (or even if they are not so considered the

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[47] Interview, the WMO Secretariat, Nov. 1969, Geneva, Switzerland.

[48] See text, supra note 8 concerning the Chicago Convention definition.

closest analogous situation is with aircraft), the problems involved in international organization ownership of aircraft may be considered as providing the legal base for further study. Article 17 of the Chicago Convention provides that aircraft possess the nationality of the State in which they are registered.[49] It must be remembered that international organizations are not States, despite the fact that they have some degree of international personality as conferred by the International Court of Justice in the Reparations Case. The Court, after attributing international personality to the United Nations, continued

> That is not the same thing as saying that it is a State, which it certainly is not, or that its legal personality and rights and duties are the same as those of a State. Still less is it the same thing as saying that it is a 'super-State'. . . .[50]

However, this seemingly negative statement must be balanced with the following statement from the same advisory opinion:

> Whereas a State possesses the totality of international rights and duties recognized by international law, the rights and duties of an entity such as the Organization (The United Nations) must depend upon its purposes and functions as specified or implied in its constituent documents and developed in practice.[51]

While the argument based on purposes and functions—that is that the United Nations has the international capacity necessary to achieve the

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[49] Chicago Conv. supra note 6 at Art. 17.

[50] Reparation for Injuries Suffered in the Service of the United Nations, Advisory Opinion, 1949 ICJ Rep. at 179.

[51] Id. at 180.

goals of the Charter—may be used satisfactorily to derive a right for the United Nations to enter into international agreements,[52] it does not necessarily follow that it can be used to infer a right that would involve it in a function not envisioned in the Charter or provided for by necessary implication. It must be realized that there can be a division of functions as to original and derivative functions and primary and secondary functions,[53] and that the functional test of whether the necessary implications exist to establish the competence of the organization to pursue a specific course of action may not always be present. In establishing the right of an international organization to conclude a treaty, the situation is presented where presumably another body recognized by international law is agreeing to enter into formal relations with such an organization, whereas with the assertion of a right to own and operate an aircraft there is no express agreement on the part of any other international body or any State. Given the fact that international

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[52] See Smith, "The Conclusion of International Agreements by International Organizations: A functional analysis applied to the agreements of the World Meteorological Organization."

[53] Weissberg, The International Status of the United Nations 330(1950). See also J. Schneider, Treaty-Making Power of International Organizations 135(1959); Jenks, "Some Constitutional Problems of International Organizations," 22 Brit. Y. B. Int'l L. (1945); H. Chiu, The Capacity of International Organizations to Conclude Treaties, and the Special Legal Aspects of the Treaties so Concluded (1966). A most concise statement of the functional approach is found in D. W. Bowett, The Law of International Institutions 278 (1963).

organizations do not embody the concept of nationality,[54] one writer has concluded that "(t)herefore, it can be safely concluded that under the regime of the Chicago Convention, international organizations cannot confer their nationality on aircraft they own or operate in the fulfillment of their purposes."[55] This same reasoning could be applied to the operation of a balloon system.

Even if the United Nations Security Council decided that for the maintenance of international peace and security (acting under Chapter VII) ownership of aircraft was necessary,[56] a problem of jurisdiction would

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[54] The counter-argument to this statement was put forward by Fitzmaurice at the pleadings of the Reparations Case when he argued that there is a special relationship of "international allegiance" between the Organization and its servants based on Art. 100 of the Charter which would provide the necessary basis for claims made by the Organization on behalf of the servants themselves in respect of the damage done to them. 1949 ICJ Rep. 123 (Pleadings).

[55] S. Shubber, "Jurisdiction Over Crimes on Board Aircraft," Dissertation submitted for the Ph.D. degree in International Law in the University of Cambridge, 250-51 (Aug. 1968). Shubber refutes the claim of Fitzmaurice by pointing out that while there might be allegiance in relation to individuals this would not hold true for chattels such as aircraft. Further, the concept of allegiance speaks only of the protection of the individual by the U.N. and does not explain the basis on which the U.N. would be able and willing to accept liability for possible claims against it in case of controversy.

[56] This decision would be binding on U.N. Members under Art. 25 of the Charter, but probably would not be binding on non-members. As to Members, under Article 103 of the Charter, their obligations under the Charter would prevail over their obligations under the Chicago Convention. See B. Cheng, Memorandum to the Air Law Committee of the I.L.A., 52nd Conf. of the I.L.A., Helsinki at 269, 279-80 (1966) where the position of non-member recognition is considered relative to the right of an international organization to bestow its internationality on an aircraft.

remain because the Tokyo Convention[57] refers only to the "State of registration of the aircraft" and not to any international organization registration. Since the United Nations does not have any penal law nor any criminal competence, an untenable situation would be created. As Professor R. Y. Jennings stated:

> . . . Civil aircraft used in the service of an international security organization, . . . are . . . excluded from the benefits of the multilateral conventions (Paris Convention and Chicago Convention) . . . New law must be devised, for the existing law provides no status whatever for any but national aircraft of a contracting State.[58]

The other option is for the United Nations or the specialized agency to seek registration for aircraft it owns in a given State.[59] In this event, the aircraft would be subject to the jurisdiction of the registration State, and the applicable national laws would govern activities

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57 Convention on Offences and Certain Other Acts Committee on Board Aircraft, signed at Tokyo, Sept. 14, 1963, ICAO Doc. 8364.

58 Jennings, "International Civil Aviation and the Law," 22 Brit. Y. B. Int'l L. 208(1945). The problem of international ownership of aircraft was also considered by the League of Nations when the advice received by the Commission Internationale de la Navigation Aérienne (C.I.N.A.) was that there was a necessity for provisions to that effect to be added to the Convention in force. Ibid.

59 This possibility was considered by Brownlie:

> Aircraft operated by the United Nations must, it seems, use a State registration, provided the relevant treaty provisions (in the Chicago Convention) allow this. I. Brownlie, Principles of Public International Law 352 (1966).

on board the aircraft under Art. 3(1) of the Tokyo Convention.[60]

No matter which alternative is considered, the problem remains of the need to alter the existing international conventions:

> It would seem then the proper solution of this difficult and delicate problem must in the long run be to provide some special status analogous to nationality for aircraft operated by an international body and to make provision for the enjoyment by such aircraft of the privileges granted in the . . . (Chicago Convention).[61]

If these alterations are made, consideration should be given at that time to the additional problem of the ownership and operation of observational balloons and balloon data systems since the problems of liability and international responsibility are essentially the same.

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[60] A variation on this idea, discussed by Shubber supra note 55 at 257 and 261, would involve the application of the "designation" principle found in Art. 18 of the Tokyo Convention to determine a State of registration. However, in this context it must be remembered that any designation to be made is to be made by the contracting States and no provision is made for designation by an international organization.

[61] Jennings, "International Law of the Air," 75 Recueil des Cours de l'Académie de Droit International 560(1949).

THE INTERNATIONAL LEGAL IMPACT OF THE USE OF SATELLITES AND OCEAN DATA SYSTEMS

I. INTRODUCTION

The Nimbus/IRLS Program and the ATS-3/OPLE Program of the National Aeronautics and Space Administration involve the use of satellites and ocean buoys to obtain data of scientific importance. In each case the buoy contains technological equipment that allows it to be interrogated by the satellite. With the development of these and other NASA programs in the future to aid in an understanding of the global observation of the weather via satellites (and since the oceans are one area where sufficient meteorological data is lacking), it is desirable to consider the international legal implications of the use of ocean buoys in a satellite system.

Further, numerous international meteorological programs are considering the use of ocean buoys and their interaction with satellites to further meteorological research. There is a specific need for a buoy system in the Global Atmospheric Research Programme (GARP) of the WMO/ICSU which is simple in construction and low cost, and it has been urged that a comprehensive design study of the buoy subsystem is urgently needed which would consider deployment, maintenance costs and communication problems.[1] The World Weather Watch of the WMO may also use buoys among other means to fulfill its scientific data-gathering requirements,[2] and various oceanographic research organizations are considering the desirability of buoys.[3]

II. THE TECHNOLOGY

Ocean buoys are capable of collecting data for measuring water temperature, air temperature, surface pressure and wind velocity to an extremely accurate degree, following which a satellite system such as the NASA Nimbus/IRLS could be used to collect and process the data. It will also be possible to use a geostationary satellite to collect the data by relay.

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[1] "The Planning of the First GARP Global Experiment," 25. Joint Organizing Committee, GARP Publication Series, No. 3 (ICSU-WMO) (Oct. 1969).

[2] "World Weather Watch: The Plan and Implementation Program," 6-7 World Meteorological Organization, Secretariat (May, 1967).

[3] (i) "Anchored buoys: Several hundred deep sea anchored buoys, fully instrumented for meteorological and sub-surface oceanographic measurements, recording over time periods of weeks to months, and radio telemetering, would be required for the IGOSS and related programs.

(ii) Drifting buoys: Some seven hundred freely drifting buoys are planned for the GARP program. Some of these, perhaps one hundred, should be fitted with recording current measuring apparatus and possibly other oceanographic instruments." "Global Ocean Research," 39 Report of a Joint Working Party of the Advisory Committee on Marine Resources Research, the Scientific Committee on Oceanic Research, and the World Meteorological Organization (Ponza and Rome, April 29 to May 7, 1969).

The Nimbus/IRLS project is being jointly conducted by NASA and the National Center for Atmospheric Research (NCAR) utilizing the IRLS (Interrogation, Recording, and Location System) to enable the satellite to communicate with remote stations such as buoys to obtain scientific data. The system is composed of the satellite, a Ground Acquisition and Command Station and the remote data platforms. There is equipment at the buoy which converts the raw data to digital form and transmits these data to the satellite.

There have also been recent tests with the ATS-3/OPLE system which utilizes OPLE (Omega Position Location Equipment) on the buoy. The tests are being conducted by NASA and the Environmental Science Services Administration (ESSA). A buoy equipped with OPLE was set adrift in the Gulf Stream off the east coast of Florida and was subsequently interrogated by an Applications Technology Satellite (ATS-3) upon command from a ground station. The buoy's navigational data were relayed through the satellite to the Goddard Space Flight Center for processing. The buoy was released about fifteen nautical miles off Miami, drifted for twenty-four hours, and was recovered about eighteen nautical miles off West Palm Beach after it had travelled sixty-six nautical miles.

A scientific choice will have to be made in the near future as to whether it is more desirable to have large, anchored, sophisticated long-life buoys or simple, expendable, free-floating buoys that could be air-dropped to reduce cost even further for specific projects. The former have been developed by the U.S. Office of Naval Research while the latter have been developed by the U.S. Scripps Institution of Oceanography and by ESSA. Generally, buoy development in the United States for purposes of atmospheric and marine sciences is carried out under the National Data Buoy Development Project of the Department of Transportation. To the extent that there will be a future joint buoy development program it is probable that the options for the types of buoys to be developed—complex, simple, anchored or free-floating—will be kept open.[4] While the U.S. Navy has developed NOMAD and MONSTER buoys for experimental purposes, further developmental effort will be required if an operational system is to be developed and this will probably be the responsibility of the Department of Transportation (Coast Guard). The Department will shortly be undertaking a research and development effort which is directed toward testing a prototype network of thirty-five buoys with necessary support facilities along the coasts of North America and in the deep ocean,[5] the result of which will be to further American technology

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[4] "Plan for U.S. Participation in the Global Atmospheric Research Program," 26-27. U.S. Committee for the Global Atmospheric Research Program, Division of Physical Sciences, National Research Council (Washington, D.C. 1969).

[5] "World Weather Program: Plan for Fiscal Year 1970" at 16-17, prepared by U.S. Departments of Commerce, Defense, Interior, State and Transportation, and the Atomic Energy Commission, National

in this area and contribute to the World Weather Program.

While there can be manned systems of buoys, these are uncommon and of no scientific or operational importance, and therefore consideration is given primarily to unmanned ocean buoy systems[6] which are differentiated primarily by size and complexity. The other significant distinction is between buoys that are anchored and those that are drifting without any means of retardation.

Aeronautics and Space Administration, and the National Science Foundation. (Mar. 1, 1969). The FY1970 effort of the Coast Guard consists of three interrelated programs, the first dealing with the lack of adequate engineering information on the reliability, survivability, and effectiveness of existing data buoy components with emphasis on sensors and moorings (five buoys). The second will deal with the design and development of the components of the system including the incorporation of an upper-air capability, and the third will be directed towards investigating long term improvements, reductions in cost, and increased capabilities. New sensors will be developed and improved materials and coatings will be investigated.

[6] The phrase "Ocean Data Acquisition Systems" has been adapted by UNESCO to define ships, platforms, telemetering and non-telemetering buoys used to gather data at Ocean Data Stations such as nearshore and offshore manned stations, unmanned stations such as those occupied by automatic buoys, and repetitive drifting stations such as are occupied by drifting buoys. See "Legal Problems Associated with Ocean Data Acquisition Systems (ODAS), A Study of Existing National and International Legislation, Prepared Jointly by the Secretariats of UNESCO and IMCO, 1962-8, at 7. [Revised under the authority of and with the assistance of the IOC Group of Experts on the Legal Status of Ocean Data Acquisition Systems] Intergovernmental Oceanographic Commission Technical Series (1969). SC. 69/XVI. 5/A, Revised IOC/INF-108. Hereinafter cited as "Legal Problems . . ."

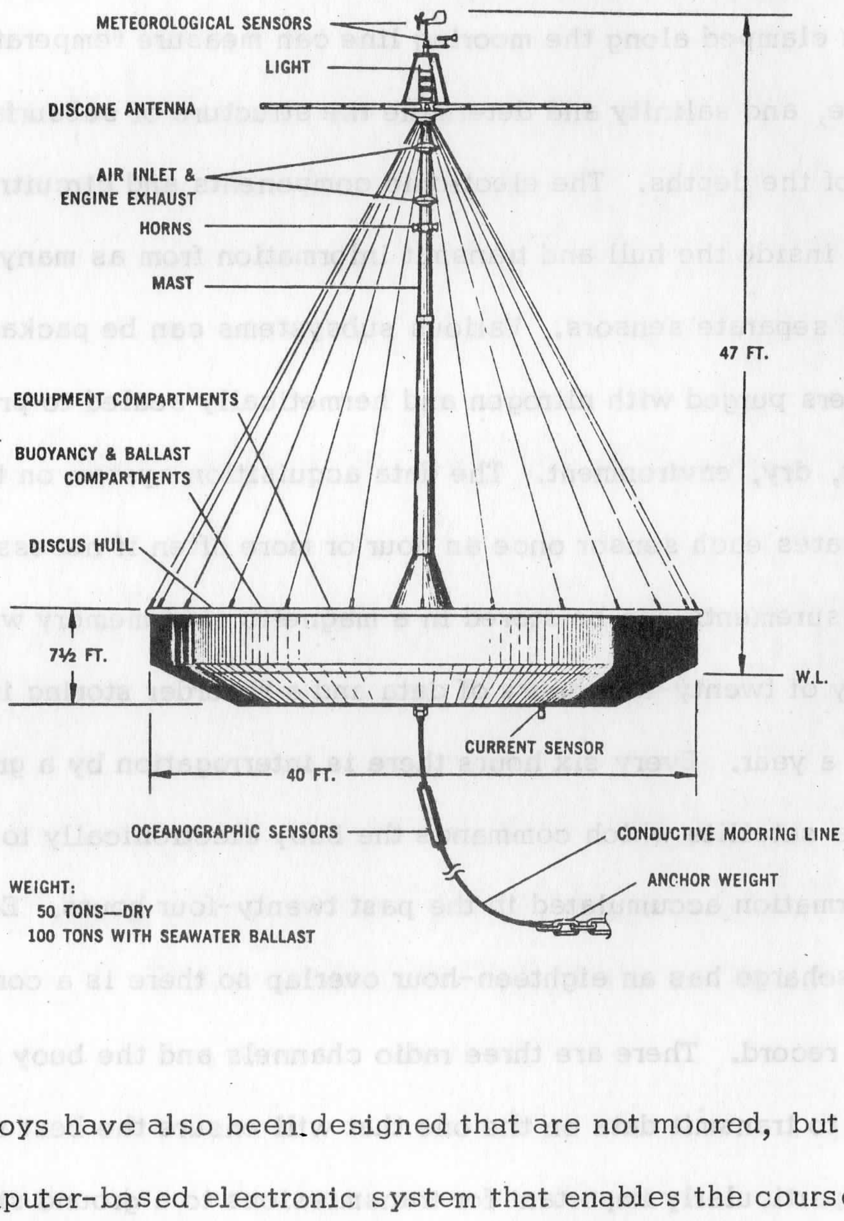
The ocean data device used by the U.S. Navy Office of Naval Research is a large, complex structure that consists of a giant pie-plate shaped buoy some forty feet in diameter and seven and one-half feet deep and containing environmental measuring instruments and power equipment to collect and transmit the data accumulated to shore. It can be moored to the ocean floor to a depth of 30,000 feet by a plaited nylon cable two inches thick. The first prototype of this buoy, ONR Buoy Bravo, has been undergoing sea trials since 1964 and is on station in the Gulf Stream. The ONR Buoy Alpha is now moored in the Pacific near San Diego where it is being used for long-range telemetry system tests, and a third buoy, the Coast Guard Large Navigation Buoy, is on station in the approaches to New York harbor.

This type of buoy is designed to operate for a year without any human maintenance, and it is possible for this period to be lengthened since the conventional propane-powered generator systems that provide electricity for the buoy's operations carry a two-year supply of fuel. Pitch and role are held to a minimum by the symmetrical discus-shape of the buoy and therefore the omnidirectional antenna is kept as nearly as possible in the proper position to radio information to a shore or satellite analysis station. The buoy is designed to withstand winds of 160 miles per hour and waves sixty feet high.

Scientific sensors are located on the thirty-eight-foot mast and on the radial spokes of the discone antenna to measure wind, humidity, precipitation, radiation, barometric pressure and compass bearing. Other sensors inside the hull and immediately under it read water temperature at the surface, wave height, period, and direction, and sensors clamped along the mooring line can measure temperature, pressure, and salinity and determine the structure of subsurface layers of the depths. The electronic components and circuitry are located inside the hull and transmit information from as many as one hundred separate sensors. Various subsystems can be packaged in containers purged with nitrogen and hermetically sealed to provide an inert, dry, environment. The data acquisition system on the buoy interrogates each sensor once an hour or more often if necessary and the measurements can be stored in a magnetic core memory with a capacity of twenty-four hours of data and a recorder storing information for a year. Every six hours there is interrogation by a ground station or a satellite which commands the buoy electronically to transmit all information accumulated in the past twenty-four hours. Each data discharge has an eighteen-hour overlap so there is a continuous record. There are three radio channels and the buoy is commanded to transmit data on the one that will ensure the best reception. This is particularly important for transmissions to a ground station since the signals would be "bounced" off of the ionosphere.[7]

[7] "Ocean Data Stations" A Report from General Dynamics, Convair Division (1969). The buoys used by the U.S. Navy's Office of Naval Research were developed and built by General Dynamics.

Chart I: A Large, Anchored Ocean Data Buoy



Buoys have also been designed that are not moored, but contain a computer-based electronic system that enables the course of the buoy to be plotted and the appropriate directions given to a servo system which manipulates a pair of rigid sails and rudders to steer the buoy on course. The current range of this device is 3,000 miles or anywhere a position fix can be attained with the satellite navigation system recently emplaced by the U.S. Navy. This device, called the SKAMP (for Station-Keeping and Mobile Platform) can be kept on its true position within 0.2 of a nautical mile and holds this position by sailing a tight back-and-forth course. The sail is constructed of reinforced, foam-filled plastic molded in the shape of a pair of parentheses sixteen feet tall. The disc-shaped hull consists of a deck plate and bottom plate with elastomer foam between which is to absorb impact and prevent damage to other craft in the event of a collision. The weight of the device is 1,800 pounds. The sensors of this device will enable it to give horizontal and vertical profiling, acoustic measurements, and also reconnaissance and electronic intelligence.[8] These last two uses point up the need to have some sort of prior agreement on the types of sensors to be employed on meteorological buoys used in any international venture. The fact that the superstructure of this device can be constructed without any metal parts so as to be virtually transparent at all radar frequencies also confirms the possible problems of security that might arise. Perhaps a useful function could be served by these buoys if they were

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[8] "SKAMP, Station-Keeping and Mobile Platform—Model QMB-1," RCA, Defense Electronics Products, Astro Electronics Division, Princeton, New Jersey, June 1969. (DEP/SCN-204-69). This device has a width of 9 feet and a height of 16.6 feet. Its sail area (projected) is 50.4 square feet and its fin area (projected) is 20.5 square feet.

equipped with sensors to monitor nuclear, biological and chemical concentrations on the high seas and as such would serve as deterrent devices to keep all nations apprised of any activity of this kind.

At present there are no systems envisaged using large drifting buoys, but tests are being conducted with small drifting buoys by the Scripps Institution of Oceanography and ESSA.

III. INTERNATIONAL LEGAL IMPLICATIONS

The impact of international law on the use of ocean data systems will be analyzed through a consideration of the existing international legislation as to the placement and use of the systems, the relevant rules for safety, and the problems of liability for the systems. While it is assumed that these systems will be placed and used by States, the possibility that an international organization such as the WMO or UNESCO would develop an operative role and seek to place and utilize such systems prompts subsequent enquiry into the legal implications of such actions.

The Relevant International Legislation

Complementary to the first assumption made above that States will be responsible for the placement and use of ocean data systems is the assumption that the majority of these systems will be placed on the high seas rather than in the territorial sea of a State or in its internal waters. Therefore consideration of the legislation pertaining to the high seas will be presented first.

The High Seas

The Geneva Convention on the High Seas,[9] which in its Preamble refers to its provisions as a codification of the rules of international law relating to the high seas, defines the high seas in Article 1 as ". . . all parts of the sea that are not included in the territorial sea or in the internal waters of a state."[10] Essentially this Convention refers to the seas beyond the territorial sea of a State with the exceptions that may be drawn with reference to the Continental Shelf. The freedom of the high seas is propounded in Article 2: "The high seas being open to all nations, no State may validly purport to subject any part of them to its sovereignty."[11] It then specifically states several freedoms of the high seas such as navigation, fishing, and laying submarine cables with reference made to these freedoms and others which are recognized by the general principles of international law. Given the fact that the International Law Commission considered the list to be

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[9] Geneva Convention on the High Seas (1958); UN Doc. No. A/CONF. 13/53(1958) reprinted in 2 Off. Rec. 135.

[10] Id. at Art. 1.

[11] Id. at Art. 2.

non-exhaustive and that there could legitimately be a freedom to undertake scientific research on the high seas,[12] it may be argued that this freedom should be included, and that the use of an ocean data buoy was an undertaking of scientific research. A further substantiating point can be made to the effect that the reason that the I.L.C. did not mention specific freedoms or include a longer list in the Convention was that some of them had simply not attained sufficient practical importance to justify special regulation. This would apply to the use of ocean data systems which has only recently been considered technically feasible.

The scope of limitation on the freedom is that States are to refrain from acts which would have an adverse effect on other States.[13] Thus the context of the provision allowing for certain freedoms recognizes that technology will present new uses of the sea that should be evaluated within a liberal interpretation of the precise terms of the Convention to allow for activities that will not be a danger or otherwise adversely affect a nation, but will, at the same time, serve some positive purpose so that the interpretation can be justified as

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[12] Commentary on the Report of the International Law Commission to the General Assembly (1956 I.L.C. Y.B. (II) at 278. See also Jessup, "The United Nations Conference on the Law of the Sea," 59 Colum. L. Rev. 253 (1959).

[13] Ibid.

furthering the regime of international law on the high seas. The test is one of "reasonableness"[14] from which the conclusion can be drawn that, to the extent that the use of ocean data systems do not harm or adversely affect any nation, this use could be included among the freedoms of the high seas within the plain meaning of the Geneva Convention.

The right to place and use ocean data systems is closely analogous to the specified rights of the Convention in any event to the extent that the purpose of the systems is to assist in the collection of data of meteorological or oceanographic importance. In fact there may be said to be a direct link between the data gathered by these systems and the subsequent aid that is provided to ships and planes for navigation purposes, to fishing fleets in the form of indications of the locations of schools of fish, and to those involved in the laying of pipelines and submarine cables regarding weather stations.

The obvious caveat is that this interpretation will not apply when other sensors besides those used for scientific purposes are included on the structure; such as those used to detect submarines or other underseas craft. It is possible that some plan for limited inspection may have to be initiated before certain nations will allow the opera-

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[14] M. McDougal and W. Burke, The Public Order of the Oceans 763 (1962).

tional use of a large number of ocean data systems on the high seas. The argument of such a nation would be that an application of the objective territorial principle[15] would be necessitated by the fact that its shipping or one of its other freedoms of the high seas was being unreasonably abridged by the presence of the ocean data systems. While it is most likely that any such dispute would be solved on the diplomatic level, it is also possible that an affected nation might decide on some measure of self-help such as disabling the device, destroying it, or confiscating it.

Another response to a buoy system by an aggrieved State may be to argue for the extension of the provisions of the Geneva Convention on the Territorial Sea and Contiguous Zone[16] which provides for coastal state control of certain activities relating to customs, immigration, and sanitation. This provision for coastal state control

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[15] The objective territorial principle is generally defined as allowing for the application of territorial jurisdiction over the high seas if the activity in question is having a harmful effect within national territory. The legal vacuum doctrine may be relied upon if there was no indication as to the ownership of the buoy and hence no assurance as to the assumption of liability.

[16] Geneva Convention on the Territorial Sea and the Contiguous Zone, Geneva, April 29, 1958(1965) U.K.T.S. No. 3, found in 52 Am. J. Int'l L. 834, 840 (1958). The relevant part of the Convention, Article 24, states: "In a zone of the high seas contiguous to its territorial sea, the coastal State may exercise the control necessary to:
(a) Prevent infringement of its customs, fiscal, immigration, or sanitary regulations within its territory or territorial sea;
(b) Punish infringement of the above regulations committed within its territory or territorial sea."

applies, however, only within the territorial sea of the coastal State and is quite clearly designed to enable that State to effectively apply its law in areas such as customs and sanitary regulations where there would be a definite harmful effect on its populace if no control were to be exercised. The extension of this provision by analogy would require a chain of argument which demonstrated that the harm done by ocean buoys had a direct, harmful effect on the coastal State. One wonders to what extent the exercise by the coastal State of "the control necessary" to prevent infringement could be broadened to include the specific acts that might be necessary to neutralize the harm caused by an ocean buoy. Finally, it would seem that States other than coastal States might find the buoys objectionable and would not be in a position to rely upon provisions designed specifically for the maintenance of law for coastal States.[17]

Inasmuch as Article 2 of the Geneva Convention refers to the exercise of the freedoms of the sea by States, it would appear that any attempt by private companies or individuals to place ocean data buoys would necessitate the conclusion that all of the enumerated and other freedoms depend on State protection and must be licensed or controlled by a State and that State control is a prerequisite for invoking

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[17] See D. Smith, International Telecommunication Control 46-47 (1969).

the freedoms. This would retain the responsibility for the use of these systems with States and would create a stable situation regarding claims for damages or other matters arising concerning the use of ocean data systems.

Even if it were assumed that the use of ocean data systems was not a protected activity under the Geneva Convention on the High Seas, it could be argued that it was an unregulated activity rather than a prohibited activity. In order for it to be a forbidden activity it would have to appear that some freedom of the high seas was being denied to some State. If it could be shown by empirical evidence that there was no hinderance to navigation, fishing, the laying of submarine cables, or flight over the high seas, then there would be no basis for denying the use. Instead of the use of ocean data systems being a right in this case, it would more closely approximate a "privilege" accorded to States within the limitations of the protection of the accepted freedoms.

Given the likelihood of future conflict over mineral rights on the ocean floor and related problems, it would appear desirable to consider the use of ocean data systems in light of the test of "reasonableness" in the context of safety rules and the freedom of navigation. If it can be demonstrated that these two limitations can be overcome, and if a State is willing to accept responsibility for the maintenance and control over such devices, it would serve the interests of all concerned to allow for their use. While it would certainly make a difference whether the determination of "reasonableness" came from an international body or the domestic courts of an adversely-affected State, it is probable that in the interests of stability and reciprocity most States would be willing to allow such devices, barring a political conflict that overshadowed the technical and legal considerations.

A further question would be whether a real obstacle was being presented to navigation. If ocean data systems "must constitute some obstacle in the way of unimpaired navigation both by their actual presence and by the necessity of protecting them from the negligence or malicious design of passing or approaching vessels,"[18] then the collection of evidence on this point would suffice to prove the case. However, in the event that the complaint was that by their very presence they constituted a violation of international law, the question of evidence as to navigational safety would not arise. It would appear that an offense against "the theory but not the true object of the freedom of the seas"[19] should not control in any controversy.

The other category of evidence to be offered would concern the scientific nature of the ocean data systems and would consist of a detailed enumeration of the sensors aboard the system and their use and an explanation of how the data obtained could be of value to all States

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[18] Lauterpacht, "Sovereignty over Submarine Areas," 27 Brit. Y.B. Int'l L. 403 (1950).

[19] Ibid.

in furthering their own national interests. It would also need to be indicated that no attempt was being made to appropriate any part of the high seas for national use.

Another approach to the problem of including the use of ocean data systems among the freedoms of the high seas would be to look to the provisions of the Geneva Convention on the Continental Shelf[20] relating to oceanographic and other scientific research.

At the outset it must be made clear that this Convention does not apply to the high seas above the Shelf since Article 3 provides:

> The rights of the coastal State over the continental shelf do not affect the legal status of the superjacent waters as high seas, or that of the air space above those waters.[21]

However, there is reference to the relationship between the coastal state and scientific research which can be of value in determining the validity of the use of ocean data systems. Article 5(1) provides that

> The exploration of the continental shelf and the exploitation of its natural resources must not result in any unjustifiable interference with navigation, fishing or the conservation of the living resources of the sea, nor result in any interference with <u>fundamental oceanographic or other scientific research carried out with the intention of open publication</u>.[22]

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[20] Geneva Convention on the Continental Shelf, U.N. Doc. A/CONF.13/L.55 reprinted in <u>Dept. of State Bull.</u> 11-21 (1958) and 52 <u>Am. J. Int'l L.</u> 858 (1958).

[21] <u>Id.</u> at Art. 3.

[22] <u>Id.</u> at Art. 5(1). (Emphasis added)

This article refers to "unjustifiable interference" with the recognized freedoms of the high seas and "any interference" with scientific research which will be openly published. As there is the possibility that data received from ocean data systems might be restricted to the countries participating in the final support for the system, this might pose a problem. However, if the data is made available to all nations, then it would appear that this provision has the general intention of promoting scientific research and now allowing a coastal State to interfere for nationalistic purposes.[23]

Further questions are raised by the provisions of Article 5(8) with reference to the necessity of obtaining the consent of the coastal State ". . . with regard to any research concerning the continental shelf and undertaken there."[24] Since ocean data systems are not involved in research concerning the continental shelf and they are located on the surface rather than on the shelf itself, it would appear that this provision would not apply. That this would appear to be the proper conclusion is supported by a further clause in the provision which states that "[N]evertheless, the coastal State shall not normally withhold its consent if the request is submitted by a qualified institution with a view

[23] See Burke, "Law and the New Technology" 214 in L. M. Alexander (ed), The Law of the Sea (1967).

[24] Continental Shelf Conv. supra note 20 at Art. 5(8).

to purely scientific research into the physical or biological characteristics of the continental shelf. . . ."[25] While again this is in reference to a request involving the shelf, it would appear desirable to consider it as a formula to be followed in justifying the use of ocean data systems. A complication might arise if any of the sensors on the ocean data device probed the continental shelf, but it is probable that the primary purpose of the device would be considered as controlling.

The coastal State does have legitimate interests to protect and it was the design of this Convention to prevent fraudulent exploration of the continental shelf of a coastal State by a foreign State without prior consent. It was not the purpose of the Convention to hinder or limit scientific progress that does not have an adverse effect on a coastal State.

The Territorial Sea and Internal Waters

Since the internal waters of a coastal State lie within the exclusive territorial sovereignty of that State under general international law, permission must be obtained for the placement and use of ocean data systems. Given the scientific objectives of the ocean data systems it is probable that a bilateral arrangement could be obtained as to their use providing that there was no major hinderance to navigation.

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[25] Ibid. The clause continues by granting the coastal State the right, if it desires, of being represented in the research and requiring that the results of the research be published.

Pertaining to the territorial sea, there is also coastal State control since the Geneva Convention on the Territorial Sea and the Contiguous Zone provides in Article 1 that

> The sovereignty of a state extends, beyond its land territory and its internal waters, to a belt of sea adjacent to its coast, described as the territorial sea.[26]

The only mitigating provision is Article 15 which states that:

> (1) The coastal state must not hamper innocent passage through the territorial sea.
>
> (2) The coastal state is required to give appropriate publicity to any dangers to navigation of which it has knowledge, within its territorial sea.[27]

In an effort to provide for ocean data systems, the similarities between the right of innocent passage and the right to unrestricted scientific research could be indicated to show that neither use causes any harm to the coastal State, that the concept of reciprocity can be implied, and that all States would benefit from the results of the data gathered. However, this simply amounts to a listing of reasons why permission should be granted for the use of such devices and does not imply a legal right. Further implications could be drawn from the articles of the Continental Shelf Convention dealing with the right of scientific research and an attempt could be made to show that the same rationale could apply equally as well to the territorial sea.

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[26] Territorial Sea Conv. <u>supra</u> note 16 at Art. 1.

[27] <u>Id</u>. at Art. 15.

The tentative conclusions drawn by UNESCO and IMCO on the question of control over ocean systems are as follows:

(1) The coastal state may exercise its sovereign rights respecting the employment of ODAS (Ocean Data Acquisition Systems);

(2) The coastal state may place such restrictions, limitations or regulations as it deems fit on the placement, purpose or use of ODAS, if these are liable to affect the safety and freedom of navigation;

(3) No one may claim an international right to place, anchor and/or operate ODAS in the territorial sea of any state without the express or implied permission of the government of that state.[28]

The first tentative conclusion, in a sense, contradicts the second, inasmuch as once the sovereignty of the coastal State is recognized it may place any restrictions it chooses on ocean buoys or any other structures whether or not the safety and freedom of navigation are affected. Further, the use of the phrase "may exercise" in the first clause implies that the coastal state may not choose to exercise its sovereign rights, but the import of the existence of coastal State sovereignty over the territorial sea is, as stated in the third clause, that the permission of the coastal State must be obtained before any ocean data device is placed in the territorial sea.

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[28] Legal Problems. . . , supra note 6 at 9. In a preliminary report by UNESCO/IOC an additional conclusion was stated which read "The coastal state may freely permit or deny permission to employ such devices." UNESCO/IOC, Preliminary Report at 5-6.

The most persuasive arguments that can be made in this circumstance involve a balancing of interests between the coastal State and the general international community regarding the free use of the ocean.[29] The coastal State has a valid interest in protecting its territorial sea from any activity that might prove harmful and in pursuing its legitimate interests in this area, but it also has an obligation not to arbitrarily hinder of obstruct scientific research providing that all nations will benefit from this research and none will be harmed. Coastal State concern with the existence of ocean data buoys would appear to involve their safe placement, lighting, marking, mode of communications, and the scope and purpose of any contained sensors.

It would appear desirable for a coastal State, upon notification of intent by a foreign State wishing to place such a buoy, to draw up a list of conditions to determine the limitations of access and to make this list readily available. Such a list would contain an enumeration of technical requirements as to size, mooring device, location, lighting, and a right of inspection in the presence of the foreign State. The inclusion of a "right of inspection" clause is an attempt to reach a middle ground between the unrestricted right of inspection that could be demanded as a sovereign right by the coastal State and the position of the sponsoring State that its device should be entitled to its

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[29] Burke, supra note 23 at 215-16.

sovereign protection. Technology will bring about a number of additional problems relating to devices to be placed in the ocean,[30] and it would seem desirable to arrive at moderate solutions to current non-political problems which could then serve as a basis for the more involved and politically-sensitive problems of the future.

The Relevant Safety Regulations

This is an uncertain area of international law since there is no international convention presently in force dealing with ocean buoys.[31] There are currently two basic systems of buoyage, the lateral and cardinal systems, which have been incorporated into the domestic laws of various States,[32] but the question here does not involve navigational buoys so much as it does a relatively new classification of buoys which are part of ocean data systems.

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[30] There are plans for establishing a world-wide marine geodetic grid system which involves placing equipment permanently on the ocean floor which could be used as a basis for an ocean meteorological network of weather observing stations. Mourad, "Marine Geodesy," Battelle Technical Review, Feb. 1965 (5) at 6. The legal aspects of such a system were considered at the First Marine Geodesy Symposium, Co-sponsored by Battelle-Columbus and the U.S. Coast Guard and Geodetic Survey, Sept. 28-30, 1966.

[31] Attempts to conclude such agreements were made at the Conference for the Unification of Buoyage and Lighting of Coasts (Lisbon, 1930), and by the League of Nations.

[32] For a listing of national buoyage practices, see "Special Publication No. 38," The International Hydrographic Bureau.

In considering these devices, the Working Group on Fixed Oceanographic Stations submitted a series of suggestions to the Maritime Safety Committee of the Inter-Governmental Maritime Consultative Organization which were considered by the Committee in 1963 and prepared as "Conclusions on the Marking of Oceanographic Stations." These conclusions were subsequently endorsed by the Council and Assembly at IMCO. They refer to two classifications of oceanographic station[33] and conclude that both should carry flashing lights for identification at night which are clearly distinct from those used on navigational buoys and other aids to navigation. The further suggestion was made that certain equipment should be fitted on these stations if practicable, such as radar reflectors (to be used unless the buoy is of such size that it is a good radar target) and fog bells or fog horns, which should not be similar to those of navigational buoys. It was also stated that radio-transmitters for direction-finding purposes could be installed. Information concerning the position, size, safe distances to be observed and other important characteristics, was said to be of necessity to

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[33] (c) equipment which, owing to size, material and construction, is less likely to cause damage through a collision. However, it may receive damage or can foul a propeller or rudder or fishing gear. Such equipment is not expected to carry personnel and it may be anchored at any distance from the coast;

(d) free-floating equipment generally small in size and operating either independently or in the proximity of research vessels or craft of the type 2(a). Such equipment can be carried away for long distances, drifting with the currents.

"Conclusions on the Marking of Oceanographic Stations," Annex III, Legal Problems . . . , supra note 6 at 39.

mariners and as such should be made available through the usual channels of radio warnings and notices to mariners, and also that the I.O.C. could use other means to disperse this information, particularly to fishing interests. Two other suggestions were made: one concerning the desirability of having the I.O.C. use numbers or other inscriptions on the buoys to facilitate identification and to discourage unauthorized handling, and the other concerning the care that should be taken by authorities operating these stations to avoid obstructing the fairways used by shipping.[34]

Generally, the problems relating to the safety of ocean data buoys remain unsolved. To some extent various national legal analogies could be applied, but there is no international legal agreement which standardizes practices and procedures. Reference can be made to the Regulations for Preventing Collisions at Sea,[35] but it would appear that the better course would be to develop a new set of rules and regulations to deal specifically with ocean data systems rather than to attempt to

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[34] Id. at 39-40.

[35] Regulations for Preventing Collisions at Sea, approved by an annex to the Final Act of the International Conference on Safety of Life at Sea (London, 1960). These regulations apply to all vessels which are defined to include "every description of water craft, other than a seaplane on the water, used or capable of being used as a means of transportation on water." The lights to be used on these vessels and other matters are dealt with by the Regulations which, in effect, are a code of conduct open for adoption by national legal systems.

draw strained analogies with existing regulations which are designed primarily to deal with safe navigation and the function of the buoy in protecting navigation, but do not serve to protect the buoy itself.

The Question of Liability with Reference to Ocean Data Systems

Since ocean data buoys have valuable electronic equipment aboard and since they are left unattended on the high seas, it is apparent that some legal means should be available to prevent unauthorized persons from stealing or destroying them. Likewise rules should be developed which define the liability of those responsible for ocean data systems so that their duties and responsibilities are made clear. Thus it would appear beneficial to examine the available legal rules to determine the extent of protection presently provided and the desirability of formulating an international agreement regarding questions of liability.

Interference with Ocean Data Buoys

It has been found that one serious problem that must be faced involving the use of ocean data buoys on the high seas is that there is a great likelihood that theft will occur, due in no small part to the value of the electronic components on the device. The legal liability for conversion, defined as civil piracy, or intentional interference with ocean data systems is derived from several sources. The Geneva Convention on the High Seas states in Article 15 that

Piracy consists of any of the following acts:

(1) Any illegal acts of violence, detention or any act of depredation, committed for private ends by the crew or the passengers of a private ship or a private aircraft, and directed:

(a) on the high seas, against another ship or aircraft, or against persons or property on board such ship or aircraft;

(b) against a ship, aircraft, persons or property in a place outside the jurisdiction of any State.[36]

The reference to "property in a place outside the jurisdiction of any State" is of relevance to a consideration of ocean data systems. This international legal rule is made effective in the United States by the provision in 18 U.S.C. 1651 which states:

> Whoever, on the high seas, commits the crime of piracy as defined by the law of nations, and is afterward brought into or found in the United States shall be imprisoned for life.[37]

It would appear that destruction of the buoy, larceny, or damage to its component parts would come within the definition of piracy found in the Geneva Convention, while acts which involved the unauthorized inspection of the electronic equipment, or the theft of information from the telemetering equipment, while constituting trespass, would not come within this definition.

As to the determination of jurisdiction, conversion committed on navigable waters is usually considered to be a tort of which admiralty has jurisdiction. Further,

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[36] Geneva High Seas Conv. <u>supra</u> note 9 at Article 15.

[37] 18U.S.C. 1751.

> Cases of spoilation and damage are of admiralty and maritime jurisdiction. They include illegal seizure, or depredation of vessels or goods afloat, embracing the civil injury called piracy, which consists in an unwarranted violation of property, committed on the high seas. The injured party may proceed against the property, or its proceeds, for a recovery thereof or against the person of the wrong-doer for the damage. Every violent dispossession of property on the ocean is prima facie a maritime tort and as such subject to the maritime jurisdiction.[38]

The obvious difficulty here is that while the above refers to the American interpretation of admiralty and maritime jurisdiction, other nations will have differing interpretations of the law in this area. However, in many circumstances the national legal system will attempt to apply the rules of customary international law to contentious cases to obtain uniformity.

The lack of uniformity among national legal systems can further be seen with reference to the question of accidental interference with an ocean data buoy. In the United States there have been two cases dealing with a collision between a ship of foreign registry and a fixed oil well platform on the high seas.[39] In both cases the platforms were

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[38] Knauth's Benedict on Admiralty 371 (1958).

[39] The two cases are: Continental Oil Co. v. M.S. Glenville, D.C. S.D. Texas, 1962, 210 F. Supp. 865; Placid Oil Co. v. SS Willowpool, D.C. E.D. Texas, 1963, 214 F. Supp. 449. Note, however, that Canada would not consider such a collision to be between a moving and an anchored ship. Letter from Assistant Deputy Minister, Marine, Canada Dept. of Transport to the Secy. of the Canadian Committee on Oceanography Jan. 4, 1963.

lighted in accordance with U.S. regulations and there was no impairment of visibility. The courts found that the cases came under the rules governing collision between a moving vessel and one at anchor, and held that there was a presumption of fault which the moving vessel would have to overcome. In both cases the presumption was not overcome and the decision was against the moving vessels. It would appear that the similarity between ocean data buoys and oil drilling platforms is sufficient to suggest that future cases would result in the same presumption being raised and the decision going against the moving vessel. One question would arise in relation to the size of the ocean data station; the argument being that the buoy was sufficiently small to be a hazard for a ship even though marked and lighted in the appropriate fashion.

In France, the detailed definition given to "abordage" (collision) and the facts essential for its occurrence—the involvement of two ships and the immediacy of the damage—coupled with further provisions applying to collisions between one ship and a fixed structure or a floating object, would indicate that the analogy to a collision between a moving and anchored vessel would not be applied.[40] In England, on the other hand, a broader rule is found to the effect that

> Where damage is done to persons or to property of any kind on land or water, owing to the negligent navigation or management of a vessel, a cause of action arises against

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[40] 3 Rippert, Droit Maritime 11-14 (1953).

those who, by their own negligence or by the negligence of their servants or agents, caused such damage to be done.[41]

Further variations will be found in the domestic law of other States, thus indicating a need for uniformity in this area.

While there are some international rules concerning the problems of collisions at sea,[42] the question remains largely one of applying national law.[43] Factors to be considered by national courts would include the place of the collision or seizure, the nationality and domicile of the parties involved, and the immediate physical conditions. This latter category would include the size, weight, and form of the buoy; whether it was in or near recognized sea lanes; whether notice was given in the usual form; whether warning devices were attached

[41] Marsden on Collisions at Sea 3(1953). The essential elements of actionable negligence in a collision of two vessels under English law were stated in The Dundee [(1823) 1 Hag. Ad. 109 at 120].

[42] See, International Convention for the Unification of Certain Rules of Law with Respect to Collision between Vessels (1910); International Convention for the Unification of Certain Rules relating to Civil Jurisdiction in Matters of Collission or other Incidents of Navigation (1952); International Convention for the Unification of Certain Rules relating to Penal Jurisdiction in Matters of Collission or other Incidents of Navigation (1952).

[43] The Geneva Convention on the High Seas provides:
In the event of a collision or any other incident of navigation concerning a ship on the high seas, involving the penal or disciplinear responsibility of the master or of any other person in the service of the ship, no penal or disciplinary proceedings may be instituted against such persons except before the judicial or administrative authorities either of the flag state or of the state of which such a person is a national." Geneva High Seas Conv. supra note 9 at Art. 11, para. 1.

to the buoy; and whether it was serving a scientific function. Some combination of the above factors would be used to determine liability in accordance with the applicable domestic law rules and conflict of law rules of the court in which the action was brought.

A final problem here involves the right of salvage on the high seas, salvage being defined as the right to a reward for saving maritime property from peril at sea. Experience has suggested that salvage rules may, in fact, be hindering the use of ocean data buoys on the high seas since it encourages the unauthorized collection of buoys which are functioning normally by cutting the mooring cables and subsequent application for a reward. There is a need for discussion on whether salvage rules should apply to ocean data buoys, and if so, to what extent. This, and the other problems discussed above, could be solved by promulgating an international agreement regarding ocean data systems.

Ownership and Operation by an International Organization

The question has arisen as to whether an international organization has the right to own and operate ocean buoys as part of its functions. Specifically, the question could be raised as to whether the World Meteorological Organization (WMO) or the United Nations Educational, Scientific and Cultural Organization (UNESCO) have the right to own and operate ocean data buoys as part of the WMO World Weather Watch or some other scientific program. In a publication prepared jointly by UNESCO and IMCO the following statement appeared:

> There would seem to be no reason to doubt the legal capacity of UNESCO and WMO to employ ODAS (Ocean Data Acquisition Systems) of any type or description. If either Organization has the legal competence to operate an ocean-going vessel for research purposes, it should be legally competent to operate a fixed vessel or smaller unmanned device for similar purposes.[44]

It would appear, however, that there may be some question concerning the right of United Nations agencies either to operate ocean-going vessels or to operate fixed vessels or unmanned devices. The argument put forward in support of this capability is that the matter has been considered in relation to ownership of vessels by the United Nations and resolved positively and that this conclusion applies likewise to the specialized agencies.

In reference to United Nations Ownership of a vessel, a Rapporteur of the International Law Commission was requested to investigate the problem and his report concluded that the United Nations had this right.

Consideration was given to statements in the Reparations Case[45] to the effect that the U.N. had the competence required to enable it to effectively discharge its functions, and the conclusion was drawn that this must apply to specialized agencies as well. However, it must be remembered that the same section of the Reparations Case makes

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[44] Legal Problems . . . , supra note 6 at 17.

[45] Reparations for Injuries Suffered in the Service of the United Nations, ICJ Rep. (1949) at 179.

the statement that "This is not the same thing as saying it is a State, which it certainly is not, or that its legal personality and rights and duties are the same as those of a State . . ."[46] It is entirely possible that the ownership of a ship or ocean buoy does not come within the scope of functions of the United Nations, nor for that matter within the limited scope and functions of the specialized United Nations agencies.

The argument is further made that the Convention on Privileges and Immunities of the Specialized Agencies[47] allows for the capacity of the specialized agencies to acquire and dispose of immovable and movable property, and that

> . . . their property and assets, wherever located and by whomsoever held, shall enjoy immunity from every form of legal process except insofar as in any particular case they have expressly waived their immunity. It is however understood that no waiver of immunity shall extend to any measure of execution.[48]

The conclusion here is that "the application of these provisions to a vessel belonging to UNESCO and flying the United Nations flag would give it a status similar to that conferred, under international law, on

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[46] Ibid.

[47] Adopted by the U.N.G.A. Nov. 21, 1947.

[48] Id. at Art. III, Sec. 4. Section 5 of that Article continues by stating:

> The property and assets of the Specialized Agency, wherever located and by whomsoever held, shall be immune from search, requisition, confiscation, expropriation and any other form of interference, whether by executive, administrative, judicial or legislative action.

State ships engaged on public service."[49]

The question, however, is not so much one of protecting the ship as it is ensuring that States would be in a position to make effective claims against those responsible for the ships or buoys in the event of negligent operation or some other possible conflict. There would appear to be direct conflict between the above argument and Article 5 of the Geneva Convention on the High Seas which states:

> Ships have the nationality of the state whose flag they are entitled to fly. There must exist a genuine link between the State and the ship; in particular, the State must effectively exercise its jurisdiction and control in administrative, technical, and social matters over the ships flying its flag.[50]

To what extent could a specialized agency of the United Nations, or the United Nations itself be responsible for exercising jurisdiction and control over the ships flying its flag? To what extent would there be an assumption of liability by the U. N. for damage caused by its ocean data buoys to ships flying national flags? Even if the concept of ownership of ships by the United Nations was accepted, the problem would then arise as to registration.

> The legal system of the flag State applies to the vessel authorized to fly the flag, and in this respect the flag of the United Nations, or of another international organization

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[49] "Joint Operation of Oceanographic Vessels—Legal Status," UNESCO/NS/Ocean 95(7) Jan. 29, 1960.

[50] Geneva High Seas Conv. supra note 9 at Art. 5.

> cannot be assimilated to the flag of a State. Especially with regard to the civil and criminal law applicable aboard ship, there would be no solution of the problem.[51]

There is an apt analogy to the problems engendered by suggestions that there can be international organization ownership of aircraft. This argument can be similarly refuted with the statement that the applicable Conventions refer to the State of registration and that summarily "(n)ew law must be devised, for the existing law provides no status whatever for any but national aircraft of a Contracting State."[52] It would then follow that "(t)herefore, it can be safely concluded that under the regime of the Chicago Convention, international organizations cannot confer their nationality on aircraft they own or operate in the fulfillment of their purposes."[53]

Thus, from the available information, it would appear that there is not a clear right for an international organization to own and operate ocean data buoys, and that further research will have to be conducted

[51] François, "Supplementary Report on the Right of International Organizations to Sail Vessels under their Flags," II Y. B. of Int'l L. Comn. (1956) at 103, para. 7-8. See also D. P. O'Connell, I, International Law 112 (1965).

[52] Jennings, "International Civil Aviation and the Law," 22 Brit. Y. B. Int'l L. 208(1945).

[53] S. Shubber, "Jurisdiction Over Crimes On Board Aircraft," at 252-53. Dissertation submitted for the Ph. D. degree in International Law in the University of Cambridge, Aug. 1968.

to specifically determine the rights of the United Nations and whether there is a direct devolvement of such rights upon the U. N. specialized agencies.

The Need for an International Agreement

Given the general nature of the existing international legislation and the complex problems surrounding questions of liability concerning the use of ocean data buoys, the need can be seen for the promulgation of a comprehensive international agreement. The benefits to be derived from such a document would include a lessened risk of violence in the event of a collision or some other mishap involving ocean data systems, and the likelihood that prior agreement on conditions of use and security by the major powers would encourage the smaller nations to abide by the established rules. Further, promulgating an agreement would appear a more favorable course than attempting to fit older formulations of international law within the frame of reference of this new technology, particularly when the procedures for reaching international agreement have proven successful in instances such as the Test Ban Treaty and the Outer Space Treaty.

The Initial American and Soviet Positions

For any international agreement to be effective there must be the support of the major powers. This support is particularly relevant since the subject involves the use of scientific instruments on the high seas and problems of inspection, control, and military security. Support for the idea of an international agreement to deal with ocean data systems is found in the United States Report to the Intergovernmental Oceanographic Commission:

> Since these meteorological and oceanographic "observing buoys" are a relatively new development and in most cases will not readily fit into established concepts, their status and treatment probably could be most effectively determined by an international convention.[54]

Specific suggestions were made as to what points should be covered by the convention which included: the means of inspection that will be necessary, the type of protection from interference that will be given, the determination of the enforcing group, and the establishment of an effective international system for the settlement of disputes.

The Soviet Union was also in favor of an international agreement that would deal with the use of ocean data buoys.[55] Among the problems

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[54] "Legal Status of Fixed Oceanographic Stations," United States Report to Intergovernmental Oceanographic Commission (IOC), Mar. 21, 1966, reprinted in Legal Problems . . . *supra* note 6 at 26. Later in the Report it was stated that:

> If one of the objects of interest is to prevent all unauthorized access to fixed stations and to deter the taking of information therefrom, it seems that additional international agreement should be sought. *Id.* at 29.

[55] "Comments Submitted by Competent Soviet Agencies in Response to a Request of the Secretary of the Intergovernmental Oceanographic Commission Concerning the Legal Status of Fixed Oceanographic Stations," June, 1963, reprinted in Legal Problems . . . *supra* note 6 at 29. Hereinafter cited as "Soviet Comments . . ."

that were thought to be significant were: the need for all countries to participate in drafting the convention, the development of a system of promulgation to keep mariners informed of all fixed oceanographic devices operating in the high seas, the acceptance of State responsibility for all fixed oceanographic devices located in territorial waters, the standardization of marking and lighting for buoys on the high seas, restriction of placing of buoys in busy shipping lanes and other determined areas in the high seas, and the supervision and protection by research vessels of free-floating buoys.

There is a specific reference by the Soviet Union to the need for a provision ". . . stipulating that no country, ship or naval vessel has the right to remove equipment, instruments, apparatus or taped automatic measurements from another country's fixed stations."[56] However, this request is coupled with a statement to the effect that at the same time that information is circulated as to the position of ocean data buoys, directions should also be given for monitoring the information broadcast by any such station. This would appear to dispel any doubts that may arise concerning a limitation on the free exchange of information gathered from ocean data buoys. It is also an indication of the fear of the Soviet Union that these devices will be used for military purposes. This is substantiated by a further

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[56] Id. at 30.

statement that

> The convention should emphasize that fixed oceanographic stations sighted in the open sea are liable to destruction whenever their owner has failed duly to publicize their purpose and precise position.[57]

Another reason for the Soviet desire to publicize the location of the buoys is that it is their view that only if there has been a failure to publicize the station's position, aims, and identification marks can there be liability on the part of the State for a collision. The other situation requiring an assumption of liability would be where the buoy was placed in such a manner as to be poorly visible either in the day-light or by night.

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[57] Ibid. The promulgation of an agreement such as that proposed by the U.S. and the U.S.S.R. in Geneva in November 1969 which would outlaw fixed installations of offensive nuclear weapons (nuclear mines and silos for housing nuclear weapons) and chemical and biological warfare devices, could go far in alleviating mutual suspicion of spying devices in ocean buoys. As in other areas the problem of inspection is left to the two superpowers. The IOC Group of Experts on the Legal Status of Ocean Data Acquisition Systems considered the problem of illegal (spying) systems being purposely allowed to drift into the territorial waters of a State and stated that the right of the coastal State to remove any system entering its territorial waters was absolute and that proof of legality based on correct marking and prior promulgation of intent could be the prerequisites for return of the systems to their owners. "Summary Report of the Second Meeting of the IOC Group of Experts on the Legal Status of Ocean Data Acquisition Systems, UNESCO, Paris, Jan. 13-16, 1969 [Sixth Session, UNESCO, Paris Sept. 2-13, 1969] SC/IOC-VI/INF. 142, SCE/9/89/M-ODAS, IOC/EC-1/2, Paris, May 12, 1969.

The Soviet Union also was of the opinion that special international rules were necessary to ensure the physical security of ocean buoys since there were known cases where stations had been damaged or stolen by unauthorized persons.

> Problems of liability of others in deliberate or accidental interference with fixed oceanographic stations, including theft of information and equipment by private individuals, should be settled by the countries concerned in the usual manner, except that such countries should convey all relevant information to the Intergovernmental Oceanographic Commission.[58]

It is assumed that the reference to "the usual manner" refers to diplomatic negotiation. This would differ from the U.S. statement which referred to the need for the establishment of a system for the settlement of disputes. The Soviet statement also did not refer to the problems of inspection and appeared to rely upon the notification by the responsible State as to the purpose of the buoy. As long as each State could monitor the data being transmitted by the buoy, it would apparently be in a position to determine whether there were any additional transmissions or whether any of the data transmitted constituted a security risk.

The Development of Draft Articles

The Intergovernmental Oceanographic Commission (I.O.C.) had initially requested a study of the legal status of ocean buoys at its

[58] Soviet Comments, supra note 55 at 30.

first session in 1961[59] which resulted in a Preliminary Report[60] and a further resolution that called for the Director-General of UNESCO and the Secretary-General of IMCO to prepare a further report for the third session of the I.O.C.[61] A circular letter was sent out in conformance with this resolution to determine existing legislation and views,[62] and a reference list of analogous international agreements was prepared.[63]

At the first meeting of the IOC Group of Experts on the Legal Status of Manned and Unmanned Ocean Data Stations[64] in September, 1968, an endorsement was given to the recommendation of the Bureau and Consultative Council to the effect that UNESCO be asked to study the possibility of convening a Preparatory Conference on the Legal

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[59] Intergovernmental Oceanographic Commission, Res. I-7 "Fixed Stations." See Appendix I.

[60] UNESCO Doc. NS/IOC/INF-34. Subsequently revised and included as Part I of "Legal Problems, . . . supra note 6 at 7-18.

[61] Intergovernmental Oceanographic Commission, Res. II-18, "Legal Status of Fixed Oceanographic Stations." See Appendix II.

[62] Circular Letter NS/8/89E, Nov. 23, 1962 was sent to all members of the I.O.C. Responses were received from Argentina, Canada, Denmark, Federal Republic of Germany, Netherlands, Philippines, United Kingdom, United States, and the U.S.S.R.

[63] See Appendix III.

[64] See "Summary Report of the IOC Group of Experts on the Legal Status of Manned and Unmanned Ocean Data Stations," First Meeting, Sept. 18, 19, 1968. IOC/INF-141, AVS/9/89M-ODAS, Paris, December 20, 1968.

Aspects of the Use of Oceanographic Buoy Stations. Consideration was also given to the need for adequate documentation on any legal problems which might arise in the framework of IGOSS and WWW.[65]

The second meeting of the Group of Experts was held in January, 1969,[66] during which a framework paper[67] was prepared and circulated in an attempt to gather comments, amendments and suggestions for improvement of the draft which will be used as a guide for a final paper to be prepared as the main working document for the proposed preparatory meeting of governmental experts to study the legal status of ocean data acquisition systems which is scheduled to be held in mid-1970.

At the third meeting of the IOC Group of Experts held in Oct.-Nov. 1969 the responses of interested countries and international

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[65] To date, the WMO has not prepared any documentation dealing with the legal problems that will arise from the use of buoys either in the WWW or in the GARP experiments. Interview, WMO, November, 1969, Geneva, Switzerland.

[66] See "Summary Report of the IOC Group of Experts on the Legal Status of Ocean Data Acquisition Systems (ODAS)," Second Meeting, Jan. 13-16, 1969, SC/IOC-VI/INF. 142, SCE/9/89M-ODAS, IOC/EG-1/2, Paris, May 12, 1969.

[67] Id. at Annex I. The paper was divided into four main headings which were: (1) Existing national and international legislation, (2) Prevention of impediments to navigation and fishing (including safety of both life and property) from damage caused by ocean data aquisition systems (ODAS), (3) Protection of ODAS from damage and loss (including safety of life): liability for compensation in the event of damage, and (4) Legal aspects of exchange of data obtained from ODAS.

organizations[68] to the framework paper were discussed along with a draft convention which will be considered during the 1970 meeting. A number of relevant points were made in the comments received pertaining to the framework paper and the matters for discussion relative to the draft convention. One interesting distinction was alluded to by the International Hydrographic Bureau (IHB) which considered that the responsibility for informing the Hydrographic Services of the existence of ocean buoy systems ". . . must fall on the bodies using the ODAS."[69] This raises the possibility of a distinction between ownership and use since the buoy systems could be used by the World Weather Watch or GARP while being owned by a particular nation. While it could be assumed that it would be the responsibility of the nation to report the existence of any buoys to the IHB, it might also be the concurrent responsibility of any involved group such as WWW or GARP, and the liability for non-action might rest with both the

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[68] Collection of comments which have been received concerning the "Framework Paper" on problems to be resolved in clarifying the legal status of ODAS: First increment, SC/IOC. EG-1/2(a) Aug. 11, 1969; Second increment, SC/IOC. EG-1/2(b) Oct. 7, 1969; Third increment, SC/IOC. EG-1/2(c) Oct. 8, 1969; Fourth increment, SC/IOC. EG-1/2(d) Oct. 17, 1969.

[69] "Comments of IHB concerning IOC circular letter No. 243A of 20 May 1969 on the Legal Status of ODAS." Attachment to letter from the IHB to UNESCO of June 14, 1969. reprinted in the first increment supra note 68.

organizations and the nation involved.

In the event of international organization ownership of a buoy system, further problems would arise as to the responsibility for reporting accurately the existence of the buoys to the IHB. This problem is further complicated by the reference in the Report of the Second Meeting of the IOC Experts to the effect that ". . . any such set of international legal regulations, which are eventually developed, should apply both to ODAS (or networks of ODAS) forming part of internationally organized programmes (such as IGOSS, WWW, etc.) as well as to systems placed by individual countries or agencies."[70] This distinction was queried by the FAO and the statement made that this raises the broader question of ". . . whether consideration will be given to the possibility of ODAS being owned or operated by intergovernmental organizations and ways in which such organizations would be bound by, or able to implement, the regulations concerned."[71]

The real question is raised by reference to the ability of an intergovernmental organization to implement the regulations and be bound by adverse decisions if found to be liable. The resolution of this question will require consideration of the basic issue of whether an inter-

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[70] Second Meeting of IOC Experts supra note 66 at Annex I at 3.

[71] Letter from the Director, International Agency Liaison Division, FAO to the Secretary of the IOC, UNESCO dated Sept. 10, 1969, reprinted in the third increment supra note 68.

national organization can legally own and operate ocean data devices, which in turn relates to the need for a decision on whether international organization ownership of vessels is legally possible.

It will also be necessary to consider the future development of ocean-going vessels with reference to the criteria to be established for determining the frangibility of a moored or free-floating ocean data buoy. I. M. C. O. points out that even a small, frangible device for data acquisition ". . . which is harmless to a conventional cargo ship or tanker may present a danger to 'captured air-bubble vehicles' of light construction which may in the not distant future be moving in and over the water at 40 or 50 knots."[72] This is the same sort of question that is raised in terms of aircraft safety where the use of balloon data systems may prove frangible to ordinary jet engines and windshields but not so to smaller planes which may occupy the same airspace. A further question could be put as to whether there was any automatic destruction device on the large buoys that could be activated if they broke away from their mooring in a storm or were otherwise lost? As to the free-floating buoys, should there be a destruction device that can be activated if they are lost by their interrogating or tracking devices?

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[72] "IMCO Comments on the Report of the IOC Group of Experts on the Legal Status of ODAS," reprinted in the fourth increment, supra note 68 at 1.

While it is realized that ocean buoys have been used for many years by the U.S. Coast Guard and other agencies, the technology that has allowed for the creation of the "monster" buoys and the deployment of hundreds of buoys on the oceans for scientific purposes necessitates the examination of the liability and compensation problems that will arise in case of a collision or other form of accident. It may very well be that by reason of being invisible or incapable of identification in geographical terms, free floating buoys may constitute prima facie a hazard to navigation for which insurance will be required to guarantee satisfaction of liabilities in respect of any damage to vessels.[73]

While it is normally assumed that the data obtained from ocean data systems will be available to all nations, the point has been raised as to the need to distinguish between data exchange, data publication, and access to data by techniques such as monitoring.[74] If a standard of freedom of access to information is to be established, it should be done so in explicit terms in any international agreement that is formulated. It should further be decided whether the Russian proposal that information to enable monitoring should be distributed

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[73] Id. at 4.

[74] Id. at 6.

by the State responsible for a buoy is satisfactory, or whether the international obligation ought only to be to distribute or publish the data at a later date.

A further problem that will have to be dealt with concerns the assertion by Peru, Ecuador, and Chile of a territorial limit of 200 sea-miles over which they claim sovereignty and jurisdiction and over which they claim the right to interfere with oceanographic research and to require positions of ODAS to be altered.[75] Peru has also put forward an interesting view on the question of responsibility for tampering and theft of ocean buoys:

> We do not consider that an international convention could operate equally effectively in all States, since theft could be committed by persons at very different levels of culture (depending on the state of development their countries had reached), i.e. the same degree of guilt can hardly be attached to someone who is uneducated or even illiterate from somewhere, say, in Africa as to someone well-educated from a European country who thieves professionally. It is felt that each State should have its own legislation, based on an internationally accepted compromise.[76]

Leaving aside the dubious distinction between professional and amateur regarding the motivation of the theft of a buoy, it is difficult to see

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[75] Letter from the Ministry of Education, Permanent Secretariat of the Peruvian National Commission for UNESCO, dated Aug. 29, 1969 enclosing doc. V.200-064 from the Peruvian Oceanic Institute, both reprinted in the second increment, _supra_ note 68 at 5-8.

[76] _Id._ at 7.

how the realization of the worth of the object stolen should be the basis for a compromise on national legislation, if in fact national legislation is to be considered the most desirable solution. What would seem to be needed in the countries referred to is an educational program designed to demonstrate that buoys found on the high seas are not to be stolen. This would be preferable to one solution to the problem of theft that has been put forward, and that is to electrify or put a self-destructive device on each buoy that would be activated if any tampering occurred. If different levels of punishment are meted out for the same crime, this will only encourage nationals of certain countries to take up thievery "professionally" since the punishment would be negligible if based on some sort of educational test related to cultural development.

Another problem area that could prove quite significant is that dealing with the allocation of frequencies for use by ocean buoys. Communication channels will be needed for nearly simultaneous transmission from multiple buoy systems and also for the command nets linking the buoys with the other parts of the system such as the satellite or the shore-based command station. As ocean data systems become operational there may be difficulties in obtaining the required frequencies[77] and research evaluation in this area should be begun

[77] Sullivan, "International Regulation of Communications for Oceanographic Equipment" 195 in L. M. Alexander (ed.), The Law of the Sea (1967).

as soon as practical. At present the only response from the ITU has been to suggest the inclusion of the following paragraph in the proposed convention:

> Telecommunications required for the Ocean Data Acquisition Systems shall be established and operated in conformity with the provisions of the International Convention in force and the administrative regulations annexed thereto.[78]

To the extent that priorities will have to be developed, particularly when satellites are used as a part of the system, thought should be given to criteria to be used for establishing these priorities.

Proposed Articles for the Preliminary Draft Convention

The third meeting of the IOC Group of Experts on the Legal Status of Ocean Data Acquisition Systems was held in Paris from October 27 through November 14, 1969. During this meeting the Framework Paper was restructured and expanded and it was expected that this revision would be continued at the next meeting of the Group which is to take place in London during the period of June 15 through June 26, 1970. This Framework Paper serves as the basis for the draft convention articles[79] which were extensively considered within the framework of

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[78] Letter from the Secretary-General of the ITU to UNESCO, dated Aug. 28, 1969 reprinted in the second increment supra note 68 at 3.

[79] See, "Summary Report of the Third Meeting of the IOC Group of Experts on the Legal Status of Ocean Data Acquisition Systems," UNESCO, Paris, 27 Oct.-14 Nov. 1969, SC/IOC.EG-1/7, SCE/9/89M-ODAS, Paris, 20 Dec. 1969, hereinafter cited as "Summary Report..." The Framework Paper will be used as a working document

the need for preparing a document which would contain general principles in its provisions and would also contain an annex with specific regulations and technical details of a regulatory nature.[80] It was further decided that the convention was to cover all aspects of the use of ocean data systems and not simply those international programs sponsored by the WMO or the IOC.

for a meeting of governmental experts in mid-1971 who will prepare a draft International Convention on the Legal Status of Ocean Data Acquisition Systems. This meeting did not specifically consider questions pertaining to data exchange or telecommunication since these topics were being dealt with by separate groups: data exchange by the IOC Working Group on International Oceanographic Data Exchange, and telecommunication by the Joint WMO/IOC Group of Experts on Telecommunications.

[80] The Technical regulations in the annexes will cover the specific requirements of marking, signal characteristics, safety of life provisions, notification and related matters. The reason for this division is that the annexes will have to be altered as the technology changes. Included among the recommendations of the Group of Experts were two statements of relevance to the development of the annexes. Recommendation 3 referred to the desirability of Commission (Intergovernmental Oceanographic Commission) action at the next meeting of the IMCO Sub-Committee on Safety of Navigation in April of 1970 since this Sub-Committee will be drafting proposals concerning the lighting and marking of ocean data systems as well as relevant notification aspects. There was further interest in having the IMCO body that deals with the safety and design characteristics of offshore oil rigs consider also the problems of ocean data systems.

Recommendation 4 requested IMCO to prepare a set of criteria relating to the construction and employment of ocean data systems which may present particular hazards to servicing or other personnel such as those involving the use of explosives, high voltage equipment, flammable, toxic or radio-active substances or automatic rocket propelled radiosondes. [A draft document entitled "Guide to the Safe Design, Construction and Use of Radioisotopic Power Generators for Certain Land and Sea Applications" prepared by the International Atomic Energy Agency and the European Nuclear Energy Agency deals with the criteria as to radio-active substances and will probably be incorporated into the annexes of the convention.]

The proposed articles for the preliminary draft convention dealing with ocean data systems provide an indication of the law to be developed in this area and as such require a detailed examination. One interesting fact was that there was apparent disagreement at the third meeting as to the general principle that the deployment of ocean data systems should be one of the forms of exercising freedom of the high seas as recognized by international law. This disagreement reflects the discussion above concerning the absence of specific reference to these devices in existing conventions and international legal rules. It would seem that this problem should be resolved at an early stage in the drafting process inasmuch as the rules to be developed will differ depending on the legal status of the devices. Particularly if it is decided that the placing of ocean data buoys is not to be considered a freedom of the sea, then further discussions will be necessary to decide on the precise legal position regarding their use. Despite this conflict, it is generally realized that there cannot be unregulated deployment of these devices since they can be a danger to shipping and safe navigation, that international cooperation on the part of States and international organizations is necessary, and that uniform rules should be established. The substance of these views is put forward in the Preamble to the proposed articles for the preliminary draft convention.[81]

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[81] The States-Parties to the present Convention,

Recognizing that the deployment of ODAS is one of the forms of exer-

Article 1 of the proposed articles lists the relevant definitions, the most important being that of the "ocean data acquisition system" which is defined as follows:

> Ocean Data Acquisition System (ODAS) means a structure, platform, vessel, craft, buoy or other contrivance, together with its appurtenant equipment—deployed for the purpose of detecting, sensing or sampling the characteristics of the environment of the ocean, the superjacent atmosphere, or the subjacent seabed or the subsoil

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cising freedom of the high seas, as recognized by International Law;

Noting that deployment of ODAS is of great importance for promoting the peaceful understanding and exploration of the oceans;

Considering that an important principle in the deployment of ODAS is close international cooperation of States in understanding the oceans on the basis of a long-term and expanded programme of oceanic exploration and research;

Bearing in mind the growing significance of the Integrated Global Ocean Station System (IGOSS) and the World Weather Watch (WWW) as international systems for the acquisition of oceanographic and meteorological data;

Noting the principle of voluntary exchange of oceanographic and other data obtained through the deployment of ODAS;

Taking into account that unregulated deployment of ODAS can be a danger to shipping and safe navigation, as well as to the interests of the ODAS owners;

Believing that it is necessary to broaden coordination on the part of the Intergovernmental Oceanographic Commission (IOC)/Unesco, the World Meteorological Organization (WMO) and the Inter-Governmental Maritime Consultative Organization (IMCO) in the deployment of ODAS, as well as of dissemination of the data obtained from such ODAS;

Desiring to establish uniform rules governing the deployment of ODAS,

Have agreed as follows:

"Preamble to the Proposed Articles for the Preliminary Draft Convention" found in Annex IV of the Summary Report . . . supra note 79.

thereof, and, in appropriate cases, storing or transmitting such data. The term also includes any similar contrivance deployed in association with one or more ODAS, for the sole purpose of the storage or onward transmission of data collected by such ODAS.[82]

Distinctions are further made between manned and unmanned devices and anchored and drifting devices. A question arises as to the classification of the SKAMP type of device discussed earlier which is not anchored or moored but which keeps a constant station and is not free-floating in the usual sense. It is possible to fit this type of device within the definition of "drifting" or "free-floating,"[83] but it would appear desirable to add a new category to deal with this type of device since it does differ significantly from the common form of free-floating buoy.

The second article considers the freedom of deployment of buoy systems and raises several problems for resolution. The article provides:

(1) All States, whether coastal or not, have the right to deploy ODAS in the high seas, on a basis of equality, in accordance with the provisions of the present Convention.

(2) The Parties recognize the right of an intergovernmental Organization to deploy ODAS, provided such Organization declares its acceptance of the provisions of this Convention, in which event the provisions shall then apply to such organization.

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[82] Proposed Articles . . . supra note 79 at Art. 1.

[83] "Drifting" (or "Free-floating") means a system designed to be buoyant in or on the water and free to move, but not having the capability to change its course to avoid collision with another ODAS or vessel." Id. at Art. 1(d).

> (3) The deployment of ODAS shall be conducted by States and intergovernmental Organizations in accordance with the freedom of the high seas and, as such, shall be undertaken with reasonable regard for the interests of other States in their exercise of the freedom of the high seas.[84]

The major problem raised by this provision relates to the right of an international organization to deploy ocean data devices. For the reasons stated earlier, it is suggested that international organizations may not be capable of accepting the responsibility for damage caused by these devices and may not provide the necessary satisfaction to States wishing to assess liability for particular actions. The fact that these proposed articles were drawn up by a group working under the auspices of an international organization and that a number of international organizations have commented on the work of the Group[85] may have affected the inclusion of clause two. This matter will need to be further discussed when governmental representatives meet to consider the final terms of the Convention. The most apt analogy will probably be to the Outer Space Treaty which is formulated exclusively in terms of State responsibility.

The other question raised by this provision has to do with the existence of a "right" to deploy ocean data systems on the high seas, and this will depend on the resolution of the question of whether or not the deployment of these devices on the high seas is included among

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[84] Proposed Articles . . . <u>supra</u> note 79 at Art. 2.

[85] Comments had been received by UNESCO regarding the Framework Paper from IMCO, IABO, IAEA, ICES, IHB, ITU, ICPC and FAO.

the freedoms of the high seas. It would seem that one of the reasons for formulating a Convention on this subject would be to limit the number of these devices on the high seas and that one of the articles might deal with the limitations to be imposed on the placement of the devices utilizing some sort of allocation formula which would employ a determination of the maximum number of devices to be allowed and would then apportion a certain amount to each State. The determination of the percentage to be allotted to each State would result in implementation difficulties, but the process would be similar to the allocation that takes place with regard to telecommunication frequencies and which will eventually take place with regard to the location of geo-stationary satellites. The necessity for a balancing is indicated in the third clause of Article 2 which refers to the deployment of the devices with reasonable regard to the interests of other States in their exercise of the freedom of the high seas. In recognition of these problems, Article 3 which refers to coordination among the parties to the Convention contains the qualifying clause "as far as possible" to limit the requirement for co-operation, and only requires the submission of matters requiring coordination to the IOC/UNESCO, IMCO or the WMO when those matters lie within the competence of such Organizations.

While the deployment of ocean data systems on the high seas is to be regulated by the terms of the Convention, their deployment in the territorial sea, internal waters, or on the continental shelf of a State remains under individual State control. The main issue is one of State sovereignty and is seen clearly in the provisions of Article 4:

> (1) A coastal State has exclusive jurisdiction over the deployment of ODAS in its territorial sea and internal waters. No State may deploy ODAS in the territorial sea or internal waters of another State without the express consent of that State.
>
> (2) A coastal State has the exclusive right to decide the use to which data collected by ODAS in its territorial sea and internal waters may be put. If the ODAS concerned is registered in another State, that State has the right to prior notice as to that decision before the ODAS is deployed.[86]

It is probable that some observers would favor the drafting of an article where the right of scientific investigation was given primacy and the coastal State was required to show good cause why it would not permit the placing of an ocean data device in its internal or territorial waters. This, however, goes contrary to the existing law which provides for the exercise of State sovereignty without any limiting conditions. The situation is further complicated by the second clause of Article 4 which allows coastal State control over the dissemination of data collected by any devices, whether domestic or foreign. This means that even if a device is placed by the coastal State that it may decide not to release all of the data collected, and that this would be condoned by the Convention. This State could also limit the data dissemination of any buoys placed by foreign States and would probably be even more likely

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[86] Proposed Articles . . . <u>supra</u> note 79 at Art. 4.

to do so. While one concession is made to require a prior determination by the coastal State, this does not limit their <u>de facto</u> control inasmuch as their determination of what data to allow could change with time and the subsequent exercise of sovereignty would not be questioned.

The ambiguity involving ocean data systems and the continental shelf is resolved by providing that these systems ". . . may be deployed to detect, sense, sample, store or transmit the characteristics of the ocean environment and the superjacent atmosphere over the continental shelf <u>as these waters form part of the high seas.</u>"[87] When the devices are used to collect data regarding the shelf itself, then the provisions of the Geneva Convention on the Continental Shelf are to apply according to the clause 2 of Article 5 of the proposed articles. The arguments cited earlier regarding the applications of the Continental Shelf Convention could be used here to precisely define the type of device and the sensors that would be allowed for scientific investigations.

The situations of accidental entry and return of ocean data devices are dealt with by Article 6. Reference is made to the necessity for the "innocent entry" of the device into the territorial waters of a State and to the requirement for return upon demand following the owner's payment

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[87] <u>Id.</u> at Art. 5(1). (Emphasis added)

of any reasonable expenses that may have been incurred in the recovery of the device.

Article 7, concerning registry, provides that ocean data systems not required to be registered as ships should be entered on a special registry for these devices. The one controversial clause in this Article deals with the establishment of a registry by an intergovernmental organization ". . . by which such Organization shall in consequence be assimilated to a Registry State."[88] As only States will be parties to the Convention, some question is raised as to the validity of allowing the registration of these devices by international organizations. Clause 3 of Article 7 continues by stating that:

> Such Organization shall take the necessary measures to apply the provisions of this Convention or enter into an agreement with a Party for the registration of ODAS owned by such Organization or for the measures to be undertaken to apply one or more of the other provisions of this Convention.[89]

If a State is willing to accept responsibility for an international organization concerning registration or the application of other provisions of the Convention, this might provide a satisfactory solution to the problem, but it is doubtful that one State would be willing to accept this responsibility since it would not have complete control over the activities of the international organization.

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[88] Id. at Art. 7(3).

[89] Ibid.

The question of operation of ocean data systems by international organizations arises again in connection with the provisions of Article 8 concerning jurisdictional matters. Clause 1 of this article provides that the registry state shall exercise jurisdiction in all matters over ODAS registered in such State. It does not provide for registration and the assertion of jurisdiction by an international organization, and thus would appear to eliminate the option found in Article 7 which allowed such an organization to apply the provisions of the Convention. Clause 2 specifically states that on the high seas the registry State exerts exclusive jurisdiction, and this reinforces the impact of clause 1 relative to State control. Clause 3 of the article indicates that the registry State cannot claim any rights over the adjacent or underlying seabed if the ocean data system rests on the seabed, and this is in accord with generally accepted principles of law. There was disagreement, however, over the last clause of the Article, clause 4, which stated that:

> The immunities of any ODAS deployed by a State or inter-governmental Organization from the jurisdiction of any other State shall be regulated by the rules of International Law and any relevant treaties.[90]

It is possible that this was too vague a reference and would allow for claims of immunities to be made in unwarranted situations. It also

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[90] Id. at Art. 8(4).

raises the question of security and the possible need for some sort of inspection of ocean data systems to ensure that they are not carrying military devices that could be harmful to State security.

Illegal acts pertaining to ocean data systems are dealt with by Article 9 which prohibits State, individual or intergovernmental organizations interference or removal. On the matter of sanctions, however, Article 9(2) only provides that each state shall take the necessary legislative measures to ". . . provide that any act of detention or seizure not in accordance with this Convention of an ODAS, by any person, shall be a punishable offense."[91] The following clause in the Article provides that:

> Each Party shall take the necessary legislative measures to ensure that the owner of a registered ODAS has an enforceable legal right to recover possession of any part of such an ODAS which has been the object of any act of the kind referred to in paragraph 2 of this article, as well as a similar right to compensation for any consequential damage.[92]

The content of Article 9 points up the declaratory nature of the proposed Convention and its reliance on the good will of the States to enact the necessary domestic legislation.

Regarding the effectiveness of domestic legislation, while under most systems of domestic law there is a civil action right of recovery,

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[91] Id. at Art. 9(2).

[92] Id. at Art. 9(3).

This is not universal. Even if States take action to implement the appropriate measures, it is still possible that the conditions for its application will be different so that uniformity will be lacking. In the event of a criminal offense regarding ocean data systems, it would also appear desirable to develop some set of uniform penal sanctions. The traditional rules of criminal law make it almost impossible to meet the standards of guilt in reference to thefts or other crimes from ocean data stations, and therefore it might prove desirable to shift the burden of proof in a criminal action so that the person involved would have to demonstrate that his action was lawful. This would create basic problems in countries such as the United States where one of the basic tenets of criminal law is that guilt has to be proven. Another difficulty is that penal jurisdiction ordinarily extends only to the territorial limitations of the State. At the present time there is no way for a State to exert its criminal jurisdiction over an act committed by non-nationals on the high seas. There are instances where a State has extended its jurisdiction to cover the acts of its citizens on the high seas[93] but this is not a common procedure. Ordinarily the course of action open is that of diplomatic protest which may or may not be effective, and the

[93] The Marine &c., Broadcasting (Offences) Act (1967) of Great Britain extends coverage of the Act to United Kingdom citizens who do the prohibited acts "on or over the high seas" and to any person who does them in the United Kingdom, in external waters, or in a United Kingdom ship or aircraft located elsewhere. See D. D. Smith, International Telecommunication Control 86-91 (1969).

success or failure of such an attempt may not relate directly to the merits of the case but rather to the current international political situation. International law provides for the exercise of powers of detection, apprehension and sanction over ships of a foreign flag only in a few situations which are carefully specified and regulated.[94] Perhaps a solution would be to emphasize and enlarge the application of Article 10 of the proposed Convention which provides that:

> Any act denounced as piracy in International Law, if directed against a manned ODAS, shall be considered as piracy and dealt with as such.[95]

The drawback here is that only manned devices are referred to while unmanned devices are not included. It may be possible to consider the application of the Geneva Convention on the High Seas to unmanned devices through the provision applying to acts of piracy against property in a place located outside the jurisdiction of any State.[96]

Article 16, which deals with collision liability, provides that the general rules of International Law concerning vessels shall be applied

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[94] It might be possible to draw an analogy to Article 9 of the Convention on Conduct of Fishing Operations in the North Atlantic to allow States to board vessels of a foreign State to investigate the commission of a crime involving ocean data systems.

[95] Proposed Articles . . . supra note 79 at Art. 10.

[96] See the discussion above on "Interference with Ocean Data Buoys."

by the adjudicating forum except as provided by the article. The special provisions of the article concern the burden of proof and place it on the owner of the vessel involved in a collision with an anchored ocean data device, and on the owner of the device when it is free-floating or drifting. The fulfillment of the burden would involve demonstrating compliance with the Convention provisions on notification and marking and signal characteristics.

Article 17, pertaining to salvage, applies the generally-accepted rules to the salvage of manned devices but provides that unmanned devices which are registered shall not be subject to salvage except as provided by the article. The provisions of the article are that either an agreement can be made between the owner of the device and the salvor or notice can be given in accordance with Article 11 of the Convention. Parties to the Convention are also called upon to take the necessary steps to prohibit the award of salvage in domestic judicial or administrative proceedings in conformity with the article. In the event of any dispute, the burden of proving notice is to lie with the salvor. Finally, States are called upon by Article 18 to take the necessary legislative measures to ensure that the owner of a vessel who has suffered a loss in avoiding the destruction of an ocean data system can be indemnified by the owner of the device.

The subsequent provisions of the proposed Convention are reasonably clear and raise no immediate problems. The subject matters dealt with include ocean data system marking and signal characteristics, their use as aids to navigation, their construction, arrangement, and safety provisions, and their requirements as to safe deployment.

APPENDIX I

Intergovernmental Oceanographic Commission: Resolution I-7 — "Fixed Stations"

The Intergovernmental Oceanographic Commission,

Considering the attached report NS/IOC/INF. 16[1], prepared by the ad hoc working group on fixed stations,

1. Recommends to Member States that they provide the Secretariat of IOC annually with full information on what stations of the various types are in operation, what data are being gathered from them and at what time intervals, and on plans for future developments (including technical information on engineering and instrumental matters);

2. Recommends to Member States concerned that they make fuller use of weather ships for the needs of oceanography;

3. Recommends to Unesco that steps be taken in consultation with IMCO to clarify the legal status of unmanned and manned observing buoys;

4. Requests the Bureau to establish a working group of experts from Member States, WMO and other appropriate international organizations, to study the existing network of fixed stations and the needs of extending it (types, number, locations, kinds of observations and their

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[1] This report is not attached to the Appendix.

spacing in time) and prepare proposals for meeting these needs. The working group should report to the next session of the IOC. Expenses of the individual members, including travel should be met by the member governments and organizations having representatives on the working group, or by Unesco.

APPENDIX II

Intergovernmental Oceanographic Commission: Resolution II-18 — "Legal Status of Fixed Oceanographic Stations"

The Intergovernmental Oceanographic Commission,

Recalling that resolution No. 7 of its first session[1] recommended to Unesco that steps be taken in consultation with IMCO to clarify the legal status of unmanned and manned observing buoys,

Having considered document NS/IOC/INF. 34[2] entitled "Preliminary Report of the United Nations Educational, Scientific and Cultural Organization and the Intergovernmental Maritime Consultative Organization on the Legal Status of Unmanned and Manned Buoys," and document NS/IOC/2-5(b), The Report of the Working Group on Oceanographic Stations.

Noting the need for further clarification of the legal status of fixed oceanographis stations and the establishment of safety rules for their proper use,

Decides:

1. To request the Director-General of Unesco, in consultation with the Secretary-General of IMO, to study further the relevant existing international maritime conventions with the view of defining in a

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(1) See Appendix I.

(2) Revised version, SC69/XVI. 5/A.

new international convention the legal status of fixed oceanographic stations.

2. To request members of the Intergovernmental Oceanographic Commission to report to Unesco during the first half of 1963:

(a) on their domestic laws, regulations, orders, court and administrative decisions, diplomatic correspondence and any other legal authority concerning such fixed oceanographic stations;

(b) on their regulations and practices concerning the marking and identification of fixed oceanographic stations;

(c) on what legal problems, if any, they would wish considered in a new international convention concerning fixed oceanographic stations, together with the possible solutions that might be adopted in an international convention.

3. To request the Secretary of the Commission to inform the Maritime Safety Committee of IMCO of all suggestions emanating from the Commission and from the implementation of this resolution concerning the marking, the identification and any other safety aspects of fixed oceanographic stations.

4. To express the wish that the Maritime Safety Committee of IMCO study such suggestions and other safety aspects of the use of fixed oceanographic stations and indicate the results of its study and deliberations to the Commission.

5. To request the Director-General of Unesco to continue his close co-operation with the Secretary-General of IMCO on all legal aspects of fixed oceanographic stations.

6. To request the Director-General of Unesco to present a report to the next session of the Commission on the different questions dealt with in this resolution together with any suggestions he may deem appropriate.

APPENDIX III

Analogous International Agreements and other Relevant Documents

The following list of international conventions and agreements may be considered as providing source material for the drafting of a convention dealing with the placement of ocean data systems. The list represents the existing legislation in this area concerning buoys or codifying analogous subjects.

1. The Antarctic Treaty, Washington, 1 December 1959 (402 United Nations Treaty Series, p. 71).

2. Convention on the Liability of Operators of Nuclear Ships, Brussels, 25 May 1962 (reproduced in Singh, International Conventions on Merchant Shipping, London, Stevens & Co., 1963, p. 1071, hereafter cited as "Singh").

3. Convention on the Territorial Sea and the Contiguous Zone, Geneva, 29 April 1958 (UN Conf. on the Law of the Sea, Official Records, Volume II, Plenary meetings, Doc. A/Conf. 13/38 (1958).).

4. Convention on the High Seas, Geneva, 29 April 1958 (UN Conf. on the Law of the Sea, Official Records, Volume II, Plenary meetings Doc. A/Conf. 13/38 (1958)).

5. Convention on Fishing and Conservation of the Living Resources of the High Seas, Geneva, 1958 (UN Conf. on the Law of the Sea, Official Records, Volume II, Plenary meetings, Doc. A/Conf. 13/38 (1958)).

6. Convention on the Continental Shelf, Geneva, 29 April 1958 (UN Conf. on the Law of the Sea, Official Records, Volume II, Plenary meetings, Doc. A/Conf. 13/38 (1958)).

7. Agreement for a Uniform System of Buoyage and Rules Annexed thereto, Geneva, 13 May 1936, League of Nations (Communication and Transit), Document C261 M154, 1936, VIII, 11.

8. International Convention for the Unification of Certain Rules of Law with Respect to Collisions between Vessels, Brussels, 1910 (103 British and Foreign State Papers, p. 441, and in 7 Martens, N. R. G. (3rd ser.) p. 728, and in Singh p. 1047).

9. International Convention on Certain Rules concerning Civil Jurisdiction in Matters of Collision, Brussels, 10 May 1952. (UN Registration No. 6331, 2 October 1962, Singh, p. 1131).

10. International Convention for the Unification of Certain Rules relating to Penal Jurisdiction in Matters of Collision or other Incidents of Navigation, Brussels, 10 May 1952 (UN Registration No. 6332 (2 October 1962), Singh, p. 1134).

11. International Convention for the Protection of Submarine Telegraph Cables, 14 March 1884 (75 Brit. and For St. Papers, p. 356; 11 Martens (2nd ser.), p. 281; 2 US Treaties and Conventions, p. 149; Singh, p. 275).

12. International Agreement concerning Manned Lightships not on their Stations, Lisbon, 23 October 1930(112 L. N. T. S., p. 21, Singh, p. 8).

13. Exchange of Notes concerning the Mutual Delivery of Buoys, Germany and Denmark, 5 and 29 January 1904 (Danmarks Traktater, Vol. 6 (1901-1907)).

14. Convention regarding the Regime of the Straits, Montreux, 20 July 1936 (173 L. N. T. S., p. 213, Singh, p. 1189).

15. Convention on International Civil Aviation, Chicago, 7 December 1944 (15 United Nations Treaty Series, p. 295) and Annex 12 to this Convention on Search and Rescue.

16. International Convention for the Safety of Life at Sea, London, 10 June 1948 (164 United Nations Treaty Series, p. 113).

17. Convention for the Unification of Certain Rules relating to Assistance and Salvage of Aircraft or by Aircraft at sea, Brussels, 29 September 1938 (Hudson, International Legislation, Volume VIII, 135, Singh, p. 1116).

18. Convention for the Unification of Certain Rules with respect to Assistance and Salvage at Sea, Brussels, 23 September 1910 (103 British and Foreign State Papers 441, Singh, p. 1112).

19. Treaty between the U. S. A. and Mexico for the sending of vessels for purposes of assistance and salvage, Mexico, 13 June 1935 (168 League of Nations Treaty Series, p. 135).

20. Exchange of notes constituting an agreement between the U. S. A. and Canada relating to air search and rescue operations along their common boundary, Washington, 24 and 31 January 1949 (43 United

Nations Treaty Series, p. 119).

21. Agreement between the U. S. A. and Canada for the promotion of safety on the Great Lakes by means of radio, Ottawa, 21 February 1952 (205 United Nations Treaty Series, p. 293).

22. Agreement between Sweden and the USSR concerning co-operation for the saving of lives in the Baltic Sea, Moscow, 29 September 1954 (202 United Nations Treaty Series, p. 259).

23. Agreement between Rumania and Hungary concerning air transport, Bucharest, 3 February 1956 (362 United Nations Treaty Series, p. 233).

24. Agreement between Austria and the USSR concerning air transport, Vienna, 9 November 1955 (255 United Nations Treaty Series, p. 247).

25. Agreement between the USSR, Bulgaria and Rumania concerning co-operation for the saving of human lives and assistance to vessels and aircraft in distress in the Black Sea, Moscow, 11 September 1956 (266 United Nations Treaty Series, p. 221).

26. Exchange of notes constituting an agreement between the Netherlands and the Federal Republic of Germany concerning co-operation for the saving of human lives in the North Sea, the Hague, 25 and 30 January 1958 (315 United Nations Treaty Series, p. 117).

27. International Regulations for preventing Collisions at Sea, 1948. Approved by the International Conference on Safety of Life at

Sea, on 10 June 1948 (191 United Nations Treaty Series, p. 20).

28. Exchange of notes constituting an interim Agreement between the United States of America and Canada relating to the establishment of a Network of Seven Weather Stations in the Pacific Ocean. Washington, 8 and 22 June 1950 (87 United Nations Treaty Series, p. 390).

29. Exchange of Notes Constituting an interim Agreement between the United States of America and Canada relating to the Establishment of a Network of Seven Weather Stations in the Pacific Ocean. Washington, 8 and 22 June 1950 (70 United Nations Treaty Series, p. 116).

30. North Atlantic Ocean Weather Stations Agreement, London, 12 May 1949 (101 United Nations Treaty Series, p. 92).

31. Agreement between the Governments of Norway, Sweden and the United Kingdom relating to a Joint Ocean Weather Station in the North Atlantic, Oslo, 28 February 1949 (29 United Nations Treaty Series, p. 54).

32. Agreement between the United States of America and the United Kingdom of Great Britain and Northern Ireland for the Establishment of an Oceanographic Research Station in the Turks and Caicos Islands, Washington, 27 November 1956 (282 United Nations Treaty Series, p. 44).

33. Agreement between the United States of America and the Government of the United Kingdom of Great Britain and Northern Ireland for the Establishment of Oceanographic Research Stations in the

Bahama Islands, Washington, 1 November 1957 (299 United Nations Treaty Series, p. 168).

34. Agreement between the Government of the United Kingdom of Great Britain and Northern Ireland and the United States of America for the Establishment in Barbados of an Oceanographic Research Station, Washington, 1 November 1956 (299 United Nations Treaty Series, p. 424).

35. Final Act of the Fourth International Civil Aviation Organisation Conference on North Atlantic Ocean Stations, Paris, 25 February 1954 (215 United Nations Treaty Series, p. 250).

36. Agreement on North Atlantic Ocean Stations, Paris, 25 February 1954 (215 United Nations Treaty Organisation, p. 268).

37. Agreement between Sweden and Norway relating to the Operation of Joint Ocean Weather Stations in the North Atlantic, Stockholm, 28 May 1955 (262 United Nations Treaty Series, p. 168).

IMPACTS OF RECENT ADVANCES IN SATELLITE METEOROLOGY ON WATER RESOURCES MANAGEMENT

Gene E. Willeke*

Power Generation

Forecast Uses

Long-range forecasting is useful in power generation operations for three primary reasons: it can help increase the supply of electricity, help forecast the demand, and help to schedule maintenance better.

The amount of energy that can be produced depends upon the amount of water available and the head at the time of power generation. Both these factors are dependent upon precipitation, evaporation, seepage, snowmelt, and other hydrologic factors. To the extent that they can be adequately forecast, more energy can be developed from the available water by reducing the amount of water spilled and by generating at higher heads.

The demand for power depends in part upon weather variables, especially temperature, cloudiness, windiness, and precipitation (Figures 1-1 and 1-2).

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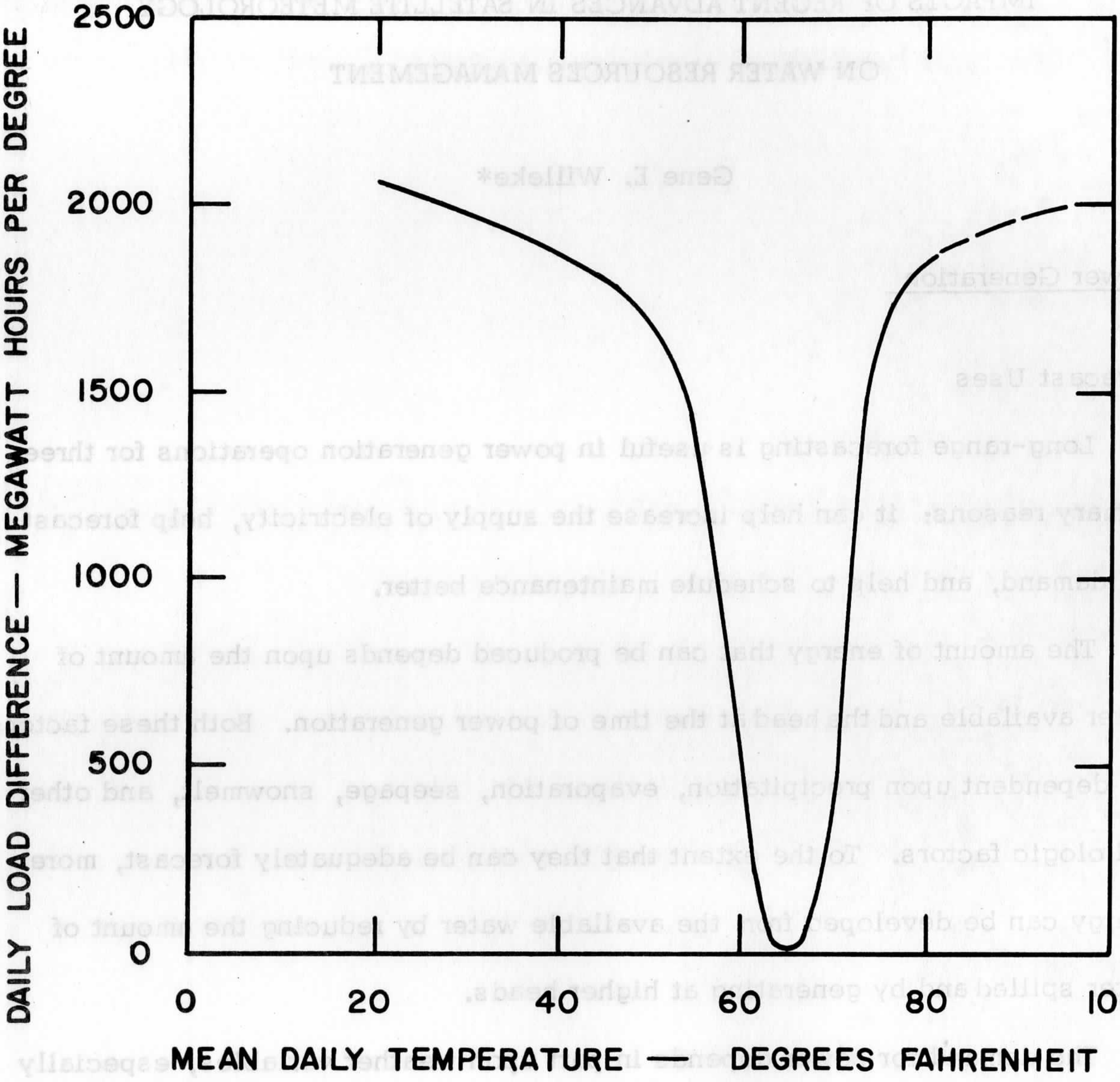
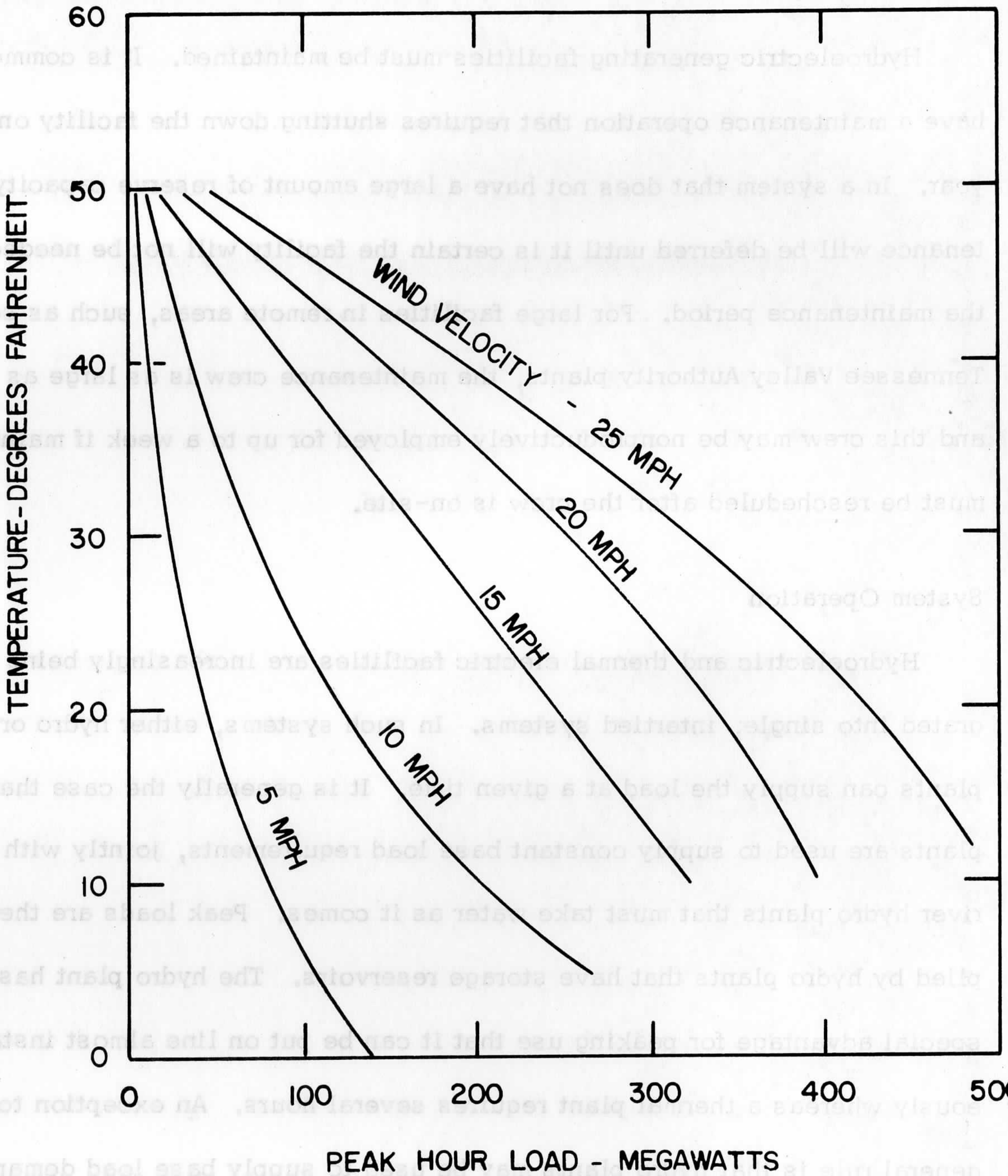
*Civil Engineering Dept., Stanford University, California. The author is grateful for the assistance of many people in the preparation of this report. Of special note are the persons interviewed in the course of project investigations. Mr. Brook Kraeger conducted some of the interviews and did the computer simulation study. Mr. Terry Anderson assisted in some of the computer simulation work and in literature search.



SOURCE: COOPER, 1969

EFFECT OF UNIT TEMPERATURE DIFFERENCE

FIGURE 1-1



SOURCE: COOPER, 1969

EFFECT OF WIND VELOCITY ON PEAK HOUR HEATING LOAD

FIGURE I-2

Hydroelectric generating facilities must be maintained. It is common to have a maintenance operation that requires shutting down the facility once a year. In a system that does not have a large amount of reserve capacity, maintenance will be deferred until it is certain the facility will not be needed during the maintenance period. For large facilities in remote areas, such as some Tennessee Valley Authority plants, the maintenance crew is as large as 60 men and this crew may be nonproductively employed for up to a week if maintenance must be rescheduled after the crew is on-site.

System Operation

Hydroelectric and thermal electric facilities are increasingly being integrated into single, intertied systems. In such systems, either hydro or thermal plants can supply the load at a given time. It is generally the case that thermal plants are used to supply constant base load requirements, jointly with run-of-river hydro plants that must take water as it comes. Peak loads are then supplied by hydro plants that have storage reservoirs. The hydro plant has the special advantage for peaking use that it can be put on line almost instantaneously whereas a thermal plant requires several hours. An exception to this general rule is that hydro plants may be used to supply base load demand during times of high flow; otherwise, water would be spilled and not used for power generation.

Integration of systems is not limited to a small geographic area. Very extensive regions such as the western United States are now linked by interties that, in effect, make it possible for power to be transmitted very long distances, through wheeling arrangements. Such interties are useful in smoothing out load curves. A simple example will illustrate the point. Near a time zone boundary, the load curves may be similar but displaced from each other by an hour because of the time change differential. If power is transmitted across the time zone boundary, the combined load curve will be flatter than either of the two component curves. This has the desirable property that less generating capacity is needed to supply the demand. The energy supplied is the same, but the power capacity requirement is reduced.

Communication Behavior

The existence of integrated power supply systems requires complex communications to make optimal production scheduling possible. At the present time, there is a heavy reliance on telephone communication. Power dispatchers in one place call power dispatchers in another place to negotiate the sale or purchase of power and to prescribe the amounts of power to be generated at each facility. In turn, information is relayed back to power dispatchers regarding weather conditions, precipitation, condition of the plant, etc.

Much of the actual computation work for power scheduling is now done by computers, but it must be emphasized that there is still judgment and negotiation involved in day-to-day operation of power facilities.

The use of computers in the future to take over more of the day-to-day scheduling is virtually a certainty. As algorithms are developed to duplicate or improve on present decision-making techniques, they will be incorporated into system operations.

Facility and System Variations

Long-range weather forecasts have a somewhat different use for each kind of hydroelectric facility and for each operating system.

For a run-of-river facility, with substantially no storage, the operator will generate power continuously with minor variations during the day, except during periods of equipment maintenance or no flow. A long-range weather forecast will provide the operator with a better knowledge of the hour-to-hour and day-to-day output of the plant. With this knowledge, he will be better able to schedule production at other facilities in the system and to make good purchase and sale decisions. If high flow were predicted, production would be reduced at thermal plants and increased at hydro plants. Surplus power would be sold, if possible, to other users in the intertied system.

With a pondage facility, in which storage is available for up to several days or more, the forecast of flow would be used to reduce spill of water, produce as much power as possible, and use the pondage facility for daily peaking, thus reducing the peaking demand at storage facilities.

With a single-purpose power storage reservoir, the operator would like to prevent spillage of water, and would like to be able to generate peaking power at the times when it has the highest economic value. The latter objective is met by having a high pool elevation so that a given quantity of water will generate more power by falling through a high head. This must be balanced against the safety of the structure. If the reservoir is full when a large flood comes, and the spillway has inadequate capacity to pass the flood, the dam may be endangered, causing great loss of property and, often, life.

Weather forecasts provide a basis for realizing something approaching an optimal combination of the above objectives.

With a multiple-purpose storage reservoir, the requirements for power must be balanced with the requirements for other purposes. There is usually both complementarity and conflict of purpose. For example, water released for irrigation purposes may also be passed through turbines to generate power; this is a complementary use. On the other hand, the ideal flood control situation is an empty reservoir, the reverse of the ideal power situation, thus leading to a conflict situation.

In all the above situations, load and resource would be enhanced by the long-range weather forecast. The same would be true in regard to scheduling maintenance.

Economic Significance of Forecasts

Although additional costs would be incurred in using long-range forecasts the additional benefits will greatly exceed the additional costs. The value of the forecasts, however, would be expected to vary considerably from system to system and basin to basin.

In a basin such as the Columbia River Basin, precipitation occurs primarily in the headwaters, and is stored and released successively into a number of downstream reservoirs at each of which power is produced. Here, the value of long-range forecasts of the resource would not be large. This is true because once the precipitation has fallen, it may be accounted for quite accurately and projections of water availability made for a considerable time in the future.

Only during the rainy season could one expect to realize significant new information about the resource availability. The principal value of satellite meteorology for a basin such as the Columbia in providing data about resource availability may be in accurate measurements of such things as areal snow coverage, snow depth, and water content.

On the load forecast side, long-range weather forecasts of temperature, wind, cloudiness, and precipitation would be of considerable value in more sharply defining expected load curves. This would reduce the necessity for emergency measures to provide power and would reduce water wastage.

All told, the aggregate potential value of ten-to-fourteen day forecasts for the resource, the load, and maintenance is probably not more than 2% to 3% of gross sales. The large base to which this percentage is applied makes the dollar value large.

There are factors that will prevent the realization of the potential value of long-range forecasts. The application of appropriate hydrologic analysis techniques to currently available weather data varies from excellent to mediocre. Also, institutional objectives will sometimes act to prevent the optimization of power production. As an example, one of the California irrigation districts considers that its primary function is the provision of irrigation water. Power is produced incidentally. The form of its objective is such that, even with its present facilities, it is not realizing as much value from power production as it could (without jeopardizing irrigation supply). Sales agreements between different power producers are sometimes such that surplus power cannot be sold even though another power marketer in the system may be generating power with thermal plant and could use the hydro power.

Parameter and Communication Requirements

For estimates of resource availability, precipitation parameters are of most importance. Quantitative precipitation forecasts and temperature are especially important. For areas that receive significant amounts of snow, it is of great value to obtain periodic estimates of areal coverage, depth, and water content of snow pack. When the ground is not covered with snow, it would be of some value, theoretically, to have measurements of soil moisture content. In practice, indexes of soil moisture content are calculated from precipitation and evaporation data. If the soil moisture measurements from satellite were better than the indexes, they would surely be used on a routine basis.

For load estimates, the most valuable parameters are temperature, wind velocity and direction, cloudiness, and precipitation. These parameters are of most importance in extreme conditions, as is shown in the accompanying figures. As temperature decreases in the Tennessee Valley, the generating capacity required to supply the heating load increases markedly with both an incremental temperature change and an incremental wind velocity change. Cloudiness primarily affects the demand for lighting. During periods of precipitation, the demand for pumping water for irrigation of lawns, parks, etc., decreases.

Without exception, the large institutional users interviewed expressed a preference for direct communication with computers. Although few would be equipped to use such data today, it is certain that most users would be able in a few years to accommodate direct data transmission from computer to computer. It is also considered necessary to have the same data transmitted in some kind of hard copy (maps, tables, narratives). This copy would be used in qualitative interpretation, for permanent records, and for a backup source in the event of computer difficulties. Oral communication by telephone and radio would be of less importance for long-range forecasts than for present one-day forecasts.

For accurate twelve-to-twenty-four-hour forecasts, the above comments apply except that oral communication would continue to be important.

The comments above regarding computer reception of data almost necessarily imply time-shared computers. Hardly any of the institutional users have exclusive use of a computer for forecasting and scheduling purposes. The exceptions are the Pacific Gas and Electric Company and the projected use of a small, real-time control computer by the Metropolitan Sanitary District of Greater Chicago. (The Metropolitan Sanitary District of Greater Chicago may be a small producer of power at some future date as storm water is drained into large underground tunnels, passing through turbines on the way down.)

Flood Damage Reduction

Methods

Flood damage reduction can be accomplished either by keeping people and property away from water or keeping water away from people and property. The former is normally achieved in two ways. First, through control of occupancy of areas subject to flooding (by zoning or by public information programs) people are induced not to live in such areas or to engage in economic activity there.

An alternative and supplementary method is to provide warnings of imminent flooding, so that people can evacuate the area of flooding and either remove damageable property or take precautions to minimize flood damage to property left in the flooding zone.

Several methods may be used, alone or in combination, to keep water away from people. The simplest and most direct is the use of levees or dikes, built between flood waters and people or property.

A second method is that of storing water in reservoirs during the course of a flood, and releasing the water at rates of discharge less than would cause flooding below the reservoir. Sometimes these reservoirs are used only for flood control purposes. In other cases, the reservoirs are multiple purpose; water is stored during flood periods and all or a portion of the stored water is used for other purposes, including municipal, industrial, or agricultural supply, recreation, the generation of electricity, and maintenance of navigation levels below the reservoir.

The third class of methods includes channel modifications. Obstructions in the channel may be removed, channels may be straightened, lined, or otherwise expanded in capacity. These measures usually have the effect of carrying water away more rapidly and/or at lower stages.

Role and Value of Forecasts

In all these methods of flood damage reduction, long-range weather forecasts can be of value in two ways. First, and most important from a dollar standpoint, is flood warning. The ability to give advance warning so that measures can be taken to prevent flood damage is perhaps the most important method of flood damage reduction to be exploited in the last two decades. The economic importance accrues from the ability to reduce greatly flood damage by evacuation or temporary flood-proofing and from the fact that floods are relatively rare occurrences. The significance of the latter point is that during non-flood periods such advantages as may be inherent in flood-plain utilization can be realized.

The second way in which long-range forecasts can be of value in flood damage reduction is in providing data that allows better operation of flood control facilities. Reservoir storage does most to reduce flood peaks if storage begins at the proper time. In the simple case, if the reservoir were filled during the early part of the hydrograph rise, there is no capacity left to store water in the peak of the hydrograph and the outflow peak is of approximately the same order of magnitude as the inflow peak. On the other hand, if storage space is reserved for the period including the hydrograph peak, peak reduction can be considerable.

In a few instances, channels may be operated to achieve flood damage reduction. A notable example is the Chicago Sanitary & Ship Canal which has control works at its lower end and inlet works at its upper end (through which water from Lake Michigan enters for dilution of waste effluents). See Figure 2-1. Prior to a storm, the inlets may be closed and the outlet works opened to provide space that can be used to accommodate flood waters. It takes several hours to get the water moving in the channel. About a twelve-hour advance warning is crucial to effective operation of the control works.

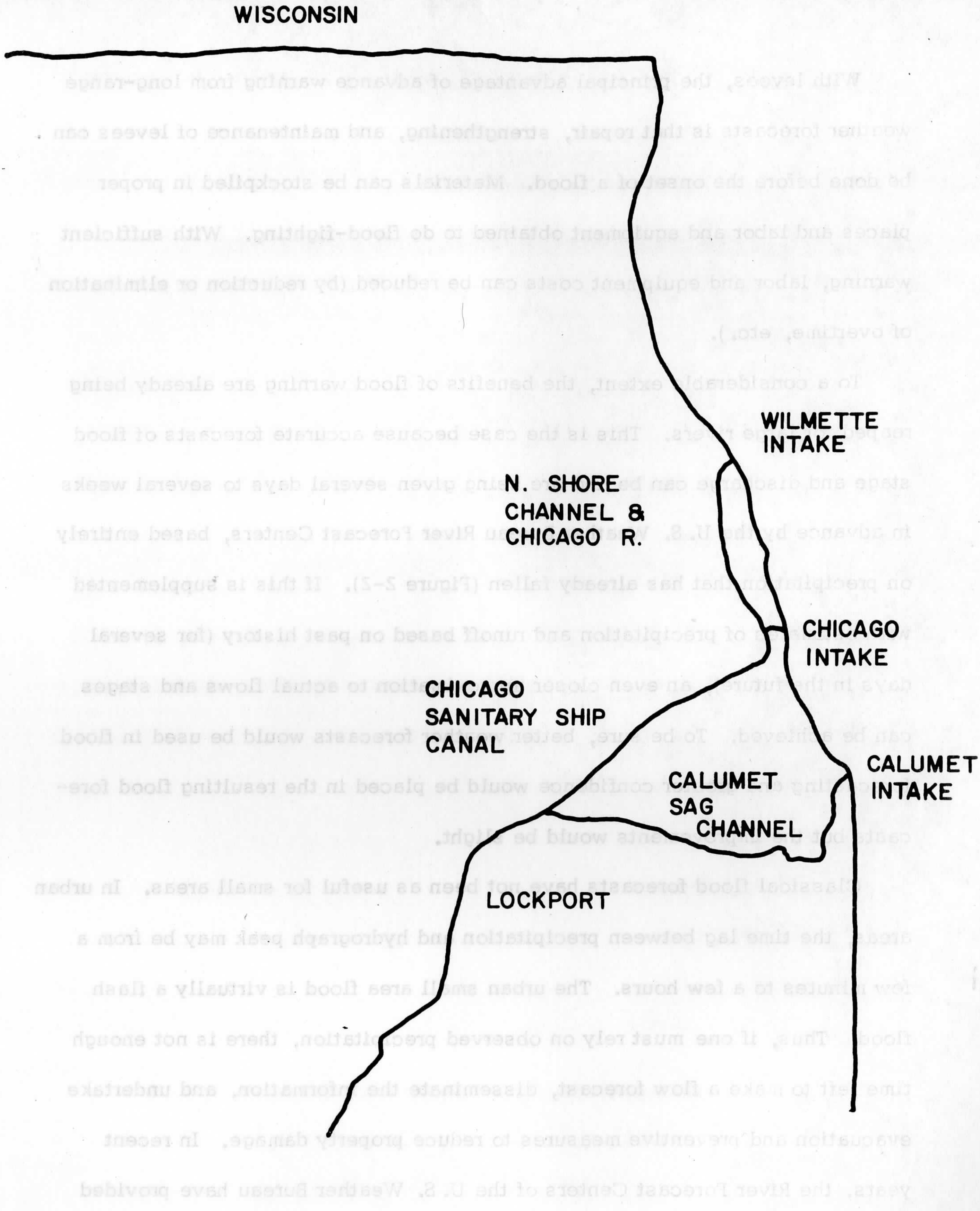

WISCONSIN
WILMETTE INTAKE
N. SHORE CHANNEL & CHICAGO R.
CHICAGO INTAKE
CHICAGO SANITARY SHIP CANAL
CALUMET INTAKE
CALUMET SAG CHANNEL
LOCKPORT

FIGURE 2-1

With levees, the principal advantage of advance warning from long-range weather forecasts is that repair, strengthening, and maintenance of levees can be done before the onset of a flood. Materials can be stockpiled in proper places and labor and equipment obtained to do flood-fighting. With sufficient warning, labor and equipment costs can be reduced (by reduction or elimination of overtime, etc.).

To a considerable extent, the benefits of flood warning are already being reaped for large rivers. This is the case because accurate forecasts of flood stage and discharge can be and are being given several days to several weeks in advance by the U. S. Weather Bureau River Forecast Centers, based entirely on precipitation that has already fallen (Figure 2-2). If this is supplemented with estimates of precipitation and runoff based on past history (for several days in the future), an even closer approximation to actual flows and stages can be achieved. To be sure, better weather forecasts would be used in flood forecasting and greater confidence would be placed in the resulting flood forecasts but the improvements would be slight.

Classical flood forecasts have not been as useful for small areas. In urban areas, the time lag between precipitation and hydrograph peak may be from a few minutes to a few hours. The urban small area flood is virtually a flash flood. Thus, if one must rely on observed precipitation, there is not enough time left to make a flow forecast, disseminate the information, and undertake evacuation and preventive measures to reduce property damage. In recent years, the River Forecast Centers of the U. S. Weather Bureau have provided methods of making crude forecasts on the spot. Indexes of soil moisture con-

FLOW OF INFORMATION IN RIVER FORECASTING

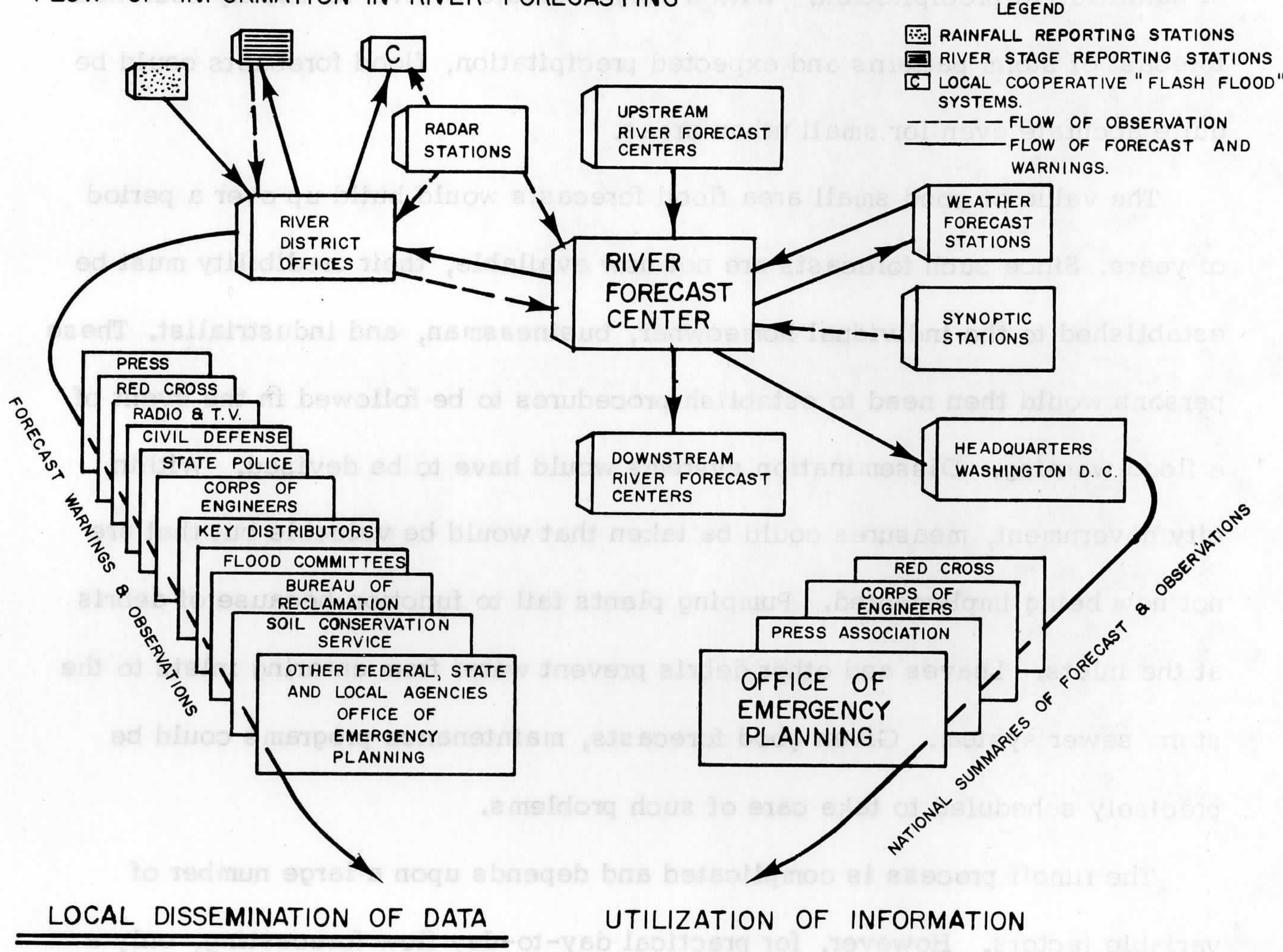


FIGURE 2-2

ditions are regularly provided to responsible local officials such as city engineers, public works directors, etc. that, together with forecasts of precipitation, enable the local official to assess flood potential and provide warnings. These forecasts of flood potential are severely limited by weather forecasts, especially of quantitative precipitation. With a very accurate twelve-to-twenty-four-hour forecast of storm patterns and expected precipitation, flood forecasts could be quite accurate even for small urban areas.

The value of good small area flood forecasts would build up over a period of years. Since such forecasts are not now available, their credibility must be established to the individual homeowner, businessman, and industrialist. These persons would then need to establish procedures to be followed in the event of a flood warning. Dissemination systems would have to be devised. Within city government, measures could be taken that would be valuable but that are not now being implemented. Pumping plants fail to function because of debris at the inlets. Leaves and other debris prevent water from entering inlets to the storm sewer system. Given good forecasts, maintenance programs could be precisely scheduled to take care of such problems.

The runoff process is complicated and depends upon a large number of variable factors. However, for practical day-to-day flow forecasting, only a few factors are needed to do creditable work. Most important is a quantitative forecast of precipitation, the dominant factor in the runoff process. Ideally, this forecast would give a time-space-intensity pattern of precipitation, e.g., in the southern third of San Mateo County at elevations above 500 feet msl, there will be .5 inch of rainfall between 3 P.M. and 4 P.M. today. If snow is a factor, temperature forecasts are also needed to help estimate snowmelt rates.

Of the potential ways in which weather forecasts could be of service in reducing flood damages, it must be pointed out that because of constraining factors—physical, economic, institutional, and legal—not all the benefits can be realized. The following two examples are typical.

Many flood control reservoirs are constructed to operate automatically. Gates are not operated according to a method designed to produce optimal flood peak reduction. Rather, the reservoir acts in a completely predictable fashion for every flood. The outflow depends entirely upon the depth of water in the reservoir.

If the reservoir does not have flood control as a purpose—an institutional and legal factor—it will most likely be operated for its intended purposes and no significant flood control benefits will be realized. The absence of outlet works having significant capacity precludes effective control of flood storage capacity.

Water Quality Management

Forecasts of weather and streamflow are little used in water quality management at the present time. Both are of potential value. The applications are rather simple.

When the receiving waters, especially streams, have low capacity to accommodate waste effluents, there may be a material advantage in being able to store waste effluent for a short period of time before release. During this period, some further oxidation of wastes will occur, reducing the demand on the oxygen resources of the stream. If the flow increases, it has a higher assimilative capacity. Thus, it would be advantageous to store wastes, guided by forecasts of streamflow (which, in turn, would be based on weather forecasts).

During storm periods, waste treatment plants are often subjected to much higher flows than normal, higher than the hydraulic capacity of the plant. In such a situation, raw or partially treated sewage is often discharged directly to receiving waters. Temporary storage of storm waters for later treatment would make it possible to treat all or, at worst, a higher percentage of the storm waters.

Waste treatment plants that use chemicals in treatment would be able to do a slightly better job of inventory if long-range forecasts were available. Additionally, to the extent that future knowledge of waste characteristics (such as temperature) were important, the operation would be improved.

The above cited methods of improving water quality management can only partly be given as benefits of weather forecasts. Most of these benefits could be achieved with present forecasts but are not being used.

Twelve-to-twenty-four-hour forecasts of precipitation would be of value in cities using the principles of a system in use in Minneapolis-St. Paul, Minnesota. Storms fill only portions of the storm sewer system while other portions are partially or completely empty. Given favorable topography, flow can be diverted from one portion of a sewer system to another portion by manipulating gates, valves, etc. The Minneapolis-St. Paul control system utilizes a real-time process control computer to manipulate valves, gates, and inflatable dams in sewers. Given an accurate forecast several hours in advance, this operation could be improved somewhat. As of January 1970, weather forecasts are not used in operation of the system. Oral communication with the U. S. Weather Bureau is used frequently to obtain information about weather conditions but the information is not used directly in the computer control system. The managers of the system have stated (Anderson, 1970) that, with further development work, forecasts could be incorporated.

Municipal and Industrial Water Supply

Municipal and industrial water supply relies on wells, run-of-river withdrawal from streams, and surface storage reservoirs. The value of long-range weather forecasts varies widely depending upon the source of supply and the nature of the demand.

For an ordinary ground-water supply, the amount of withdrawal that can be made does not depend significantly upon short-term weather conditions. For most ground-water supplies, the effect of changes in precipitation, for example, will not be felt for many years. Thus, for ground-water supplies, the only value of long-range weather forecasts is for forecasting demand.

For a supply that depends upon run-of-river withdrawal from streams, long-range weather forecasts enable better forecasts of streamflow. This, in turn, enables better, less expensive water treatment and, when water must be rationed, enables better decisions on the allocation of water to various users.

Surface supplies that use storage reservoirs are usually operated on an annual cycle. Water is stored during periods of runoff and is withdrawn through the year to meet demands for water. It is not common to have over-year storage in a municipal and industrial water supply reservoir. Thus, short-term estimates of runoff are of some value in estimating the amount of water available for supply. As a rule, this would be needed only in dought periods, once in several years.

Municipal water supply managers tend to be individuals not tied in with extensive weather data systems. They may or may not have training in hydrology. Their ability to predict runoff from rainfall varies considerably. Few municipal water supply managers would use computers for flow forecasting. These conditions lead to the conclusion that conventional methods of disseminating forecasts should be continued for these persons. Ideally, flow forecasts would be prepared by a regional or state agency and disseminated directly to municipal water managers for use. Significant economies would result from the extensive use of computers and trained hydrologists. For the larger rivers, this function is already being performed by River Forecast Centers of the U. S. Weather Bureau, though not fully utilized by municipal water supply managers. For the smaller streams, there is an information gap.

Irrigation

Irrigation Characteristics

Irrigation is seasonal, spring through fall, in the United States. For surface supply situations, water is stored in reservoirs during the winter and spring precipitation period and released during the irrigation season. Reservoirs often provide over-year storage. Water may be stored for periods of several years to smooth out long-term fluctuations in streamflow.

The ideal situation from an irrigation standpoint is to have a full reservoir at the beginning of the irrigation season in the spring. Operation of irrigation supply reservoirs is in accordance with this objective.

Irrigation is frequently, however, only one of several objectives of a reservoir. Power generation, flood control, water quality enhancement, municipal and industrial supply, and recreation or some combination of these purposes are, with irrigation, joint uses of the storage facilities.

The addition of other purposes contributes to the overall economic efficiency of the project. However, the functions have elements of competition with irrigation as a purpose and the benefits for the several functions cannot all be maximized simultaneously. Demand for power does not necessarily coincide with demand for irrigation releases. Again, a reservoir is most valuable for flood control if it is empty, the reverse of the ideal situation for irrigation and power.

Value of Forecasts

The value of weather forecasts to the irrigation user is of two kinds: forecasting the supply of water and forecasting the irrigation demand. A critical period in irrigation operations on the supply side is the latter part of the run-off period in a year when the reservoir is near its maximum possible level for the year. Adequate forecasting can forestall unnecessary spillage in the last weeks of the runoff season, thus coming closer to the irrigation goal of a full reservoir at the beginning of the irrigation season. (Spills would be incurred for the purpose of ensuring flood storage capacity or to prevent damage to the dam, spillway, and downstream areas, if a large storm occurred in this period.)

Where much of the precipitation falls as snow, as is the case in much of the western U.S., the most important parameters in the runoff season are temperature and quantitative precipitation. Temperature is of importance in estimating snow melt, quantitative precipitation is valuable for estimating runoff from precipitation that has not yet fallen.

Estimates of the amount of snow on the ground are of as much of more importance than forecasts of future precipitation. Operating decisions in California are frequently made on the basis of monthly water supply outlooks. These outlooks are the result of analysis of data from snow surveys and precipitation gage catches. Both the snow surveys and the gauge catches are used as indexes of snowpack water content. These indexes are correlated with measured runoff. The relationships are then used to predict runoff at various points. These seemingly crude relationships have worked rather well and most errors in estimating the volume of total runoff can be between 10 and 20 percent. The procedures suffer, as does any index procedure, when conditions are markedly different from the conditions during the period on which the relation was based.

The potential contribution of satellite meteorology in this situation is clear. Ideally, one would like to have maps giving the areal extent of snow coverage, the depth of snow and the water equivalent of the snow pack. Given such data, additional refinements could be made in estimating the amount and timing of runoff. Such improvements would be of special importance to small basins.

Over large basins, errors tend to be averaged out in index prediction methods. For small basins, the relative errors are larger.

Communication

The communication behavior of irrigation managers varies widely. The U. S. Bureau of Reclamation, for example, can be in constant communication with the Weather Bureau and other suppliers of data such as the California Department of Water Resources. At the other extreme, small irrigation districts rely very heavily on published data such as the monthly water supply outlooks and do much less analysis of hydrologic data. In terms of economic efficiency, there is an institutional gap. It would be quite feasible for a firm or agency, public or private, to prepare flow forecasts and operational advice for a large number of irrigation districts. This would certainly enable better use to be made of meteorological and hydrological data by fulltime experts equipped with the best in computers and communication devices.

Navigation

In the United States, inland navigation is conducted on the Great Lake and on many navigable rivers, notably the Ohio River-Mississippi River system. Some critical factors in inland navigation include the expected depth of water in navigation channels, time of ice formation and breakup, and storms. Long-range weather forecasts are relevant to all these factors.

Minimum Depths

The U. S. Weather Bureau River Forecast Centers make low-flow forecasts on some rivers, including the Ohio and Mississippi Rivers, for navigation purposes. These forecasts are quite accurate for periods of several days. Accuracy would be less if unexpected heavy rain storms occur in summer or fall. If, for example, a shipper were considering shipping a barge tow that had a large draft (approaching the minimum depths in the system) he would be in a better position to make his decision if he had forecasts covering the entire period of transit of the barge tow. This period of time would extend up to several days.

Ice Conditions

Ice formation and breakup is important on the Great Lakes and in the northern navigable rivers. Accurate timing predictions of these conditions may make a difference of several days in the navigation season at each end. The consequences of incorrect estimates are of two kinds. If the estimated time of ice formation is too early, fewer barge tows can be moved from upstream points, entailing an economic loss. If the estimated time of ice formation is too late, barge tows may be trapped in the ice, resulting either in the destruction of barges and loss of cargo or having the barges tied up at an upstream point for the winter, without the possibility of use elsewhere. In either case, economic loss is incurred. Similar illustrations apply at the other end of the season, although ice breakup and flood conditions, occurring simultaneously, alter the discussion somewhat in that high water, as well as ice, will inhibit shipping.

Storms

Storm warnings are of importance in shipment scheduling. A transit of one or more of the Great Lakes takes time. Present warnings of storm activity are not sufficiently long-range to prevent having a ship caught on a lake during a storm severe enough to wreck the ship. The same is true of small craft on even a larger scale. A recent such disaster occurred July 4, 1969 on Lake Erie. Accurate twelve-to-twenty-four-hour forecasts would be of great help for the small craft and of some help to the large ships. For the large cargo ships, forecasts several days in advance could effectively prevent the loss of any ship due to severe storms on the Great Lakes.

Some of the more dramatic losses of ships on the Great Lakes as a result of storms are as follows: November 18, 1958, U. S. Freighter Carl D. Bradley, sunk on Lake Michigan, thirty-three lives lost. November 9, 1913, ten steamers sunk in storm on Lakes Superior and Huron, with 230 lives lost.

Communication Behavior

The users of forecast data in navigation operations can be considered as sophisticated users. They are institutional users, either governmental agencies such as the U. S. Weather Bureau and the U. S. Army Corps of Engineers, or they are shipping companies making major operational decisions.

The kinds of forecast data that would be of most use to navigation users would be temperature, precipitation, and wind. Temperature would relate to ice formation and breakup as well as flow forecasts. Precipitation would relate to flow forecasts. Wind data is of importance from an operational point of view in terms of predicting such things as waves and steering.

Summary and Conclusions

Nearly all water resource managers should potentially be able to realize gains from long-range weather forecasts or from data available as a result of satellite meteorology. Given the present advanced state of water management, gains would generally be small percentage improvements. Many would be difficult to measure, even if realized. However, the small percentage gains would still be appreciable sums in the aggregate.

Present decision processes allow or can allow for the probability of future weather conditions. To the extent that this is done, some of the potential benefits of long-range weather forecasts would not be realized. They will reduce uncertainty and allow another degree of approximation. The agencies that are presently doing a good job of flow forecasting and water management will likely be the agencies best able to utilize the long-range forecasts.

There are areas of water management in which even existing weather forecasts are not used to enhance management. These include water quality management, urban storm drainage (with a few exceptions), some utilities and special water districts. Improved long-range forecasts of weather may help give rise to changes in institutions, attitudes, and objectives that now inhibit use of forecasts.

Although there are major regional differences, long-range weather forecasts are important throughout the year. In the West, precipitation forecasts are most valuable in the wet season, November-May, whereas temperature, humidity, and wind would be of most value in the remaining months. Where there is a possibility of high precipitation throughout the year, all the forecasts are of value throughout the year.

Data requirements for water resource management include:

a. Quantitative precipitation forecasts—amount, timing, kind, and areal extent;

b. Quantitative precipitation estimates—for previous events, such as snow pack characteristics—and better interpretation of rain gage catches;

c. Temperature forecasts and estimates;

d. Humidity forecasts and estimates;

e. Wind speed forecasts;

f. Radiation estimates;

g. Cloudiness forecasts and estimates;

h. Soil moisture estimates.

In the above data requirements, it is of special value to have forecasts and estimates at the extreme of weather conditions. In the absence of forecasts, it is often assumed that normal or average conditions will prevail in the future. Therefore, departures from normal are very important.

For almost all institutional users, it would be desirable to be able to communicate forecast data directly to a computer. As a general rule, this should be backed up with some type of hard copy amenable to visual examination.

With few exceptions, there is a relatively small number of people and an even smaller number of discrete offices that directly use weather forecasts in making operational forecasting decisions. These offices would generally have the financial capability to install special equipment and train people to use forecasts.

In power generation, forecasts are valuable for three primary reasons: increasing the supply of electricity, forecasting the demand and maintenance scheduling.

Flood damage reduction will be enhanced by long-range weather forecasts both by giving more warning to flood plain occupants and by making possible better reservoir operation. Because most of the benefits of forecasts are already being reaped on river basins with large drainage areas using existing weather forecasts, it seems clear that the largest benefits will accrue to small watersheds, especially those in urban areas.

Although the potential for using flow forecasts in a water quality management program is large, application at the present time is minimal. Long-range forecasts can be of appreciable value.

The value of forecasts in water supply for municipal, industrial, and agricultural uses is highly variable from place to place depending upon the hydrological situation. On the average, significant benefits could be realized.

Benefits to navigation would be classic ones of avoiding ship destruction in storms and of extending navigation seasons in waterways susceptible to freezing conditions.

One recommendation seems in order. At this stage, the impacts on water resources management have been studied in sufficient depth to ascertain that the benefits from satellite meteorology will be significant. There appears to be no need for further assessment of value. The relevant question has turned to the impact of water resource management requirements for data on the design of satellite meteorology programs. The data needs and communication requirements that have been itemized basically meet that need. Further refinement needs to await systems design.

APPENDIX A

List of Interviews

The primary research technique was direct interview of water resource managers. This technique was chosen because of the short time available for study, and because of the desirability of observing the institutional and communicative framework within which water resource operating decisions are made.

The Agencies interviewed included federal, state, local, and special-purpose governmental bodies, a consulting firm, and a public utility. The list follows.

Federal Agencies

Weather Bureau

Kansas City River Forecast Center

Office of Hydrology, Washington, D. C.

Portland, Oregon River Forecast Center

Corps of Engineers

Kansas City District

Office, Chief of Engineers, Washington, D. C.

North Pacific Division Office, Portland, Oregon

Bureau of Reclamation

Region 2 Office, Sacramento, California

Federal Water Pollution Control Administration

Headquarters, Washington, D. C.

Great Lakes Region, Chicago, Illinois

Bonneville Power Administration, Portland, Oregon

Tennessee Valley Authority, Chattanooga, Tennessee

State Agency

California Department of Water Resources

Local and Special Governmental Agencies

Metropolitan Sanitary District of Greater Chicago

Modesto Irrigation District, California

Turlock Irrigation District, California

City and County of San Francisco, California

Consulting Firm

Watermation, Inc., St. Paul, Minnesota

Public Utility

Pacific Gas & Electric Co., San Francisco, California

Others

Ernest Brater, Hydrologist, University of Michigan

APPENDIX B

Streamflow Forecasting and Forecast Dissemination

Streamflow Forecasting

For illustrative purposes, the methods of streamflow forecasting used by the Tennessee Valley Authority and the Kansas City Weather Bureau River Forecast Center will be described. With minor variations, similar techniques are used by other river forecast centers of the Weather Bureau and by the relatively few additional agencies that routinely prepare streamflow forecasts.

The technique of streamflow forecasting by these agencies is a classic technique that has been adapted to machine computation. An estimate of runoff is made based on precipitation and antecedent conditions. This estimate is combined with a unit hydrograph which translates the volume of runoff into a time distribution of runoff at a point on the stream. These estimates are made for each subarea in the entire basin. The hydrographs of flow at these separate points are combined into hydrographs at forecasting points by a procedure known as flow routing.

The runoff volume estimate is generally made by a correlation process using an index of antecedent precipitation (Linsley, Kohler, and Paulhus, 1959, Fig. 8-6), week of year, and precipitation as predictors of runoff. These variables are normally correlated graphically. The graphical correlations have been converted for computer usages either to a set of tables identical to the graphical relation or to equations that allow direct computation of runoff from the predictors.

The unit hydrograph is simply the hydrograph of runoff that would be produced if an inch of runoff were to occur in a specified duration (six hours in the TVA and generally six hours for the Weather Bureau River Forecast Centers). Linear basin response is assumed. Thus, the hydrograph of 1/2 inch of runoff is obtained by multiplying the ordinates of the unit hydrograph by one-half.

Channel or reservoir storage has the effect of attenuating the time base and lowering the peak of an inflow hydrograph. The process of accounting for these effects is known as streamflow routing. "Given the flow at an upstream point, routing may be used to compute the flow at a downstream point" (Linsley, Kohler, and Paulhus, 1959, p. 216).

A scenario of daily streamflow forecasting has been given for the TVA system (Cooper, 1966). The procedure for the Kansas City Weather Bureau River Forecast Center is similar in its basic elements except for the fact that the computer operations are physically in the building.

Each morning, within the space of one hour, reports of observed rainfall data from about 240 stations are received in the office of the TVA River Control Branch in Knoxville, Tennessee. The rainfall amounts are punched, together with factors based on current hydrologic conditions, on IBM cards from the record sheets and checked from a printed copy. The card image information is transmitted by a remote access device to the TVA Computing Center in Chattanooga, Tennessee to an IBM 360/50 computer. The data is processed by the computer using the rainfall-runoff correlation/unit hydrograph/flow routing process to produce flow estimates at all required points, currently 84 in number, including forty reservoirs. This information is then transmitted back via the remote access system to Knoxville.

The method of streamflow forecasting that will increasingly be used in the future utilizes a digital model of the runoff process. It can use hourly precipitation profitably and easily. Experimental work is being done to transmit precipitation data directly to computer storage for processing. A computer model is currently being used in Portland, Oregon, for flow forecasting in the Columbia River Basin.

Snowmelt forecasting is crude for small areas and short time intervals at the present time. Runoff estimates are made for periods of one to several months in advance. Watershed conditions at the beginning of the snow season, precipitation recorded at index stations, snow-course weights, and temperatures are used in statistical relations for the actual forecast. Such forecasts are used extensively by water managers. Uncertain elements in estimating maximum runoff potential at the present time include areal extent of snow coverage and water equivalent of the snow pack. For short-term predictions, temperature, precipitation, and wind velocities are critical.

Forecast Dissemination

From the Weather Bureau River Forecast Centers, information on impending floods and flood conditions is transmitted to River District offices of the Weather Bureau for distribution and dissemination to local agencies. Generally, each town or country will have its own plans in the event of a flood warning; consequently, responses to flood predictions will be quite varied. Usually, action from the River District Officer will be through the local press, Red Cross, radio and TV, Civil Defense, State Police, Corps of Engineers, local flood committees, Bureau of Reclamation, and Soil Conservation Service.

The Corps of Engineers may assist a local community with last minute flood preparation such as temporary dikes or levees or raising the existing levees in anticipation of the flood crest. The flood warning will give residents time to protect buildings, evacuate low-lying areas and remove personal property from the flood area. The Red Cross will have an opportunity to prepare for refugees and ensuing health hazards which usually accompany flooding.

APPENDIX C

Interview Summaries

In this appendix, the most pertinent points of the major interviews are summarized. Because some of the agencies have similar functions and methods of operations, some repetitious data have not been included. These pertain especially to methods of streamflow forecasting and forecast dissemination, subjects that have been dealt with in Appendix B.

U. S. Weather Bureau

Interviews were conducted in three Weather Bureau Offices, including the Office of Hydrology in Washington, D. C.

The essential elements of streamflow forecasting and information dissemination are as given in Appendix B. The Weather Bureau ultimately plans to have river forecast center operations for all areas of the country except the area covered by the Tennessee Valley Authority which independently forecasts streamflow. As of 1969, forecast service was available for about 3/4 of the coterminous United States.

Flow and water level forecasts are made at more than 2500 points on rivers in these areas. The actual number varies throughout the year because more forecasts are made during flood periods. For example, in the Kansas City River Forecast Center, a minimum forecast would cover twelve points for each of three consecutive days—thirty-six forecasts. The number of forecasts has reached 576 in a single day. The average number is 125-150 per day.

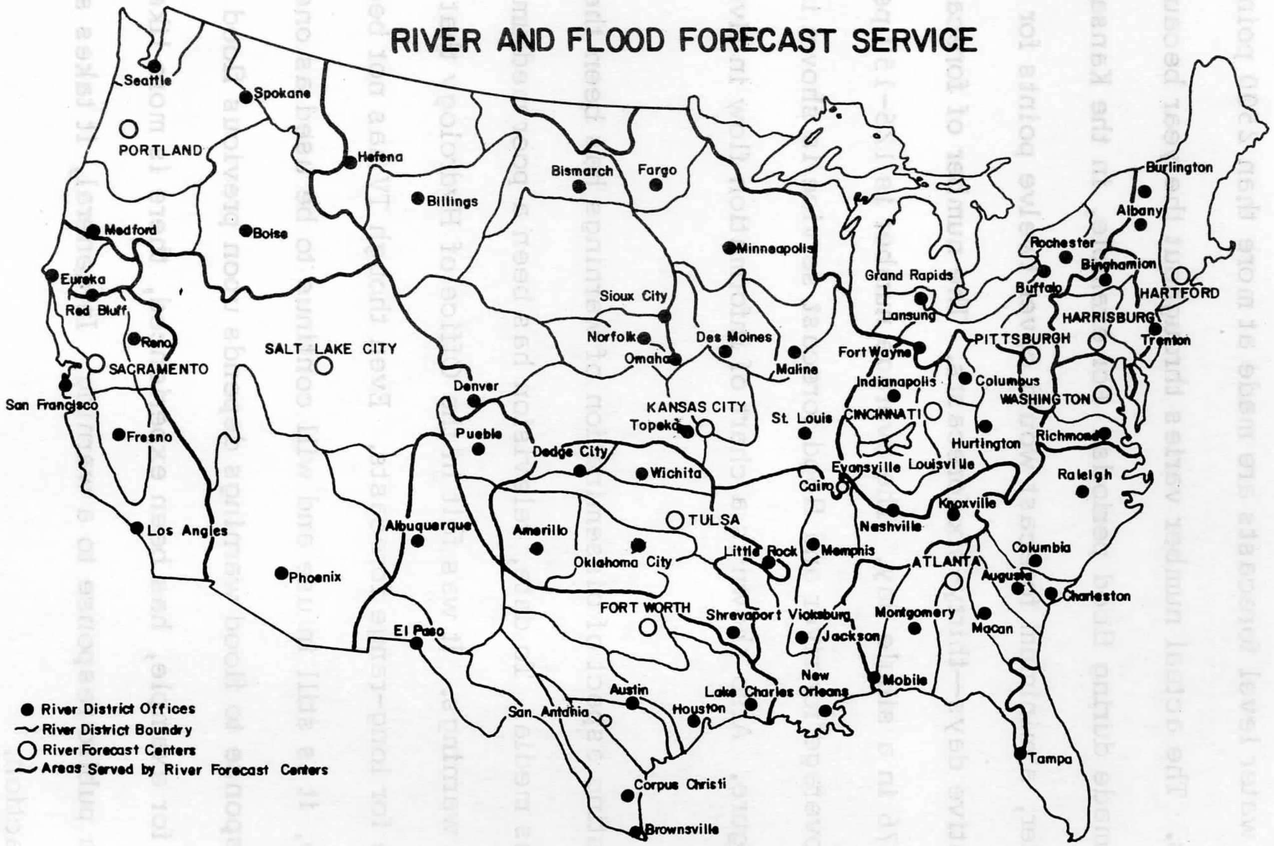
Area of coverage for river and flood forecast service is shown in the accompanying figure. Also shown is a chart of information flow in river forecasting.

An interesting aspect of dissemination of warnings has been the effectiveness of various media. To date, television has been a poor medium for disseminating urgent warnings. It was felt in the Office of Hydrology that TV may be more effective for long-range forecasts. Even though TV has not been particularly effective, it is still in use and will continue to be used as one medium.

Public response to flood warnings depends upon previous flood experience. If a disaster, for example, has been experienced, there is more likelihood that there will be a public response to a warning. In general, it takes something to get public action.

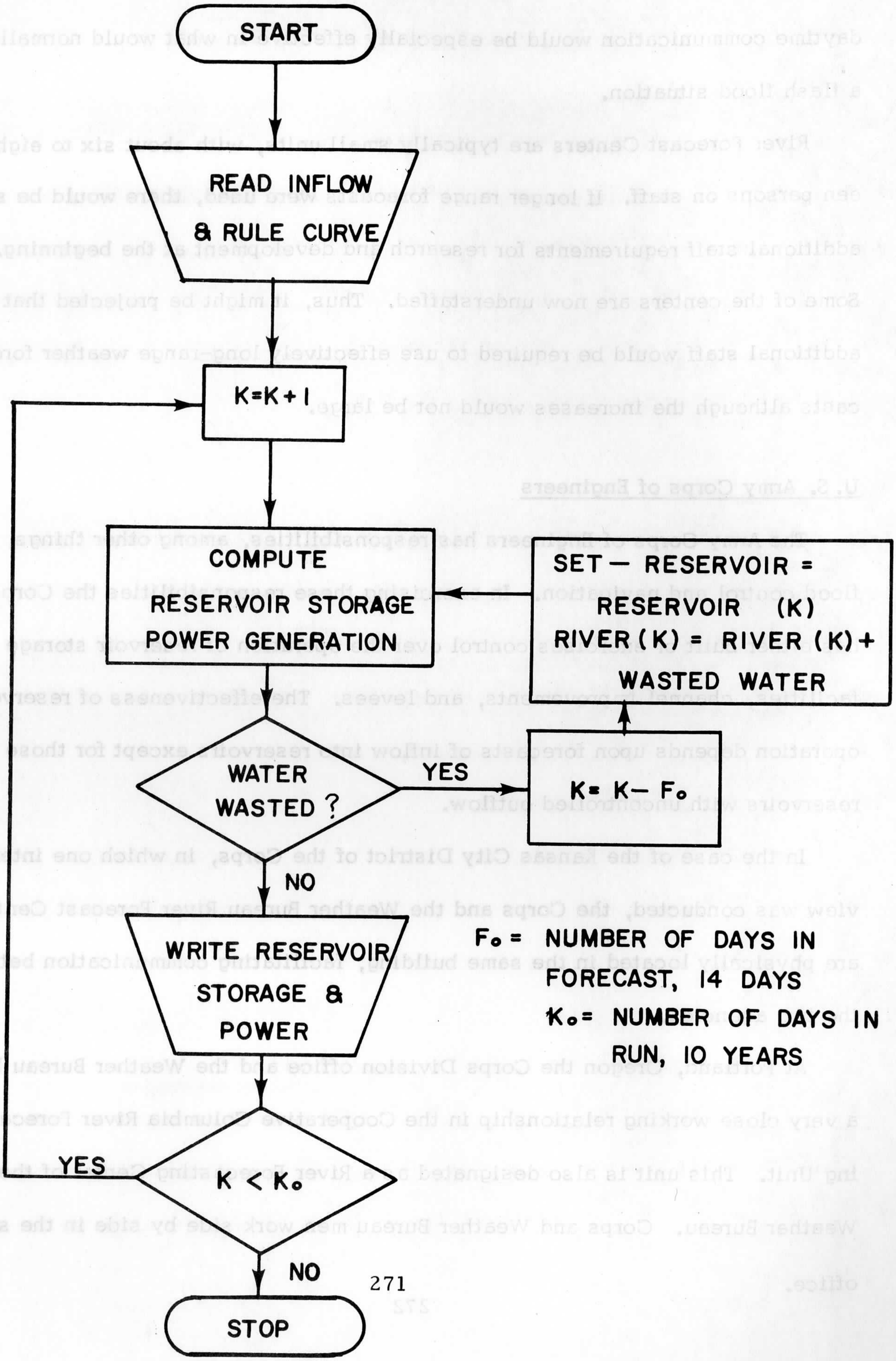
Communication of urgent warnings is especially difficult at night. Forecasts of sufficient accuracy that could be given far enough in advance to allow

RIVER AND FLOOD FORECAST SERVICE



Source: Floods and Flood Warnings, U.S. Department of Commerce
Environmental Sciences Services Administration, 1969

SIMULATION FLOWCHART



daytime communication would be especially effective in what would normally be a flash flood situation.

River Forecast Centers are typically small units, with about six to eighteen persons on staff. If longer range forecasts were used, there would be some additional staff requirements for research and development at the beginning. Some of the centers are now understaffed. Thus, it might be projected that additional staff would be required to use effectively long-range weather forecasts although the increases would not be large.

U. S. Army Corps of Engineers

The Army Corps of Engineers has responsibilities, among other things, for flood control and navigation. In exercising these responsibilities the Corps has either built or exercises control over the operation of reservoir storage facilities, channel improvements, and levees. The effectiveness of reservoir operation depends upon forecasts of inflow into reservoirs except for those reservoirs with uncontrolled outflow.

In the case of the Kansas City District of the Corps, in which one interview was conducted, the Corps and the Weather Bureau River Forecast Center are physically located in the same building, facilitating communication between the two agencies.

At Portland, Oregon the Corps Division office and the Weather Bureau have a very close working relationship in the Cooperative Columbia River Forecasting Unit. This unit is also designated as a River Forecasting Center of the Weather Bureau. Corps and Weather Bureau men work side by side in the same office.

In addition to reservoir operation, the Corps does emergency work on levees during flood periods. These operations gain from long-range forecasts to the extent that men and materials may be more properly dispatched to places of need.

Long-range forecasts have a rather unusual potential relative to the design of reservoirs by the Corps of Engineers. Whereas it is conventional design practice in a multiple-purpose facility to use storage jointly for the various purposes, the Corps of Engineers generally designs on the basis of discrete layers of storage for each purpose. This conservative practice would likely be influenced toward joint use of storage if long-range weather forecasts of tested accuracy were available. The ultimate result would be more effective use of reservoirs and less costly facilities to achieve project purposes.

The Corps district offices are responsible for large geographic areas. As more refinement is needed in operations, these large areas will be subdivided into smaller and smaller units. Watershed models are available that can utilize large quantities of input information and produce forecasts of flow for very small areas. In the Kansas City District, a full analysis of a storm of large areal extent would include data from perhaps 2000 rainfall stations. With present methods, this data from precipitation stations must be punched on cards for computer input. On a large-scale flood in 1967, more than half a day was required simply to punch the cards for input to the computer. For the largest storm of record as much as 8 hours would be required. These time requirements underscore the importance of transmitting weather forecast data in computer compatible format.

On the Missouri River, navigation is normally possible from March 21 to December 1 below Gavins Point. Adequate long-range temperature forecasts could have the effect of extending the navigation season as much as two weeks, one week at each end of the season.

One of the most significant variations between the operations of the various districts of the Corps of Engineers is the difference in hydrology and climate. In the Pacific Northwest, e.g., the critical factor is snowmelt in upstream areas. In the Midwest and North East, both rain and snow are important in upstream and downstream areas. In the South East, snow is of no importance but hurricanes are of great importance.

U.S. Bureau of Reclamation, Sacramento

The Bureau of Reclamation has general organizational responsibilities for the Central Valley Project in California. The reservoirs in this Project are operated for flood control, irrigation, water supply, water quality, navigation, power generation, and recreation purposes. This multiplicity of purposes makes optimum operation a complex task, highly dependent on adequate forecasts of hydrologic and meteorologic parameters.

The Bureau itself prepares forecasts of inflows to its reservoirs, generally at ten-day intervals. This relatively infrequent interval reflects in part the large size of Bureau reservoirs, 240,000 to 4,500,000 acre-feet of storage. To date, digital computers are not used extensively in forecast operations, but development of computer capability is underway now and within a few years the Bureau will be relying on the computer very heavily.

In the Central Valley operations there are economic losses that result from inadequate forecasts. The most clear cut are losses in hydropower generation. The Bureau engages in wheeling arrangements through the Pacific Gas and Electric Company. It buys and sells some power through PG & E. The losses occur through not being able to plan detailed operations far enough in advance to switch power generation from one reservoir to another and from not having a market for potential power at times. In both cases, water is spilled that could have been used for generation of electricity.

The amount of loss in this system resulting from inadequate forecasts cannot be estimated without extensive simulation studies far beyond the scope of the present work. A reasonable assumption is that losses do not exceed a few percent of gross production. In making this assumption, it is implicit that only the forecast is responsible for loss. This is not strictly the case because during flood periods at night there may not be sufficient demand for electricity to equal the supply available from hydro plants. The essential requirement is that the minimum load exceed the total hydro supply for a period long enough to shut down thermal plants. As demand increases with time this condition will be met even though it is not being met now.

Data desired by the Bureau office in Sacramento include rainfall, snow, and temperature distributions, wetness indexes of the watershed, vegetative cover, and data on the recession of the snow peak.

Federal Water Pollution Control Administration

Persons interviewed knew of essentially no extensive use made of weather forecasts in water quality management in the United States other than by the Ohio River Valley Sanitation Commission.

Possible uses of weather forecasts in water quality management are as follows:

1. To enable the use of holding basins in which treatment plant effluent could be held until flows in the receiving channel were high enough to allow maintenance of adequate quality.
2. To enable the use of holding basins to receive excess storm flows until they could be treated in the sewage treatment plant.
3. To help control operation of overflow devices on combined sewers.
4. To enable alteration of treatment methods depending upon expected weather and flow conditions.

In water quality management research, long-range forecasts and even accurate short-range forecasts would allow the dispatching of men to measure flow and quality of water in sewers and channels.

Bonneville Power Administration, Portland, Oregon

The Bonneville Power Administration was established for the purpose of coordinating the marketing of hydroelectrical power generated by federal projects in the Columbia River basin. Its long-range responsibilities include the planning for future demands and how best these demands can be met. The short-range operation, day to day and week to week, comprise the most critical part of the operation.

Initially the B. P. A. makes a forecast of electric power loads on a daily, weekly and monthly basis. Each day a forecast for the next day is prepared; forecasts three days to a week or a month into the future are prepared once or twice a week depending upon the variability of the weather. These load forecasts are usually based on past historic power requirements and temperature. The load forecast is related to these predictors by a multiple regression procedure. For example, if today were Monday, tomorrow's forecast of electrical power load may depend upon the load today, the load last Tuesday, the load of the Tuesday before last, the load at this time last year and the temperature tomorrow. Different empirical relations, including different variables, are developed for each season or time of year. Probably the most significant variable is temperature. The one-day estimate of temperature, received from the U. S. Weather Bureau, is used directly. Forecasts further into the future depend upon past historic mean temperatures. Temperature forecasts are made for the prime load centers of Seattle, Spokane and Portland.

Some kind of flow forecasts are received from the Weather Bureau for all of the year. From April to July, daily forecasts are made. Because the B. P. A. is mainly concerned with only twenty-seven power generating dams, seventeen of which are federal, it has developed an empirical rainfall-runoff model that can be operated manually. Basically this includes variables to evaluate the soil moisture (the wetter the soil the more runoff), rainfall duration, rainfall amounts, and temperature when snow must be considered. It is necessary for the B. P. A. to have this rough model because the Corps of Engineers and Weather Bureau do not always issue detailed forecasts the year around. Inflows from the rainfall-runoff model and estimates of daily electrical demand are then entered into a power generating schedule computer program that produces a best operating schedule for the seventeen federal reservoirs, which are basically on the same river and highly interdependent. Most of these power dams have little storage so that a downstream dam would have to release water in proportion to releases from upstream dams to avoid spilling. There are also many private power dams that often optimize their own needs to the detriment of the entire system. Thus, an optimal release schedule is extremely difficult to obtain.

Communication is a key part of B. P. A. 's operation. Not only must information on reservoir operation be transmitted to operators, but in order to make maximum utilization of the facilities and water, power is bought and sold within the intertie system, through a complex set of arrangements. This operation requires considerable communication with other utilities in other regions. Much of this is done by telephone. Several modes of communication are in regular use, including teletype, telephone microwave transmission, radio, and personal carriers.

Tennessee Valley Authority

The Tennessee Valley Authority (TVA) has constructed and operates dams and reservoirs on the Tennessee River and its tributaries for improved navigation on the Tennessee River and for flood control and power generation. It also has secondary responsibilities for related resource development (Cooper, 1969).

There are now twenty-nine TVA hydro plants. It also directs power operations for six privately owned plants and seven multiple-purpose projects of the U. S. Army Corps of Engineers on the Cumberland River. Early in 1969, the total hydro and thermal installed capacity of this complex was about 18 million kilowatts, the nation's largest power system (Cooper, 1969).

The combined drainage area of the Tennessee River-Cumberland River Basins is almost 59, 000 square miles.

Flow Forecasting

The Tennessee Valley Authority uses a daily reporting network for the Tennessee and Cumberland Rivers of about 240 stations. This includes gauges at substations and power houses, special observers, U. S. Weather Bureau gauges, and talametered gauges. There are about 650 rain gauges in all for the Cumberland and Tennessee Rivers. From the daily reporting network, observations are obtained at either six-hour or two-hour intervals. The rest of the gauges are read once daily or upon request.

The basic stream flow forecasting procedure utilizes a coaxial precipitation-runoff relationship. It is programmed and run on an IBM 360/50 computer at Chattanooga. Point rainfall estimates are converted to point runoff estimates and the runoff is weighted.

The Water Control Planning group in Knoxville receives the rainfall data from the daily reporting network. The data is punched on cards and, via an analex system, transmitted from Knoxville to Chattanooga at 9:00 each morning where all flow estimates are computed and transmitted back to Knoxville. Forecasts are prepared normally for the next five days. In some cases up to a ten-day forecast is prepared. The entire process of receiving rainfall data and punching it on cards takes about one-half hour from 8:00 to 8:30 each morning. The job of punching data on cards requires about fifteen minutes.

There are some problems with Weather Bureau gauges that are read only at World Meteorological Organization time. This causes some discrepancy when there is a difference between WMO time and local time. Data from the Cumberland River Basin comes in about an hour later than the remainder of the reporting network because it comes through the U. S. Weather Bureau.

Data comes by many modes. Some is communicated orally by telephone or radio. Some is transmitted by facsimile. Some comes via teletype.

The smallest area for which flow forecasts are prepared is about forty square miles. The largest is about 3000-4000 square miles. The general size ranges between 300 and 1000 square miles. Flow forecasts are prepared for each of eighty-four separate points, including forty reservoirs. Flow forecasts are disseminated six days a week to the public. About six or seven copies are used within TVA.

At times, in the past, private firms have been engaged to prepare special forecasts either of temperature or precipitation. There is currently no regular special forecast prepared by private firms.

The TVA pays about $65,000 per year to the Weather Bureau for maintaining "qualified quantitative precipitation forecast meteorologists." A QPF is issued each day before 8:00 A. M. If anything special is seen by the U. S. Weather Bureau meteorologists on their precipitation maps, radar, etc., they are expected to contact TVA.

At about 11:00 A.M., cyclic or diurnal temperature projections are received for four separate stations. Revisions are made in these forecasts at 4:00 P.M. During floods and cold seasons, October 15 - April 15, additional forecasts are issued at 10:30 P.M., especially for temperature. This is used in load projections.

A full staff is on hand eight hours a day, Monday to Friday, four hours Saturday and four on Sunday. In addition, flow forecasters are on alert. During the flood season a staff is on duty until 9:00 P.M. every day. In all cases, there are persons on duty at the power station and at the load dispatching centers in Chattanooga.

Forecast Dissemination

Within TVA the Daily River Bulletin is disseminated to anyone who wants it. It is also sent free by mail to members of the general public who request this Daily River Bulletin. About 2,000 copies of the Daily River Bulletin are disseminated. Half of these are printed in Knoxville and half in Chattanooga. They are then sent through the regular mail. The Power Systems Operation Group gets a five-day forecast.

TVA teletypes forecasts to the Weather Bureau which in turn disseminates forecasts to the Associated Press, UPI, or individual newspapers. TVA contacts the Corps of Engineers, in Nashville, directly. During the flood season TVA disseminates data to the Ohio River Division of the Corps, to industries, and to the city of Chattanooga. Recently a recorded message has been used that industries desiring this information can dial by telephone.

In general, TVA is satisfied with their method of communications. Within TVA, in the Water Control Planning and Power Divisions, between one and two dozen people directly use weather forecasts and flow forecasts.

Data Needs

The data needs of TVA are primarily accurate forecasts of temperature and quantitative precipitation. In addition, it would be desirable to have information on soil moisture, radiation, humidity, ground cover (vegetation), and snow cover.

To utilize longer-range forecasts, no significant changes in either budget or personnel would be required. However, in reservoir operations, more staff and budget would be required.

Probably two to five years of accurate forecasts would be required to establish their credibility. It does depend to some degree on the number of verifications that have been achieved.

Power

TVA continuously loses energy because of poor forecasts. This applies to both the quantitative precipitation forecasts and temperatures. If the temperature fluctuates as much as 2°F., this effect is noticed. At the present time plus or minus 1°F. amounts to about 120 megawatts of capacity. It takes four to eight hours to put a thermal unit on line.

The largest loads are in the winter with electric heating. Summer air conditioning and sale are increasing to the point where the summer peaks are almost as high as the winter peaks. In winter the effect of temperature changes is felt in the power system within six to eight hours. In the summer the effect of heat or humidity is noticed within a couple days.

The amount of dollar loss depends on the use condition, and may run from $10,000 to $100,000 per day. If customers with TVA contracts are cut off, some loss occurs. Industrial users are the first to be cut off.

The total revenue loss, considering all factors in weather forecasts, probably ranges between a fraction of 1% and a few percent of the gross revenue (about $300,000,000 per year).

Maintenance

Maintenance of equipment could be improved materially with a two-week forecast or even a one-week forecast. It would reduce the amount of overtime, the number of men required to maintain the equipment, and damage to equipment. A sixty-man crew may be sent to work on a piece of equipment. If this crew must be idle for as much as a week until a decision is made to take a unit out of operation, there are no alternative uses for the labor of these men. The maintenance problems lead not only to large costs but also to seasonal hiring and seasonal unemployment. Spring and fall are the prime maintenance seasons and men move from place to place, coming from all over the country to work in the Tennessee Valley. Two weeks to one month is generally required for the maintenance of a unit and each unit is worked on once a year.

Flood Damage Reduction

Flood operations could almost always be improved and storage space used more effectively if better forecasts were available. There would, however, be little improvement in flood damage reduction for the bigger cities. More than one day's warning can now be given to the city of Chattanooga.

The most inaccurate weather forecasts are in the period from October to December. The quantitative precipitation forecasts are the most inaccurate and tend to be low.

California Department of Water Resources

The California Department of Water Resources is responsible for long-range planning, data collection, and operation of the California Water Project. The Water Project collects water in northern California, especially in Oroville Reservoir, and transports this water to areas in central and southern California for a variety of uses by means of pumping stations, aqueducts, and tunnels.

The Department cooperates in the California Cooperative Snow Survey for spring and summer runoff, working closely with the Weather Bureau. During the flood season, it also is involved in the preparation of hourly flood forecasts. The Department has a data collection network supplementing the basic network of the Weather Bureau.

The publication "Water Conditions in California" is issued by the Department. It gives monthly runoff for the snowmelt runoff season, February to May. Special forecasts are given on request. Regular forecasts are made of inflow to Oroville Reservoir on a weekly basis and daily flows are forecast for the Sacramento River at Sacramento.

The move toward computer compatible data collection is well underway with the Department. Almost seventy-five stations can be interrogated from a central point and readings taken very rapidly. About a third of them are interrogated by computer and the rest could be so adapted. Punched paper tape is used as the input medium.

All forecast procedures are in the form of computer programs. During flood periods, forecasts are made in real time.

The most important data needs of the Department that could be expected from long-range weather forecasts are wind, temperature, and quantitative precipitation.

Metropolitan Sanitary District of Greater Chicago (MSD)

MSD is responsible, among other things, for controlling the flow of water from Lake Michigan into the Illinois River system and for controlling the flow in the Chicago area channels by manipulation of Lockport Dam, three Lake Michigan inlets, and sewer overflow devices. The latter function is to prevent flooding in the Chicago area and to enhance water quality as much as possible by flow manipulation.

MSD employs a private meteorology consulting firm, Murray and Trettel, Inc., Northfield, Illinois to help give advance warning of incoming precipitation. This warning, generally given six hours in advance, includes the type of precipitation expected, the time of beginning of precipitation, and a narrative summary in a remarks column. This firm has nine to ten meteorologists on duty around the clock.

Under present conditions in the Chicago area, MSD needs a twelve-hour notification of timing and quantity of precipitation expected, an accurate areal definition of precipitation coverage, and a very accurate four-to-six-hour QPF (quantitative precipitation forecast).

MSD is not now using a computer for forecasting and operating purposes but is considering purchase of a small, process-type computer that would utilize a simple model of the channel system in day-to-day operations.

During a storm situation, the channel system is drawn down to provide storage by closing the intakes from Lake Michigan and opening gates at Lockport, Illinois.

Sewer controls are exerted at the treatment plants. Flow into the interceptor system can be shut off; the flow is diverted into local sewers by remotely operated gates. The guide to operation of these gates is the amount of flow into the treatment plants.

There are twelve remote-recording rain, and fourteen water level gauges. An eleven-station quality network went into operation in summer 1969. As there is no data base, little is being done with this data operationally. When water quality operation is a part of the daily policy, three to four days advance warning on weather conditions will be desirable.

Flooding in a metropolitan area like Chicago is a small area problem. In such situations, time is of the essence in forecasting. Highly detailed forecasts are also essential.

One special situation in urban areas could eventually profit from long-range forecasts. The presence of leaves and debris inhibits flow of water from the land surface into the sewer systems. If there were advance notice and the city were equipped to engage in a concentrated leaf-removal campaign, some flood damage could be averted. Chicago does not now have a leaf-cleaning program, although some of the suburbs do.

Data Requirements

An accurate QPF with delineation of areal boundaries is the most essential data requirement. Temperature and soil moisture forecasts would also be available. All data should be completely computer compatible.

The MSD office is staffed twenty-four hours a day with at least one person per shift. In critical periods, more men are on duty. The office has or would be willing to obtain any communication equipment needed to receive forecasts.

Modesto and Turlock Irrigation Districts and City and County of San Francisco

The Modesto and Turlock Irrigation Districts jointly operate a single irrigation storage reservoir. Some of the operations are conducted with the City and County of San Francisco, who maintain three smaller domestic water supply reservoirs in the upstream area and make snow observations in the watershed.

The general operating policy is one of maintaining a full reservoir as much of the time as possible in order to supply agricultural demands for irrigation water. Power is generated as a secondary purpose. Regulations for flood control operation are issued by the Corps of Engineers. The Irrigation Districts conform closely to these flood control regulations.

In the Modesto Irrigation District, water is supplied at no charge to members of the District. The Turlock Irrigation District has a nominal charge for water based on assessed valuation of land. Power is sold to the Districts at quite low rates. These rates have, however, been sufficient to pay off all costs of facilities.

Water supply forecasts are made by the California Department of Water Resources. Seasonal forecasts (by month) are issued. The Districts generally consider these forecasts adequate given their present operating policies. Only during the early part of the runoff season, November, December, and January is there considered to be any significant problem with forecasts. In these periods, runoff from rain would take place. During the remainder of the season, runoff is primarily from snowmelt. The monthly forecasts are relatively more useful for the snowmelt situation than for tain.

If the reservoir owned by the Districts were to be operated for maximum economic efficiency, short-term (less than a month) forecasts would become more useful. More power could be generated and less water spilled.

To test the effect of change in policy and of forecasts of flow, a simulation model was developed. In this model, a simplified treatment of the existing reservoir with a simple set of operating policies was assumed. The existing reservoir normally spilled about 20% of the inflow; that is, the water was not used for irrigation or power generation. A ten-year historic record of inflows was used to evaluate the benefits of a fourteen-day forecast.

The simulation program projected fourteen days (for each day of operation) and checked for spills. If a spill were indicated, its volume or a fraction thereof would be run through the turbines to generate power fourteen days before the indicated spill would occur. Thus, more storage capacity would be available in the reservoir at the time of expected large inflows and less water would be spilled.

Over this particular ten-year period, the use of a fourteen-day forecast in this manner increased the total power generation by 2%.

Definite conclusions as to the total saving in water loss and accompanying increased power generation cannot be reached from such a simple simulation. It is not even an accurate representation of the situation for the simple reservoir. However, it is clear that savings could be made. The amount depends not only upon system characteristics but also upon the degree of organizational coordination and cooperation among the various power producers and marketers.

Pacific Gas and Electric Company

The Pacific Gas and Electric Company, based in San Francisco, California, is a privately owned utility that distributes natural gas and electricity directly to homes and industries in central and northern California. A portion of the power distributed is generated by PG & E at its own thermal and hydro electric power plants. It also distributes some power generated by federal agencies in the Central Valley of California and purchases power from other producers for distribution. About one-fourth of the PG & E generating capacity is hydro.

The water supply for the hydro generation is mostly snowmelt runoff. Forecasts of snowmelt runoff may be assumed to have an accuracy of 15% to 20%. A statistical correlation technique is used. Forecasts are made for about twenty-five subbasins varying in size from about thirty to about 3000 square miles. Reservoirs in the system vary in size from about 400 acre-feet up to about 1,000,000 acre-feet.

An unusual feature of the PG & E operation is that some attempts at weather modification are made in the months November to April. Consideration is being given to weather modification in the summer months but no such attempts have yet been made or planned.

There is little water spill from the hydro reservoirs. Forecasts and operating capabilities are adequate to minimize water wastage. In that water has more or less value depending upon the time and conditions of release, some economic loss is sustained by inaccurate forecasts, both of water supply and of demand.

Demand forecasting is especially important to PG & E because they supply both natural gas and electricity. Demand forecasts are made for the spectrum of time horizons from twenty-four hours to seven years in the future. Of special value in improving demand forecasts would be accurate forecasts of temperature and solar radiation.

At the present time, PG & E uses a substantial amount of manual computation. Load estimates, for example, are calculated manually. However, a greatly expanded use of computers for all phases of the operation is planned. In general, the use of changed methods and equipment is a function of the relative profitability of the proposed change. Any innovation that could be shown to be profitable would likely be adopted. This would apply to communications methods, computational techniques, etc.

The PG & E staff expressed the opinion that with greatly expanded weather forecasts, more staff would be required.

APPENDIX D

References

1. Anderson, James J., Watermation, Inc., St. Paul, Minnesota, personal communication, January 5, 1970.

2. Cooper, Alfred J., "The Role of Weather Forecasts in TVA Reservoir Operations," paper presented at the February 3-7, 1969 ASCE National Meeting on Water Resources Engineering at New Orleans, Louisiana.

3. Cooper, Alfred J., "Short-Term Streamflow Forecasting for Hydro Plant Operations," River Control Branch, TVA, Knoxville, Tennessee, 1966.

4. Linsley, Ray K.; Kohler, Max A.; and Paulhus, Joseph L. H. Hydrology for Engineers. McGraw-Hill Book Co., Inc., 1958.

THE IMPACT OF ACCURATE ONE-WEEK WEATHER FORECASTS,

PROVIDED BY SATELLITE, ON THE DEMAND FOR OUTDOOR RECREATION

Paul A. Nelson*

Abstract

Advances in satellite meteorology may soon make possible very accurate long-range weather forecasts. This paper predicts the impact of accurate one-week weather forecasts on the demand for twenty-one forms of outdoor recreation and examines the socioeconomic characteristics of those individuals expected to benefit most.

A mail survey of households is conducted to obtain current data. Information about household recreational planning horizons, vacation selection patterns, and major recreational possessions is used to determine the freedom which a household has to react to accurate one-week forecasts. Indications of probable increased participation are obtained from responses to three questions about how respondents would react in specific hypothetical situations. Qualitative aspects

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*Social Systems Research Institute, University of Wisconsin. The author is indebted to Professor Kenneth R. Smith for the help and advice he has provided during this research. Helpful comments were provided during early stages of this research by Elizabeth L. David, James P. Gilligan, Harry P. Sharp, and Stephen C. Smith of the University of Wisconsin. The author wishes to thank N. H. Hoveland and Ross Offord of the Wisconsin Department of Natural Resources for assistance in selecting the sample of Wisconsin residents used in this study, and Carol D. Norling of the University of Minnesota for assistance in coding and keypunching data.

of recreation and weather are explored to determine the sensitivity of participation to weather. The possibility of crowding and congestion of recreational facilities during periods of ideal recreational weather is examined. A model is developed which uses the above information to predict changes in recreational participation.

It is found that average national participation in outdoor recreation will increase by approximately 5%; crowding and congestion will occur at ski areas during periods of ideal skiing weather; and income, age, and education will not be barriers to benefiting from accurate one-week forecasts among those people who currently engage in outdoor recreation.

I. Introduction

Advances in satellite meteorology may soon make possible very accurate long-range weather forecasts. The purpose of this study is to predict the impact of accurate one-week weather forecasts on the demand for outdoor recreation in the United States. Three kinds of information are desired. The first kind of information is the expected changes in annual adult participation in twenty specific forms of outdoor recreation which are typically engaged in away from home. The second kind of information is an assessment of the qualitative impact of accurate one-week weather forecasts on recreational experiences. The third kind of information is the socioeconomic characteristics of those individuals who are expected to benefit most from accurate one-week forecasts.

Past studies of adult participation in outdoor recreation are examined to select an area of the United States in which recreational participation patterns closely resemble those of the entire nation. A mail survey of a sample of households in this area is conducted to obtain information on recreational participation during the last year, socioeconomic characteristics, dependence of recreational activity on weather, and the decision process involved in planning outdoor recreation activities. The particular behavior of the sample is related to the nation as a whole through statistical comparisons with an older national survey.

Information about household recreational planning horizons, vacation selection patterns, and major recreational possessions is used to determine the freedom which a household has to react to accurate one-week weather forecasts. Indications of probable increased participation are obtained from responses to three questions about how respondents would react in specific hypothetical situations. Qualitative aspects of recreation and weather are explored to determine the sensitivity of recreation participation to weather. The possibility of crowding and congestion of recreational facilities during periods of ideal recreational weather is examined as an effect of better weather information. A model is developed which uses the above information to predict changes in recreational participation. The predictions for the sample are then adjusted to yield national predictions. The socioeconomic characteristics of those respondents who would benefit most from better weather information are examined. Concluding remarks are then made on the impact of accurate one-week forecasts on the demand for outdoor recreation.

II. Survey Procedure and Description

Survey Strategy

This study seeks to predict changes in national recreational behavior brought about by accurate one-week weather forecasts. To achieve this objective, a survey strategy was chosen which took advantage of information already available from previous studies. The strategy involves focusing intensively on those categories of households in a representative area of the nation which are expected to provide the largest contribution to whatever changes occur. To the extent that this is possible, a small sample can generate a great deal of predictive power. Because of the large amount of information desired from each household, a mail survey approach was chosen.

A previous study has demonstrated that national recreational behavior is replicated to a remarkable degree in the State of Wisconsin.[1] For this reason, the survey focused exclusively on Wisconsin residents. Although the survey obtained data from all members of the responding households, only that pertaining to the head of each household was used. To a large extent, the recreational behavior of a wife parallels that of her husband. Inclusion of both husband and wife in the sample would consequently bias the results, particularly the results of those tests which relate recreational participation to the socioeconomic characteristics of the husband alone. Children, particularly those under twelve, tend to reflect their parents recreational behavior as defined in this study. Consequently, they were not included.

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[1] Elizabeth David, Outdoor Recreation in Wisconsin (Preliminary Draft), p. 1.

The survey was intentionally biased in favor of households which actually participate in outdoor recreation. This reflects an assumption that only households which currently engage in outdoor recreation away from home can be expected to contribute significantly to whatever changes in recreational behavior result from better weather information. The survey focused on middle and upper income households in non-rural areas because past studies[2] have indicated that households with annual incomes below $5, 000 and households engaged in agriculture participate relatively infrequently in outdoor recreation as defined in this study. The result is that only 4.7% of the adults included in this survey did not participate in any form of outdoor recreation during the past year whereas past studies[3] of Wisconsin and of the United States indicate that 10% of all adults did not participate.

Sample Description

The survey strategy described above requires a sample composed of middle and upper income households in non-rural areas of Wisconsin which are likely to have participated in at least one form of outdoor recreation during the past year. The primary sample used in this study consisted of 669 households in the Milwaukee area of Wisconsin. Milwaukee was chosen because it was the largest city in the state, and because its diversity of industrial and service employment supported a wide variety of households. Milwaukee households

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[2] Outdoor Recreation Resources Review Commission, "Participation in Outdoor Recreation: Factors Affecting Demand Among American Adults," ORRRC Study Report 20, Washington, D.C., 1962, p. 10; David, op. cit., p. 5.

[3] ORRRC, op. cit., p. 4; David, op. cit., p. 17.

were selected from the mailing list of the Wisconsin Conservation Bulletin, a Wisconsin Department of Natural Resources periodical sent to approximately 212,000 Wisconsin households. This mailing list was chosen because the periodical's readers tend to be interested in outdoor recreation, but not necessarily avid enthusiasts of any one particular form of recreation. Mailing lists from periodicals which cater to avid enthusiasts of particular forms of recreation were avoided because avid enthusiasts tend to be less dependent on weather than more casual participants.

To supplement the primary sample, two smaller samples were chosen from other areas of Wisconsin. Sixty-eight households were included from smaller Wisconsin communities. These names were chosen from the season membership lists of three Wisconsin ski areas. The principal function of this sample was to permit a comparison of the reaction of users to the reactions of the ski managers. This aspect of the study is described in Section VI. Another small sample of households from Madison was included. These names were chosen at random from telephone listings. Names were cross-checked with directories of personnel associated with the University of Wisconsin at Madison. Names were eliminated if an association was found. This was done because the primary purpose of the Madison sample was to test the effectiveness of the questionnaire before it was printed in final form for use on the other samples.

Response Rate

Mail questionnaires are notorious for their poor response rates. Every effort was made to conduct the survey in such a way as to achieve a reasonably good response rate. The questionnaire was carefully designed over a three-month period. It was tested on a sample of thirty Madison households not connected in any way with the University of Wisconsin. The test response rate was 56.7%, quite good for a mail survey of the general public which does not involve straightforward opinion questions. A copy of the questionnaire is provided in the appendix. The questionnaires were printed on high quality bond in booklet form with large type and easy-to-follow directions. The questionnaires were mailed with a short cover letter and a business reply mail envelope. The addressee envelopes were stamped by hand to make the survey appear as personal as possible.

At the time when statistical tests were initiated for this study, 719 responses had arrived representing a response rate of 33.7%. At the time this section was prepared, 754 responses had arrived representing a response rate of 35.6%. These thirty-five additional responses were not included in the tests reported in this study, but they were checked for compatibility with those already included. It is anticipated that approximately 100 more responses will eventually be received raising the response rate to 49%. Unfortunately, these late responses cannot be utilized in this study because of time constraints.

Table 1 provides more detailed information on the response rate. The highest rate, remarkably, was on the test survey of Madison. In the Milwaukee area, the sample is divided into eight areas. The first three areas represent the city's central business district. Questionnaires were mailed to these individuals at their business addresses. These individuals tended to be lawyers and businessmen earning over $10,000 per year. Area 4, where the lowest

Table 1

Sample Composition and Response Rate

Area	Responses	Rate
Milwaukee 1	18	50.0%
Milwaukee 2	68	41.7%
Milwaukee 3	13	48.1%
Milwaukee 4	77	24.8%
Milwaukee 5	19	41.3%
Milwaukee 6	44	28.6%
Milwaukee 7	300	38.0%
Milwaukee 8	130	32.2%
Ski Areas	68	42.5%
Madison	17	56.7%

response rate was achieved, is a predominantly white, lower middle-class factory-worker district. Areas 5 and 6 are predominantly black, lower middle-class factory and service worker districts. Areas 7 and 8 are predominantly white middle-class districts on the south and north sides of Milwaukee, respectively.

A telephone follow-up survey of nonrespondents from the Milwaukee sample was conducted to determine the reasons for nonresponse. No systematic relationship between nonresponse and recreational participation was identified.

Measures of Recreational Participation

This study follows the convention established by the Outdoor Recreation Resources Review Commission of classifying participation in a recreational activity as frequent (5 or more times a year), seldom (1 to 4 times a year), and never. This classification is based on the assumption that exactly how many times a person engages in an activity is less important than whether or not he does so with reasonable frequency. A person who never participates in a particular activity is given a score of zero for that activity; a person who seldom participates is given a score of one; and a person who frequently participates is given a score of two. Composite activity scores are computed for each person. by summing the scores he receives for each of the activities under consideration. In this study, twenty specific activities plus one dummy activity for non-specified forms of recreation are examined, so the composite activity score for any individual could range from zero to forty-two.

Recreational Participation of the Sample

Recreational information is provided in Table 2. Column (1) shows how many of the 719 respondents engaged in each activity at least once during the past year. By far the most popular type of recreation is fishing. Over half of the sample engages in hunting, swimming, picknicking, and pleasure driving. On the other hand, less than 10% of the sample engages in sport flying, horseback riding, and sailing. Column (2) shows the average number of times each of the 719 respondents engaged in each activity. By this measure, pleasure driving, playing outdoor games and sports (golf and tennis, mainly), and fishing are the most popular. Column (3) shows the average (arithmetic mean) activity scores for each activity. This measure provides a somewhat more useful view of the relative popularity of each activity. This average can range from zero to two. Values close to two indicate that almost all respondents are frequent participators in that activity. This measure is less sensitive to extremely high rates of participation by just a few respondents. Columns (4) and (5) provide information about those respondents who frequently participate in a given activity. Average activity scores for these people are exactly equal to two by definition.

Table 2

Recreational Participation of Respondents

Activity	Number who do at least once (1)	Average times done (2)	Average activity score (3)	Those with scores of 2: Number (4)	Those with scores of 2: Average times done (5)
Hunting	374	5.3	0.839	229	15.2
Fishing	551	13.1	1.334	408	22.2
Camping	217	1.5	0.402	72	10.6
Hiking	269	3.7	0.573	143	16.3
Sledding	97	0.5	0.163	20	8.1
Tobogganing	75	0.3	0.117	9	7.2
Snow skiing	84	1.6	0.203	62	17.9
Snowmobiling	141	1.3	0.245	35	21.9
Ice skating	95	0.5	0.170	27	7.6
Swimming	397	8.8	0.929	271	22.3
Canoeing	121	1.1	0.234	47	14.1
Sailing	60	0.9	0.135	37	16.6
Motorboating	318	6.9	0.741	215	21.8
Water skiing	83	1.2	0.168	38	19.6
Picnicking	412	4.2	0.907	240	10.8
Horseback riding	55	0.2	0.088	8	11.9
Pleasure driving	423	15.8	1.111	376	29.9
Sport flying	31	0.5	0.060	13	28.6
Bicycling	139	2.8	0.309	83	22.5
Playing outdoor games and sports	326	13.2	0.832	272	34.4
Other	44	2.1	0.114	38	40.2

Socioeconomic Characteristics of Sample

Table 3 provides descriptive information about the socioeconomic characteristics of the sample.

Comparison of Sample with National Survey

The Survey Research Center of the University of Michigan conducted two surveys of representative cross-sections of American adults in 1959 and 1960 for the Outdoor Recreation Resources Review Commission. ORRRC Study Report 20, published in 1962, uses data from these surveys to analyze factors affecting demand for outdoor recreation among American adults. The ORRRC study focuses on participation in outdoor swimming, boating, fishing, hunting, skiing, and other winter sports, hiking, driving for sightseeing and relaxation, nature or bird walks, picnics, camping, and horseback riding. It relates recreational participation to several socioeconomic variables. By comparing the socioeconomic characteristics and recreational participation of this study sample to the ORRRC study sample, the applicability of results supported by the study sample to the nation can be evaluated.

The 2,750 households included in the ORRRC sample and the 719 households included in this study's sample are categorized according to family income, education of family head, paid vacation of family head, age of family head, and life cycle. Chi-square tests are applied to the numbers of people in a two-way table of sample versus category for each of the five comparisons to determine if the two samples are significantly different from each other. Since the ORRRC study data is over ten years old, it is expected that ORRRC

Table 3

Sample Socioeconomic Characteristics

Characteristic	Number
Marital Status of Household Head	
Single	57
Married	613
Separated, divorced, widowed	47
Sex of Household Head	
Male	688
Female	30
Household Housing	
Farm	6
House	588
Mobile home	2
Apartment	113
Hours per Week Worked by Household Head	
Retired	85
20 or less	9
21 to 34	13
35 to 44	406
45 to 60	171
Over 60	30
Household Income	
Under $5,000	55
$5,000 to $7,999	77
$8,000 to $10,000	157
$10,000 to $15,000	263
Over $15,000	143
Education of Household Head	
Less than 9 years	53
9 to 11 years	126
High school diploma	191
Some college	181
College degree	163

continued

Table 3 (Continued)

Characteristic	Number
Paid Vacation of Household Head	
None	173
1 week	16
2 weeks	124
3 weeks	123
4 weeks or more	259
Age of Household Head	
18 to 24	18
25 to 34	107
35 to 44	161
45 to 54	185
55 to 64	163
65 or over	81
Life Cycle of Household	
Single adult	57
Married adult, No children under 18	327
Married adult, Children under 6	107
Married adult, Children 6 to 18	228

sample income, education, and weeks of paid vacation will be substantially below that of the 1970 data used in this study. During the decade of 1960's, average family nominal income, education, and weeks of paid vacation rose substantially. On the other hand, there is no reason to expect any significant change in the age of family heads or in family life cycles. Table 4 provides the information resulting from the tests. The samples are found to be significantly different from each other on the basis of family income, education, and paid vacation. For age and life cycle, however, the chi-square statistics are so

Table 4

Comparison of Socioeconomic Characteristics
(Percent of Samples)

Factor	Study	ORRRC	Chi-Square Test*
Family Income			
Under $5,000	7.91	53.4	χ^2 = 33.352
$5,000 to $7,999	11.08	28.4	DF = 3
$8,000 to $9,999	22.59	9.5	Significant at .001
$10,000 or over	58.42	9.1	
Education of Family Head			
Less than 9 years	7.42	33.90	χ^2 = 27.498
9 to 11 years	17.65	20.07	DF = 4
High school diploma	26.75	24.08	Significant at .001
Some college	25.35	10.40	
College degree	22.83	11.18	
Paid Vacation of Head			
None	24.06	50.14	χ^2 = 36.539
1 week	2.23	8.67	DF = 4
2 weeks	17.25	23.91	Significant at .001
3 weeks	17.11	11.20	
4 weeks or more	36.02	6.08	
Age of Head of Family			
18 to 24	2.54	5.13	χ^2 = 4.600
25 to 34	14.97	20.47	DF = 5
35 to 44	22.52	22.51	Not significant at .01
45 to 54	25.87	19.27	
55 to 64	22.80	16.44	
65 or over	11.33	16.18	
Life Cycle			
Single adult	7.93	19.18	χ^2 = 11.248
Married, no children	45.48	30.10	DF = 3
Married, children 5 or less	14.88	25.38	Not significant at .01
Married, children between 6 and 18	31.71	25.34	

*Chi-square tests were performed on numbers of respondents in two-way tables. Percentages are provided only for visual comparisons.

small that we must reject the hypothesis that the two samples are different in terms of age and life cycle.

Table 5 provides the information resulting from a comparison of the two samples in terms of recreational participation. Since the ORRRC study considers fewer activities than this study, it was necessary to redefine certain activities. For this comparison, boating represents canoeing, sailing, motorboating, and water skiing. Winter sports include sledding, tobogganning, snow skiing, snowmobiling, and ice skating.

A previous study of outdoor recreation in Wisconsin[5] indicates that Wisconsin adults tend to participate more frequently in boating and winter sports than adults do nationally. For this reason, we would expect significant chi-square statistics for boating and winter sports. We would expect the two samples to be alike for all other forms of recreation. Table 5 reveals that the two samples are alike for all forms of recreation except pleasure driving, fishing, boating, and winter sports. The significant differences for boating and winter sports were expected. The difference for pleasure driving could have resulted from a difference in definitions. The ORRRC questionnaire used the label "driving for sightseeing and relaxation." This survey's questionnaire simply used the label "pleasure driving." The fact that Wisconsin residents are shown to fish more than the national average was not determined in previous studies of Wisconsin recreation. This is probably a reflection of a bias in the sample. Although the survey strategy used in this paper is far from the pure

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[5] David, op. cit., pp. 1-2.

Table 5

Comparison of Activity Scores
(Percent of Samples)

Activity	Score	Study	ORRRC	Chi-Square Test*
Pleasure Driving	0 1 2	43 7 51	27 24 47	$\chi^2 = 13.306$ DF = 2 Significant at .005
Picnics	0 1 2	42 24 34	33 35 31	$\chi^2 = 3.181$ DF = 2 Not significant at .01
Swimming	0 1 2	48 16 36	54 19 26	$\chi^2 = 2.249$ DF = 2 Not Significant at .01
Fishing	0 1 2	39 19 42	61 18 20	$\chi^2 = 12.190$ DF = 2 Significant at .005
Boating	0 1 2	50 16 34	71 16 12	$\chi^2 = 13.770$ DF = 2 Significant at .005
Hunting	0 1 2	69 13 18	82 8 9	$\chi^2 = 5.434$ DF = 2 Not significant at .01
Hiking	0 1 2	65 18 17	79 11 8	$\chi^2 = 6.180$ DF = 2 Not significant at .01
Camping	0 1 2	74 18 8	84 9 6	$\chi^2 = 3.945$ DF = 2 Not significant at .01
Horseback Riding	0 1 2	94 5 1	92 4 3	$\chi^2 = 1.519$ DF = 2 Not significant at .01

continued

Table 5 (Continued)

Activity	Score	Study	ORRRC	Chi-Square Test*
Winter Sports	0	64	93	$X^2 = 26.710$
	1	18	4	DF = 2
	2	18	2	Significant at .001

*Chi-square tests were performed on numbers of respondents.

cross-section approach, the sample is considered to be roughly representative of the set of United States households which can be expected to contributed toward whatever changes in demand for outdoor recreation occur as a result of accurate one-week weather forecasts.

III. Potential for Forecast Influence

Introduction

Recreational activity is sometimes scheduled far in advance. If a family wishes to spend a summer vacation at a lake cottage, the head must request vacation from his place of employment and arrange to rent a cottage and perhaps a boat, too, sometimes months in advance. Perhaps his children have to make special arrangements for a vacation. A son might have to find someone to take his paper route while he is gone and a daughter might have to reschedule her piano lessons. To the extent that plans such as these must be made more than one week in advance, one-week weather forecasts could be expected to exert little influence on recreational behavior. To be able to take advantage of accurate one-week forecasts, an individual has to have a certain amount of freedom in the use of his time.

A past study[6] has indicated that people are generally not capable of predicting how they would behave if the world were radically different from the one they live in. To predict the impact of technological advances on human behavior, it is usually necessary to develop a solid foundation for analysis which delineates the boundaries of the possible results by recourse to information other than pure opinion. In this section, the freedom which individuals have to react to accurate one-week weather forecasts is explored. Three types of information are used. The first concerns the time frames within which respondents are in the habit of deciding when to go, for how long to go, where to go, and what to do on weekend and holiday pleasure trips. This information reflects the various commitments and constraints associated with a household's leisure time. The second type of information concerns the length of advance notice which the head of a household must give his employer to request a week or more of vacation. The third type concerns the major recreational possessions of the household. It represents the independence of the individual from recreational facilities which must be reserved in advance. For example, if an individual owns a summer cottage, he does not have to make prior arrangement for its use.

Assuming rational behavior, individuals with considerable freedom of the type described above can be expected to make use of accurate long-range weather forecasts in their plans for outdoor recreation. However, better weather information need not influence people to recreate more frequently during the year.

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[6] Hacke, James E., Jr., "Anticipating Socioeconomic Consequences of a Major Technological Innovation," Stanford Research Institute, October, 1967.

It may simply result in influencing them to recreate the same number of times during the year, but during periods of more favorable recreational weather. Possibly, if it can be assumed that some people strive to achieve some minimum level of annual recreational satisfaction, the potential for planning recreation during more favorable periods of weather might lead to an actual decline in their annual recreational participation. To solve the problem of predicting whether better weather information will result in increased, unchanged, or decreased annual participation, more information is required. First, some idea of whether an individual really desires to increase his recreational participation is needed. This question is examined in Section IV. Next, some idea of how important weather itself is to the success of an individual's recreational experience is required. This question is dealt with in Section V. Finally, some method of integrating these several kinds of information is necessary to yield predictions on changes in participation. This is done in Section VII.

Planning Horizon

Survey respondents were asked to specify how early they make decisions regarding when to go on weekend or holiday pleasure trips, for how long to go, where to go, and what to do. Table 6 provides the number of people who made each decision within four time frames. Subtotals are computed for the first two time frames. These are the respondents who make their decisions in one week or less, and can consequently use one-week forecasts in their planning.

Of the four planning horizon decisions, "when to go" is clearly the most important with respect to the impact of better weather information. In a very

Table 6

Planning Horizon Time Frames

	When to go #	When to go %	How long to go #	How long to go %	Where to go #	Where to go %	What to do #	What to do %
Less than one day in advance	32	4.451	32	4.451	46	6.398	104	14.464
One day to one week in advance	204	28.372	199	27.677	153	21.279	179	24.896
Subtotal Those who decide in one week or less	236	32.823	231	32.128	199	27.677	283	39.360
One week to one month in advance	243	33.797	217	30.181	213	29.624	166	23.088
Over one month in advance	193	26.842	170	23.644	213	29.624	152	21.140
Not ascertained	47	6.536	101	14.048	94	13.074	118	16.412
Total	719	100.	719	100.	719	100.	719	100.

real sense, this is a decision concerning whether or not to recreate outdoors at all. The decision "for how long to go" is important too because it affects the actual quantity of recreation performed in one week or less. Being able to decide "where to go" on short notice implies that the respondent does not have to spend a lot of time and effort investigating which of a large number of potential recreation sites satisfies the requirements of his household. Perhaps past investigations and experience have enabled him to select several favorite recreation sites which he frequently visits, or perhaps his household is flexible enough so that it can adapt to the limitations of any site. Whichever the case, the household can reach a decision on short enough notice to be able to use one-week forecasts in the decision process. Weather information could certainly be used in the decision "what to do." For example, a respondent might decide to go fishing rather than swimming and water skiing if cool and cloudy weather were forecasted for the next weekend.

Vacation Selection

Another characteristic of households which would affect the potential impact of better weather information on recreational activity is the time frame within which an individual is capable of obtaining permission from his employer to take a vacation. Clearly, a self-employed individual with no pressing responsibilities could take a vacation from his work whenever he felt that he would be able to participate in a successful recreational experience. Patterns of vacation selection will be examined to determine what proportion of the sample would be able to take a week or more off from employment for a vacation within a short enough time frame to be influenced by accurate one-week forecasts. Table 7 provides the number of respondents who could obtain vacations from employment within specified time frames.

Table 7

Selection Time Frames for Paid Vacation

Time Frame	Number	Percent
One week or less	133	18.498
One week to one month	163	22.671
More than one month	208	28.830
Not able to choose	26	3.616
No paid vacation	161	22.392
Not ascertained	28	3.894

Approximately 18% of the sample can take vacations from employment on one week of notice or less. These individuals could plan vacations of one week or more on the basis of accurate one-week forecasts. It is this group, then, which will be assumed to contribute the most to changes in recreational behavior during vacations longer than weekend or holiday outings.

The individuals with no paid vacation include the eighty-five retired respondents plus the self-employed and those engaged principally in professional work and sales. As a group, the retired cannot be expected to contribute significantly to changes because they tend to suffer from serious physical and financial constraints. Transportation also seems to be a problem for them. Although 88% of them own automobiles, they generally express difficulties in having to drive long distances. By and large, their vacation patterns tend to be tied to those of their children and other close relatives which, in turn, are subject to the vacation from employment patterns of the rest of the sample. The self-employed are not really free to go on a vacation any time they please. They tend to be high-income attornies, physicians, and sales representatives. These individuals tend to have pressing professional commitments which override the capability to take a vacation whenever they feel like it. In fact, vacation from home patterns for these individuals indicate that they are more likely to go on a one-month vacation once a year than several shorter vacations scattered throughout the year.

Major Recreational Possessions

A final characteristic of households which would affect the potential impact of better weather information on recreational activity is possession of certain major recreational items such as automobiles, cottages, campers, canoes, sailboats, rowboats, and motorboats. Households which possess these items are free from the constraint of having to make travel reservations, rent summer cottages, and rent or reserve boats prior to their recreation unlike households without these items. Much less preparation is required to spend a weekend at one's own summer cottage where blankets and linen, clothes and equipment, and perhaps food are already stored than to set out for a rented cottage taking along everything that might be needed. Table 8 provides the number of households in the sample which have each of these recreational items.

Table 8

Major Recreational Possessions

Possession	Number	Percent
Automobile	686	95.41
Summer Cottage	153	21.28
Camper or travel trailer	87	12.10
Canoe, sailboat, or rowboat	230	31.99
Inboard or outboard motorboat	303	42.14

An automobile is obviously a great aid to the participation in recreation away from home. Since over 95% of the respondents possess cars, however, its usefulness in discriminating freedom to react is minimal.

A summer cottage is the most important recreational possession considered in this study with respect to the probable impact of long-range forecasts. People who own cottages generally also own boats, and are inclined to participate frequently in a variety of water sports. They are also somewhat immune from the problem of congestion which will be dealt with in Section VI.

Table 9 indicates that eighty-seven respondents have campers or travel trailers. This recreational possession enables respondents to hunt, fish, hike, camp, and pleasure drive without dependence on commercial forms of lodging.

It is also seen that 230 respondents have canoes, sailboats, or rowboats, and 303 respondents have inboard or outboard motorboats. Possession of a boat enables a household to engage in various types of water sports without having to rent or reserve a boat prior to participation.

Freedom to React Index

Ten attributes have been described above which contribute to the freedom of an individual to react to accurate one-week weather forecasts. Now, these ten attributes will be considered together in an attempt to assess the overall freedom which individuals have to react to one-week forecasts. Weights are assigned to the ten attributes designating their relative importance in determining the freedom which individuals have to react to forecasts. The assignment of these weights was arbitrary. It reflects our judgment on the importance of each attribute. Other reasonable weights could have been chosen. Our judgment was guided by four assumptions. First, that the typical individual engages in at least twice as much recreational activity on weekends and holidays as he does on longer vacations from home. Second, that the decision "when to go" is the most important planning horizon decision. Third, that possession of a summer cottage is much more important in determining annual recreational participation than the other possessions considered. And fourth, that possession of a car, though critical to the performance of most forms of outdoor recreation, is discounted in importance for discriminating recreational behavior because almost all respondents have cars.

Table 9 provides the set of weights and the numbers of respondents who have each attribute. The sum of these weights is twenty-five. Each individual, regardless of his attribute, is assigned an additional weight of one to permit some of the computations which follow. Consequently, if an individual has all ten attributes, the sum of his weights would be twenty-six; if he had none, his weight would be one. Most respondents had several attributes, but no respondent had all ten.

Weights were computed and summed for each respondent. Table 10 provides the average activity scores for each of the three classes of respondents based on the sum of their weights. The deviation of the class average activity score from the average activity score for the entire sample is also provided.

The first class of 249 respondents have weights totaling six to fifteen. These people have several of the attributes dealt with in this section. Their average activity scores are all above average except for the activity "other." Their composite activity score is 0.8 points above average.

The third class is the one of most importance to this study. The 126 respondents in this class have the most freedom to adjust their recreational behavior on the basis of accurate one-week forecasts. The sum of their weights ranged from sixteen to twenty-six indicating, among other things, they can decide "when to go" in one week or less, or can obtain vacation from employment in one week or less, or both. A sum of sixteen or higher could not be attained without at least one of these two key attributes. The average composite activity score for this class was 10.651, approximately 1.0 above average. However, eight average activity scores were below average: camping, sledding, picknicking, horseback riding, sport flying, bicycling, playing outdoor games and sports, and "other." On the other hand, the 126 respondents in this class have activity scores far above average in hunting, and the water-based activities of fishing, swimming, and motorboating.

Table 9

Summary of Attributes

Attribute	Weight	Number	Percent
Decide "when to go" in one week or less	6	236	32.8
Decide "how long to go" in one week or less	2	231	32.1
Decide "where to go" in one week or less	1	199	27.7
Decide "what to do" in one week or less	1	283	39.4
Can obtain vacation from employment in one week or less	5	133	18.5
Have a car	3	686	95.4
Have a summer cottage	4	153	21.3
Have a camper or travel trailer	1	87	12.1
Have a canoe, sailboat, or rowboat	1	230	32.0
Have an inboard or outboard motorboat	1	303	42.1

Table 10

Respondents Classified by Freedom to React

Activity	Sample Average	Sum of Weights: 1 to 5 Ave.	Dev.	Sum of Weights: 6 to 15 Ave.	Dev.	Sum of Weights: 16 to 26 Ave.	Dev.
Hunting	0.839	0.558	-0.281	0.977	0.138	1.016	0.177
Fishing	1.334	1.108	-0.226	1.378	0.044	1.659	0.325
Camping	0.402	0.373	-0.029	0.436	0.034	0.365	-0.037
Hiking	0.573	0.514	-0.059	0.602	0.029	0.611	0.038
Sledding	0.163	0.124	-0.039	0.209	0.046	0.111	-0.052
Tobogganing	0.117	0.100	-0.017	0.128	0.011	0.119	0.002
Snow skiing	0.203	0.096	-0.107	0.267	0.064	0.238	0.035
Snowmobiling	0.245	0.157	-0.088	0.291	0.046	0.294	0.049
Ice skating	0.170	0.129	-0.041	0.183	0.013	0.214	0.044
Swimming	0.929	0.815	-0.114	0.951	0.022	1.095	0.166
Canoeing	0.234	0.145	-0.089	0.282	0.048	0.278	0.044
Sailing	0.135	0.064	-0.071	0.169	0.034	0.183	0.048
Motorboating	0.741	0.542	-0.199	0.770	0.029	1.056	0.315
Water skiing	0.168	0.112	-0.056	0.198	0.030	0.198	0.030
Picnicking	0.907	0.916	0.009	0.936	0.029	0.810	-0.097
Horseback riding	0.088	0.060	-0.028	0.108	0.020	0.087	-0.001
Pleasure driving	1.111	1.080	-0.031	1.134	0.023	1.111	0.000
Sport flying	0.060	0.048	-0.012	0.070	0.010	0.056	-0.004
Bicycling	0.039	0.245	-0.064	0.372	0.063	0.262	-0.047
Playing outdoor games and sports	0.832	0.747	-0.085	0.898	0.066	0.817	-0.015
Other	0.114	0.141	0.027	0.110	-0.004	0.071	-0.043
Number	719	249		344		126	
Average Composite Activity Score	9.672	8.076		10.468		10.651	

IV. Increased Participation

Introduction

In this section, an attempt is made to find out which respondents are likely to increase their recreational participation if accurate one-week forecasts were available. Three questions are used to obtain an indication of whether or not a respondent will increase his participation in a particular activity. Special effort was made to structure these questions into specific enough forms so that respondents could be expected to express usable predictions of their future behavior.

Favorite Recreation Sites

The first question asked for information about the places at which respondents frequently recreate. They were asked if they would go to these favorite sites more often if they knew for sure a week in advance what each week's weather would be like. Four responses were possible. Table 11 provides the numbers of respondents who chose each response.

Respondents were also asked to specify what types of recreation they generally engaged in at these favorite sites. Table 12 provides a summary of what forms of recreation are performed at favorite sites and what proportion of each would be increased if accurate one-week forecasts were available. Since respondents sometimes specified more than one favorite recreational site or more than one activity as being done there, the columns will not sum to any of the totals shown in Table 11.

Column (1) in Table 12 provides the number of respondents who participated in a given activity at a favorite site. Column (2) transforms these numbers into percentages of all the respondents who engaged in that acitivity. Hence, 58.9 percent of all respondents who fished at least once during the past year fished at one of their favorite sites. It can be seen that the percentages in the second column of numbers varies widely from 1% to well over 50%. Information about favorite sites, however, is not of direct interest to this study. What is of interest is the anticipated response to better weather information. Column (3) shows the number of respondents who would increase participation in a particular activity. Column (4) shows these numbers as a percent of the corresponding numbers in column (1). Hence, 43.2% of the 147 respondents who hunt at favorite sites will hunt more often with better weather information. These percentages, too, vary widely.

Table 11

Favorite Site Response

Response	Number
No, I do not have any favorite recreation areas to which I have gone several times in the past few years.	152
Yes, I would probably go to these favorite sites more often.	245
No, I would probably go to these favorite sites about the same number of times as I have done in the past.	315
No, I would probably go to these favorite sites less frequently than in the past.	7

Table 12

Activities Respondents Perform at Their Favorite Recreational Areas

Activity	Number who engage in activities at a favorite recreational area (1) # who do there	(2) % of those who do at all	Number who would participate there more often with one week weather forecasts (3) # who would	(4) (3) as a % of (1)
Hunting	147	39.3	63	43.2
Fishing	325	58.9	141	43.5
Camping	63	29.0	37	58.7
Hiking	29	10.7	6	20.6
Sledding	1	1.0	0	0.0
Tobogganing	1	1.3	0	0.0
Snow skiing	33	39.3	14	42.4
Snowmobiling	6	4.2	3	50.0
Ice skating	2	2.0	0	0.0
Swimming	89	22.4	43	48.3
Canoeing	7	5.8	3	42.8
Sailing	6	10.0	4	66.7
Motorboating	38	11.9	18	47.3
Water skiing	8	9.6	5	62.5
Picnicking	21	5.1	10	47.6
Horseback riding	1	1.8	1	100.0
Pleasure driving	10	2.3	3	30.0
Sport flying	0	0.0	0	-
Bicycling	5	3.5	2	40.0
Playing outdoor games and sports	20	6.1	9	45.0
Other	17	38.6	5	29.4

Favorite Types of Weather

The next question respondents were asked was what kinds of weather they preferred. They were asked if they preferred any of eight specific types of weather. Another space was left for them to specify any other type of weather they preferred. They were also asked to specify the types of recreation they enjoyed participating in during their favorite types of weather. Information about their weather preferences is described in Section V. What is of interest here is that they were then asked if they would increase their participation of the specified forms of recreation if they knew what the weather would be like one week in advance. This information is summarized in Table 13.

Column (1) is the number of respondents who engaged in a specific activity during any of nine possible favorite types of weather. Hence, 241 respondents

Table 13

Respondents Who Would Recreate More Often During Their Favorite Types of Weather with One Week Forecasts

Activity	(1) Number who perform during their favorite type of weather	(2) Number who would increase participation with forecasts	(3) (2) as a % of (1)
Hunting	241	190	78.8
Fishing	439	388	77.0
Camping	76	59	77.6
Hiking	91	60	65.8
Sledding	6	5	83.3
Toboganning	3	3	100.0
Snow skiing	37	28	75.7
Snowmobiling	13	10	77.0
Ice skating	8	8	100.0
Swimming	163	128	78.5
Canoeing	18	9	50.0
Sailing	31	26	84.0
Motorboating	76	63	82.8
Water skiing	21	18	85.7
Picnicking	45	35	77.8
Horseback riding	7	6	85.7
Pleasure driving	44	30	68.2
Sport flying	8	8	100.0
Bicycling	16	10	62.5
Playing outdoor games and sports	93	77	82.8
Other	32	19	59.4
Average percentage who would increase: 76.9%			

hunt during weather which they have designated as being their favorite. Column (2) is the number of these people who also checked that they would increase their participation if one-week forecasts were available. Column (3) contains the numbers from the second column transformed as percentages of the numbers in the first column. Hence, 78.8% of the 241 respondents who hunt during their favorite type of weather would increase their participation in hunting if better weather information were available. An average of about 77% of the respondents who recreate during their favorite types of weather would increase participation.

New Participants

Finally, respondents were asked if there are any forms of outdoor recreation which they would really like to do but just have not been able to find the right time to do it in the last year or more. If there were any such activities, they were asked to specify which ones and to decide if better weather information would help them to plan ahead and find the time to do these forms of outdoor recreation. The results are summarized in Table 14.

Column (1) shows that the largest number of new participants would be in fishing. Hence, fifty-three respondents who have not fished recently would in the future if better weather information were available. Column (2) contains the numbers from column (1) transformed as a percent of the total number of respondents who currently engage in a given activity. Hence, the twenty-two new hunters who would appear if one-week forecasts were available would increase the number of people who currently hunt (374 respondents from Table 2) by 5.9%. The numbers in Column (2) vary widely. The largest percentage increase would be in snow skiing. Eleven new participants generated by better weather information would increase the total number of skiers by 13.1%.

Table 14

New Participation

Activity	(1) Number of New Participants	(2) % of Current Participants
Hunting	22	5.9
Fishing	53	9.6
Camping	19	8.7
Hiking	4	1.5
Sledding	0	0.0
Tobogganing	1	1.3
Snow skiing	11	13.1
Snowmobiling	1	0.7
Ice skating	0	0.0
Swimming	14	3.5
Canoeing	5	4.1
Sailing	3	5.0
Motorboating	8	2.5
Water skiing	5	6.0
Picnicking	4	0.9
Horseback riding	3	5.4
Pleasure driving	11	2.6
Sport flying	2	6.4
Bicycling	1	0.7
Playing outdoor games and sports	23	7.0
Other	4	9.1

V. Qualitative Aspects of Recreation and Weather

Introduction

Obviously, better weather forecasts would have little impact on recreational participation if recreation were insensitive to weather. In this section, the qualitative impact of weather itself on outdoor recreation will be investigated. An attempt is made to find out which specific recreational activities are most sensitive to weather. Next, the different types of weather respondents prefer for different types of activities are explored. Then, an analysis is made of recreational experiences spoiled by unanticipated bad weather. Finally, narrative comments by respondents on the qualitative impact of weather on their recreation are summarized and discussed.

Weather Sensitive Activities

Respondents were asked if they participated in any forms of outdoor recreation which require a specific type of weather to be enjoyed. The answers to this question are summarized in Table 15. The first two columns of numbers pertain to respondents who participated in weather-sensitive activities one to four times in the past year. Hence, sixteen people who participated in hunting one to four times during the past year judged hunting to be highly sensitive to weather comprised 11.0% of all respondents who participated from one to four times in hunting during the past year. Evidently over half of those who ski infrequently judge skiing to be sensitive to weather conditions. On the other hand, none of those who infrequently participate in pleasure driving consider it to be sensitive to weather.

Table 15

Activities Judged by Respondents As Particularly Sensitive to Weather

Activity	By respondents with an activity score of 1 for chosen activity: # who judged	By respondents with an activity score of 1 for chosen activity: % of all with score of 1	By respondents with an activity score of 2 for chosen activity: # who judged	By respondents with an activity score of 2 for chosen activity: % of all with score of 2
Hunting	16	11.0	61	26.6
Fishing	28	19.6	149	36.5
Camping	22	15.2	17	23.6
Hiking	5	4.0	7	4.9
Sledding	3	3.9	1	5.0
Tobogganing	1	1.5	2	22.2
Snow skiing	12	54.5	55	88.7
Snowmobiling	6	5.7	16	45.7
Ice skating	7	10.3	4	14.8
Swimming	15	11.9	43	15.9
Canoeing	2	2.7	8	17.0
Sailing	5	21.7	19	51.3
Motorboating	9	8.7	38	15.1
Water skiing	3	6.7	11	28.9
Picnicking	5	2.9	15	6.3
Horseback riding	1	2.1	0	0.0
Pleasure driving	0	0.0	0	0.0
Sport flying	2	10.5	3	25.0
Bicycling	1	1.8	5	6.0
Playing outdoor games and sports	4	7.4	39	14.3
Other	1	16.7	3	7.9

For those respondents who frequently participate in an activity (five or more times a year: activity score of two), the next two columns of numbers give the same type of information; sixty-one frequent hunters (26.6% of all frequent hunters) judged hunting to be particularly sensitive to weather. It is also seen that 88.7% of the frequent skiers consider skiing to be particularly sensitive to weather.

Weather Preferences

Participation in a particular activity on a given day with accurate one-week forecasts will depend on how many people like to perform that type of recreation during the kind of weather which occurs on that day. Hence, it is useful to have some idea of what types of weather people prefer for particular activities.

Table 16 provides information about respondents' weather preferences. Eight specific types of weather and one unspecified type of weather were used when recording respondents' weather preferences. The eight specific types of weather are very crudely defined. Actually, it is quite difficult to develop a system for describing weather which is particularly meaningful with respect to outdoor recreation. It is seen that respondents have widely differing weather preferences for hunting. Three respondents prefer warm, sunny, windy weather; twenty-five prefer cool, rainy, calm weather. For fishing, too, preferences differ. The numbers in Table 16 do not necessarily sum to the total number of respondents, 719, because many respondents chose several types of activities, or simply expressed no preference at all for weather. Each type of weather is preferred by at least someone for some kind of activity. However, warm, sunny, not windy weather is clearly the most popular, and warm, rainy, windy weather is clearly the most unpopular. This kind of information is useful for predicting whether recreational facilities would become crowded during periods of a specific type of weather with one-week forecasts.

Table 16

Activities Respondents Perform in Their Favorite Types of Weather

Activity	WSW	WSN	WRW	WRN	CSW	CSN	CRW	CRN	OTHER
Hunting	3	18	1	2	17	91	38	25	46
Fishing	27	222	15	48	14	80	8	18	7
Camping	12	49	1	1	3	8	1	1	0
Hiking	15	23	3	3	13	29	1	1	3
Sledding	0	0	0	0	0	1	0	0	5
Tobogganning	0	0	0	0	1	0	0	0	2
Snow skiing	0	2	0	0	1	12	0	0	22
Snowmobiling	0	0	0	0	1	3	0	0	9
Ice skating	0	0	0	0	1	3	0	0	4
Swimming	32	115	2	2	3	6	1	0	2
Canoeing	4	10	0	0	0	4	0	0	0
Sailing	20	2	2	0	5	1	1	0	0
Motorboating	8	50	0	2	1	13	0	1	1
Water skiing	2	18	0	0	0	1	0	0	0
Picnikcing	6	33	0	0	2	4	0	0	0
Horseback riding	1	0	0	0	3	3	0	0	0
Pleasure driving	3	11	1	3	6	19	0	1	0
Sport flying	1	4	0	0	0	3	0	0	0
Bicycling	1	4	0	1	2	8	0	0	0
Playing outdoor games and sports	6	55	0	0	3	28	1	0	0
Other	6	11	0	1	3	6	1	2	2

WSW: Warm, sunny and dry, windy.
WSN: Warm, sunny and dry, not windy.
WRW: Warm, cloudy or rainy, windy.
WRN: Warm, cloudy or rainy, not windy.
CSW: Cool, sunny and dry, windy.
CSN: Cool, sunny and dry, not windy.
CRW: Cool, cloudy or rainy, windy.
CRN: Cool, cloudy or rainy, not windy.
Other: Respondents described.

Activities Ruined by Weather

Respondents were asked if they had any recreational experience during the past year spoiled by unanticipated bad weather. Over 25% of the respondents did. Most spoiled experiences were caused by unanticipated rain. Table 17 provides a summary of the recreational experiences affected by unanticipated

Table 17

Recreational Experiences Spoiled by Unanticipated Rain

Activity	(1) People who engage in activity	(2) People who were rained out	(3) (2) as a % of (1)
Hunting	374	17	4.8
Fishing	551	85	15.4
Camping	217	26	11.9
Hiking	269	13	4.8
Sledding	97	0	0.0
Toboganning	75	0	0.0
Snow skiing	84	8	9.5
Snowmobiling	141	2	1.4
Ice skating	95	0	0.0
Swimming	397	30	7.6
Canoeing	121	3	2.4
Sailing	60	5	8.3
Motorboating	318	23	7.2
Water skiing	83	4	4.8
Picnicking	412	29	7.0
Horseback riding	55	0	0.0
Pleasure driving	423	2	0.5
Sport flying	31	1	3.2
Bicycling	139	3	2.1
Playing outdoor games and sports	326	12	3.6
Other	44	9	20.5
Percent of sample who were rained during past year: 26.6%			

rain. Column (1) contains the number of respondents who engaged in a given activity at least once during the past year. Column (2) provides the number of people who on at least one occasion during the past year had to cancel their participation in that activity because of unanticipated rain. Column (3) contains these numbers transformed as a percent of the total number of respondents who engage in that activity. Hence, seventeen hunters (4.8% of the 374 hunters in the sample) had at least one hunting experience spoiled because of unanticipated rain. Of the specified activities, the highest percent was achieved in fishing in which 15.4% of the fishermen had at least one fishing experience spoiled by rain. Of special interest is the fact that picknicking, which has the widest reputation for being spoiled by rain, has a relatively low percentage incidence of being spoiled by rain, 7%.

Narrative Comments by Respondents

Respondents were asked to remark on the influence of better weather information on their recreational activities. Table 18 summarizes this information. The exact comments appearing in the table represent an attempt to generalize many specific comments. Having read all of the narrative remarks several times, a few recurring themes were expressed in the form of the hypothetical comments appearing in Table 18. Then, each narrative remark was reviewed to see if the respondent wrote anything which explicitly agreed with one of the hypothetical comments. The numbers of such agreements were recorded and appear as the numbers in column (1). Column (2) contains these numbers transformed as a percentage of the 719 respondents. Hence, 111 respondents (15.4%

Table 18

Narrative Comments by Respondents

Type of Comment	(1) Number	(2) Percent
In Favor of One Week Forecasts		
"It would greatly improve my recreational enjoyment"	111	15.4
"It would help me to drive:	11	1.5
"It would help me to select clothes and equipment"	9	1.2
"It would help me locate game and fish"	15	2.1
"It would permit me to take better advantage of weather once I am on my vacation"	11	1.5
"It would permit me to take my family along"	3	0.4
"It would help me on the job"	13	1.8
Against One Week Forecasts		
"I recreate in any kind of weather"	37	5.1
"It would crowd roads and recreational facilities during good weather"	5	0.6
"I plan my vacations too far in advance for forecasts to matter"	15	2.1
"I want weather control, not more forecasts"	5	0.6
About Local Weather Forecasts		
"Local weather reports should be better coordinated and more substantive"	17	2.4
"Local weather reports should give forecasts for other parts of this state and for nearby states"	11	1.5
"Snow conditions in different places should be more readily available"	4	0.5

of all respondents), wrote some remarks which said in effect that one-week forecasts would greatly improve their recreational enjoyment. These percentages, consequently, are not to be taken as estimates of the percent of the sample or the population which has a particular view. Almost half of the respondents made no narrative comments. Those who did generally confined their remarks to only one or two of the fourteen areas listed.

The first series of comments addresses the qualitative impact of weather information on recreation. It can be seen that besides improving recreational enjoyment directly, it can help in terms of driving conditions, clothes and equipment selection, and wildlife patterns. It helps those people who plan long vacations to take advantage of weather once on vacation. It sometimes helps to permit taking the entire family along. Several firemen, mailmen, and a youth camp administrator noted that it would help them in their job duties.

The next series of comments addresses the negative effects of better weather information. Over 5% of the sample claim that they can recreate in any type of weather. These are mainly hunters. Though this may be true, several of these same people noted that better weather information would help them drive, select clothing or equipment, or locate wildlife. Other people felt that crowding would result during periods of ideal recreational weather. Some people simply make their plans so far in advance that weather information cannot be considered. Finally, some people want weather control, not prediction.

The last section of remarks pertains to radio and television weather broadcasts. Several people complained about the low quality of televised weather reports. Apparently, television weather reports from different channels in the

Milwaukee area frequently conflict with each other. Emphasis is placed on humor and gimmicks with little time remaining for substantive weather information. Others would like to see some weather information given for other parts of Wisconsin and for adjoining states. Still others would like to have better reports on snow conditions both on roads and at ski areas.

VI. Possibility of Crowding and Congestion

Introduction

In this section, the possibility of crowding and congestion of recreational facilities during periods of ideal recreational weather will be examined. This will be accomplished by focusing on three selected ski areas. Skiing can be characterized as requiring special facilities and special weather. Much skiing is done at commercial ski areas equipped with dressing and comfort facilities, lounge facilities and restaurants and ski lifts. Although these facilities are flexible enough to accommodate varying numbers of people, they can become crowded in the sense that participants must wait as long as an hour to get on to the ski lift. Weather also greatly affects skiing. The primary consideration is the quantity and quality of the snow. Wind and visibility are important. If accurate one-week forecasts were to cause unusually large crowds at ski areas during periods of ideal ski weather, these areas would become so congested that skiers would not experience a very enjoyable period of recreation. Some people might begin to consider skiing only during periods of non-ideal weather in order to avoid the crowds. These types of adjustments might slightly reduce the magnitude of the crowds as more and more people became tired of the congestion on ideal days, but it would probably not eliminate the congestion.

Ski Area Managers

Managers of three small ski areas in Northern Wisconsin were asked to state their opinions on the impact of accurate one-week forecasts on crowding and congestion. The top portion of Table 19 provides their response. Two felt that it would occur, one that it would not.

Ski Area Users

These three areas had differing proportions of season ticket holders among their users ranging from less than 10% to over 50%. All three areas performed most of their business on weekends. Questionnaires, identical to those used for the rest of this study (Appendix), were sent to season ticket holders for these areas. The proportion of the respondents who were in the habit of deciding "when to go" on ski trips in one week or less varied from 24% to 62%. However, the proportions who said that they would ski more often at these areas with one-week forecasts varied only from 35.5% to 37.5%. Hence, about 36% of the season ticket holders can be expected to increase their participation. This implies that they would ski more often during periods of ideal skiing weather. This is a clear indication that crowding and congestion probably will result.

Table 19

Crowding and Congestion
Ski Area Survey

Information	Camp 10	Manitou	Kettle Morraine
Manager predicts:			
"small change in usage patterns with one week forecasts"	-	-	Yes
"much larger crowds at good times, much smaller crowds at poor times with one week forecasts"	Yes	Yes	-
Ski area has:			
Percent of users who are season ticket holders:	50%+	10%-	11-25%
Percent of skiing done on weekends:	75%+	75%+	75%+
Information from respondents:			
Number of respondents:	31	8	25
Those who decide "when to go" in one week or less:			
Number	11	5	6
Percent	35.5%	62.5%	24.0%
Those who would ski more often at their ski area with one week forecasts:			
Number	11	3	9
Percent	35.5%	37.5%	36.0%

VII. Impact Predictions

Introduction

In this section, a model will be developed which uses the information obtained in the previous sections to predict the impact of accurate one-week forecasts on recreational participation. The initial predictions for the sample are described. Then, these predictions are adjusted for the significant differences of the sample from the nation discovered in Section II. The socioeconomic characteristics of those who are predicted to benefit from better weather information are discussed.

Procedure

The following model was used to predict the participation of a respondent in each of the twenty-one considered recreational activities in an environment of accurate one-week weather forecasts:

$$PP_i = AP_i + FW \times WDW_i \times NCW \times (FSD_i + FWD_i + NPD_i), \quad i = 1, 21 .$$

PP_i represents the number of times a particular respondent is predicted to participate in activity i if one-week weather forecasts were available.

AP_i represents the actual number of times a particular respondent claimed to have participated in activity i during the past year.

FW represents the freedom-to-react weight based on the characteristics of the respondent discussed in Section III. The function of this weight is to magnify whatever change in participation is computed in the expression within parentheses. FW receives a value of one if the respondent's freedom-to-react weights total five or less. A value of one for this factor, in effect, provides no magnification of the change. This reflects the reasoning developed in Section III that a respondent with a small amount of freedom to adjust his behavior within a one-week time frame can be expected to contribute very little to whatever changes occur. FW receives a value of two if the respondent's freedom-to-react weights total six to fifteen. This, in effect, doubles whatever change is computed. An individual with a great deal of freedom to adjust his behavior on short notice, hence with freedom-to-react weights totaling sixteen or more, is assigned a value of 2.5 to FW. This more than doubles whatever change is computed.

WDW_i represents a weather-dependent activity weight for activity i. If the respondent has stated that activity i is particularly sensitive to weather, then WDW_i is assigned a value of 1.25. This has the effect of magnifying whatever change is computed by 25%. If the respondent has not stated that activity i is particularly sensitive to weather, WDW_i is assigned a value of one. A value of one for this factor has the effect of providing no magnification of the change.

NCW represents the respondent's narrative comments on the impact of accurate one-week forecasts on his participation. If the respondent stated that it would have substantial, beneficial impact on his recreational participation, NCW is assigned a value of 1.25. This has the effect of magnifying whatever change is computed by 25%. If the respondent made no comment to that effect, NCW would be assigned a weight of one and would cause no magnification.

The three terms in parentheses form the actual change in participation. The previous three factors operate to magnify this expression if it takes on a non-zero value. This expression can take on a non-zero value if any of the three terms or any two of the three are assigned a value of one. The three terms in this expression refer to the three sources of information on increased participation discussed in Section IV.

FSD_i represents the favorite recreational sites question. If a respondent stated that he would increase his recreation at one of his favorite sites with better weather information <u>and</u> if the respondent also stated that he participated in activity i at that site, then FSD_i is assigned a value of one. Otherwise, it is assigned a value of zero.

FWD_i represents the favorite-types-of-weather question. If a respondent stated that he would increase his recreation during his favorite type of weather with better weather information <u>and</u> if the respondent also stated that he participates in activity i during his favorite type of weather, then FWD_i is assigned a value of one. Otherwise, it is assigned a value of zero.

NFD_i represents the new-participation question. If a respondent stated that he would begin participating in activity i for the first time in recent years with better weather information, then NPD_i is assigned a value of one. Otherwise, it is assigned a value of zero.

This technique for predicting change depends exclusively on a respondent's specific assertion that he will increase participation in activity i for determining whether or not a change will occur in activity i. Once this is determined by the three terms in parentheses, the other factors are brought into operation to determine the magnitude of the change. This magnitude is then added to the respondent's actual participation to get predicted participation. This procedure is applied to all 719 respondents for all twenty-one activities.

Impact on Sample Participation

Table 20 provides information on the general impact of accurate one-week forecasts on the sample. Column (1) shows the numbers of respondents who would increase participation in each of the activities. The largest absolute response is fishing. The smallest is in sledding. Column (2) contains the numbers of respondents who actually participated in each activity at least once during the last year. Column (3) contains the number of respondents who would increase participation expressed as a percentage of the number who actually participated one or more times during the last year. This provides a measure of the impact on specific activities. Consequently 43.6% of the hunters and 54.2% of the fishermen can be expected to increase their participation of hunting and fishing respectively if accurate one-week forecasts are made available. On the other hand, only 5.1% of the sledders and 5.3% of the tobogganers can be expected to increase their participation. Of special interest to the discussion on crowding and congestion in Section VI, 47.9% of the snow skiers can be expected to increase their participation. Column (4) contains the number of respondents predicted to increase participation expressed as a percentage of the entire sample. These figures give some idea of the impact on the entire population. Thus 22.7% of the heads of households can be expected to hunt more than they currently do, if at all, with better weather information. Increased participation in fishing affects 43.0% of the heads of households. On the other hand, increases in participation in sledding and tobogganing affect

Table 20

Impact on Respondents

Activity	(1) Number predicted to increase	(2) Number who now do	(3) (1) as a % of (2)	(4) (1) as a % of the sample
Hunting	163	374	43.6	22.7
Fishing	309	551	54.2	43.0
Camping	80	214	36.8	11.1
Hiking	51	269	19.0	7.1
Sledding	5	97	5.1	0.7
Tobogganing	4	75	5.3	0.6
Snow skiing	40	84	47.9	5.6
Snowmobiling	11	141	7.7	1.5
Ice skating	7	95	7.3	1.0
Swimming	138	397	34.7	19.2
Canoeing	16	121	13.2	2.2
Sailing	23	60	38.3	3.2
Motorboating	68	318	21.7	9.5
Water skiing	25	83	30.1	3.5
Picnicking	42	412	10.2	5.8
Horseback riding	8	55	14.6	1.1
Pleasure driving	39	432	9.2	5.4
Sport flying	9	31	29.0	1.2
Bicycling	10	139	7.2	1.4
Playing outdoor games and sports	77	326	23.6	10.7
Other	25	44	56.8	3.5

fewer than 1% of the heads of households in the sample.

Table 21 provides actual changes in participation rates and activity scores predicted to occur due to accurate one-week forecasts. Column (1) contains

Table 21

Impact on Participation

Activity	Average predicted times done	Average increase in times done	Average predicted activity score	Average increase in activity score
Hunting	5.95	0.69	0.897	0.058
Fishing	14.56	1.44	1.414	0.090
Camping	1.78	0.32	0.453	0.051
Hiking	3.81	0.14	0.608	0.035
Sledding	0.47	0.01	0.168	0.006
Tobogganing	0.27	0.01	0.121	0.004
Snow skiing	1.82	0.21	0.221	0.018
Snowmobiling	1.37	0.05	0.250	0.006
Ice skating	0.50	0.03	0.172	0.003
Swimming	9.33	0.52	0.985	0.056
Canoeing	1.19	0.05	0.243	0.010
Sailing	1.01	0.09	0.143	0.008
Motorboating	7.11	0.24	0.773	0.032
Water skiing	1.25	0.10	0.182	0.014
Picnicking	4.35	0.12	0.919	0.013
Horseback riding	0.25	0.02	0.960	0.008
Pleasure driving	15.91	0.11	1.135	0.024
Sport flying	0.55	0.03	0.065	0.006
Bicycling	2.79	0.03	0.312	0.003
Playing outdoor games and sports	13.43	0.25	0.857	0.025
Other	2.21	0.07	0.136	0.022

the average predicted participation per year for each activity. Column (2) provides the average increase in participation over participation actually accomplished during the past year. Hence, the average respondents hunt an additional 0.69 times during the year over and above the number of times he participated during the past year without accurate one-week forecasts. (Old participation plus 0.69 equals 5.95.) The largest average increase is seen to be 1.44 in fishing. This means that the average respondent fishes almost one and a half times per year in addition to what he regularly does. This certainly is a substantial impact.

The third and fourth columns pertain to activity scores. These are somewhat better measures of recreational participation because they are not influenced by extremely large participation rates on the part of relatively few individuals. An activity score takes on a maximum value of two when a respondent's participation rate is at least five. Thus, this measure is two whether the respondent fishes five times or fifty times per year. Consequently, it yields a better indication of the impact of changes in participation on the entire sample. The average increases in the average activity scores shown in the fourth column indicate more modest changes in recreational activity. The largest response indicated in column four is 0.090 for fishing. Hunting, swimming, and camping follow with the second, third, and fourth largest responses. The smallest responses are seen to be in ice skating, bicycling, and tobogganing.

Table 22 shows a different kind of response. It indicates the number of new frequent participators resulting from better weather information. All of these individuals have activity scores of two for the respective activities.

Table 22

Impact on Frequent Participators

Activity	(1) Number of actual frequent participators	(2) Number of predicted frequent participators	(3) Increase
Hunting	229	255	26
Fishing	408	445	37
Camping	72	97	25
Hiking	143	153	10
Sledding	20	23	3
Tobogganing	9	10	1
Snow skiing	62	67	5
Snowmobiling	35	39	4
Ice skating	27	29	2
Swimming	271	292	21
Canoeing	47	52	5
Sailing	37	39	2
Motorboating	215	229	14
Water skiing	38	41	3
Picnicking	240	246	6
Horseback riding	8	8	0
Pleasure driving	376	380	4
Sport flying	12	13	1
Bicycling	83	83	0
Playing outdoor games and sports	272	277	5
Other	38	38	0

Column (3) shows the number of new frequent participators. Twenty-six individuals are shown to have become frequent hunters as a result of better weather information. Fishing had the largest response with thirty-seven new frequent participators. The smallest response is in bicycling with no new frequent participators. The reason activity scores and frequent participators are stressed in this analysis is that it is assumed that the precise number of times a respondent hunts or fishes during the year is less important for evaluating his welfare than the fact that he does participate frequently (five or more times per year).

Impact on National Participation

In Section II, it was found that the sample significantly differed from an older national sample in participation in pleasure driving, fishing, boating, and winter sports. The difference in pleasure driving will have to be tolerated because it involved a fundamental difference in definitions. There is no way to separate out this sample's participation in pleasure driving into "driving for sightseeing and relaxation," and some other component. However, adjustments can be made for fishing, boating, and winter sports. The model developed in the first part of this section was used a second time with adjustments made on the AP_i term (actual participation during the past twelve months) for fishing, boating (canoeing, sailing, motorboating, and water skiing), and winter sports (sledding, tobogganing, snow skiing, snowmobiling, and ice skating). Actual participation rates for fishing, the four components of boating, and the five components of winter sports were reduced by a constant percentage weight to lower the average activity scores to the ORRRC survey levels. The results of

Table 23

Adjusted Impact on the Nation

Activity	(1) Average increase in times done	(2) Average increase in activity score	(3) Increase in number of frequent participators	(4) Number predicted to increase
Fishing	1.44	0.072	31	309
Canoeing	0.05	0.007	3	16
Sailing	0.94	0.006	2	23
Motorboating	0.24	0.030	12	68
Water skiing	0.10	0.011	3	25
Sledding	0.01	0.006	2	5
Tobogganing	0.01	0.004	1	4
Snow skiing	0.21	0.016	4	40
Snowmobiling	0.05	0.006	3	11
Ice skating	0.03	0.003	2	7

these adjustments are presented in Table 23.

Column (1) contains the average increase in participation, and column (4) contains the number of respondents predicted to increase their participation. Glancing at the corresponding entries in Table 21 and Table 20, it can be seen that these numbers have not changed at all. This is a necessary result of the model, since AP_i, the only element which has been changed, does not directly enter into the computation of the increase component of increased participation, and hence, number of people who would increase their participation. The numbers in the middle two columns do, however, change. But the changes are extremely slight except in the case of fishing. Most of the inferences drawn directly from the sample, then, could be applied directly to the nation with little modification.

Socioeconomic Characteristics of Those Helped

The average increase in composite activity score was 0.491. This represents the average sum of all increases in activity scores. This amounts to a 5% increase in total recreational activity. To see precisely which classes of society would benefit the most from better weather information, respondents were placed into three groups: Those whose composite activity scores reflected no change; those whose composite activity scores rose by one; those whose composite activity scores rose by two or more. There were 484 respondents in the first group. This does not mean that these people did not increase participation at all. They could have increased participation in fishing, for example, from seven times per year to 100 without any change showing in either the fishing activity score or the composite activity score. Rather, this measure picks up changes from no participation at all to participating one to four times in an activity, and changes from participating one to four times in the activity to frequently participating in the activity. These, by assumption, are the important changes. Within each of the three groups, respondents are separated into categories by socioeconomic characteristics. Chi-square tests are applied to these groupings to determine whether or not significant differences exist among the groupings. Table 24 contains the results.

The results are rather surprising. There are no significant differences in characteristics by groupings. Hence, income distribution is the same for those who benefit much from better weather information as it is for those who do not benefit at all. At this point, however, it is necessary to qualify these findings. This survey was not truly representative in the sense of covering all classes in

Table 24

Socioeconomic Impact

Characteristic	Change in CAS 0	1	2+	Significance
Age of household head				
18 to 24	11	4	3	χ^2 = 19.844
25 to 34	68	22	17	DF = 10
35 to 44	98	46	17	Not signifi-
45 to 54	122	37	26	cant at .01
55 to 64	113	31	19	
65 and over	68	10	3	
Family income				
Under $5,000	41	6	8	χ^2 = 8.814
$5,000 to $7,999	54	17	6	DF = 8
$8,000 to $9,999	104	35	18	Not signifi-
$10,000 to $15,000	165	63	35	cant at .01
Over $15,000	103	27	13	
Education of household head				
Less than 9 years	38	9	6	χ^2 = 5.848
9 to 11 years	88	25	13	DF = 8
High school diploma	126	40	25	Not signifi-
Some college	111	46	24	cant at .01
College degree	117	30	16	
Family life cycle				
Single adult	41	14	2	χ^2 = 12.118
Married adult no children under 18	213	57	31	DF = 6 Not signifi-
Married adult Children under 6	124	46	35	cant at .01
Married adult Children 6 to 18	106	33	17	
Employment status of head				
Retired	67	11	8	χ^2 = 5.844
Not retired	417	138	88	DF = 2 Not signifi- cant at .01

society. Specifically excluded were the very poor in the cities and those on farms. This was done, as indicated in Section II, to get at the people expected to benefit from better weather information. The poor and those on farms were excluded because past studies have indicated that they rarely participate in the types of recreation considered in this study. Consequently, we cannot say that all income classes in society will benefit equally from this public project to improve weather predictions. On the contrary, we know that they will not. What we can say is that income, education, age, and the like do not influence the benefits received from better weather information among urban people who actually do engage in outdoor recreation. We can say that the rich urban yacht owners benefit no more than the less affluent urban boaters. We can say that retired urban people who recreate benefit as much as young urban people who recreate.

Predicted Impact on Recreational Participation (for heads of households)

1. Total average national participation in outdoor recreation should increase by approximately 5%.

2. The number of people who ski at least once during the year should increase by about 10%. Increases between 5% and 10% in the number of participants should occur in fishing, camping, outdoor games and sports (mainly golf and tennis), sport flying, water skiing, hunting, horseback riding, and sailing.

3. Over half of the people who currently fish should increase their annual participation in fishing. From 30% to 50% of the people who currently engage in the following activities should increase their annual participation: skiing,

hunting, sailing, camping, swimming, and water skiing.

4. Over 20% of all heads of households would increase participation in fishing, hunting, and swimming.

5. On the average, all households should fish about one and a half times per year. Annual average increases should be about 0.70 for hunting, 0.50 for swimming, 0.30 for camping, and 0.25 for outdoor games and sports and for motorboating.

Predicted Qualitative Impact

1. Crowding and congestion should occur in ski areas during periods of ideal skiing conditions, particularly on weekends.

2. Over a quarter of the urban households had at least one recreational experience spoiled by unanticipated rain during the past year. This spoilage may be nearly eliminated.

3. Over 80% of all skiers, and over 20% of all sailors, fishermen, and hunters prefer special types of weather for their respective forms of recreation. These people will be able to schedule their respective activities for periods when their preferred types of weather will occur.

4. In addition to increasing participation, accurate one-week weather forecasts would aid people in locating wildlife, selecting recreational clothes and equipment, and in driving.

Predicted Socioeconomic Impact

1. Among those people who currently engage in outdoor recreation of the types considered in this study, income, age, and retirement are not barriers to

benefitting from accurate one-week forecasts.

2. We do not know to what extent accurate one-week forecasts can be expected to benefit those not represented in this sample. As shown in Table 4, these are primarily those with less than average educations and paid vacations, and those living outside urban areas, especially farmers.

APPENDIX

Scanner's note:

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WEATHER INFORMATION IMPACT SURVEY

...To develop and apply models and methods for better understanding, forecasting, and planning socioeconomic systems.

Section I: FAMILY CHARACTERISTICS

PART A: THESE QUESTIONS PERTAIN TO THE HEAD OF YOUR FAMILY.

1. Age. ☐ 18-24 ☐ 35-44 ☐ 55-64
   ☐ 25-34 ☐ 45-54 ☐ 65 and over

2. Marital Status. ☐ Single ☐ Married
   ☐ Separated, divorced, widowed, other.

3. Sex. ☐ Male ☐ Female

4. Education. ☐ Less than 9 years ☐ Some College
   ☐ 9 to 11 years ☐ College degree
   ☐ High School degree

PART B: THESE QUESTIONS PERTAIN TO YOUR ENTIRE FAMILY.

1. Income. (Include spouse's income, if any.)
   ☐ under $5,000 ☐ $10,000 to $15,000
   ☐ $5,000 to $7,999 ☐ over $15,000
   ☐ $8,000 to $9,999

2. Housing. ☐ Farm ☐ Mobile home
   ☐ House ☐ Apartment. If so, is it a high rise?
   ☐ Yes ☐ No

3. Check the appropriate box if you have any of the following:
   ☐ Car ☐ Canoe, sailboat, or rowboat
   ☐ Summer Cottage ☐ Inboard or outboard motorboat
   ☐ Camper or travel trailer

Section II: EMPLOYMENT

DIRECTIONS: THESE QUESTIONS PERTAIN TO THE HEAD OF YOUR FAMILY.

1. What kind of work do you do? ______________________

   If retired, check here and skip this section. ☐

2. Check all of the following which pertain to your occupation:

   ☐ I work inside most of the time.

   ☐ I work outdoors most of the time.

   ☐ My work involves travel within and around the community in which I work.

   ☐ My work involves some overnight travel.

3. How many hours per week do you usually work?

   ☐ 20 or less　　☐ 45 to 60

   ☐ 21 to 34　　☐ over 60

   ☐ 35 to 44

4. Are you entitled to a paid vacation?

   ☐ No. (Please go to question 5.)

   ☐ Yes. If so, how many weeks per year? ________

   Can you select which weeks they will be?

   ☐ No.　　☐ Yes. If so, how much advanced notice must you give your employer before you can take a week or more off for a vacation?

   ☐ One week or less.

   ☐ One week to one month.

   ☐ More than one month.

5. Do you generally spend your annual vacation at home?

   ☐ Yes.　　☐ No.

Section III: OUTDOOR RECREATION

1. Did you go on any vacations or pleasure trips away from home during the last twelve months?

☐ No. ☐ Yes. If so, please answer the following:

	First Vacation Or Trip	Second Vacation Or Trip	Third Vacation Or Trip	Fourth Vacation Or Trip
How many days were you away from home on each of your vacations or trips? (If you had more than four vacations or trips, consider the four longest ones.)	____	____	____	____
Approximately how far from home did you go on each? (Check the applicable box for each vacation or trip.)				
Less than 100 miles.	☐	☐	☐	☐
100 to 250 miles.	☐	☐	☐	☐
250 to 1,000 miles.	☐	☐	☐	☐
Over 1,000 miles.	☐	☐	☐	☐

What forms of outdoor recreation, if any, did you or your family participate in on these vacations or pleasure trips?

First vacation or trip: ______________________________

Second vacation or trip: ______________________________

Third vacation or trip: ______________________________

Fourth vacation or trip: ______________________________

2. When you plan a weekend or holiday pleasure trip away from home, how early do you generally make the following decisions? (Check the appropriate box for each column.)

	When to go	How long to go	Where to go	What to do
Less than one day in advance.	☐	☐	☐	☐
One day to one week in advance.	☐	☐	☐	☐
One week to one month in advance.	☐	☐	☐	☐
Over one month in advance.	☐	☐	☐	☐

3. Approximately how many times during the last twelve months have you and the other members of your family done each of the outdoor recreation activities listed below? (Please enter the age and sex of all of your children, even infants.)

	Self	Spouse	Child 1 Age ___ Sex: ☐Boy ☐Girl	Child 2 Age ___ Sex: ☐Boy ☐Girl	Child 3 Age ___ Sex: ☐Boy ☐Girl	Child 4 Age ___ Sex: ☐Boy ☐Girl	Child 5 Age ___ Sex: ☐Boy ☐Girl	Child 6 Age ___ Sex: ☐Boy ☐Girl
Activity	Times Done	Times Done	Times Done	Times Done	Times Done	Times Done	Times Done	Times Done
Hunting								
Fishing								
Camping								
Hiking								
Sledding								
Tobogganing								
Snow skiing								
Snowmobiling								
Ice skating								
Swimming								
Canoeing								
Sailing								
Motorboating								
Water skiing								
Picnicking								
Horseback riding								
Pleasure driving								
Sport flying								
Bicycling								
Playing outdoor games and sports								
Other. Describe:								

4. Did you make plans for any vacations or pleasure trips away from home during the last twelve months which had to be modified at the last minute because of unanticipated bad weather?

☐ No. (Please go to question 5.)

☐ Yes. Please describe what happened. ____________

____

____

Did your original plans include any types of outdoor recreation activities?

☐ No.

☐ Yes. What types of outdoor recreation activities?

____

5. Do you participate in any forms of outdoor recreation which require a specific type of weather to be enjoyed? (Skiing, sailing, etc.)

☐ No. (Please go on to question 6.)

☐ Yes. What types of outdoor recreation?

____

6. Do you have one or two favorite recreation areas to which you have gone several times in the past few years?

☐ No. (Please go to question 7.)

☐ Yes. If so, please answer the following:

	Area One	Area Two
Where are they? City or county:	______	______
State:	______	______
What forms of recreation, if any, do you do there?	______	______
On the average, how often have you gone there each year?	______	______

If you knew for sure a week in advance what each week's weather would be like, would you go to these favorite sites more often?

☐ Yes, I would probably go there more often.

☐ No, I would probably go there about the same number of times as I have done in the past.

☐ No, I would probably go there less frequently.

7. What types of weather do you prefer for vacations and pleasure trips?

☐ No preference. (Please go to question 8.)

☐ I prefer the following types of weather:

Types of weather. (Check all that you prefer.)	Types of outdoor recreation, if any, I like to engage in during this type of weather.
☐ Warm, sunny and dry, windy.	
☐ Warm, sunny and dry, not windy.	
☐ Warm, cloudy or rainy, windy.	
☐ Warm, cloudy or rainy, not windy.	
☐ Cool, sunny and dry, windy.	
☐ Cool, sunny and dry, not windy.	
☐ Cool, cloudy or rainy, windy.	
☐ Cool, cloudy or rainy, not windy.	
☐ Other. Please describe: ______	

If you knew what the weather would be like up to one week in advance, do you think you would be able to take advantage of your favorite types of weather more often than in the past to participate in outdoor recreation activities?

☐ Yes. ☐ No.

8. Are there any forms of outdoor recreation activity which you would really like to do but just have not been able to find the right time to do in the last year or more?

☐ No. (Please go to question 9.)

☐ Yes. What types of outdoor recreation? ______

______

Do you think that if we had accurate one week weather forecasts, you would be able to find the time to begin to do these types of outdoor recreation?

☐ No. Better weather information would not help.

☐ Yes. Better weather information would help me to plan ahead and find the time to do these forms of outdoor recreation.

9. If you have any other remarks about the influence of better weather information on your recreation activities, please write them below:

THE POTENTIAL IMPACT OF ADVANCED SATELLITE WEATHER FORECASTING ON THE SKIING INDUSTRY: A CASE STUDY

James P. Gilligan and David D. Gow*

Introduction

The importance of outdoor recreation in the American social and economic environment is suggested by national data collected by the President's Outdoor Recreation Resources Review Commission in 1960. In the period June, 1960 to May, 1961, 90% of all Americans participated in some form of outdoor recreation on 4.4 billion occasions. At that time the Commission predicted a 50% increase in outdoor recreation participation by 1976. In 1967, however, the Bureau of Outdoor Recreation updated this figure. The data available for 1960-65 showed that outdoor recreation participation in summer had increased by 51%.

This growth in participation has been consistent with other changes in society at large: the increase in population, the economic boom of the sixties,

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Our appreciation is expressed to the members of the Space Science and Engineering Center and of NASA who established interdisciplinary meetings to provide guidance and integration of effort in the case study approach. We wish further to acknowledge the excellent cooperation of ski area owners and managers in their responses to field interviews and mail questionnaires.

Special thanks are also extended to Maurice L. Warner and Wayne L. Albrecht, Research Assistants, who contributed in major ways to parts of the project.

the higher levels of income, increasing leisure time, more formal education and increased mobility. Such variables as age, income, education, occupation, place of residence and, to a lesser extent, sex, help to determine who will or will not participate.

Skiing has been no exception to this boom. The data available on the growth of skiing over the past decade show a considerable degree of variance. To avoid bias, two sets of data are published: one from the U. S. Bureau of Outdoor Recreation and the other from Mr. R. A. Des Roches, executive vice president of Ski Industries America, which represents the manufacturers, distributors and retailers of skiing equipment in the United States. These data are personal estimates only and are not officially sanctioned by Ski Industries America.

Despite the sizeable differences in available estimates of skiing activity in the United States, there is general agreement on the rapid increase of skiing and ski area development during the past decade. The projections for skiing increase in the next decade agree with growth estimates for other kinds of outdoor recreation during this period. The present size of the ski industry is reflected, at minimum, in the estimate of nearly 5 million individual skiers and nearly a thousand ski areas. The economic value of this industry is suggested by Des Roches' data listing gross retail sales* for 1969-70 of $1. 14 billion with projections of a fourfold increase by 1979-80.

---

*Gross retail sales include all retail expenditures on ski clothing, equipment, footwear, accessories, lift tickets, travel, food, lodging, entertainment, etc.

Table 1. Skier Numbers and Growth in the United States

	Bureau of Outdoor Recreation	Des Roches*
No. of skiers in 1960	2,633,000	1,574,250
No. of skiers in 1965	5,650,000	2,754,250
% increase 1960-1965	115%	74%
No. of skiers in 1970		4,858,500
% increase 1965-70		76%
% increase 1960-70		208%
No. of skiers in 1980		13,795,200
% increase 1970-80		183%
Annual growth rate 1970-1980		10%
No. of ski shops (1970)		5,748
No. of ski areas (1970)		925

*Mr. Des Roches' figures are an aggregate of his estimates of "hard core" skiers, those who ski twelve or more days per year, and occasional skiers, those who ski fewer than twelve days per year, but visit ski areas and purchase clothing and equipment.

Purpose of Study

The purpose of this case study was to determine to what extent ski resort management and planning are currently influenced by weather conditions and weather forecasting and to estimate possible changes that may result from improved weather forecasting and communication.

Methodology

Several criteria were used in selecting the regions and specific ski operations to be sampled. Recognizing the probable differences in ski area weather conditions and management practices that exist between various sections of the United States, four regions were selected as a representative cross section of major ski area zones. The regions were California, Colorado, the Lake States (Michigan, Wisconsin, and Minnesota) and New England (Vermont and New Hampshire).

A second criterion was that all ski areas sampled should be within a half-day drive from major metropolitan centers. This factor was based upon preliminary field interviews that indicated the use of these areas comprised a major proportion of total United States skiing and that weather forecasting information and ski area management changes were more significant to one-day and week-end skiing activities than to more extended ski vacations. Ski sites closest to most major urban areas are often also the most variable in natural snow conditions suitable for skiing. More isolated ski areas appeared to be more heavily utilized by extended ski vacationers for whom day-to-day skiing weather variations were not a principal determinant of time and place for vacationing.

Efforts were also made to distribute the sample among ski areas of differing capacities, from small limited facility operations to major ski area complexes, to determine possible differences in use of weather forecasts as related to area management.

After preliminary visits to ski areas in California, Colorado and Wisconsin, a questionnaire was constructed and mailed to ski resort operators in the four principal sample regions guided by the criteria previously indicated. As a follow-up, personal observations and interviewing were also conducted at representative sites to check contradictions and accuracy of questionnaire responses.

Questionnaires were also mailed to several ski resorts outside the principal sample regions to determine if there were major deviations in conditions or responses from the principal sample regions. Response rate to the mailed questionnaire was 67.5% with a total of 166 respondents (see Table 2 and Figure 1).

Use data, showing number of skiers on a daily basis for a single season, were obtained for five resorts: three in Wisconsin, one in New Hampshire, and one in Colorado. These use data, together with corresponding daily weather data, were subjected to a regression analysis to reveal how significant past weather factors and day of week were in determining skiing use.

The study also included a review and analysis of existing published information related to the influence of weather and weather forecasting on skiing and ski resort management (see bibliography appended).

The questionnaire was designed to elicit information and data about the following aspects of ski resort planning and management:

1. Effects of weather on skiing use.
2. Most important weather factors in ski resort operations.
3. Effects of <u>present</u> weather forecasts on ski resort operations.
4. Effects that <u>improved</u> weather forecasts might have on <u>present</u> ski resort operations.
5. Effects that <u>improved</u> weather forecasts might have on <u>future</u> ski resort operations.

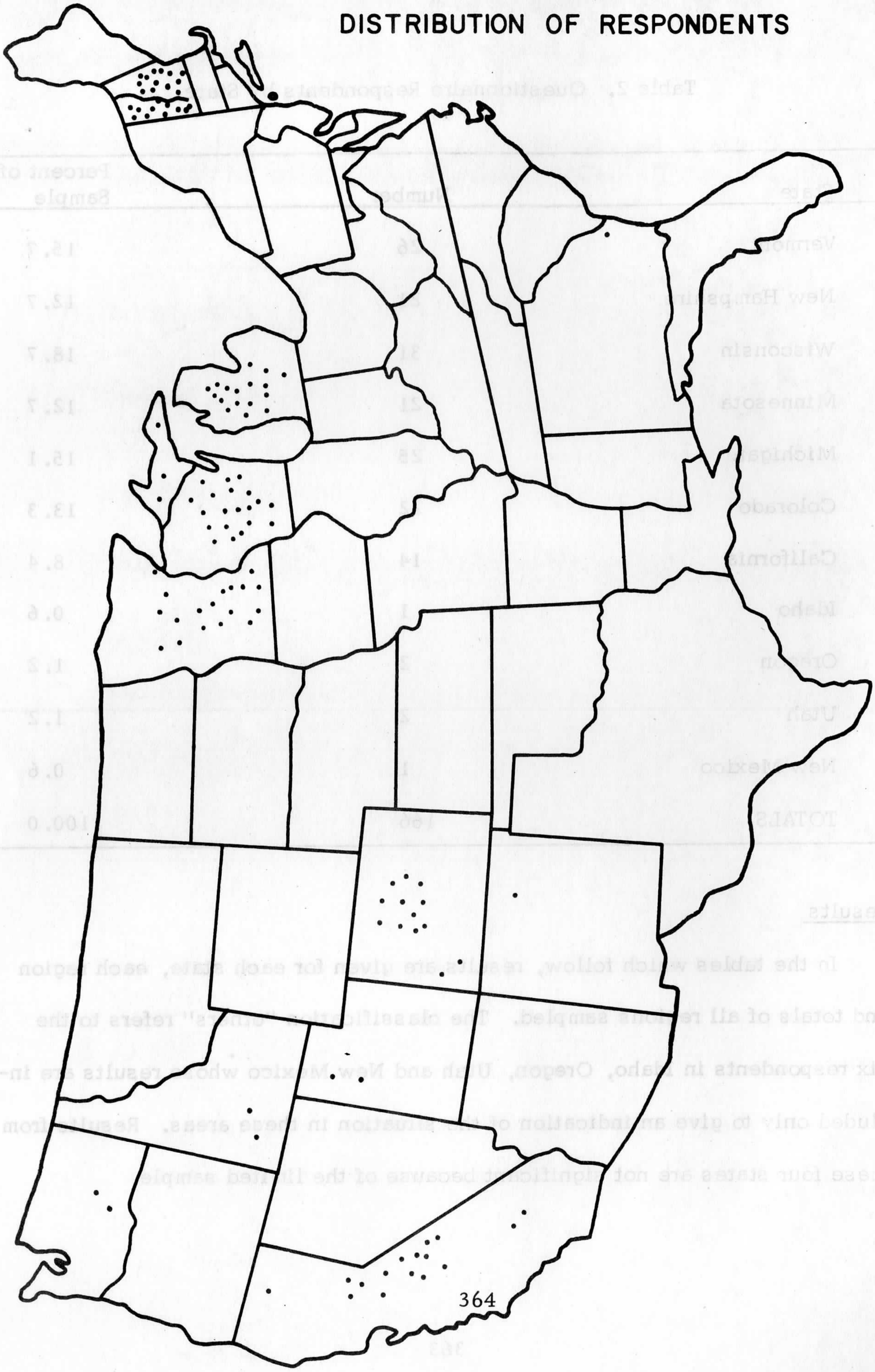
Table 2. Questionnaire Respondents by State

State	Number	Percent of Sample
Vermont	26	15.7
New Hampshire	21	12.7
Wisconsin	31	18.7
Minnesota	21	12.7
Michigan	25	15.1
Colorado	22	13.3
California	14	8.4
Idaho	1	0.6
Oregon	2	1.2
Utah	2	1.2
New Mexico	1	0.6
TOTALS	166	100.0

Results

In the tables which follow, results are given for each state, each region and totals of all regions sampled. The classification "others" refers to the six respondents in Idaho, Oregon, Utah and New Mexico whose results are included only to give an indication of the situation in these areas. Results from these four states are not significant because of the limited sample.

FIGURE 1.
DISTRIBUTION OF RESPONDENTS



SECTION I

1. Effects of weather on skiing use

Respondents indicated that individual weather factors of temperature, precipitation and wind and various combinations of these factors commonly caused adverse skiing conditions and a significant drop in skiing use (see Tables 3 and 4).

Winter rain and prolonged snow-melting temperatures followed by freezing temperatures and subsequent surface icing conditions were critical factors limiting skiing at periodic intervals in most regions of the country. These factors can also reduce snow to unacceptable skiing depths. However, in Colorado and California prolonged snow-melting temperatures were less critical factors, and in Colorado rain was indicated as a rare and unimportant influence on skiing use.

Although snow-melting temperatures are most critical influences on skiing use in several regions of the country, it should be noted that prolonged very cold temperatures also can reduce skiing activity, particularly in New England and the Lake States. Very low temperatures were less critical factors in California and Colorado.

Occasional seasons or periods of insufficient snowfall or excessive snowfall also ranked high as a predominant factor in limiting skiing, particularly in New England and California. These minimum or maximum periods of snowfall were less predominant in Colorado. Combinations of air moisture and temperature conditions producing fog or low cloud conditions obscuring visibility on ski slopes are also occasional detriments to skiing in a few regions.

Table 3. Number of Respondents Who Thought Specific Weather Factors Caused Decrease in Skiing Use

Weather factor	Rain	Icy slopes	Fog	High wind velocity	Wind direction	Very heavy snowfall	Insufficient snowfall	Blowing snow	Prolonged snow-melt temperatures	Prolonged cold spell	Avalanches	Road conditions
Vermont	24(24)	24(25)	16(23)	21(25)	10(21)	18(23)	18(22)	20(24)	22(22)	17(23)	0(22)	16(25)
New Hampshire	20(20)	20(21)	9(19)	16(20)	5(18)	12(20)	19(20)	11(19)	14(19)	15(21)	0(19)	6(20)
Wisconsin	28(30)	22(28)	9(26)	16(24)	10(24)	14(26)	21(29)	11(26)	24(28)	26(29)	0(24)	10(25)
Minnesota	17(19)	18(18)	2(17)	12(18)	5(16)	9(18)	13(18)	11(18)	12(17)	18(20)	1(17)	9(18)
Michigan	22(23)	19(20)	7(16)	15(19)	6(13)	8(17)	15(21)	8(16)	13(18)	10(17)	0(16)	10(19)
Colorado	1(19)	12(21)	7(19)	16(20)	5(18)	7(20)	13(21)	14(20)	10(19)	10(20)	3(20)	18(21)
California	11(13)	10(13)	6(14)	9(13)	7(11)	10(12)	10(13)	3(10)	6(12)	3(11)	2(13)	9(13)
Other	5(6)	5(5)	3(5)	6(6)	2(3)	5(5)	3(4)	4(5)	4(4)	4(5)	3(5)	5(5)
New England	44(44)	44(46)	25(42)	37(45)	15(39)	30(43)	37(42)	31(43)	36(41)	32(44)	0(41)	22(45)
Lake States	67(72)	59(68)	18(59)	43(61)	21(53)	31(61)	49(68)	30(60)	49(63)	54(66)	1(57)	29(62)
Nationally	128 (154)	130 (151)	59 (139)	111 (145)	50 (124)	83 (141)	112 (148)	82 (138)	105 (139)	103 (146)	9 (136)	83 (146)

The first number in each box is the number of respondents who felt that the specific weather factor under discussion did affect skiing use. The figure in parentheses is the total number of responses to each question.

Table 4. Percent of Respondents Who Thought Specific Weather Factors Caused Decrease in Skiing Use

	Rain	Icy slopes	Fog	High wind velocity	Wind direction	Very heavy snowfall	Insufficient snow	Blowing snow	Prolonged snow-melt temperature	Prolonged cold spell	Avalanches	Road conditions
Vermont	100	96	69.1	84	47.6	78.3	81.8	83.3	100	73.9	-	64
New Hampshire	100	95.2	47.4	80	27.7	60	95	57.9	73.7	71.4	-	30
Wisconsin	93.3	78.6	34.5	66.7	41.7	53.9	72.4	42.3	85.7	88.3	-	40
Minnesota	89.4	100	11.8	66.7	32.1	50	72.2	61.1	70.6	90	5.8	50
Michigan	95.6	95	43.7	78.9	46.1	47	71.4	50	72.2	58.8	-	52.6
Colorado	5.2	57.7	36.8	80	27.7	35	61.9	70	52.6	50	15	85.7
California	84.6	76.9	42.9	69.2	63.6	83.3	79.9	30	50	27.3	15.4	69.2
Other	83.3	100	60	100	666.7	100	75	80	100	80	60	100
New England	100	95.6	59.5	82.2	39.5	69.7	88	72.6	87.8	72.7	-	48.9
Lake States	93	89.4	35.1	70.5	32.6	50.8	72	50	77.7	81.8	1.8	46.7
Nationally	83.1	86.1	42.4	76.5	40.3	58.8	75.7	59.4	75.5	70.6	6.6	56.8

These percentages are based on information provided in Table 3. If 40% or more of respondents in any region thought a weather factor influenced skiing use, then it was included in the summary.

Another predominant weather factor having important impact on skiing volume in all regions is wind velocity. High velocity winds cause uncomfortable skiing environments, snow drifting over packed ski slopes, "white out" visibility reduction and occasional shut-down of ski lifts. Wind direction was also cited as an important factor in California areas but was relatively unimportant in other regions.

Many ski area operators, especially in the western states, indicated that winter road conditions leading from metropolitan areas to ski sites often played a significant role in determining amounts of skiing use at specific times.

SECTION 2

2a. Weather Forecast Factors of Importance to Ski Resort Operators

Respondents were asked which items they regularly checked in available weather forecasts. Nationally, the most important factors were temperature, precipitation and wind velocity. Of these, temperature and precipitation were indicated in all regions as of primary importance with wind velocity of lesser significance. Cloud cover was included as a minor factor in checking weather forecasts. These responses coincide with the important factors listed in Section 1 and are tabulated for each state in Table 5.

2b. Sources utilized for Weather Forecasts

Ski resort operators obtain weather forecast information primarily from the following sources: 1) local radio and TV stations; 2) direct weather bureau station reports (e.g., airports); and 3) private weather forecasting firms.

The large majority obtained their information from local or regional radio

Table 5. Percentage Distribution of Specific Weather Factors Regularly Checked in Weather Forecasts by Respondents

	Specific Weather Factor					
	Temp.	Precipi-tation	Wind Velocity	Cloud Cover	Other	None
Vermont (26)	92.3(24)	96.2(25)	69.2(18)	50(13)	3.8(1)	0.0(0)
New Hampshire (21)	85.7(18)	90.5(19)	57.1(12)	38.1(8)	0.0(0)	4.8(1)
Wisconsin (31)	87.1(27)	74.2(23)	38.7(12)	22.6(7)	3.2(1)	6.4(2)
Minnesota (21)	85.7(18)	80.9(17)	42.9(9)	19.0(4)	0.0(0)	4.8(1)
Michigan (25)	80.0(20)	84.0(21)	40.0(10)	24.0(6)	0.0(0)	12.0(3)
Colorado (22)	63.6(14)	72.7(16)	50.0(11)	31.8(7)	13.6(3)	4.5(1)
California (14)	78.6(11)	71.4(10)	35.7(5)	28.6(4)	7.1(1)	0.0(0)
Other (6)	66.7(4)	83.3(5)	50.0(3)	50.0(3)	16.7(1)	0.0(0)
New England (47)	89.4(42)	93.6(44)	63.8(30)	44.7(21)	2.1(1)	2.1(1)
Lake States (77)	84.4(65)	79.2(61)	40.3(31)	22.1(17)	1.3(1)	7.8(6)
National (166)	81.9(136)	81.9(136)	48.8(81)	31.3(52)	4.2(7)	4.8(8)

If 40% or more of respondents checked a specific weather factor, then this factor was regarded as significant and included in the summary. The figure in parentheses after each state is the number of respondents from that state who answered the question. The figure in the box is the percentage of respondents who answered that particular part of the question. The figure in parentheses after each percentage is the number of respondents who answered that particular part of the question. <u>This format is used in all subsequent tables unless otherwise stated.</u> Often the row totals for each state will exceed 100%. This is because respondents may have checked more than one part of the question.

and TV stations, and nearly half of the ski resort operators responding utilized direct weather bureau station reports. About 17% employed the services of private weather forecasting firms, particularly in New England, Michigan and Colorado (see Table 6).

2c. Accuracy of Present Weather Forecasts

Nationally, respondents felt that one-day and five-day weather forecasts were the most accurate. This was true on a regional level with the exception of Michigan and Minnesota where five-day forecasts were regarded as more accurate than one-day forecasts. However, 44.7% of the respondents felt that present weather forecasts, irrespective of their length, were too inaccurate to cause any changes in planning or management.

This skepticism was particularly noticeable in Colorado (59.1%), Wisconsin (51.6%), California (50%) and New Hampshire (47.6%). For some respondents, however, hope springs eternal—thirteen checked all four categories in Table 7.

SECTION 3

3. Effects of Present Weather Forecasts on Ski Resort Management

In the previous section concerning the accuracy of weather forecasts and their influence on management, 44.7% of respondents indicated that none were accurate enough, thus implying that they made no changes in response to weather information. In this section respondents were asked what changes they made in response to weather forecast information, and 28.9% did not respond. Is it fair to assume that they made no changes?

On closer inspection some of those who had earlier admitted that they

Table 6. Sources Used by Ski Resort Operations for Obtaining Weather Forecast Information

	Source				
	1	2	3	4	5
Vermont (26)	92.3(24)	34.6(0)	42.3(11)	0.0(0)	0.0(0)
New Hampshire (21)	80.9(17)	42.9(9)	19.0(4)	4.8(1)	0.0(0)
Wisconsin (31)	80.6(25)	45.2(14)	3.2(1)	9.7(3)	3.2(1)
Minnesota (21)	90.5(19)	33.4(7)	4.8(1)	4.8(1)	4.8(1)
Michigan (25)	68.0(17)	40.0(10)	28.0(7)	8.0(2)	0.0(0)
Colorado (22)	81.8(18)	45.5(10)	13.6(3)	18.2(4)	4.5(1)
California (14)	64.3(9)	64.3(0)	7.1(1)	7.1(1)	0.0(0)
Other (6)	83.3(5)	100 (6)	0.0(0)	16.7(1)	0.0(0)
New England (47)	87.2(41)	38.3(18)	31.9(15)	2.1(1)	0.0(0)
Lake States (77)	79.2(61)	40.3(31)	11.7(9)	7.8(6)	2.6(2)
National (166)	80.7(134)	44.6(74)	16.9(28)	7.8(13)	1.8(3)

would make no changes, in this section admitted that they did. Some of those who had earlier admitted that they would make changes did not bother to answer this section. These contradictions indicate that perhaps ski resort operators do not like to admit weather forecasts have any marked effects on their planning or management and that they themselves are unclear in their own minds about exactly which length of forecast does affect management, if at all. However one interprets these inconsistencies, it is clear that many ski resort operators in the sample were highly skeptical of weather forecasts, although in field

Table 7. Lengths of Forecast Regarded as Most Accurate by Respondents

	Length of Forecast			
	1-day	5-day	30-day	None
Vermont (26)	61.6(16)	38.4(10)	-	34.6(9)
New Hampshire (21)	42.9(9)	19.0(4)	-	47.6(10)
Wisconsin (31)	41.9(13)	19.4(6)	-	51.6(16)
Minnesota (19)	31.6(6)	63.2(12)	-	31.6(6)
Michigan (24)	37.5(9)	50.0(12)	20.8(5)	33.4(8)
Colorado (22)	36.4(8)	13.6(3)	-	59.1(13)
California (14)	57.1(8)	28.6(4)	-	50.0(7)
Others (6)	50.0(3)	50.0(3)	-	66.7(4)
New England (47)	53.2(25)	29.8(14)	-	40.4(19)
Lake States (74)	37.8(28)	40.5(30)	6.8(5)	40.5(30)
National (163)	44.2(72)	33.1(54)	3.1(5)	44.7(73)

interviews operators did concede after reflection that accurate weather forecasts would play an important role in their daily and weekly planning and management.

Nationally, the management aspects affected by weather-forecast information ranked in order of importance were:

1. planning personnel numbers
2. ordering restaurant and ski shop supplies
3. planning personnel deployment
4. advertising

Regionally, this pattern held true for New England and the Lake States. In

Colorado "planning personnel deployment" and "planning personnel numbers" occupied first place. In California the ranking was as follows (only 8 respondents):

1. ordering supplies
2. planning personnel deployment
3. advertising
4. planning personnel numbers

The results are tabulated in Table 8.

SECTION 4

4. Effects That Improved Weather Forecasts Might Have on PRESENT Ski Resort Operations

Respondents were asked to check off the following from a list of ten aspects of ski resort operations:

a. those aspects which could be carried out more efficiently with better forecasts

b. the length of forecast required

c. the critical weather factors that would have to be included in this forecast

a. Aspects. Nationally, the aspects most likely to be affected are: 1) season opening date; 2) slope care; and 3) number of employees. Regionally, there were certain differences. These differences are presented in Tables 9 and 10. A cross in Table 9 indicates that 40% or more of the respondents said that particular aspect of ski management would be affected by improved weather forecasts. Table 10 shows the percentage response for each management aspect by

Table 8. Aspects of Ski Area Management Affected by Weather-Forecast Information

	Aspect			
	a	b	c	d
Vermont	62.5(15)	50.0(12)	37.5(9)	37.5(9)
New Hampshire (18)	77.8(14)	44.4(8)	38.9(7)	66.7(12)
Wisconsin (19)	73.7(14)	31.6(6)	36.8(7)	52.6(10)
Minnesota (18)	72.2(13)	50.0(9)	38.9(7)	61.1(11)
Michigan (16)	93.8(15)	75.0(12)	25.0(4)	81.2(13)
Colorado (12)	66.7(8)	66.7(8)	16.7(2)	41.7(5)
California (8)	12.5(1)	37.5(3)	25.0(2)	62.5(5)
Others (3)	33.3(1)	100 (3)	33.3(1)	33.3(1)
New England (42)	69.0(29)	47.6(20)	38.1(16)	50.0(21)
Lake States (53)	79.2(42)	50.9(27)	35.1(18)	64.2(34)
National (118)	68.6(81)	50.2(61)	33.1(39)	55.9(66)

a. Planning personnel numbers
b. Planning personnel deployment
c. Advertising
d. Ordering restaurant and ski shop supplies

state and region.

b. Length of forecast required. Respondents were asked to specify the length of forecast required for each management aspect that they checked off. The results are an aggregate of the responses to the eight aspects listed in Table 11. It was felt that one comprehensive table would be more useful than eight separate ones. When and if improved weather forecasts are introduced, it is

Table 9. Management Aspects Which Would be Affected by Improved Weather Forecasts by Region

Management Aspect	Season opening	Season closing	Roads and parking	Slope care	Snow making	Advertising	Stocking of food and ski shop items	Number of employees
Nationally	X			X				X
New England	X	X	X	X		X	X	X
Lake States	X	X		X	X			X
California	X		X	X		X	X	X
Colorado	X		X	X				

unlikely there will be eight distinct types of forecasts for ski areas. Much more likely is one comprehensive forecast.

Nationally, the lengths of forecast desired are predominantly of four types, with relatively minor differences in the following order of importance:

1. one week
2. one day
3. five day
4. three day

Regionally, the same lengths of forecasts are desired though often in a different order of importance. Colorado is the exception where one-month forecasts are the most popular. The results are listed in Table 11. The number after each state is the number of responses from that state to the eight management aspects

Table 10. Percentage of Respondents Who Thought Specific Aspects of Management Would Be Affected By Improved Weather Forecasts

	Season opening	Season closing	Road & parking area maintenance	Slope care	Snow making	Advertising	Avalanche control	Equipment & facilities maintenance	Stocking of food and ski shop items	Number of employees
Vermont (26)	57.7(15)	34.6(9)	53.8(14)	61.6(16)	38.4(10)	46.2(12)	-	15.4(14)	34.6(9)	46.2(12)
New Hampshire (21)	76.2(16)	47.6(10)	23.8(5)	57.1(12)	23.8(5)	47.6(10)	-	28.6(6)	61.9(13)	66.7(14)
Wisconsin (31)	64.5(20)	29.0(9)	25.8(8)	41.9(13)	51.6(16)	38.7(12)	3.2(1)	12.9(4)	25.8(8)	32.6(10)
Minnesota (21)	85.7(18)	61.9(13)	38.1(8)	38.1(8)	52.4(11)	38.1(8)	-	4.8(1)	38.1(8)	47.6(10)
Michigan (25)	52.0(13)	40.0(10)	20.0(5)	40.0(10)	40.0(10)	28.0(7)	-	12.0(4)	32.0(8)	48.0(12)
Colorado (22)	59.1(13)	22.7(5)	50.0(11)	59.1(13)	18.2(4)	27.2(6)	27.2(6)	22.7(5)	13.6(3)	31.8(7)
California (14)	64.3(9)	35.7(5)	50.0(7)	42.9(6)	21.5(3)	42.9(6)	14.3(2)	28.6(4)	50.0(7)	50.0(7)
Other (6)	83.3(5)	-	66.7(4)	83.5(5)	-	50.0(3)	50.0(3)	-	33.3(2)	50.0(3)
New England (47)	65.9(31)	40.4(19)	40.4(19)	59.6(28)	31.9(15)	46.8(22)	-	21.3(10)	46.8(22)	55.3(26)
Lake States (77)	66.2(51)	41.6(32)	27.3(21)	40.3(31)	48.1(37)	35.1(27)	1.3(1)	10.4(8)	31.2(24)	41.6(32)
National (166)	65.7(109)	36.7(61)	37.4(62)	50.0(83)	35.5(59)	38.6(64)	7.2(12)	16.3(27)	34.9(58)	45.2(75)

Table 11. Percentage Distribution of Respondents Desiring Specific Length of Weather Forecast

	Length of Forecast							
	1 day	3 days	5 days	1 week	2 weeks	3 weeks	1 month	Over 1 month
Vermont (97)	30.9(30)	22.7(22)	20.7(20)	18.6(18)	2.0(2)	-	4.1(4)	1.0(1)
New Hampshire (85)	28.3(24)	18.8(16)	29.4(25)	17.6(15)	3.5(3)	-	2.4(2)	-
Wisconsin (96)	20.8(20)	16.7(16)	9.4(9)	34.4(33)	4.2(4)	3.1(3)	10.4(10)	1.0(1)
Minnesota (84)	16.7(14)	11.9(10)	19.0(16)	23.8(20)	14.3(12)	1.2(1)	13.1(11)	-
Michigan (75)	14.7(11)	13.3(10)	14.7(11)	30.7(25)	17.3(13)	-	9.3(7)	-
Colorado (62)	19.4(12)	17.7(11)	16.1(10)	12.9(8)	6.5(4)	1.6(1)	22.6(14)	3.2(2)
California (50)	16.0(8)	8.0(4)	34.0(17)	16.0(8)	6.0(3)	-	8.0(4)	12.0(6)
Other (22)	13.6(3)	22.7(5)	18.2(4)	9.1(2)	18.2(4)	-	9.1(2)	9.1(2)
New England (182)	29.7(54)	20.9(38)	24.7(45)	18.1(33)	2.7(5)	-	3.3(6)	0.6(1)
Lake States (255)	17.6(45)	14.1(36)	14.1(36)	29.8(76)	11.4(29)	1.6(4)	11.0(28)	0.4(1)
National (571)	21.4(122)	16.5(94)	19.6(112)	22.2(127)	7.9(45)	0.9(5)	9.5(54)	2.1(12)

in Table 9. The number in brackets in each box is this number according to the length of weather forecast desired.

c. Critical weather factors involved. Respondents were asked to specify the critical weather factors involved in each management aspect that they checked off. The results are an aggregate of the responses to the eight aspects listed in Table 9. Nationally, the critical weather factors involved, in order of importance, are:

1. snow
2. temperature
3. humidity
4. wind

Of these snow and temperature forecasts are of predominant importance. There are certain regional variations in terms of precedence which are shown in Table 12. The number after each state is the number of responses from that state to the eight management aspects in Table 9. These totals are smaller than those given in Table 11 because some respondents, while they checked off the management aspect, did not specify the critical weather factors involved. The numbers in brackets are a breakdown of the total in terms of specific weather factors.

Respondents were also asked to predict how skiers would respond if more accurate weather information were available. Nationally, 60.5% predicted there would be more skiers as a result of favorable forecasts and fewer skiers as a result of unfavorable forecasts. However, 29.9% predicted no changes in

Table 12. Specific Weather Forecast Factors Desired by Respondents

	Specific Weather Factor				
	Temp.	Snow	Humidity	Wind	Rain
Vermont (74)	58.1(43)	77.0(57)	25.7(19)	32.4(24)	2.7(2)
New Hampshire (76)	65.8(50)	82.9(63)	35.5(27)	22.3(17)	2.6(2)
Wisconsin (65)	75.4(49)	64.6(42)	27.7(18)	23.1(15)	1.5(1)
Minnesota (58)	70.7(41)	65.5(38)	31.0(18)	19.0(11)	3.4(2)
Michigan (52)	76.9(40)	84.6(44)	48.1(25)	15.4(8)	-
Colorado (44)	47.7(21)	84.1(37)	22.7(10)	22.7(10)	-
California (26)	30.8(8)	92.4(24)	7.7(2)	15.4(4)	-
Other (13)	30.8(4)	92.3(12)	30.8(4)	23.1(3)	-
New England (150)	62.0(93)	80.0(120)	30.7(46)	27.3(41)	2.7(4)
Lake States (175)	74.3(130)	70.9(124)	34.9(61)	19.4(34)	1.7(3)
National (408)	62.7(256)	77.7(317)	31.5(123)	22.5(92)	1.7(7)

use as a result of improved weather forecasting. This pattern holds true regionally with the exception of California where there was more optimism. Is this pessimism justified? There is some evidence from field interviews to suggest that skiers in some regions are influenced more by existing weather in their resident location than by favorable weather forecasts for ski areas in their region: e.g., "I may intend to go skiing fifty miles away; but when I get up on Saturday morning, there's a blizzard blowing outside. Irrespective of the weather forecast or conditions reported at the ski site, I return to bed and give up all thoughts of skiing for that weekend." The results are tabulated in Table 13.

Table 13. Respondents' Opinions of How Skiers Would React to Improved Weather Forecasts

	Predicted Response			
	1	2	3	4
Vermont (24)	62.5(15)	33.8(8)	4.2(1)	-
New Hampshire (20)	70.0(14)	25.0(5)	5.0(1)	-
Wisconsin (30)	50.0(15)	33.3(10)	13.3(4)[a]	3.3(1)
Minnesota (19)	63.2(12)	31.6(6)	5.2(1)	-
Michigan (22)	68.2(15)	31.8(7)	-	-
Colorado (22)	45.4(10)	31.8(7)	18.2(4)[b]	4.6(1)
California (14)	71.4(10)	14.3(2)	14.3(2)[c]	-
Other (6)	66.7(4)	33.3(2)	-	-
New England (44)	65.9(29)	29.5(13)	4.6(2)	-
Lake States (71)	59.2(42)	32.4(23)	7.0(5)	1.4(1)
National (157)	60.5(95)	29.9(47)	8.3(13)	1.3(2)

Column 1 — much larger crowds at "good" times; much smaller crowds at "poor" times

Column 2 — no change likely

Column 3 — other (see footnote)

Column 4 — 1 + 3

[a] a. "perhaps a better understanding by the skier when conditions are good or bad"
b. "skiers are very fickle—never know"
c. "more consistent crowds"
d. "change would be small"

[b] a. "large crowd always"
b. "the only loss in skier use is from bad road conditions on the mountain passes"
c. "more predictable volume of skiers"
d. "much larger crowds at 'good' times"

[c]a. "better use in marginal weather times that are now inaccurately reported as 'poor' or worse!"
b. "there is so little trust in forecasts, people just come when they can"

SECTION 5

5. Effects That Improved Weather Forecasts Might Have on Future Ski Resort Operations

Nationally, ski resort operators said they would do the following if improved weather forecasts were available: 1) make week-to-week personnel arrangements more flexible; or 2) greater promotion of skier group contracts and activities. However, 35.5% of respondents said they would make no changes as use fluctuations would pose no new problems or possibilities. Field interviews indicated that most operators were highly optimistic of their abilities to handle sizeable increases of skiers on any given day. Skier reactions, however, suggest that ski areas and facilities have saturation limits when skiers begin to seek sites of lower density use. Regionally, the same pattern held true for New England and the Lake States. In Colorado and California the order of preference was reversed, and the percentage of those who would make no changes decreased, 30% and 21.4% respectively. The results are shown in Table 14.

At the time this survey was conducted, during the spring of 1970, season ticket holders and group contracts accounted for only a small percentage of total skiing use in the areas surveyed. Nationally, 76.8% of respondents indicated that season tickets and group contracts accounted for 25% or less of their total skiing use. Regionally, more than 70% of respondents in each area

Table 14. Percentage Distribution of Possible Changes Resulting From Improved Weather Forecasts

	Changes					
	1	2	3	4	5	6
Vermont (24)	20.8	4.2	12.5	29.2	250.0	8.5
New Hampshire (19)	36.8	26.3	26.3	36.8	31.6	-
Wisconsin (30)	40.0	33.3	16.7	30.0	43.3	-
Minnesota (19)	47.4	36.8	15.8	47.4	31.6	-
Michigan (21)	19.0	33.3	23.8	47.6	28.6	-
Colorado (20)	40.0	5.0	5.0	35.0	30.0	10.0
California (14)	50.0	14.3	-	35.7	21.4	14.3
Others (5)	20.0	40.0	-	20.0	40.0	20.0
New England (43)	27.9	14.0	18.6	32.6	41.9	4.7
Lake States (70)	35.7	34.3	18.6	40.0	35.7	-
National (152)	34.9	23.0	14.5	36.2	35.5	4.6

Column 1 — greater promotion of group contracts and season tickets
Column 2 — add to ski area facilities
Column 3 — develop alternative recreation activities (indoor or outdoor)
Column 4 — make week-to-week personnel arrangements more feasible
Column 5 — no changes
Column 6 — other

indicated the same results and in California the percentage jumped to 92.9%. There would appear to be a large potential for promoting group contracts and season tickets. The results are given in Table 15.

It was suspected that the size of the operation might have some effect on the potential for change. The majority of respondents handled less than

Table 15. Percentage Distribution of Season Ticket Holders and Group Contracts

	Percentage of Season Ticket Holders and group contracts		
	0-25%	26-50%	More than 50%
Vermont (26)	73.1	23.1	3.8
New Hampshire (21)	76.2	23.8	-
Wisconsin (29)	75.9	17.2	6.9
Minnesota (21)	90.4	4.8	4.8
Michigan (25)	68.0	24.0	8.0
Colorado (22)	72.7	27.3	-
California (14)	92.9	7.1	-
Other (6)	66.7	33.3	-
New England (47)	74.5	23.4	2.1
Lake States (75)	77.3	16.0	6.7
National (164)	76.8	19.5	3.7

50,000 skiers annually. The breakdown is shown in Table 16.

When size is cross-tabulated with the most popular changes in Table 14, greater promotion of group contracts and season tickets, making week-to-week personnel arrangements more flexible, and no changes whatsoever, these operations handling up to 100,000 skiers a year have the greatest potential for change. This is shown by the results in Table 17.

Table 16. Size of Skiing Operations

Size	Number	Percent
less than 50,000 skiers	112	67.5
50,000 - 100,000 skiers	26	15.7
100,000 - 150,000 skiers	22	13.2
more than 150,000 skiers	6	3.6
	166	100.0

Table 17. Percentage Distribution of Most Popular Changes by Size of Operation

	Changes		
	1	4	5
less than 50,000 (104)	33.6	36.5	37.5
50,000 - 100,000 (24)	37.5	37.5	25.0
100,000 - 150,000 (19)	42.1	26.3	36.3
more than 150,000 (5)	20.0	60.0	40.0

Column 1 — greater promotion of group contracts and season tickets
Column 4 — more flexible personnel arrangements
Column 5 — no changes

These percentages are percentages of the total number of respondents for each size category. The results for those operations handling more than 150,000 skiers are not significant due to the size of the sample.

Relationship of Weather Factors to Actual Skiing Use

As an adjunct to the questionnaire responses, an evaluation was made on the relationship of weather factors to actual skiing use at several selected areas. Using daily use records for a recent ski season and corresponding daily weather records for the selected ski areas, the data were subjected to regression analyses. The objective was to determine if there were significant correlations between various weather factors and amounts of skiing use on specific days.

Analyses on use and weather variables were conducted for the following areas:

Alpine Valley, Madison, Wisconsin	1968-69 season
Trollhaugen, Dresser, Wisconsin	1969-70 season
Loveland Basin, Georgetown, Colorado	1968-69 season

Two other areas, one in New Hampshire and one in Wisconsin, were also included in the regression analyses, but the results were omitted from this report because of insufficient data.

The weather variables analyzed were maximum temperature, new snow, snow-on-ground, sky cover, average wind speed, wind direction, barometric pressure and percent of possible sunshine. The only variables remaining in the equation, using a .10 in and .25 out, were maximum temperature, average wind speed and snow-on-ground. The use variable was the dependent variable regressed on the days of the week and the weather variables listed above. Two equations were determined for each site:

1. Days of week as base (independent) variables and weather variables as free (independent) variables.
2. All independent variables as free variables.

In the summary that follows, attention should be given to the coefficient of determination (r^2) and to the significance level of the F-ratio. The coefficient of determination represents the fraction of the total variation of the dependent variable (use) explained by all independent variables currently in the equation and $1 - r^2$ is the fraction of the total variation that is unexplained. The significance level of the F-ratio indicates whether the entire equation as listed is significant and can be used for forecasting skiing use given the values of the independent variables in the final equation. A value below .10 or .05 is normally considered adequate for showing it is significant. In all analysis for this project it was 0.00 and all equations would be considered significant.

The results of the regression analyses show consistency among the various areas studied regarding use and the independent variables Saturday, Sunday, wind, temperature and snow-on-ground. Two equations for each area were included because the r^2 values could be increased by allowing additional variables into the equations. The variables included were frequently not as significant as desired and contributed very little to the predictive value of the equation. Considering the small increase in r^2 gained by including these insignificant variables, the free variable model (equation 2) would appear to be superior to the base variable—free variable model (equation 1) in all cases.

Selecting the three equations with the better coefficient of determination, one from each area, we have coefficients of 49.5%, 62.9% and 58.6%, respectively. These leave 50.5%, 37.1% and 41.4% respectively of unexplained variation. Since the analysis contained all the weather variables available as reported in the local climatological data summaries published by the U. S. Department of Commerce, it would seem reasonable to attribute this unexplained variation in use to nonweather variables. We feel that nonweather variables such as slope care, presence of snow-making equipment, and advertising could be included in the model.

In their answers to the questionnaire, respondents indicated a need for accurate short-range forecasts in making decisions about advertising and slope care. In a study by Echelberger and Shafer, advertising alone had a high predictive value. Therefore, it seems likely that the inclusion of these non-weather but weather-related variables would increase the coefficient of determination. We were unable to include them in the model due to lack of data at this time.

Alpine Valley

1) Days as base variables

$$Y_c = 815.32 + 1501.69X_1 + 1932.75X_2 + 686.71X_3 + 428.30X_4 + 577.86X_5 + 697.99X_6 + 860.48X_7 - 17.03X_8 - 40.58X_9 + 41.15X_{10}$$

X_1 = Saturday

X_2 = Sunday

X_3 = Monday

X_4 = Tuesday

X_5 = Wednesday

X_6 = Thursday

X_7 = Friday

X_8 = Temperature

X_9 = Average wind speed

X_{10} = Snow-on-ground

Coefficient of determination is .4948 (49.5%). The variables significant at the .05 level are Saturday, Sunday, temperature and average wind speed. Significance level of F-ratio = 0.0000

Alpine Valley

2) All free variables

$$Y_c = 1353.87 + 863.48X_1 + 1311.78X_2 + 41.84X_3 - 16.33X_4 - 32.87X_5$$

X_1 = Saturday

X_2 = Sunday

X_3 = Snow-on-ground

X_4 = Temperature

X_5 = Average wind speed

Coefficient of determination is .4730 (47.3%). All variables are significant at the .10 level and all except average wind speed and snow-on-ground at the .05 level.
Significance level of F-ratio = 0.0000

Trollhaugen

1) Days as base variables

$$Y_c = -199.367 + 784.921X_1 + 908.526X_2 - 123.025X_3 - 183.783X_4 - 185.368X_5 - 68.424X_6 + 14.780X_7 - 95.119X_8 + 41.182X_9 - 21.306X_{10}$$

X_1 = Saturday

X_2 = Sunday

X_3 = Monday

X_4 = Tuesday

X_5 = Wednesday

X_6 = Thursday

X_7 = temperature

X_8 = new snow

X_9 = snow-on-ground

X_{10} = wind

Coefficient of determination is .6287 (62.9%). The variables significant at the .05 level are Saturday, Sunday, temperature, new snow and snow-on-ground. Wind is significant at the .10 level and the others are significant within the .20-.65 interval. Consequently, they would be regarded as insignificant and as contributing little to the predictive value of the equation.
Significance level of F-ratio = 0.0000.

Trollhaugen

2) All free variables

$$Y_c = -328.838 + 14.874X_1 + 41.404X_2 - 94.410X_3 - 20.094X_4 + 899.864X_5 + 1020.398X_6$$

X_1 = Temperature

X_2 = Snow-on-ground

X_3 = New Snow

X_4 = Wind

X_5 = Saturday

X_6 = Sunday

Coefficient of determination is .6202 (62.0%). Variables significant at the .05 level are X_1, X_2, X_3, X_5 and X_6. All variables are significant at the 0.10 level and the constant is significant at the .1395 level.
Significance level of F-ratio = 0.0000.

Loveland Basin

1) Days as base variables

$$Y_c = 763.310 + 797.775X_1 + 781.805X_2 - 244.077X_3 - 172.095X_4 - 51.182X_5 - 67.763X_6 - 10.355X_7 - 9.002X_8 + 4.082X_9$$

X_1 = Saturday

X_2 = Sunday

X_3 = Monday

X_4 = Tuesday

X_5 = Wednesday

X_6 = Thursday

X_7 = Temperature

X_8 = Snow-on-ground

X_9 = Wind

Coefficient of determination is .5857 (58.6%). Variables significant at .05 level are X_1, X_2, X_3, X_7, X_8 and X_9. Variables X_4, X_5 and X_6 are significant within the .1031 - .6248 interval.
Significance level of F-ratio = 0.0000.

Loveland Basin

2) All free variables

$$Y_c = 706.117 + 855.017X_1 + 868.340X_2 + 4.065X_3 - 10.403X_4 - 9.912X_5 - 172.426X_6$$

X_1 = Sunday

X_2 = Saturday

X_3 = Wind

X_4 = Temperature

X_5 = Snow-on-ground

X_6 = Monday

Coefficient of determinatin is .5793 (57.9%). All variables are significant at the .05 level.
Significance of F-ratio = 0.0000.

SUMMARY

At the present time ski resort operators are interested in weather forecasts containing information on temperature, precipitation and wind velocity. They favor one-day and five-day weather forecasts and the majority currently utilize local radio and television broadcasts for weather-forecast information. The ski resort management aspects affected by weather forecasts are planning personnel numbers, ordering restaurant and ski shop supplies, planning personnel deployment and to a lesser extent advertising. However, nearly half the operators queried are very skeptical of present weather forecasts, even one-day predictions, and regard them as too inaccurate to be of use in their planning and management operations.

If improved weather forecasts were presently available, those management aspects affected nationwide would include season opening date, slope care and number of employees. In some regions additional aspects of season closing, stocking of supplies, advertising, road and parking maintenance and snow making would also be influenced by better weather forecasts. In the long run improved weather forecasts would result in more flexible personnel arrangements and greater promotion of group contracts, season ticket sales and organized activities. These improved forecasts would have to include information about precipitation, temperature, humidity and wind on a one-day to one-week basis. Many respondents indicated that they would make no changes as a result of improved forecasts. They appeared to be optimistic about their ability to handle the larger crowds that might result. As most skiing use occurs at weekends, the

capital investment required to expand present operations might not be economically viable unless there was a change in the present five-day, Monday through Friday, work week.

Regression analyses on the relationship of weather factors to actual skiing use for several selected areas showed a consistent correlation between amount of use and weather factors of temperature, snow-on-ground and wind as well as particular days of week (Saturday and Sunday). However, there were 40% - 50% of unexplainable variations not related to weather factors or day-of-week which may be due to such nonweather variables as slope care, snow-making equipment, advertising, road conditions and residence-to-resort travel time. These variables were not included in the predictive models. The results of Echelberger and Shafer's study of ski resorts in northeastern states indicate that skiing use is related to a resort's average total advertising budget, driving time from metropolitan centers and average percent of the advertising budget used for broad coverage advertising (magazines, radio and television).

The majority of respondents predicted more skiers at their resorts if accurate favorable ski weather forecasts were available and fewer skiers if the forecasts were unfavorable. This response agrees with W. A. Leuschner's study where weather variables were ranked first by ski area operators as influencing skiing activity. Further substantiation of this prediction is found in a recent study by Paul Nelson. As part of his study, he sent questionnaires to season ticket holders at three skiing resorts in Wisconsin also included in this survey. From their responses he predicted that about 36% of season ticket holders could be expected to increase their participation. Projecting his results nationally, he also predicted that the number of people who ski once during the year will increase by 13.1% and that crowding and congestion will occur in ski areas during periods of ideal skiing conditions, particularly on weekends.

In considering the problems of developing and communicating accurate weather forecast information to skiers and for specific ski sites in a wide variety of limited-area locations, attention should be directed to a special aspect, developed from field observations, most common in some western mountain regions. This is the variation of precipitation, temperature and wind conditions that often are related to elevational differences at ski resorts in very mountainous areas. Situations can occur where snow depths are inadequate or minimal for skiing near the resort base facilities. However, at the same time, 1,000 or 2,000 feet above the base facilities at the upper half of skiing slopes, snow fall and temperature regimes may have created excellent ski conditions. Therefore, forecasts for such specific areas, to be most useful, may have to consider the influence of elevational differences on specific weather factors.

BIBLIOGRAPHY

Besch, George C. 1963. Land Use and Other Considerations Needed for Developing Winter Sports Areas in Michigan. Master's thesis submitted to Department of Resource Development, Michigan State University.

Bickert, C. von E., J. L. Oldham, and J. J. Ryan, 1969. A Profile of the Tourist Market in Colorado - 1968. Industrial Economics Division, Denver Research Institute, University of Denver.

Bureau of Outdoor Recreation, 1967. Outdoor Recreation Trends. U. S. Government Printing Office, Washington, D. C.

Christiansen, R. A., S. D. Staniforth, A. Johnson, and R. Cooper, 1968. The Wisconsin Ski Industry: Some Economic Aspects. Research Report No. 33, Research Division, College of Agricultural and Life Sciences, University of Wisconsin.

Clawson, Marion, 1958. Statistics on Outdoor Recreation. Resources for the Future, Inc., Washington, D. C.

Crapo, Douglas and Michael Chubb, 1969. Recreation Area Day Use Investigation Techniques: Part 1, A Study of Survey Methodology. Technical Report No. 6, Recreation Research and Planning Unit, Department of Park and Recreation Resources, College of Agriculture and Natural Resources, Michigan State University.

Des Roches, R. A., 1970. Fact Sheet on Skiing. (Personal Estimates of Author). Ski Industries America, New York (mimeo).

Drapper, Norman and Harry Smith, 1967. Applied Regression Analysis. John Wiley and Sons, Inc., New York.

Flory, John A., 1964. Economic Impact of Schweitzer Basin Ski Resort, Sandpoint, Idaho. U. S. Area Redevelopment Administration. ARA Casebook 11L1-11.

Echelberger, Herbert and Elwood L. Shafer, Jr., 1970. Snow + (X) = Use of Ski Slopes. Journal of Mrketing Research, Vol. VII (August, 1970), 388-92.

Federal Reserve Bank of Boston, 1960. The Ski Lift Business in New England. Research Report No. 11.

Federal Reserve Bank of Minneapolis, 1964. Ski Resorts in the Ninth District. Business Report Series No. 1.

Frutiger, Hans, 1964. Snow Avalanches Along Colorado Mountain Highways. U. S. Forest Service Research Paper RM-7.

Gabelein, H. and P. W. Willis, 1966. The Vermont Ski Market 1965-66. Montpelier, Vermont Development Department.

Herrington, Roscoe B., 1967. Skiing Trends and Opportunities in the Western States, U. S. Forest Service Research Paper INT-34.

Judson, Arthur, 1964. The Weather and Climate of a High Mountain Pass in the Colorado Rockies, U. S. Forest Service Research Paper RM-16.

Leuschner, William A., 1970. Skiing in the Great Lakes States: The Industry and the Skier, Forest Service Res. Paper N. C. -46, N. Central Forest Exp. Sta., St. Paul, Minnesota.

Michigan Department of Conservation, 1966. Michigan Outdoor Recreation Demand Study Vol. II. Technical Report #6.

Michigan State University, 1967. Park and Recreation Bibliography. Extension Bulletin 603, Department of Resource Development, Cooperative Extension Service.

Nelson, Paul, 1970. The Impact of Accurate One Week Weather Forecasts on the Demand for Outdoor Recreation, Social Systems Research Institute, Publication QMiE 7041, University of Wisconsin, Madison.

Outdoor Recreation for America, 1962. A Report to the President and to the Congress by the Outdoor Recreation Resources Review Commission, U. S. Government Printing Office, Washington, D. C.

Pinkerton, J. R. and M. J. Pinkerton, 1969. Outdoor Recreation and Leisure: A Reference Guide and Selected Bibliography. Research Center, School of Business and Public Administration, University of Missouri, Columbia, Missouri.

Rand, McNally and Company, 1969. Ski Guide. Rand, McNally and Company, New York.

Starch, Daniel and Staff, 1967. A Profile of Affluence: The Adult Male Skier. Universal Publishing and Distributing Company, New York.

U. S. Department of Commerce, 1964. The Skier Market in Northeast North America, Area Redevelopment Administration. U. S. Gov't Printing Office, Washington, D. C.

U. S. Department of the Interior, 1968. Index to Selected Outdoor Recreation Literature (Winter, 1966-Spring, 1967), Vol. II. Bureau of Outdoor Recreation, Washington, D. C.

U. S. Department of the Interior, 1969. Index of Selected Outdoor Recreation Literature (1967). Vol. III. Bureau of Outdoor Recreation, Washington, D. C.

U. S. Department of the Interior, 1970. Outdoor Recreation Research: A Reference Catalog: 1969. No. 3. Bureau of Outdoor Recreation, Washington, D. C.

APPENDIX

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THE IMPACT OF SATELLITE DATA ON THE WEATHER SERVICE

THE GOVERNMENT WEATHER SERVICE

Meteorological Mission

By a joint resolution of the Forty-first Congress, which President Grant signed in 1870, the Secretary of War was "...authorized and required to provide for taking meteorological observations, at the military stations in the interior of the continent, and at other points in the States and Territories of the United States, and for giving notice, on the northern lakes and on the seacoast of the approach and force of storms."[1] From this resolution the National Weather Service[2] was born. Through 100 years of its existence, its primary function—to observe and forecast the weather—has remained the same, yet the Weather Service and other government meteorological services today do far more than merely observe and forecast.

To understand the present role of the weather services, it is necessary, in looking back across this century of service, to examine not only changes in Congressional mandate, but changes in the attitudes of administrators and scientists as well. Ultimately, of course, the role of the weather services is tied to the needs of the American people and to progress in the science of meteorology.

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[1] Donald R. Whitnah, A History of the United States Weather Bureau, University of Illinois Press, 1965.

[2] From 1890 to 1970 the government weather service was called the Weather Bureau.

In 1870 the science, as such, was just taking hold. Before 1800 instruments developed in the seventeenth and eighteenth centuries had been used, mostly by individuals, in regular observations of the atmosphere. In the first four decades of the nineteenth century systems of measurements were initiated by the Surgeon General, General Land Office, and several states. Immediate collection of widespread observations became possible with operational use of the telegraph after 1844. From this year a national weather forecasting service was possible.[3]

Recognition of past services and the potential of future services was implicit in the Congressional Mandate of 1890, which enlarged the mission of the Weather Service to include, "...the forecasting of weather, the issuance of storm warnings, the display of weather and flood signals for the benefit of agriculture, commerce, and navigation, the guaging and reporting of rivers, the maintenance and operation of seacoast telegraph lines and the collection and transmission of marine intelligence for the benefit of

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[3] Its feasibility was demonstrated first by Professor Henry of the Smithsonian Institution. Cleveland Abbe and Increase A. Lapham soon saw the value of simultaneous (synoptic) observations for forecasting storms using theories of storm motion developed by Franklin, Redfield, Loomis and others. Their work coincided with efforts in Europe to establish telegraphic observations and warning systems to forestall storm disasters such as that which occurred during the Crimean War in 1854. Abbe, at the Cincinnati Observatory, developed his own network; Lapham, while supporting Abbe, proposed expansion of the service to warn of storms on the Great Lakes. Lapham's proposal captured the interest of Congressman H. E. Paine, who submitted the bill establishing the national weather service. Expansion of forecast and warning services to include all of the country was accomplished by a second Act of Congress in 1872. (Whitnah, op. cit.; Roy Popkin, The Environmental Sciences Service Administration, Frederick A. Praeger, 1967.)

commerce and navigation, the reporting of temperature and rainfall conditions for the cotton states, the display of frost and cold wave signals, distribution of meteorological information in the interest of agriculture and commerce, and the taking of such meteorological observations as may be necessary to establish and record the climatic conditions of the United States, or as are essential for the proper execution of the foregoing duties."[4]

Today this "observe and forecast" mission of the Weather Service has expanded to include worldwide observations at all levels of the troposphere and the lower stratosphere; observations for forecasts of a few hours to more than a month; forecasts of heavy snow, hurricanes, severe local storms, fire weather, air pollution, nuclear fall-out, river levels, flash floods, and storm surges.

These are the most important but by no means all of the specialized forecast services now offered to the American public. They are possible because a developing technology has produced new types and extended coverage of observations, and a far more efficient communications system.

The years since Congress restated the Weather Service's mission have seen the development of such instruments as radar, television, and radiometers; and new platforms for observation—airplanes, radiosondes, rockets and satellites. Multitudinous observations from conventional instruments as well as the new are transmitted by telephone, teletypewriter, facsimile, and radio to weather centers for analysis. These same systems, supple-

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[4]Whitnah, 60.

mented by television, wirephotos, and newspapers, distribute timely forecasts to the public.

Analysis itself, under influence of new theory and automatic data processing, has vastly changed. Forecasts now are made by computers, which simulate the atmosphere by numerical models and extrapolate at accelerated rates from initial to future states to estimate future states of the real atmosphere. Increasingly, the function of human forecasters is to review and refine machine forecasts.

The progress of the last century could not have been made without support from weather services for basic meteorological research. Although neither Congressional mandate mentions research as a specific function, from the early years of its life in good times and bad, research has been a parallel, complementary theme to the observation and forecasting mission of the Service.[5]

Although indirect authorization for this research may be found in the last part of the Congressional Act of 1890, thirty-six years were to pass

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[5] During its first 20 years, when the Weather Service was part of the Signal Corps, research was a stepchild, not always in favor. Limited research begun under Colonel Myer, first Chief of the Signal Service, was expanded by his successor, General Hazen, who also enlarged the research staff. Internal friction and uncertainty pending transfer of the Weather Service from military to civilian control led to a decline in research under General Greely, the third and last military chief of the Weather Service. This decline was sharply checked by Mark W. Harrington, who in 1890 became the first civilian Chief of the Weather Service. Harrington established a basic program of research, which the Service has never since been without. (Whitnah, op. cit.; Popkin, op. cit.)

before explicit authorization was granted. This came in 1926, when the Air Commerce Act authorized research in support of aviation.[6] Broadening of the Weather Service's mandate to include the study of thunderstorms, hurricanes, cyclones and other severe atmospheric disturbances occurred with the passage of Public Law 657.[7] Today research is supported within the Weather Service and without, on basic and applied levels from the scale of cloud physics to the scale of global circulations.

Of increasing importance in recent years is the notion that man can control weather. Except for a token involvement in the early 1890's, when Congress appropriated $9,000 for rain making,[8] the Service stood aloof from weather control until the experiments of Langmuir, Schaefer, and Vonnegut in the 1940's showed that under certain conditions modification of clouds can be effected. These results and other advances in the theory of precipitation led to active Weather Service support of weather modification beginning with cloud seeding experiments conducted in 1947-48.[9] Seeding experiments now embrace hurricanes, tropical cumulus clouds, and Great Lakes snowstorms.[10]

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[6] Whitnah, 181.

[7] Patrick Hughes, <u>A Century of Weather Service</u>, Gordon and Breach, 1970.

[8] Whitnah, 71.

[9] Whitnah, <u>op. cit.</u>; Popkin, <u>op. cit.</u>

[10] ESSA Science and Engineering, U. S. Dept. of Commerce, 1970.

Assessing the effects of seeding is aided by numerical models of convective clouds and hurricanes. Numerical modelling is also being used to test the feasibility of increasing storm rainfall in the Northeast and suppressing tornadoes, hail, and lightning from thunderstorms.[11]

Control is one aspect of weather modification; the other is inadvertent modification due to air pollution. Passage of Public Law 159 in 1955 led in 1960 to the issuance of air pollution advisories by Weather Service meteorologists at the National Center for Air Pollution Control. This function in 1967 was transferred to the National Meteorological Center, which is assisted in its monitoring responsibility by five Environmental Meteorological Support Units located in five of the largest cities of the east and midwest. Monitoring of the atmosphere to identify long-term changes in contaminant levels is carried on by the Atmospheric Physics and Chemistry Laboratory.[12] Research being conducted by various agencies within and without the National Weather Service includes theories of transport and diffusion, urban diffusion modelling, air pollution potential forecasting, dilution climatology, mesostructure within the urban boundary layer, and effects of urban and larger scale air pollution on weather and climate.[13]

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[11] Ibid.

[12] Ibid.; Frank White Smith and William D. Kleis, editors, ESSA Research Laboratories: Programs and Resources, U. S. Dept. of Commerce, 1970.

[13] Ibid.

Research, weather control, pollution and the developing science of ecology have, in the last decade, led to a marked change in the attitudes of meteorologists toward the atmosphere and the Weather Service toward its mission. This change is noted in the testimony of the Secretary of Commerce, John T. Conner, before a Congressional Subcommittee holding hearings in 1965 on a proposal to combine the Weather Bureau and Coast and Geodetic Survey to form the Environmental Science Services Administration. Conners remarked on the "...growing awareness that the sciences dealing with the physical environment are not a collection of separate and distinct fields of scientific interest, but rather a unified group of disciplines."[14]

Accompanying this integrated view of the environment is a concern, born of pollution, for its preservation. Thus, in 1970, President Nixon, presenting to Congress his plan for combining a number of federal agencies into the Environmental Protection Agency and National Oceanic and Atmospheric Administration, spoke of ensuring "...the protection, development, and enhancement of the total environment itself."[15] This idea is repeated in the words of Secretary of Commerce Stans, addressing the employees of NOAA in the first issue of NOAA magazine: "We have assured the Congress that NOAA's environmental efforts will be undertaken in a context of guarding against the thoughtless exploitation and despoilment of our air, lands

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[14] Popkin, 115.

[15] Richard M. Nixon, The President's Message to Congress on EPA and NOAA, Bull. Amer. Meteor. Soc., Vol. 51, No. 9. 1970.

and seas. We are environmentalists, and we are also conservationalists."[16]

In a speech before the "Early Results from BOMEX"[17] symposium at the University of Washington, Dr. Robert White carried this idea one step further, arguing that because environmental problems embrace multiple disciplines it is the universities, with their unique diversity, that are best able to respond. The belief that, "Cooperation and interactions between government and universities ... are essential," which has manifested itself in the location of research laboratories on university campuses, exchanges of scientists, joint programs, common use of facilities and large-scale cooperative experiments such as BOMEX, as well as grants, is not enough. According to Dr. White, "The opportunity, the power to move ahead on environmental problems really lies (in the University)."[18]

All of these elements—observations and prediction, research, modification, preservation, and cooperation with the universities—are expressed in the mission of NOAA, which is stated below.

> NOAA will explore, map, and chart the global oceans, their geological cradles, their geophysical forces and fields, and their mineral and living resources. New physical and biological knowledge

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[16]NOAA, Vol. 1, No. 1, 1970.

[17]Barbados Oceanographic and Meteorological Experiment.

[18]Robert M. White, ESSA Laboratories in University Environment, Bull. Amer. Meteor. Soc., Vol. 51, No. 4, 1970.

will be translated into systems capable of assessing the sea's potential yield, and into techniques which the Nation and its industries can employ to manage, use, and conserve these animal and mineral resources.

NOAA will monitor and predict the characteristics of the physical environment—the protean changes of atmosphere and ocean, sun and solid earth, gravity and geomagnetism—in real time, given sufficiently advanced knowledge and technology. It will warn against impending environmental hazards, and ease the human burden of hurricane, tornado, flood, tsunami, and other destructive natural events.

NOAA will monitor and predict such gradual and inexorable changes as those of climate, seismicity, marine-life distributions, earth tides, continental position, the planet's internal circulations, and the effects of human civilization and industry on the environment and ocean life.

To accomplish these objectives, NOAA will draw upon the talent and experience of its personnel, the wide range of its facilities, and mutually important links between government, universities, and industry. NOAA and its institutional partners will develop the technology and the systems with which to comprehend this broad province of service and investigation—systems leading to effective resource assessment, utilization of environmental data, environmental monitoring and prediction, and, possibly, environmental modification and control. Here, the growing family of satellites, sensors, ships, data buoys, computers, and simulators, which have enriched scientific understanding and provided the base for essential environmental services in recent decades, will find their best achievement.

In these ways, NOAA will improve the safety and quality of life, the efficiency and timing of oceanic hunts and harvests, and man's comprehension, use, and preservation of his planetary home."[19]

Conspicuously absent from this statement is any responsibility for protection. By executive decree, this function belongs to the Environmental Protection Agency, which is charged with, "The conduct of research on the

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[19] <u>NOAA, op. cit.</u>

adverse effects of pollution and ... the gathering of information on pollution..." as well as, "The establishment and enforcement of environmental protection standards..."[20] NOAA is a service and research organization whose function is to monitor, understand, predict, and perhaps ultimately to some extent control the atmospheric and oceanic environment.

D. P. McIntyre has analyzed modern national forecasting services from an organizational point of view.[21] He argues that in the early part of this century forecasting services combined research and operations in the same office and often in the same person. Output, in addition to the research, was public and special forecasts.

The demands of aviation in the 1930's resulted in greater emphasis on forecasts, a proliferation of forecast offices, and the appearance of separate support systems for professional training and, increasingly, for research. Separation of research and forecasting functions led to competition for resources between the two.

By mid-century a new concept was seen, the central analysis office, which, as it developed competence and engendered confidence, became the heart of a "cascading forecast system consisting of several units operating in series:

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[20] Nixon, op. cit.

[21] D. P. McIntyre, What's happening to the forecasting industry?, Bull. Amer. Meteor. Soc., Vol. 51, No. 4, 1970.

Central Analysis Office (CAO)—Large-scale hemispheric analysis and prognosis

Weather Centrals (WC)—Synoptic-scale analysis, prognosis and physical processes

Weather Offices (WO)—Small-scale local factors, refined timing, and actual forecast preparation and presentation.

Consumer demands continue to increase. Private forecasting and consulting firms became a part of the scene and begin the process of maturing to meet a fundamental need for organizations capable of satisfying specialized user needs. The forecasting system itself begins to become a consumer of the private firm in such areas as special studies and technological procedures, but the latter depends heavily on the former for data, raw and processed. Uncertainty exists as to the proper relative roles of each.

The seeds of the next advance are sown in this system. The new computer technology has revolutionized the meteorological technology. Of equal importance is the subtle change in the forecast system which tends to separate the production and the service functions. Thus, the CAO and Weather Centrals are for the most part involved in production of forecast parameters. The Weather Offices provide the real interface with the consumers of the system. While these latter also have forecast production functions, the split between production and service has made its appearance and is destined to have a substantial influence on the further development of the system.[22]

In its recently published "Policy on Industrial Meteorology," NOAA has tried to clarify the roles of public and private meteorology, and has come down heavily in favor of private meteorology. The text of this statement is reproduced below.

This policy statement provides general guidance to ESSA Weather Bureau employees on procedures to be followed in support of the private sector of Meteorology and Climatology. Some discussion is included

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[22] *Ibid.*

relative to the manner in which referrals to industrial meteorologists can be made.

The ESSA Weather Bureau encourages and supports a healthy growth of the qualified private sector of Meteorology and Climatology. Throughout this policy statement, references to Meteorology apply equally to Climatology. The purpose of this statement is two-fold: to restate the intent of the ESSA Weather Bureau to continue this support and to provide guidelines for determining which services should be provided by the ESSA Weather Bureau.

The ESSA Weather Bureau provides climatological, hydrological, and meteorological information; and forecasts and warnings for the public and for broad homogeneous segments of industry. The ESSA Weather Bureau is charged by law to serve the aviation, marine, and agriculture industries.

Consulting meteorologists serve specific businesses and individuals who depend upon specialized meteorological input for the efficiency of their operations which cannot be satisfied by authorized Government products or means of dissemination.

The ESSA Weather Bureau upholds the concept of an industrial meteorological sector which is vigorous, competent, responsible, profitable, service-oriented, and professional. To this end, the ESSA Weather Bureau makes its products available to and cooperates professionally with private meteorologists, and when appropriate, encourages users to avail themselves of the services of Industrial Meteorologists.

The distinction between ESSA Weather Bureau and private meteorological services is not always clear. Nor can it be. The ESSA Weather Bureau has a tremendous responsibility in preparing and disseminating Government forecasts and warnings for the public. When do its obligations end and those of private weather services begin? This is the crux of the matter. We must recognize that there is no sharp boundary since the "public" includes everyone.

Yet, there are certain distinctions that must be made to insure that the requirements of business and commerce in our growing economy are properly met by competent authority within the highest professional standards. Industrial meteorologists know their clients' requirements concerning cost/benefit considerations, and therefore are in an excellent position to help their clients effect plans which Weather Bureau employees would not be in a position to do.

Private meteorology understands that it cannot exist without governmental weather observations, communications and processing facilities.

On the other hand, the ESSA Weather Bureau considers industrial meteorologists as valuable allies who provide specialized services not available from the Weather Bureau to specific segments of industry while cooperating in disseminating some government products and aiding in the distributing of warnings involving disastrous storms affecting the safety of life and property.

The ESSA Weather Bureau and consulting meteorologists agree that there may be confusion over these responsibilities. The ESSA Weather Bureau will provide fair and unprejudiced explanations of both industrial meteorological and Weather Bureau functions, operations, advantages, and limitations to interested users. ESSA Weather Bureau employees may refer industrial and individual users to the private sector. Such users should be referred when ESSA Weather Bureau employees recognize that the user requires the specialized services of an industrial meteorologist, especially if such services are required routinely or frequently.

Without recommending any specific consulting meteorologist, ESSA Weather Bureau personnel will indicate the availability of the American Meteorological Society Professional Directory listing of consulting meteorologists. ESSA Weather Bureau employees will give or mail copies of this directory to individuals or businesses requesting specialized services.

Admittedly, there are gray areas in the definitions set forth. When it is clear that industrial meteorological services are not available to a specific industry, ESSA Weather Bureau employees are expected to use their best judgment as to what extent, if at all, they should serve the needs of industry while the sector of private meteorology develops broader coverage.

The Special Assistant for Industrial Meteorology in the ESSA Weather Bureau Headquarters provides liaison between the ESSA Weather Bureau and private meteorology. He coordinates all policy questions and represents the Director of the ESSA Weather Bureau as well as the private meteorological sector in the application of the objectives outlined above.[23]

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[23] Robert M. White, ESSA Weather Bureau—private meteorological services, Bull. Amer. Meteor. Soc., Vol. 50, No. 7.

It was stated previously that the mission of the Weather Service is defined by progress in the science of meteorology as well as the needs of the public. The interaction of these demands is seen in recent Weather Service conceptions of its forecasting mission. During the last two decades the development of a computer technology, realistic mathematical models of the atmosphere, satellites, and remote sensors have produced an optimism that, "the environmental sciences are at a turning point."[24] Central to this optimism is the belief that, as stated by Robert M. White, the Administrator of NOAA, "with adequate data about the global atmosphere, we may ultimately be able to construct mathematical models that will yield the capability to make daily weather predictions for a period of as much as two weeks ahead."[25] Because the economic potential of such forecasts seemed enormous, it was assumed by many that two-week forecasts, if indeed they are feasible, are what the public wants. However, recent National Bureau of Standards and American Telephone and Telegraph Company surveys reported by Cressman in the 1970 find "...that the public is indicating a top priority requirement for short-range local forecasts. Telephone calls for information ... (from) ... automatic multiline answering systems ... indicate the preponderance of public demand to be for local data and short-range weather forecasts...

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[24] J. P. Kuettner (Chairman), Man's Geophysical Environment: Its Study from Space, ESSA, U. S. Dept. of Commerce.

[25] Robert M. White, Meteorology on a new threshold, Bull. Amer. Meteor. Soc., Vol. 48, No. 4.

These surveys, counts of telephone contacts, and other experiences leave us with the following conclusions:

1. The primary public requirement for weather forecasts is for reliable forecasts in the six to 24-hour range, in order to allow decisions on the activities of the near future.

2. The most urgent public need is for reliable information on approaching severe weather—hurricanes, tornadoes, and snowstorms.

3. The public requirement for forecasts in the three to five-day range is relatively slight, up to now. The probable reason for this is that people often have to arrange their affairs so they can't be changed by bad weather, while in other cases retaining the option of revising their plans until the last moment. This situation will certainly adjust in time when more reliable three to five-day forecasts are available.

4. The present demands for forecasts of weather more than two days ahead come from travelers, agriculturalists, and special industrial activities. In some cases these forecasts may result in decisions involving very large amounts of money.[26]

Therefore, Dr. Cressman concludes, "Most of the severe weather and most of the public interest in ordinary weather changes are concentrated in the smaller scale and short time range. Our future emphasis on improving weather services to the public will have to be concentrated at this end of the spectrum."[27]

Efforts to extend long range forecasts to the theoretical limits of predictability will continue, but they will not be made at the expense of nowcasting—providing better short range forecasts to the public.

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[26] George P. Cressman, Public Forecasting—Present and Future, in <u>A Century of Weather Progress</u>, edited by James E. Caskey, Jr., The American Meteorological Society, Boston, 1970.

[27] <u>Ibid.</u>

Organization

ESSA—Environmental Sciences Services Administration

A primary reason for the consolidation of the Weather Bureau and the Coast and Geodetic Survey into ESSA in 1965 was organizational streamlining making possible an improved warning system for the severe hazards of nature: hurricanes, tornadoes, floods, earthquakes and seismic sea waves. Better environmental information was to be provided to such vital segments of the nation's economy as agriculture, transportation, communications, and industry. Benefits would also accrue to other Federal departments and agencies: those concerned with national defense, the exploration of outer space, the management of our mineral and water resources, the protection of the public health against environmental pollution and the preservation of our wilderness and recreation areas.

ESSA brought together a number of disciplines that were concerned with the physical environment. This integration of disciplines encouraged an integrated approach to man's physical environment and led to a better understanding of the interactions among air, sea, and earth and between the upper and lower atmosphere. It also facilitated the development and management of programs dealing with the physical environment, and increased the capability to identify and solve important long-range scientific and technological problems.

Economic and other advantages within ESSA were also foreseen. Establishment of a common communications network for all environmental hazard warnings was envisioned. Those segments of the economy that required environmental information had only to look to a single source for much of their needs. Consolidation enabled the pooling of complex and expensive facilities such as satellites, aircraft, ships, and computers, and put them to multiple geophysical uses; it also led to the establishment of a national repository of environmental information which provided comprehensive geophysical data services.[28]

NOAA—National Oceanic and Atmospheric Administration

The creation of the National Oceanic and Atmospheric Administration (NOAA) within the Department of Commerce in October 1970 went one step further towards the goal of an agency in which all governmental civilian activities concerned with the physical environment would be under unified leadership and guidance. The five major line components of ESSA—Environmental Data Service, Weather Bureau, Research Laboratories, National Environmental Satellite Center, and Coast and Geodetic Survey—were merged with agencies from other federal departments into the interim six line components of National Marine Fisheries Service, Environmental Research Laboratories, National Weather Service, Environmental Data Service, National Ocean Survey, and National Environmental Satellite Service (Fig. 1).[29]

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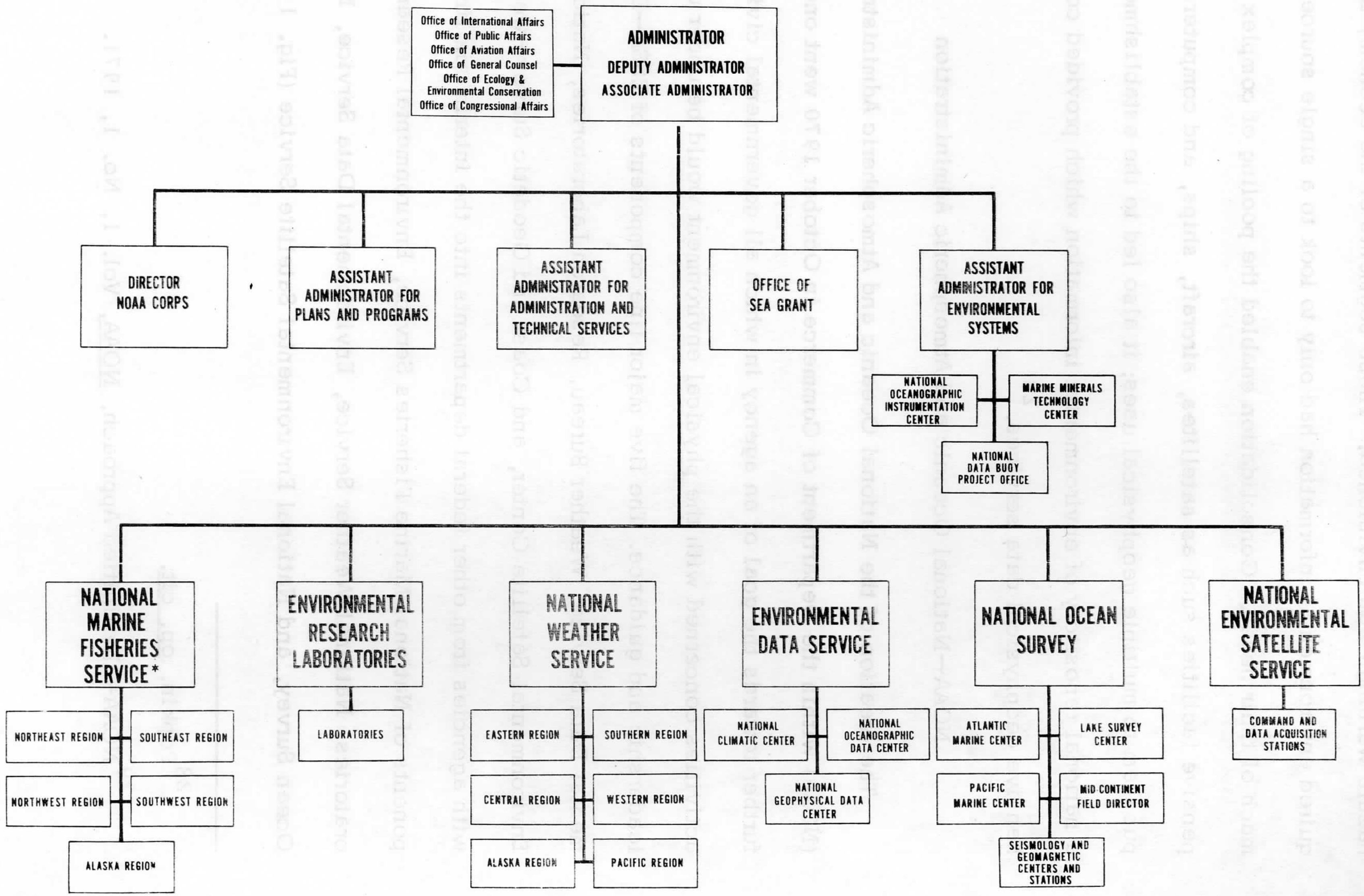
[28] Popkin, op. cit.

[29] NOAA—the Unified Approach, NOAA, Vol. 1, No. 1, 1971.

U.S. DEPARTMENT OF COMMERCE

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

(INTERIM Organization)



*MARINE SPORT FISHERIES LABORATORIES TEMPORARILY TO THE OFFICE OF THE DIRECTOR

— MARCH 1971

FIGURE I

In addition, subsidiary offices were created to administer the Office of the Sea Grant, which was transferred from the National Science Foundation. The National Oceanographic Instrumentation Center, National Data Buoy Project and Marine Minerals Technology Center were transferred from the Navy and Interior Departments and placed in the Office of an Assistant Administrator for Environmental Systems. Likewise, a Director for the NOAA Corps was named. This corps consists of officers to man the expanding research fleet of the National Ocean Survey, formerly the Coast and Geodetic Survey, and to conduct surveys in oceanography, geodesy, seismology and geomagnetism and Great Lakes research.[30]

NOAA's mission has expanded from that of ESSA's in that a more complete integration of our national programs in meteorology and oceanography has been realized.[31] Meteorologists and oceanographers have long been aware of the inseparability of gaseous and hydrous envelopes, the physical interactions of air with water, and air and water with the solid sphere of the earth, and the energy transfers from sun to earth and from earth to space. Motions obey the same physical laws in the oceans and in the atmosphere. Except that the oceanic heat engine has a giant flywheel and the atmospheric heat engine has a small flywheel, there is little dynamic difference, but because the heat engines are coupled through fluxes of heat, moisture, and momentum a sound physical understanding of the circulation of the atmos-

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[30] Ibid.

[31] ESSA, Vol. 5, No. 4, 1970.

phere—essential to improved weather forecasting by numerical modelling—can only be achieved through understanding of these complex interactions between ocean and atmosphere.

Observing and forecasting the weather continues to be the responsibility of the Weather Bureau, which was renamed the National Weather Service. Satellite observations taken by the various operational satellites are processed by the National Environmental Satellite Services and made available at NMC for help in analysis. Realtime ATS satellite pictures likewise are available at both the National Hurricane Center at Coral Gables and the National Severe Storm Forecasting Center at Kansas City.[32]

To describe the duties of the National Weather Service within the newly created NOAA, Section 12 of the US Department of Commerce Organization Order 25-5B dated 10/9/70 is quoted below:

SECTION 12. NATIONAL WEATHER SERVICE

The National Weather Service (NWS) shall observe and report the weather of the United States and its possessions and issue forecasts and warnings of weather and flood conditions that affect the Nation's safety, welfare and economy; develop the National Meteorological Service System; participate in international meteorological and hydrological activities, including exchanges of meteorological data and forecasts; and provide forecasts for domestic and international aviation and for shipping on the high seas. The Service shall be organized as set forth below.

.01 Office of the Director. The Director shall formulate and execute basic policies and manage the Service. He shall be immediately assisted by a Deputy.

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[32]A discussion of the operational use of satellite data at one of these two key warning points is given elsewhere in this report.

.02 The Office of Meteorological Operations shall observe, prepare and distribute forecasts of weather conditions and warnings of severe storms and other adverse weather conditions for protection of life and property; develop and institute policies, and plans and procedures for operation of meteorological services; and serve as the primary channel for coordinating NWS field operations.

.03 The Office of Hydrology shall provide river and flood forecasts and warnings, and water supply forecasts; conduct research to improve river and flood forecasts and warnings; and analyze and process hydrometeorological data for use in water resource planning and operational problems.

.04 The Systems Development Office shall manage, plan, design and develop a system to meet all meteorological service requirements; develop, test and evaluate techniques and equipment; translate research results into operational practices; and conduct studies associated with the design of the World Weather Watch.

.05 The National Meteorological Center shall provide analyses of weather conditions over the globe and depict the current and anticipated state of the atmosphere for general national and international uses; conduct development programs in numerical weather prediction; and lead in the extension and application of advanced techniques.

.06 The Field Structure shall consist of six regions. A region shall consist of a Regional Office managed by a Regional Director, and contain field offices and forecast centers reporting to the Regional Director.

a. Each region shall provide weather service within its prescribed geographical area by issuing forecasts and warnings of weather and flood conditions, and shall conduct operational and scientific meteorological and hydrological programs as are assigned to it.

b. Regional offices shall provide administrative and technical support for all NWS components in their respective regions and shall provide such services to other components of NOAA as determined to be practicable and advantageous to NOAA.

Communications[33]

It has been stated by a head of a European national meteorological office that the operational problems of a national weather service are as much as 90% a problem of communications. The highly perishable raw observational data has to be assembled, processed, coded, and transmitted to a national weather central for plotting and analysis and for input in numerical forecast models. At the same time these data have to be made available to other users along the line and retransmitted to foreign meteorological services. Stringent quality control measures are applied to eliminate errors and incomplete values are estimated where possible.

The data are received from the field stations over high speed teletypewriters and from ships at sea via radio. The received data are plotted on surface weather maps and upper air charts at several constant pressure levels, and analyzed charts of current weather and forecast conditions are retransmitted to the users and forecast offices in the field via facsimile.

Forecasts and warnings are issued to the public using mainly the facilities of the commercial broadcasting industry. Broadcasts originating in the local Weather Service Offices are available in some localities as are recorded telephone messages. The National Weather Service also operates a number of VHF-FM radio stations mainly for boating weather services in

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[33]Unless otherwise noted, material in this section comes from Operations of the National Weather Service, U. S. Department of Commerce, 1970.

coastal areas. Still another method of dissemination is by the use of printed weather maps in newspapers.

Looking at the NWS's communications network in more detail, we see that the teletype data collection and transmitting facilities consist of the following networks, each consisting of many circuits.

Service C collects and distributes basic surface and upper air data as well as many non-aviation weather service products.

Service A collects and distributes hourly surface observations and disseminates products of the Aviation Weather Service and "Notices to Airmen" (NOTAMS).

Service O accommodates the exchange of meteorological information between the United States and foreign countries.

RAWARC (Radar Report and Warning Coordination) collects and distributes radar reports and storm warning information and serves as a bypass to Services A, C, and O for more routine information when these circuits are busy.

NOAA Weather Wire distributes consumer-oriented weather warnings, forecasts and data to the mass media for relay to the public and various specialized users. These circuits cover as yet only about half of the United States, but do include most of the tornado-prone states.

Hot Line provides instant communications between any and/or all of the Atlantic and Caribbean hurricane service centers for the purpose of coordinating information concerning weather that is considered potentially or actually hazardous to life and property.

Fire Weather disseminates fire-weather forecasts, warnings and advisories to fire control and forest management agencies, and collects special fire weather forecasts. These circuits cover mainly the mountain states from Montana southward to the Mexican border.

Local Public Service Communications Facilities consist of local public service teletypewriter loops serving many metropolitan areas but also smaller cities. These networks distribute warnings, forecasts and selected weather data to users and to the news media for distribution to users.

The Multiple Access Recorded Telephone Announcement Systems of the WE6-1212 type provide the public with a means for direct telephone access to current warning, forecast and observation information on a demand basis. Large volume systems able to handle 200 to 1,000 calls simultaneously are available in about 15 of the larger metropolitan areas of the country. Low volume systems with access for 2 to 10 simultaneous listeners are available at another 15 to 20 large cities. The great majority of lesser cities with local Weather Service Office have telephone recording service with the type which gives only one listener access to a recording at a time. The phone will "ring through" at the end of the recording if additional information is needed.

The National Weather Service's VHF-FM Continuous Weather Transmissions has proved a most popular service in the areas where it is available. Although planned primarily as a part of the Nationwide Natural Disaster Warning (NADWARN) system, these transmitters with a range of 40-50 miles are used extensively by boating interests as a means of following movement or development of squalls and hurricanes. Local radio and TV stations are able to copy and rebroadcast weather information from these transmitters. About 25 stations are in operation mainly in the large metropolitan areas all along the East, Gulf and Pacific Coasts and at a few interior locations. The VHF-FM Continuous Weather Transmissions make weather information available to the public at all times, day and night, by means of VHF-FM continuous weather broadcasts.

Another most important area within the National Weather Service's communications system is the National Facsimile Network which serves about 250 National Weather Service Offices, 320 military and other government units, and 350 other users. The network covers the contiguous United States and extends to Alaska over military channels. The National Facsimile Network distributes a comprehensive set of charts depicting analysis, prognoses, and selected observational data. Digitized mosaics of satellite data are also included from the National Environmental Satellite Service. The great majority of the transmitted data originates from NMC in Suitland.

A second major network is the Aviation Meteorological Facsimile Network (AMFAX) which distributes analyses and prognoses to offices supporting international high altitude aviation operations. Nearly one hundred Air Force bases and NWS offices serving international airports are on these circuits.

There are two regional facsimile networks. Alaska is served by the Intra-Alaska Facsimile Network, and the Tropical Regional Analysis Facsimile

Circuit (TROPRAN) links Puerto Rico and southeastern United States forecast offices for the purpose of distributing analysis and prognosis material prepared by the WMO (World Meteorological Organization) Regional Center for Tropical Meteorology (RCTM) at Miami.

In addition to the facsimile networks utilizing telephone wires, the NWS distributes selected graphic materials to foreign meteorological services over the International Radio Facsimile Broadcasts.

An important link to provide for the exchange of meteorological data between World Weather Centers at Washington, D.C. and Moscow is the D.C.-Moscow Communications Cable Circuit. This circuit was installed particularly for the exchange of satellite cloud pictures. Other conventional meteorological information is exchanged over the circuit on a temporary basis pending full utilization of the circuit for the exchange of satellite data. These data include surface and upper air data, forecast contour charts, vertical motion charts, vorticity charts, etc. Both teletype and facsimile transmissions are used.

One other cable and teletypewriter circuit is currently used to exchange synoptic surface and upper-air data with foreign nations. This is the New York-Offenbach/Paris/Bracknell Cable Circuit. Recently a similar circuit was established to Tokyo. In addition, a high speed data link exists between Suitland and Tinker AFB in Oklahoma for the use of computer-to-computer transfer of synoptic surface and upper air data.

The communications systems discussed in the previous paragraphs consist of teletypewriter networks for assembling, disseminating and exchanging the raw data, and facsimile networks for disseminating the processed data in the form of plotted charts to Weather Service Offices and forecast centers and the sophisticated users who can afford the facsimile machine rentals and line charges. Dissemination of forecast messages and current weather information directly to the public by the National Weather Service via recorded telephone messages and radio broadcasts also were mentioned. These services are as yet only available in limited geographic areas. In most cases the NWS relies on the commercial broadcasting industry for relaying warnings, forecasts and weather information to the public. The five primary communications systems used to disseminate forecasts, warnings, and information to the public and the primary users of each system are shown in Figure 2.

This method of presenting the finished forecast product together with other general weather information to the public, using the talents of local radio or television weathermen, has worked well in some areas while in others the result has been dismal. Stations in smaller cities often cannot afford to employ a qualified person to present an information weather show or refuse to make the investment and public service suffers accordingly. There are also such problems as the announcers shortening the forecasts and perhaps in the process changing their meaning.[34] The words "warning" and "watch" are often interchanged during severe weather situations. To

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[34]Popkin, <u>op. cit.</u>

DISSEMINATION OF FORECASTS & WARNINGS TO THE PUBLIC

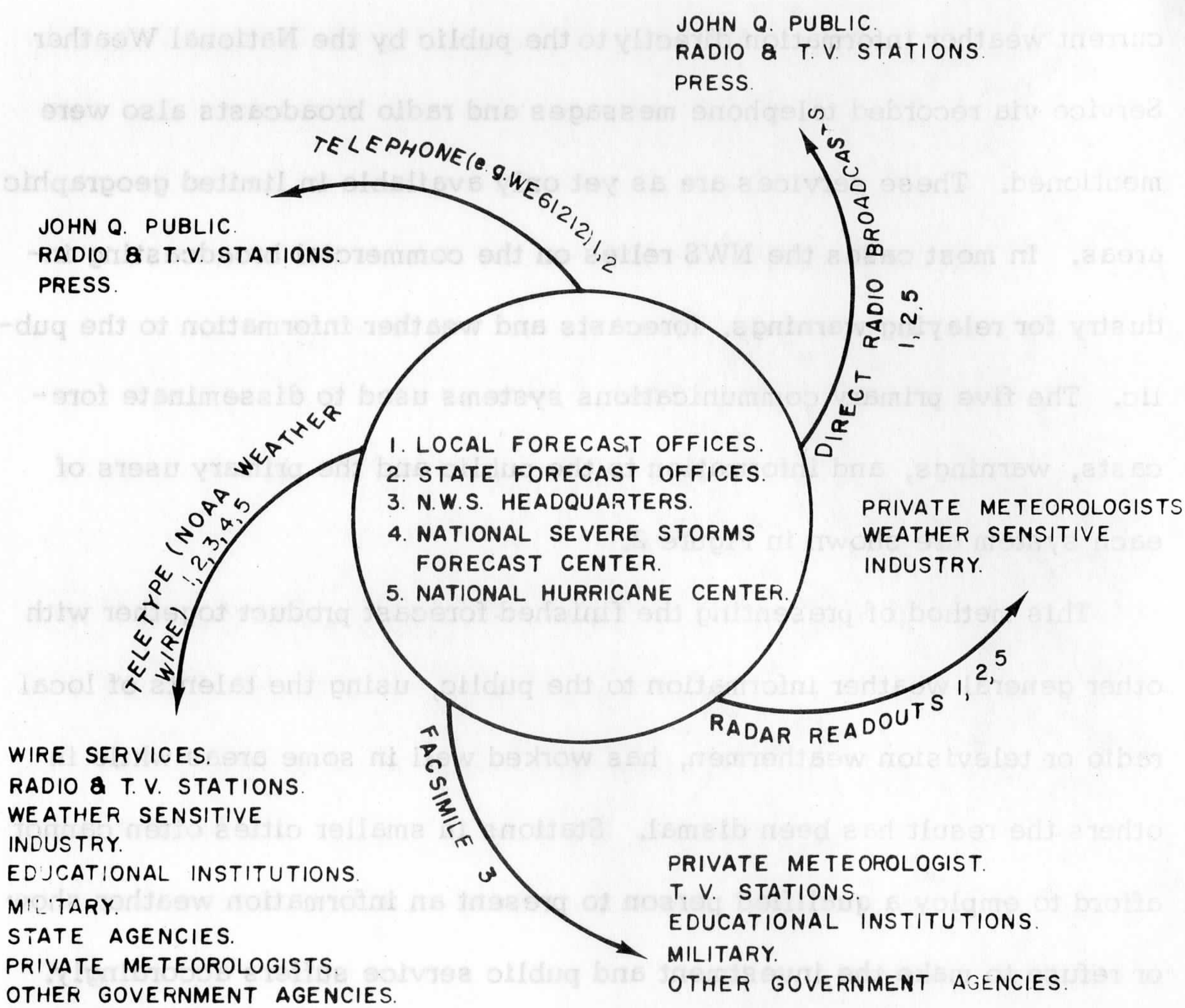

Figure 2. Five primary communications systems are used to disseminate forecasts, warnings and information from NWS offices to the public. Numbers following each system name indicate originating NWS offices.

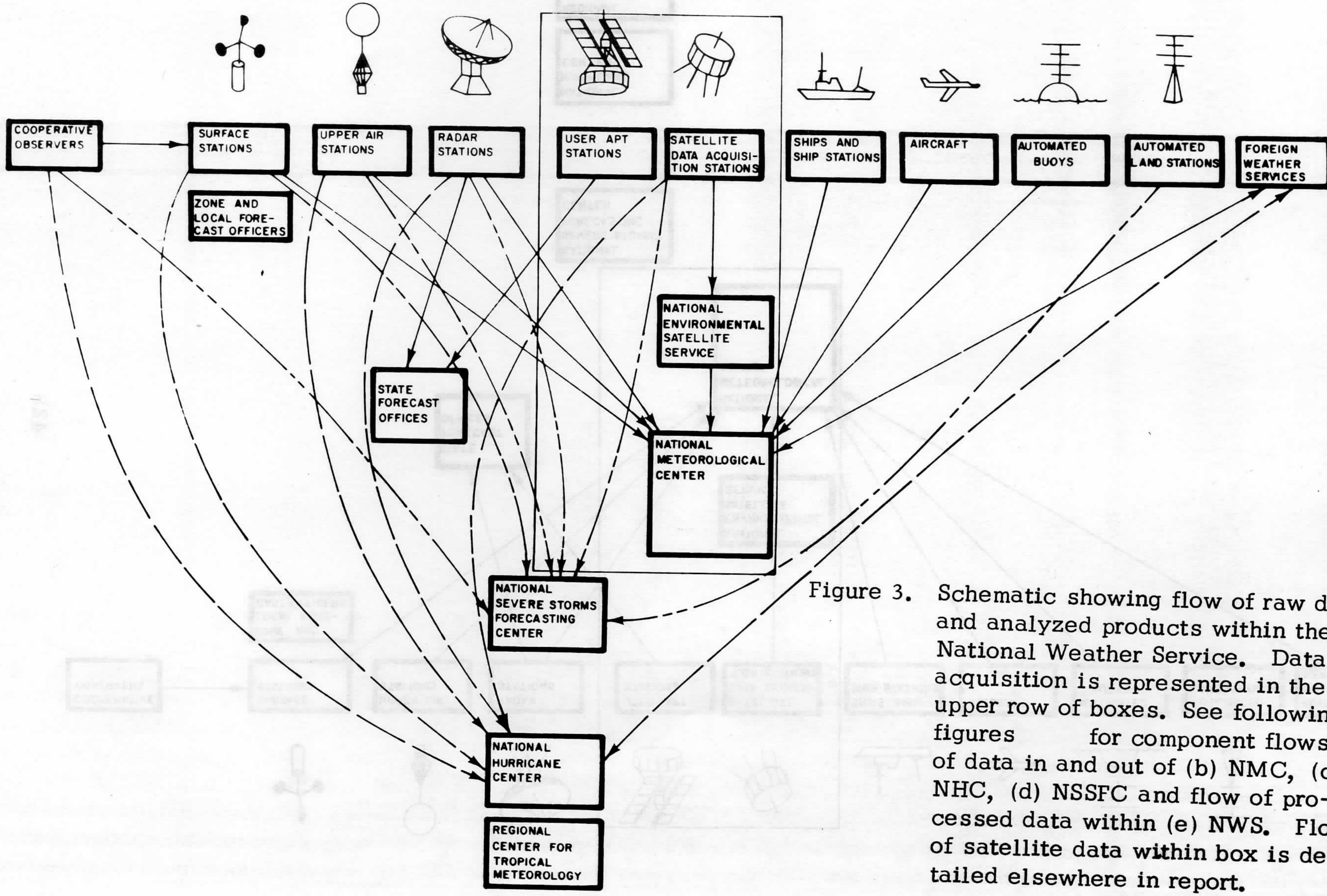

Figure 3. Schematic showing flow of raw data and analyzed products within the National Weather Service. Data acquisition is represented in the upper row of boxes. See following figures for component flows of data in and out of (b) NMC, (c) NHC, (d) NSSFC and flow of processed data within (e) NWS. Flow of satellite data within box is detailed elsewhere in report.

Flow of Raw Data and Analyzed Products

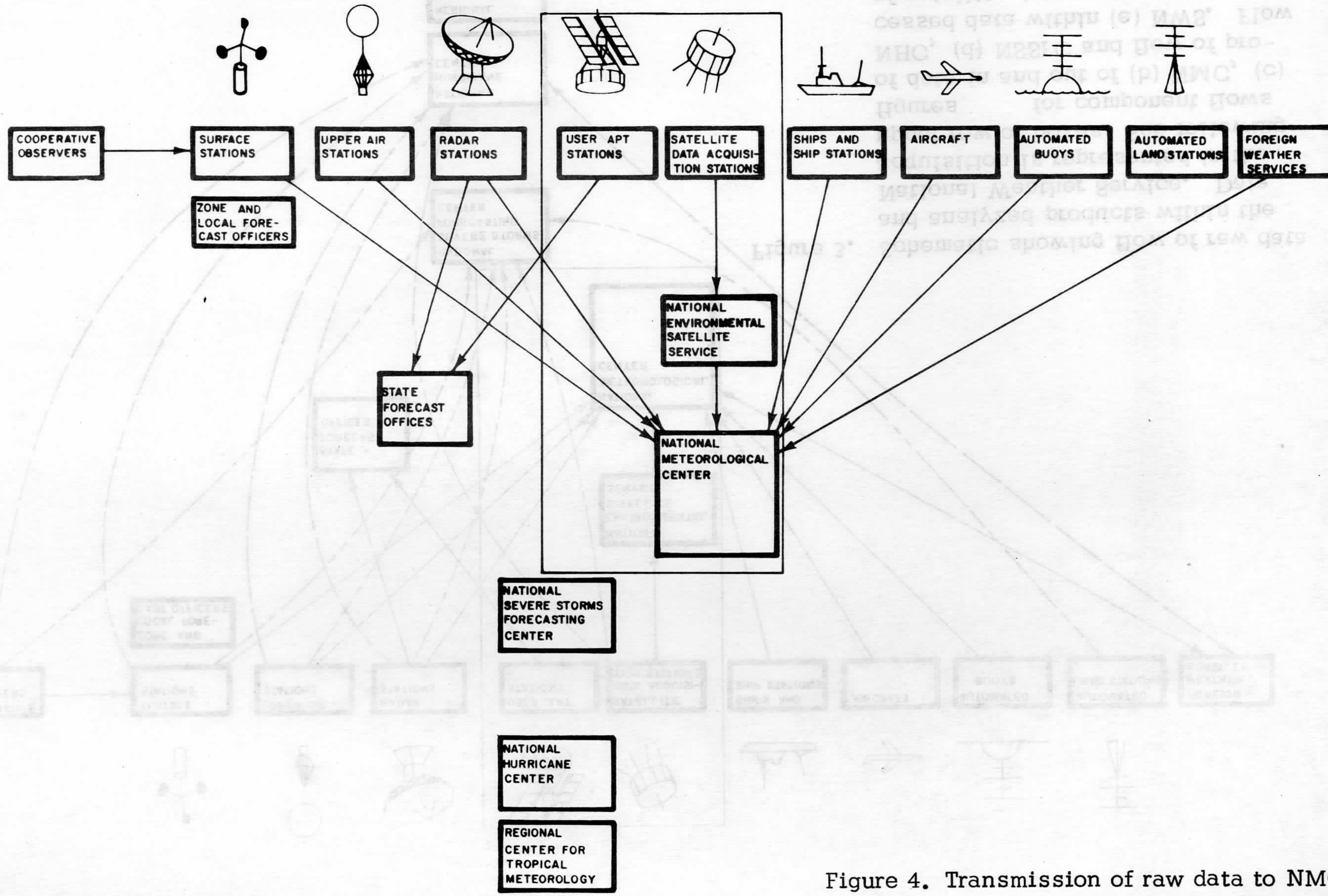

Figure 4. Transmission of raw data to NMC.

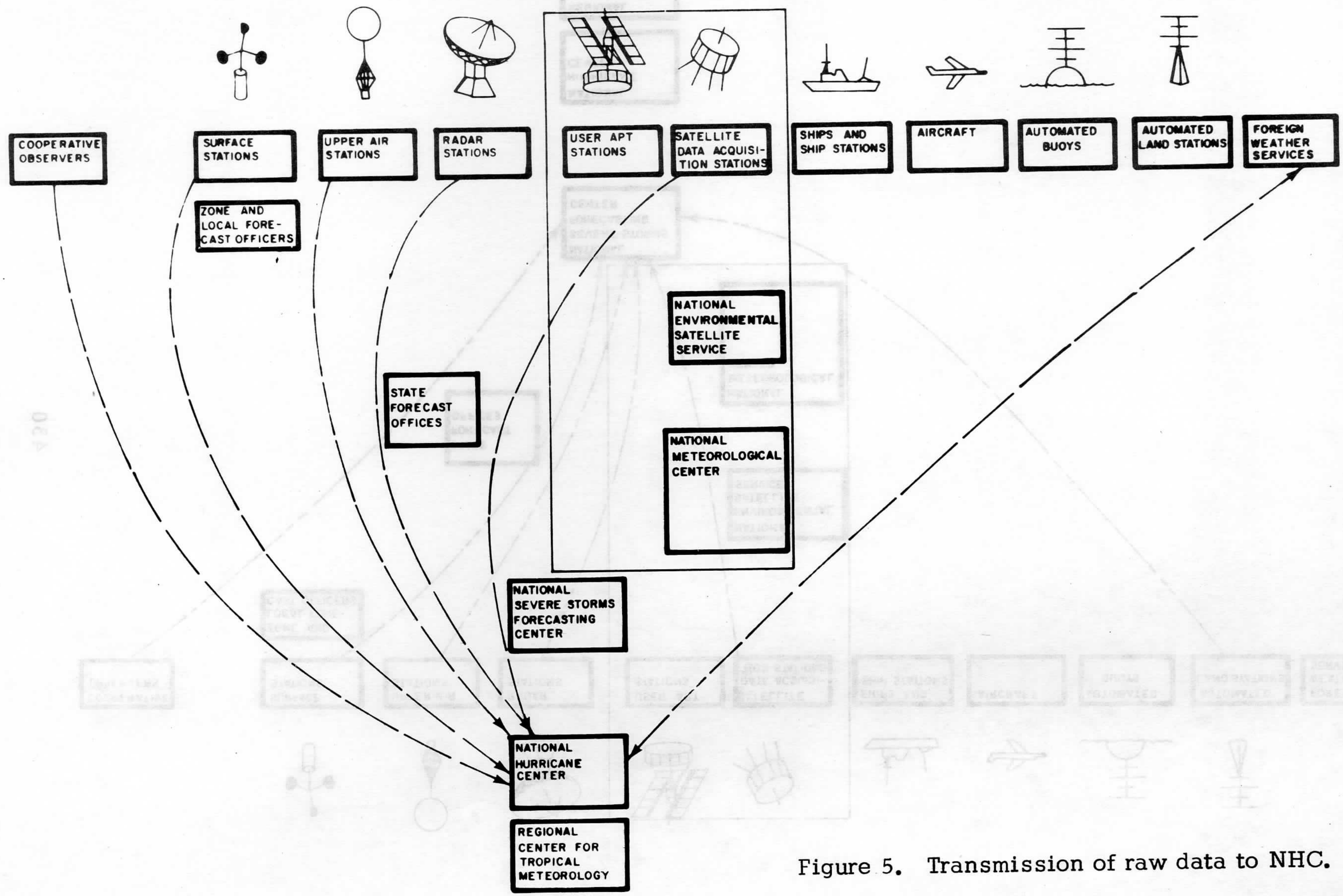

Figure 5. Transmission of raw data to NHC.

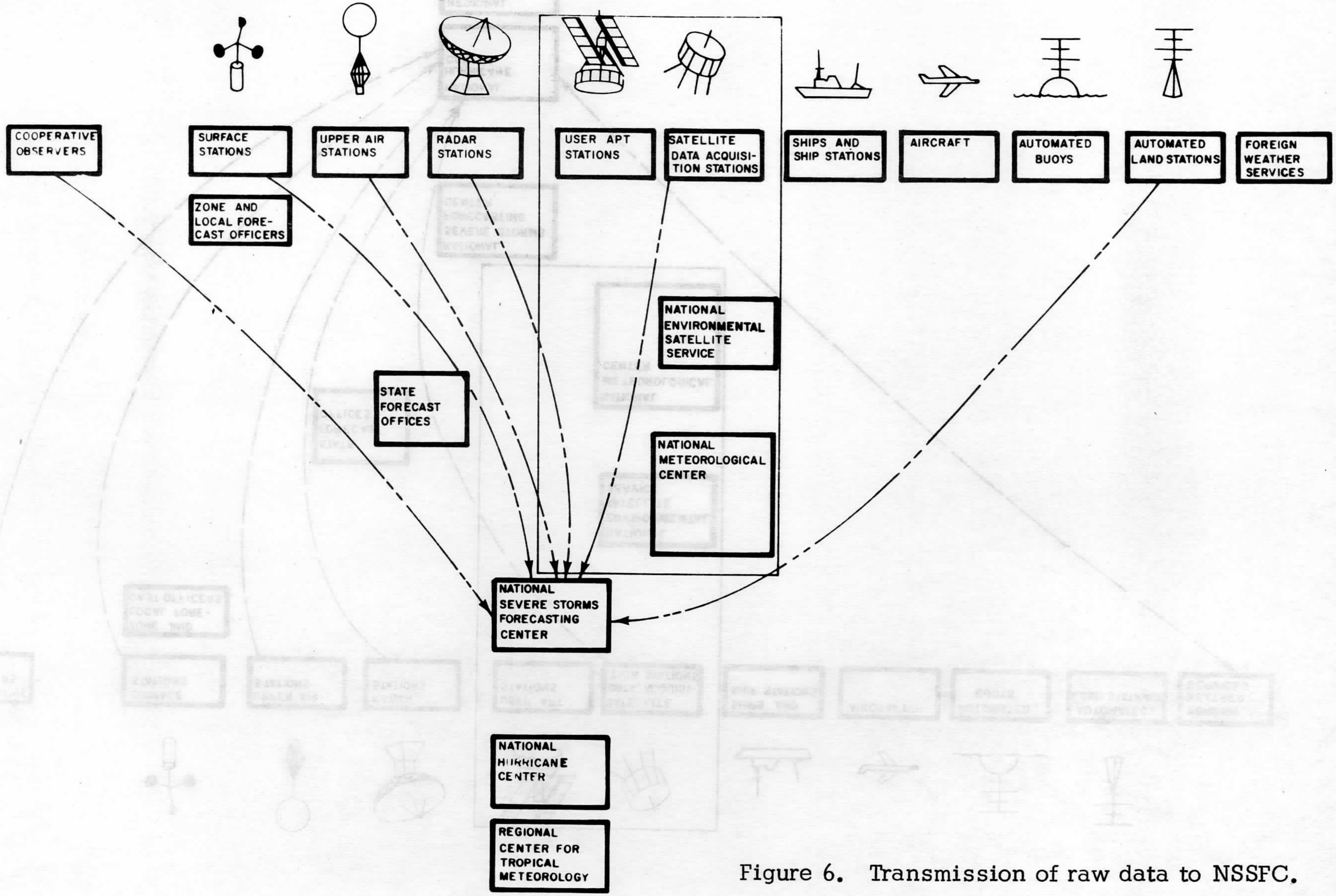

Figure 6. Transmission of raw data to NSSFC.

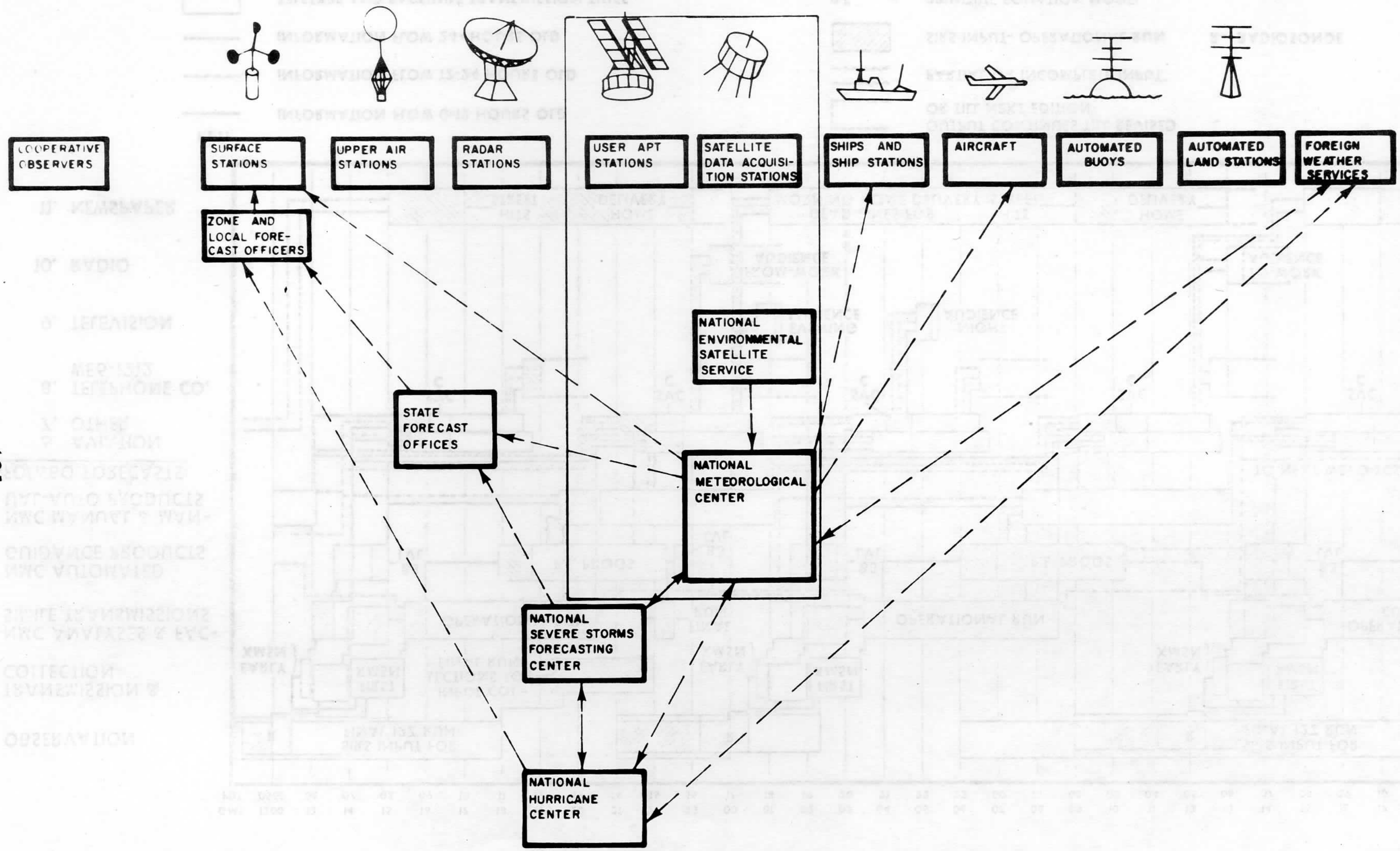

Figure 7. Transmission of processed data within NWS.

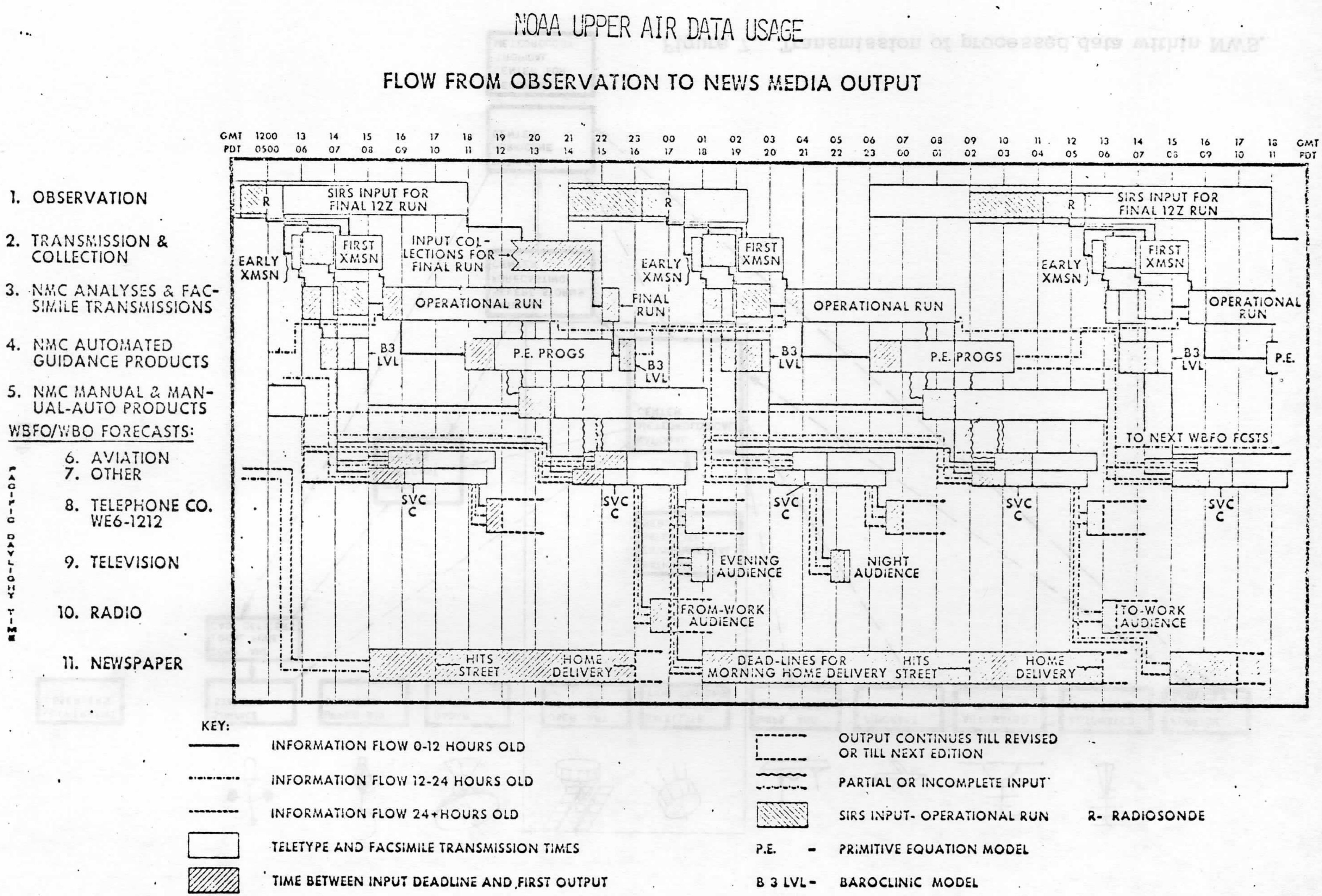
NOAA UPPER AIR DATA USAGE
FLOW FROM OBSERVATION TO NEWS MEDIA OUTPUT
1. OBSERVATION
2. TRANSMISSION & COLLECTION
3. NMC ANALYSES & FACSIMILE TRANSMISSIONS
4. NMC AUTOMATED GUIDANCE PRODUCTS
5. NMC MANUAL & MANUAL-AUTO PRODUCTS
WBFO/WBO FORECASTS:
6. AVIATION
7. OTHER
8. TELEPHONE CO. WE6-1212
9. TELEVISION
10. RADIO
11. NEWSPAPER
PACIFIC DAYLIGHT TIME
GMT
PDT
SIRS INPUT FOR FINAL 12Z RUN
R
EARLY XMSN
FIRST XMSN
INPUT COLLECTIONS FOR FINAL RUN
OPERATIONAL RUN
FINAL RUN
B3 LVL
P.E. PROGS
P.E.
TO NEXT WBFO FCSTS
SVC C
EVENING AUDIENCE
NIGHT AUDIENCE
FROM-WORK AUDIENCE
TO-WORK AUDIENCE
HITS STREET
HOME DELIVERY
DEAD-LINES FOR MORNING HOME DELIVERY
KEY:
INFORMATION FLOW 0-12 HOURS OLD
INFORMATION FLOW 12-24 HOURS OLD
INFORMATION FLOW 24+HOURS OLD
TELETYPE AND FACSIMILE TRANSMISSION TIMES
TIME BETWEEN INPUT DEADLINE AND FIRST OUTPUT
OUTPUT CONTINUES TILL REVISED OR TILL NEXT EDITION
PARTIAL OR INCOMPLETE INPUT
SIRS INPUT- OPERATIONAL RUN
R- RADIOSONDE
P.E. - PRIMITIVE EQUATION MODEL
B 3 LVL- BAROCLINIC MODEL

Figure 8.

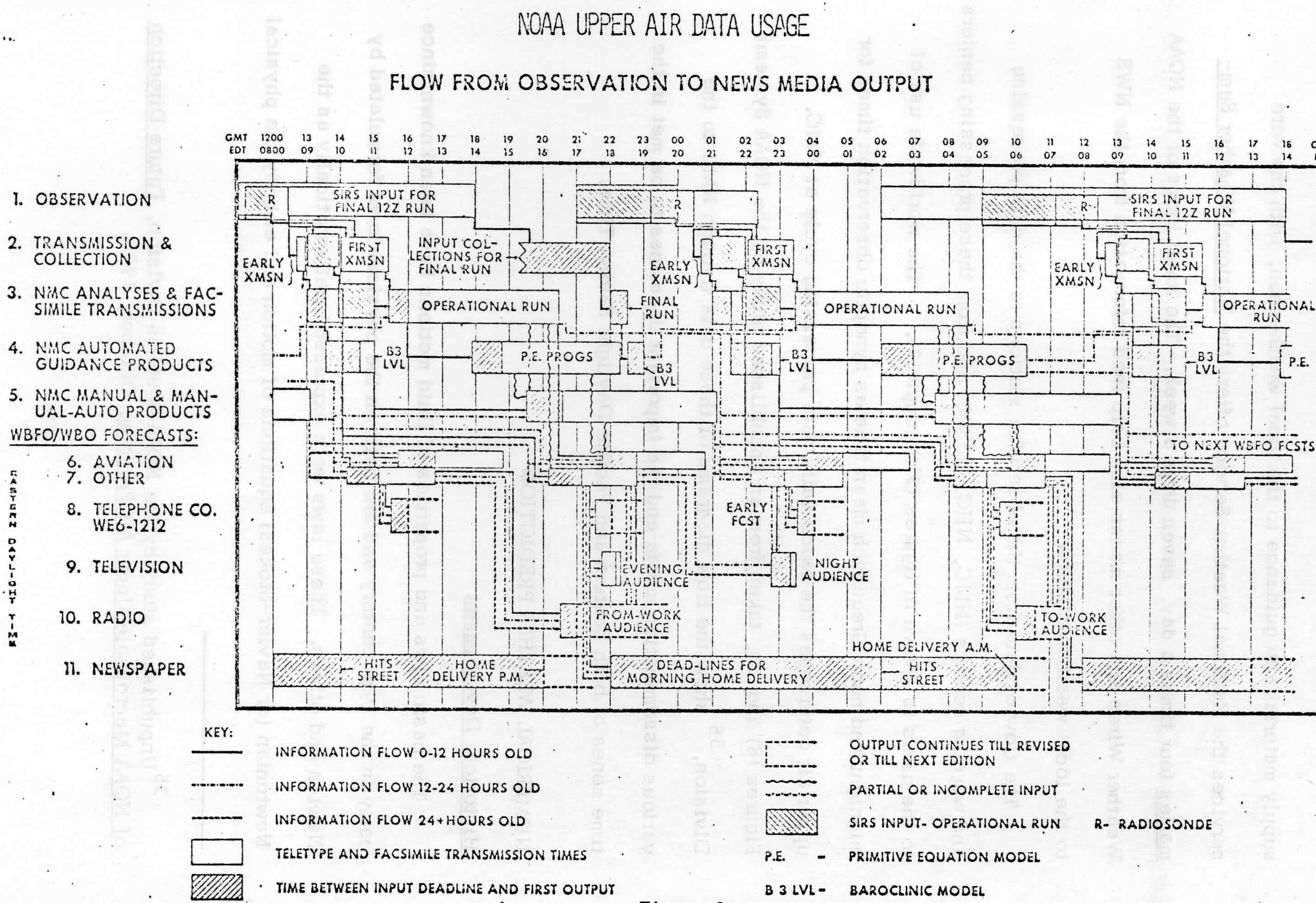
NOAA UPPER AIR DATA USAGE
FLOW FROM OBSERVATION TO NEWS MEDIA OUTPUT
GMT
EDT
1. OBSERVATION
2. TRANSMISSION & COLLECTION
3. NMC ANALYSES & FAC-SIMILE TRANSMISSIONS
4. NMC AUTOMATED GUIDANCE PRODUCTS
5. NMC MANUAL & MAN-UAL-AUTO PRODUCTS
WBFO/WBO FORECASTS:
6. AVIATION
7. OTHER
8. TELEPHONE CO. WE6-1212
9. TELEVISION
10. RADIO
11. NEWSPAPER
SIRS INPUT FOR FINAL 12Z RUN
EARLY XMSN
FIRST XMSN
INPUT COL-LECTIONS FOR FINAL RUN
OPERATIONAL RUN
FINAL RUN
B3 LVL
P.E. PROGS
P.E.
TO NEXT WBFO FCSTS
EARLY FCST
NIGHT AUDIENCE
EVENING AUDIENCE
FROM-WORK AUDIENCE
TO-WORK AUDIENCE
HOME DELIVERY A.M.
HITS STREET
HOME DELIVERY P.M.
DEAD-LINES FOR MORNING HOME DELIVERY
KEY:
INFORMATION FLOW 0-12 HOURS OLD
INFORMATION FLOW 12-24 HOURS OLD
INFORMATION FLOW 24+HOURS OLD
TELETYPE AND FACSIMILE TRANSMISSION TIMES
TIME BETWEEN INPUT DEADLINE AND FIRST OUTPUT
OUTPUT CONTINUES TILL REVISED OR TILL NEXT EDITION
PARTIAL OR INCOMPLETE INPUT
SIRS INPUT- OPERATIONAL RUN
R- RADIOSONDE
P.E. - PRIMITIVE EQUATION MODEL
B 3 LVL - BAROCLINIC MODEL
EASTERN DAYLIGHT TIME

Figure 9.

supply material and guidance to the local weathermen, with the wire services the National Weather Service offers the National Weather Summaries four times a day, seven days a week. The local loops of the NOAA Weather Wires and other means also help feed information from the NWS to the local weather casters.

The flow of data from the observing stations to the data processing and warning centers (NMC, NHC, NSSFC) and from these processing centers to the users is shown in figures (3) through (7). The worldwide use of midnight and noon Greenwich mean time as synoptic observation times for upper air determines the twice daily data processing cycle at NMC. Figures (8) and (9), taken from an unpublished study by the NOAA Systems Division,[35] show the flow diagrams of these data through NMC to the various dissemination media and the important deadlines to be met in the time zones of both Eastern and Pacific Daylight Saving Time.

NUMERICAL WEATHER PREDICTION

Historical Development

The basic laws and properties of fluid motions have been known since early in the 19th century and are built on the physical laws formulated by Newton and others. These laws were expressed mathematically as the Newtonian (or Navier-Stokes) equations of motion and embody the physical

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[35] Unpublished study by the NOAA Systems Division, Future Direction of NOAA Macroscale Upper Air Program, October, 1970.

principle of conservation of momentum. The three component equations, together with equations relating the conservation of mass and energy and the equation of state were used as early as 1858 by the German scientist von Helmholz as a possible means of dealing with the meteorological problems. At the turn of the century, the Norwegian scientist V. Bjerknes postulated in clear terms how numerical weather prediction could be applied in practice, but it was the British scientist L. F. Richardson who attempted the first large scale prediction, for an area covering western Europe and the adjacent Atlantic using one day's data.

Richardson did his calculations while serving as an ambulance driver on the western front during World War I. He published his results in 1922 and in the preface states—"Perhaps some day in the dim future it will be possible to advance the computations faster than the weather advances and at a cost less than the saving to mankind due to the information gained. But that is a dream."[36] Richardson had estimated it would take 64,000 human computers just to keep up with the weather. Richardson's attempt failed badly for many reasons and research along the lines of numerical weather prediction was discouraged.

The discovery of the relatively simple wave-like upper flow pattern around both polar hemispheres and the additional knowledge learned about

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[36] L. F. Richardson, Weather Prediction by Numerical Process, Cambridge University Press, 1922.

the distribution of temperature, pressure, humidity and wind with height helped advance theory and spurred meteorologists to a new attempt at numerical prediction. Studies by the Swedish-American meteorologist C. G. Rossby and others had shown that many aspects of atmospheric motions could be simplified without sacrificing essential meteorological content. The nonlinear hydrodynamic equations could be drastically simplified and a simple barotropic model could provide a crude theoretical basis for the prediction of the important large-scale motions of the atmosphere.

The wealth of upper air observational data during and after World War II and the development of the high speed electronic computer gave scientists the data and tools to continue where Bjerknes and Richardson had left off. It was realized then that computations on the scale of Richardson's could be carried out in hours rather than months. Some encouraging success was shown by scientists at Princeton under the leadership of von Neumann, Fjørtoft and Charney in 1950, and since then scientists in the United States and elsewhere have slowly improved on the models using increasingly faster and larger computers.[37]

Many people both within and without the Weather Service were critical of the large share of the Service's limited budget which went into support of numerical weather prediction. This effort needed very costly computers and a large staff of programmers, mathematicians and meteorologists; yet with

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[37] Philip D. Thompson, Numerical Weather Analysis and Prediction, Macmillan, 1961.

the rather limited resources available this dedicated group of mathematicians and meteorologists has succeeded in producing a gradually improved product of weather forecasting based on sound physical relationships. As observations on a global scale increase in quantity and quality and the as yet elementary numerical modelling is further improved upon, there is a hope of a vastly improved product covering a week or two into the future.

Today numerical weather prediction within NOAA is done on an operational level at the National Meteorological Center (NMC) in Suitland under the direction of Dr. Shuman. The director of the National Weather Service, Dr. Cressman, is himself a pioneer in numerical weather prediction. NMC operationally produces 24-hourly, 48-hourly and 72-hourly forecasts of the midtropospheric flow around the northern hemisphere and the corresponding surface flow patterns. Both barotropic and baroclinic forecasts are made. NOAA also maintains the Geophysical Fluid Dynamics Laboratory at Princeton University where Dr. Smagorinsky and a group of mathematicians, meteorologists and oceanographers have done much groundbreaking work in experimentation with and improvements of numerical models.[38]

Operational Use of Satellite Data at NMC

Lack of surface data over the Atlantic Ocean upwind from Europe and lack of upper air data over the entire region of concern was one of the main reasons that Richardson's experiment in 1922 failed. Even today large

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[38] Operations of the National Weather Service, op. cit.

portions of the globe, particularly in the tropics and over the oceans, are so poorly observed by conventional means that lack of data limits the accuracy of forecasts from present numerical models. To some extent satellites over the last decade have filled this void. At the beginning of 1971, operationally useful data were being received from satellites ESSA-VIII, ITOS-I, Nimbus IV, ATS I, and ATS III.[39] However, the use of these data, and those from previous satellites, has not been as extensive as one might suppose.

The Deputy Director of NMC, Harlan Saylor, is quoted below on the operational use made of satellite data in 1967.

> Some changes are made to the 500-mb. hand analyses of the height field, mostly in the Pacific Ocean area, on the basis of satellite data. Then, if warranted, bogus heights or winds based on these changes are punched on cards and entered in the numerical analysis. Most of the changes consist in the adjustment of troughs and circulation centers, although occasionally a ridge line or jet stream axis will be repositioned. Adjustments at sea level, such as a change in the location of a front, can also influence the upper-air analyses because of the thickness buildup procedures employed. Although there is little doubt but that on the average the analyses have been improved by making use of inferences from satellite pictures, there remains considerable doubt as to the impact of these improvements on the 36-hr. forecasts. The largest forecast errors consistently show up in eastern North America and off the east coast of Asia, implying that the forecasting model rather than the analysis is at fault. In any case, this situation makes it difficult to verify the influence of better analyses on the forecasts. By far the biggest difficulty in using satellite data is that one cannot

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[39] ESSA-IX and NOAA-I were in a back-up mode (personal communication, NWS).

objectively assign a number to the wind or temperature at a point in the atmosphere on the basis of cloud pictures.[40]

On the occasion of the Weather Service Centennial in 1970, the Director of the National Environmental Satellite Center, David S. Johnson, reported the following additional uses of satellite data:

> ... Quantitative estimates of the moisture field over the Pacific Ocean are produced which are used in the NMC quantitative precipitation forecast scheme. ESSA satellite cloud images have been used in the tropics to define the upper level wind field... We are now using ATS pictures in an experimental operational program, in which NMC is provided with wind data derived from ATS-I pictures over the Pacific on a daily basis... (The Satellite Infrared Spectrometer-SIRS) has been so successful that data from this sensor are now being used operationally in the National Meteorological Center's numerical analysis and the prediction scheme.[41]

An unpublished study by the NOAA Systems Division, released in October, 1970, is quoted below:

> Uncertainty as to possible impacts of the differences (between conventional and satellite soundings) has led to restricted patterns of use of the satellite data.
>
> In the operation of the NMC Analysis and Forecast system, the amount of SIRS data from experimental NIMBUS spacecraft has been far less than enough to prepare a forecast unaided. From SIRS A, no more than tens of soundings found their way into any one operational run because of uncertainty as to the accuracy of the new type of data and unsolved problems relating to updating the asynoptic data. It has thus never appeared advisable, to date, to redesign the entire NMC operation around the satellite data. Up to the present, SIRS soundings have been treated exactly as if they were balloon soundings.

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[40]E. P. McClain (reporter), The SINAP Problem: Present Status and Future Prospects, NESC Report No. 41, ESSA.

[41]David S. Johnson, TIROS I plus ten, <u>ESSA World</u>, Vol. 5, No. 1.

Satellite data are used as depicted in Figure 10. SIRS data for 12 hours centered on map time are entered once a day into the 1200 GMT "final analysis." The purposes of the final analysis are to use all available data and to produce a twelve-hour prognosis which serves as a first-guess for the subsequent analysis.

The relative effect of data entered directly in the operational analysis, as opposed to an entry via the final analysis, is difficult to assess. By this procedure, the NMC data base at 0320 GMT includes data which is a mixture of:

- o 12-hour-old conventional data, updated via 3-level 12 hour forecast
- o 6-18-hour-old satellite data, updated via 3-level 12 hour forecast
- o 0-3-hour-old satellite and conventional data

Since this procedure occurs only once per day, satellite soundings between 0200-0600 GMT and 1800-2100 GMT are not used at all.

NMC procedures which place SIRS soundings in a special category are:

- o Satellite soundings are utilized in the operational run only up to 3 hours off time, pending development of updating procedures
- o Tighter toss-out limits have been applied to SIRS A and B data because of loss of accuracy resulting from channel outages.

Another form of satellite data, quasi-objective analysis of cloud patterns, is now being used subjectively for the North Pacific Ocean area once per day. From cloud pictures scanned by the Applications Technology Satellite (ATS), and NOAA's ITOS I, independently derived contour patterns and heights of the 500 mb. surface are determined. This product, now hand-drawn, is used as a check on the accuracy of the computer-drawn 500 mb. analysis of the Pacific, where the scarcity of radiosonde observations and of satellite soundings still characterize the NMC operating procedures as sparse data area procedures.

Two levels of wind information are derived from ATS III time lapse film strips of cloud pictures. Through measurements of cloud-top

NMC ANALYSIS AND FORECAST SYSTEM
OPERATIONAL ANALYSIS FORECAST CYCLE SHOWING UTILIZATION OF SATELLITE SOUNDING DATA
ALL TIMES GREENWICH

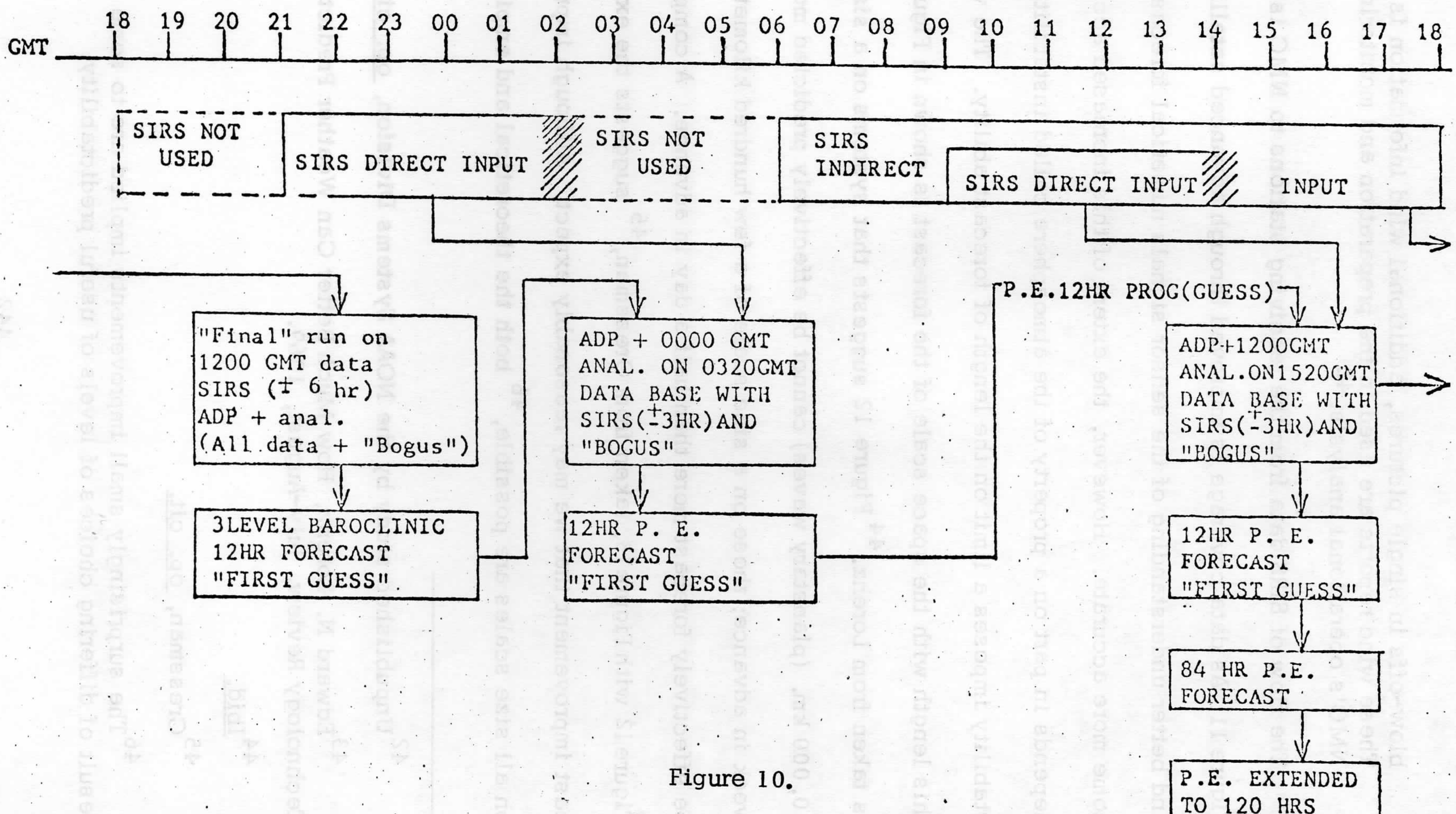

Figure 10.

blow-offs in single pictures, additional wind information is obtained. These wind reports are used in the preparation and monitoring of NMC's operational analysis.[42]

The flow of SIRS data from the receiving stations to NMC is shown in Figure 11. As data coverage is improved through advanced satellite sensors and better understanding of the sensor signals numerical forecasts will become more accurate. However, the extent of this increased accuracy depends in part on a property of the atmosphere called instability.[43] Instability imposes a limit on the length of forecast ability. The variation of this length with the space scale of the forecast is shown in Figure 12, which is taken from Lorenz.[44] Figure 12 suggests that systems on a size scale of 10, 000 km. (planetary waves) cannot be effectively predicted more than a week in advance; those on a size scale of a few hundred kilometers cannot be effectively forecast more than half a day in advance. A comparison of Figure 12 with Figure 13, taken from Cressman,[45] suggests the extent of forecast improvement that we may reasonably expect. Although improvements on all size scales are possible,[46] both the theoretical and empirical treat-

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[42] Unpublished study by the NOAA Systems Division, <u>op. cit.</u>

[43] Edward N. Lorenz, How Much Better Can Weather Prediction Become? Technology Review, July-August, 1969.

[44] <u>Ibid.</u>

[45] Cressman, <u>op. cit.</u>

[46] The surprisingly small improvements implied are to some extent a result of differing choices of levels of useful predictability.

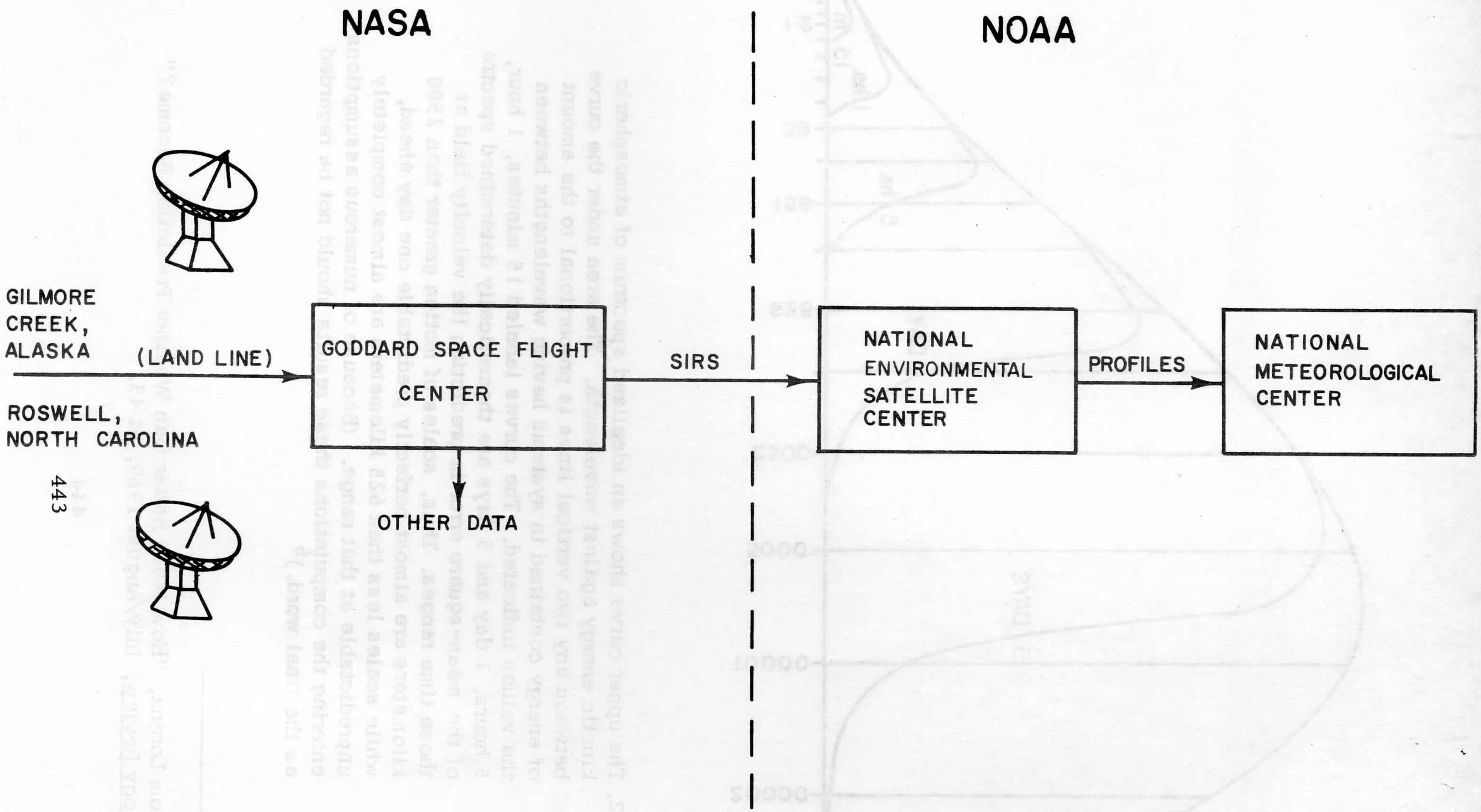

Figure 11. Flow of Nimbus SIRS data from receiving station to user.

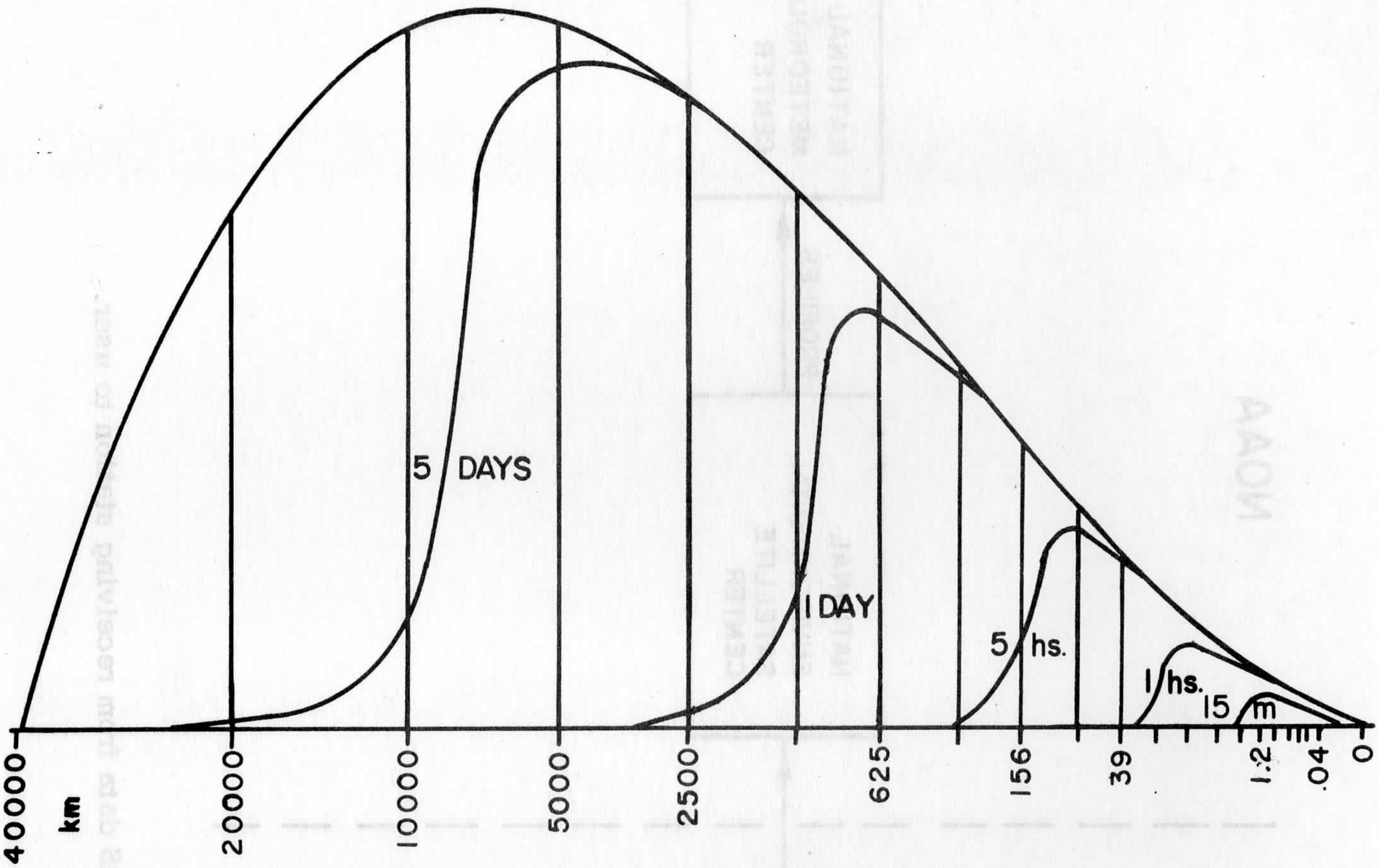

Figure 12. The upper curve shows an idealized spectrum of atmospheric kinetic energy against wavelength. The area under the curve between any two vertical lines is proportional to the amount of energy contained in systems having wavelengths between the values indicated. The curves labeled 15 minutes, 1 hour, 5 hours, 1 day and 5 days are theoretically determined spectra of the mean-square error in predicting the velocity field at those time ranges. Thus, scales of motion greater than 2500 kilometers are almost perfectly predictable one day ahead, while scales less than 625 kilometers are almost completely unpredictable at that range. (Because of numerous assumptions entering the computations these results should not be regarded as the final word.)[6]

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[6] From Lorenz, "How Much Better Can Weather Prediction Become?" Technology Review, July/August 1969, at 43.

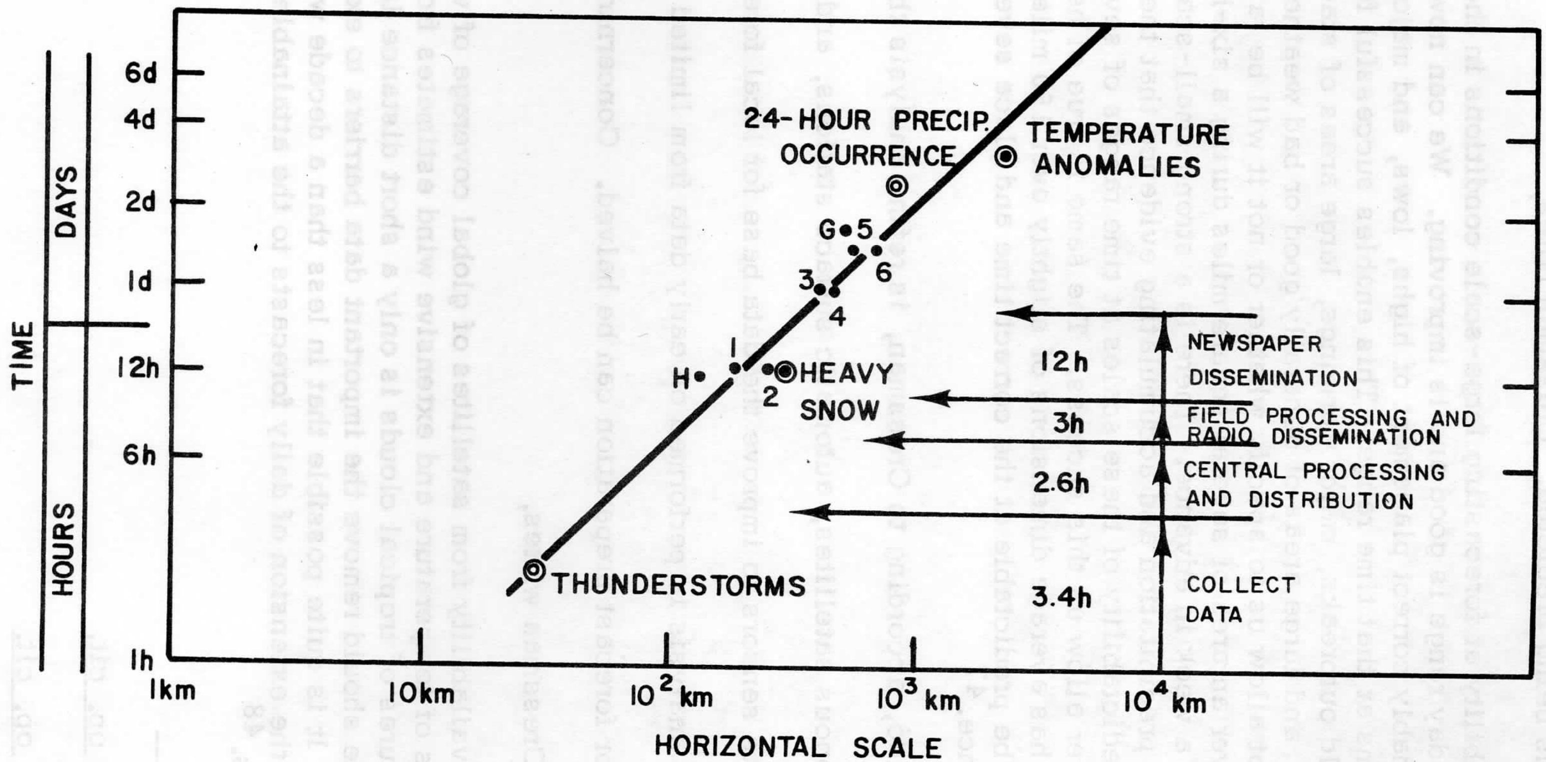

Figure 13. Limits of current predictive ability of public weather forecasts (from Cressman, op. cit.).

ments show a decrease in the limit of predictive ability with decreasing size of the systems being predicted. Cressman notes,

> Our present ability at forecasting large-scale conditions in the three to five-day range is good and is improving. We can now expect reasonably correct placement of highs, lows, and major frontal systems at that time range. This enables successful forecasting of cold outbreaks, major warmings, large areas of stagnant air flow, and large areas of generally good or bad weather. But it does not allow us to specify whether or not it will be raining or snowing over an area of several square miles during a six-hour period nearly a week in advance. There is a strong small-scale component to precipitation and accumulating evidence that the inherent unpredictability of these scales at time ranges of several days will never allow us this success. The same is true of heavy snow, which has average dimensions of slightly over 150 miles. It may never be predictable at the correct time and place several days in advance.[47]

What we can do, according to Cressman, is refine analysis through radar, geosynchronous satellites, automatic surface stations, and as yet undeveloped remote sensors to improve the data base for local forecasts. If rapid numerical analysis is performed on early data from limited areas the time needed for forecast preparation can be halved. Concerning long-range forecasts, Cressman writes,

> The regular availability from satellites of global coverage of vertical soundings of temperature and extensive wind estimates from satellite pictures of tropical clouds is only a short distance in the future. These should remove the important data barriers to extended forecasting. It is quite possible that in less than a decade we will have pushed the extension of daily forecasts to the attainable limit of usefulness.[48]

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[47]Cressman, op. cit.

[48]Cressman, op. cit.

THE OPERATIONAL USE OF SATELLITE DATA IN HURRICANE FORECASTING*

Another use of meteorological satellite data relative to short-range weather activities is that pertaining to hurricane and other weather disaster situations.

One of the first areas of operational forecasting where meteorological satellites found immediate use was in the detection and tracking of tropical cyclones. These large storms form over the tropical oceans in summer and fall and when moving over a coastal area can be very destructive due to accompanying high winds, tides and heavy rainfall. Tropical cyclones, when sustained winds reached above 75 miles per hour (force 12 on Beaufort scale) are called hurricanes in the North Atlantic (including the Gulf of Mexico and Caribbean Sea) and the eastern North Pacific over the waters between Mexico and the Hawaiian Islands. In the western North Pacific they are called typhoons, while in the Indian Ocean they are called cyclones. In the formative stages before winds reach 35 miles per hour, the tropical cyclones are termed tropical depressions, while in the intermediate stage they are known as tropical storms.

Tropical cyclones form over the oceans where sea surface temperatures over large areas exceed 80° F. Evaporation from these warm waters is ex-

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*by Hans Rosendal, Space Science and Engineering Center.

ceedingly large and with a small increase in water temperature, evaporation will show a proportionately much larger increase. If the warm, humid air in the lower layers is able to rise to the colder environment aloft, the water vapor will condense into cloud droplets on tiny salt and combustion particles always found in the air and the heat utilized in evaporating the water vapor from the sea is returned to the air and may cause the cloud droplets and surrounding air to rise to even greater heights while drawing in additional moist air from the lower layers. This is the fashion in which the cumulus clouds of the trade wind region form and build. When a cloud has reached a certain height the tiny liquid cloud droplets coalesce to form large rain drops or may freeze into ice crystals or snow flakes and precipitation may occur. Cloud droplets exist in liquid form at temperatures well below freezing. The change from liquid into ice also releases energy which heats the surrounding air, but to a much lesser extent than the earlier mentioned latent heat of evaporation which is released when cloud droplets form from the invisible vapor.

Air pressure at sea level is determined by the weight of the column of air above a point. Any heating of the air aloft due to the release of heat when cloud droplets and ice crystals form will cause air to expand and surface pressure to drop, and the surrounding air at low levels will rush in and destroy this pressure gradient. Right on the equator this in-rushing air will move directly toward the area of lowest pressure. Away from the equator air in motion will be deflected to the right in the northern hemisphere by a force caused by the rotation of the earth. Frictional and centrifugal forces also work on the moving surface air with the result that surface winds spiral inwards towards the center of low pressure in a counterclockwise fashion where the warm, moist air is forced to rise and water vapor to condense and a tropical cyclone may get started. If favorable conditions exist aloft which allows for the speedy removal of the rising air currents, then the tropical cyclone will grow in size and intensity.

Since the highly reflective cloud patterns against the background of the dark ocean tell the whole story of the development and growth of these storms, satellite observations have given meteorologists a powerful tool to monitor the development of the tropical cyclone. Before the meteorological satellites, ship and island observations and in later years reports from aircraft were the only means of detecting these cyclones, and a fair number of the storms in remote oceanic areas went undetected or were only tracked part of their lives. Clues as to whether a tropical cyclone was present in an area came from wind, pressure, cloudiness and wave information from ship and island reports. For instance, a report of westerly winds, a strongly falling barometer, the covering of the eastern sky by a dense cirrus cloud shield (of large curvature) and a high ocean swell of long period or wavelength, all pointed toward the existence of a tropical storm nearby. Hurricanes or typhoons may have a life span of a week or more as they slowly move across the ocean with a forward speed of perhaps only ten to twenty miles per hour while winds may spin around the center at well over 100 miles per hour. The tropical cyclone is known for its erratic behavior. It may suddenly change its direction or speed of forward motion. It may also rapidly change intensity due to changes in pattern of inflow at the surface or outflow aloft. Aircraft reconnaissance has therefore been extensively used to monitor these storms as they approach coastal areas. Very good correlation exists between the central pressure in a cyclone and the strength of the winds in the circulation. Tropical cyclones also vary in size. Some smaller cyclones have proven exceedingly intense over the very limited areas they cover. Also some cyclones have tornadoes associated with them usually in their eastern half.

The satellite for the first time gave the meteorologist a means of constantly watching these changes in tropical cyclones from above. TIROS I, launched in April 1960, in its first months of operation gave numerous glimpses of tropical cyclones in both the Atlantic and Pacific. Operational ESSA satellites, together with the Nimbus series, later gave complete once daily coverage of the entire earth surface. With a glance at the rectified cloud pictures a hurricane forecaster could tell if there were any tropical cyclones present and make a judgment as to size and intensity of the storms. Pictures were often a day old before they reached the hurricane forecaster but in the case of a storm far out at sea this delay was not too important. The availability of Automatic Picture Transmission (APT) on some of the later satellites gave forecasters real-time pictures of a nearby storm once a day but the quality of the transmitted pictures often left much to be desired.

A dramatic advance was made with the launching of a geosynchronous satellite, ATS III, in November, 1967. From its position 22,000 miles above the equator near the mouth of the Amazon River, a high resolution spin scan camera riding on ATS III provided the hurricane forecaster with a marvelous tool for observing the tropical Atlantic. A vast improvement in the usefulness of ATS data for forecasting was realized during the 1970 hurricane season when ESSA initiated immediate retransmission of ATS pictures from the command and data acquisition station at Wallops Island over telephone lines to the National Hurricane Center at Coral Gables. Since then Hurricane Center forecasters have had near continuous, detailed daytime coverage of the tropical Atlantic, and, most important for his forecast, they have had it in real time.

Using the ATS III satellite picture, the trained forecaster can tell with a glance if there are any tropical cyclones in existence over the tropical North Atlantic. In the case of the affirmative—where are the cyclones located? With a good gridding on an overlay and with the customary good landmarks available such as Baja California, Yucatan, Lake Okeechobee, Lake Titicaca, etc., the center of a tropical cyclone can be located with an accuracy of better than ± 1 degree of latitude. Questions concerning the size of a hurricane can easily be answered by a simple visual inspection. Intensity of the storm likewise can be estimated from several characteristics such as the tightness of the coiling of the spiral bands, the brightness of the cloud shield and its circular shape. The lack of cloudiness due to subsidence around a vigorous storm likewise seems to be a good indicator of an intense cyclone.

From successive locations the track of the cyclone is easily obtained, thus the future course and rate of movement of the hurricane can be estimated by extrapolation. Hurricanes, though, often behave extremely erratically, especially near their point of recurvature which usually is near the United States mainland. Development of improved forecasting techniques to help determine the future movement of these storms is therefore most important. Uncertainties in determining the point of landfall may result in a late issuance of warnings for the 100 miles or so of coastline threatened by the storm or the unnecessary evacuation and disruption of large bordering coastal areas. Present forecasting methods using a steering current technique or climatological analogies together with the current numerical forecasting over a data-sparse region frequently fail to predict the erratic path changes caused by changes in the pressure distribution at points often several thousand miles distant.

A visit at the National Hurricane Center and interviews with the forecasters on duty, Mr. Pelisier and Dr. Frank, on September 12, 1970, during the peak of the hurricane season showed tremendous enthusiasm on the part of these experienced forecasters for the tools that the nation's satellite program had given hurricane forecasting. Mr. Pelisier mentioned that the ATS pictures received in real time was the greatest thing that had happened in forecasting during his several years on the job. The contribution of satellites was compared to the great advance which took place when ship-to-shore broadcasts were first received more than 50 years ago. Dr. Frank was particularly interested in the embryonic stages of tropical cyclones. His study of wave disturbances coming out of Africa, the life cycles of tropical cloud clusters, and the behavior of the intertropical convergence zone was made possible through the receipt of satellite pictures.

The National Hurricane Center receives all ATS pictures, from first illumination over west Africa to sunset over the eastern Pacific. A skilled staff of photographic visual aid people constantly adds pictures during hurricane days to a loop film. This loop is played again and again to monitor in detail changes in hurricanes and to check suspect areas for cyclonic movement of cloud elements. Tremendous detail captured in the photos by the fine camera and retained through transmission was praised by both forecasters. Enlargements of cloudy areas were studied in great detail.

One comment from the photographic aides gridding the pictures concerned the added difficulties they had in doing a good job when the ATS satellite transmitted only the northern half of the picture. A sample of the National Hurricane Center's gridded pictures is enclosed.

The forecasters were asked if they thought that aerial reconnaissance into storms might be unnecessary. Their answer in general was that aerial reconnaissance of disturbances far from threatened land areas could be discontinued, but the extra information on measured wind speeds and central pressure of a storm near landfall was of immense value.

Questions were also put to the forecasters about how much they trusted estimates of intensity from the visual inspection of the hurricane on the photographs. As an example the interviewer mentioned hurricane Becky which moved inland over the Florida panhandle on July 22, 1970. Satellite pictures of this storm indicated a poorly organized cyclone which at most appeared as a marginal tropical storm. Aerial reconnaissance had, nevertheless, given indication of winds in squalls reaching hurricane intensity and a hurricane warning was issued for the threatened coastline and residents in low-lying areas were urged to move out. Becky subsequently produced heavy rains over much of the southeast including 8 inches at Tallahassee and 5 inches over portions of Georgia, but winds and tides were minimal along the coast as indicated by the satellite pictures. The reason why Becky was classified as a hurricane and the Florida panhandle area was put under a hurricane watch and warning in spite of the poorly organized appearance of the storm as seen from space was that in earlier cases tropical cyclones had intensified very rapidly near the Gulf coast before moving inland. Hurricane Audrey which drowned 400 people in the bayou country in southern Louisiana on June 27, 1957 was such a case.

Hurricane Celia, which made landfall on the lower Texas coast near Corpus Christi on August 3, 1970, was a case of a very severe hurricane indicated as such by both satellite and aerial reconnaissance and the coastal surveillance radars. Actual wind speeds at landfall were pretty much as predicted, though some criticism was aired locally about winds being much stronger. In forecasts of wind speeds, sustained wind speeds are specified and since gusts are often 30 to 40 percent higher than sustained speeds, some confusion often arises as the local press compares reports of measured gust speeds with the predicted sustained speeds.

Watching meteorologists at the National Hurricane Center at their work, it was apparent that the ATS satellite pictures were an invaluable tool for observing the tropical Atlantic. On September 12, during the interviewer's visit, hurricane Ella had just moved inland south of Brownsville. Ella had crossed inland farther south than first expected using pure extrapolation of the track west-northwestward toward the mouth of the Rio Grande. The forecaster mentioned the fact that climatologically there was a tendency for storms to swerve a little southward when hitting this coast and perhaps this was caused by frictional differences as the large vortex moved part of its circulation over rough land. Satellite pictures had been most helpful in tracking Ella as ship reports became more and more sparse as better observations and forecasts meant that ships will avoid the area.

One area particularly causing the forecasters concern was a showery region over the Bahamas just 100 miles east of Miami. Several bad hurricanes have formed in this area over the years but mostly under such flow conditions that they would move straight northward and threaten the middle or north Atlantic coast. The film loops of the day's satellite pictures showed sign of a cyclonic circulation developing with weak westerly winds just north of Cuba and the formation of an "eye." Information from the numerical forecast showed conditions not good for immediate intensification with the predicted development of a large high pressure area over the Carolinas, Georgia and northern Florida. Movement of the depression was therefore forecast to be toward the southwest across the southern tip of Florida and into the Gulf. Subsequent events showed this to be the case. Two days later the depression intensified to tropical storm strength and was named Felice. Tropical storm Felice made landfall near Galveston on September 15 and weakened rapidly as it moved northwestward over land.

The hurricane forecasters were also asked if they could think of any other area where satellites might help them in their work. A mapping of the sea surface temperature field of the tropical Atlantic was suggested as a useful piece of information helpful in determining intensity changes of a cyclone. Nighttime coverage by infrared scanning of cloud tops likewise would give additional information on location and intensity of a storm.

Flash flooding due to 19 to 15 inch rains occurring when a hurricane moves over hilly terrain has been a most devastating aspect of some hurricanes in the past. The New England hurricane of 1938 and hurricanes Carol and Hazel in 1954 and Camille in 1969 so affected the Appalachian region, causing heavy loss of life. Likewise, in the far east, typhoons crossing the Philippines, Taiwan, Japan or moving into China have wrought such destructive flooding on numerous occasions. Hurricane Camille had crossed the Mississippi-Louisiana Gulf coast on August 17, 1969 and moved northward over land about 500 miles when heavy rains on mountainous terrain within the James River basin of western Virginia during the night of August 19-20, 1969 caused a rapid rise in the river and a flood of a magnitude expected to occur once in a thousand years. Surveys found one confirmed rainfall amount of 27 inches and several of more than 20 inches from the storm while many totals ranged between 10 and 15 inches. Rainfall amounts of this magnitude were totally unexpected from a storm like Camille, which moved through the region from the west of the Appalachians at a moderate forward speed. However, satellite pictures taken by the ATS satellite the previous afternoon did show Camille as an unusually well-developed tropical storm even after having been over land for almost two days. These satellite pictures were not then available to the river forecasters and hydrologists on a real time basis.

The greatest killer and most damaging aspect of a tropical cyclone is the storm surge or "tidal wave" set up by the wind over shallow coastal waters. The strength and direction of the wind, the forward speed of the cyclone, the bottom contours and physical shape of bays and inlets together with the atmospheric pressure reduction in the center of the cyclone determine the height of this wall of water moving inland at the height of the storm. In severe cyclones a rise of about 30 feet has been experienced with wave action on top of that. Approximately 6,000 persons drowned during the Galveston Hurricane of 1900, and, as earlier mentioned, 400 people lost their lives during hurricane Audrey in 1957. Huge disasters of this nature have occurred along the shores of the China Seas and in the Bay of Bengal with the resultant loss of life in excess of 100,000 with many more dying from disease and starvation. Evacuation of exposed areas has worked well in the case of the United States with her well-developed communication and transportation system. In the densely populated Asian delta lands evacuation is usually not attempted even if the knowledge of a severe typhoon or cyclone approaching is available. Gordon Dunn, the former chief hurricane forecaster in Miami, made a survey of stricken areas in East Pakistan in late 1965 and recommended the construction of large platforms onto which the population could move during the 12 to 24 hours of storm passage.

In the last decade or so there have been many cases of hurricanes and tropical storms which have had deadly tornadoes associated with the squalls in their circulation. It is almost an automatic rule that when a vigorous hurricane makes landfall on the Gulf coast, tornado watches are also issued for the right forward (eastern) semicircle of the storm. Satellite pictures have shown that hurricanes with embedded tornadoes often have a wedge of clear air slicing into it from the southwest much like low pressure systems of the plains states when they have tornadoes associated with them. A quick visual inspection of a satellite picture might therefore indicate whether tornado watches should be issued.

The nation's satellite program has already paid off handsomely in the area of tropical cyclone meteorology. Over the years since the launching of TIROS I, meteorological satellites have revealed many storms which would otherwise have gone undetected in the Pacific and Indian Oceans. The climatology of these areas has therefore been much improved. In many cases unsuspecting ships and islands have been warned of the approach of these storms. Lives have been saved, and property has been spared. So important are these warnings that test APT receiving equipment has been installed by the meteorological services of many countries and used by their forecasters to track tropical cyclones and other disturbances. Benefits of this kind have produced great good-will towards the United States and her space program.