EXHIBIT 4

DATA AVAILABILITY

SATELLITE	SENSOR	RESOLUTION	DATES	REMARKS
NIMBUS 3	MRIR 6.7 10-11 20-23 12-4		1969 MAY 15 - JULY 18 JULY 20 - NOV. 19 NOV. 22 - 25, 28, 29, 30 1970 JAN. 9 - 11, 13 - 17, 20 JAN. 21 - 16 JAN. 28 - FEB. 4	RELATIVELY COMPLETE DIGITAL DATA VERY FEW HOURS OF DIGITAL DATA SPORADIC AVAILABILITY FAIRLY CONTINUOUS
	HRIR	8.5km (4.6m mi)	1969 APRIL 17, 19, 22 - 30 MAY 1 - NOV. 30 DEC. 23	NMRT DATA
NIMBUS 4	THIR (11.5 μ)	6.67km (4.1n mi)	1970 APRIL 10 - AUG. 31 SEPT. 1 - DEC. 27 1971 JAN. 5 - FEB. 26	CONTINUOUS SOMETIMES SPORADIC *THE FIRST 500 ORBITS OF NIMBUS 4 ARE AVAILABLE IN SPACE SCIENCE DATA CENTER (SS DC)
	(6.7 μ)	22.6km (14.0n mi)	1970 APRIL 14 - JULY 31 AUG. 1 - DEC. 22 FEB. 2, 5, 21, 22, 1971	CONTINUOUS SOMETIMES SPOTTY
NIMBUS 5	THIR (6.7,11.5um)	22km(6.7) 8km(11.5)	DEC. 72 - JUNE 74 DEC. 72 - JUNE 74	NMRT TAPES 6.7 SPORADIC DEC. 72 - FEB. 73, MAY 74 - JUNE 74 FAIRLY CONTINUOUS LATE APRIL 73 - AUG. 73 11.5 SPORADIC DEC. 72 - MAR. 73, APRIL 74 - JUNE 74 FAIRLY CONTINUOUS LATE APRIL 73 - AUG. 73, LAST HALF FEB. 74
	ESMR	25km x 25km (160km Cross Track) (45km Down Track)	DEC. 72- PRESENT	DIGITAL DATA AVAILABILITY IS POOR AUG. 73, MARCH, APRIL 73 AND ½ of AUG. 74
NOAA 2, 3, AND 4	SR	8km	JAN. 73 NOAA 2 APRIL 74 NOAA 3	- NOAA 3 IS BACK UP TO NOAA 2 - DIGITAL DATA ARCHIVED UP TO 1 YR; TAPES RECTIFIED IN LAT. AND LONG.; 1,J SYSTEM POLAR STEREOGRAPHIC ONLY - NEGATIVES SAVED; MAY BE A CHARGE FOR PICTURE
	VHRR	0.9km	SAME	- WALLOPS SAVES ONE WEEK AT A TIME, THEN ERASES. REQUESTS SENT THURSDAY TO HOLD DATA OR CAN PUT IN A CONTINUOUS REQUEST FOR DATA.
SMS	VISIBLE IR	.9km (½ mi) 7km (4 mi)	MAY 17, 1974 - PRESENT	- WESTINGHOUSE, NEAR FRIENDSHIP AIRPORT RECEIVING DATA 24 HRS, 7 DAYS A WEEK. - TO DATE PRODUCTS MOSTLY IMAGERY THOUGH SPORADIC - A TAPE BACK-UP OF ALL DATA - CODE 564 LOGGING IN DATA RECEIVED - PERMANENT LOCATION NOV. 15, 1974 @75°W - AFTER DEC. 1, 1974 PLAN TO DIGITIZE DATA
DEFENSE METEOROLOGICAL SATELLITE PROGRAM (DMSP)	VIS IR	2 mi 2 mi (1/3 mi POSSIBILITY FOR BOTH)	MARCH 73 UP TO ONE MONTH OF PRESENT	- 3 SATELLITES, EQUATOR CROSSING TIMES 0700 AND 1900, 1200 AND 2400 - IMAGERY REPOSITORY UNIV. OF WISCONSIN - DIGITAL DATA - ONLY THE PRECEEDING 4 WEEKS SAVED AT ANY ONE TIME; OFFUTT AFB

Chairman HUMPHREY. I want to apologize for my delay in getting here. We had a battle going on in the Senate.

I recall our association during the days of the Space Council. I am very pleased to have you here.

I gather that we are going to proceed with the witnesses, Dr. White, Dr. DeNoyer, and Dr. Hill Dr. White, would you proceed please.

STATEMENT OF DR. ROBERT WHITE, ADMINISTRATOR, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, DEPARTMENT OF COMMERCE

Dr. WHITE. Mr. Chairman, members of the Technology Assessment Board, it is with great pleasure that 1 appear before you today to discuss the relationship between technology and agricultural productivity as it pertains to the work of the National Oceanic and Atmospheric Administration. Weather and food productivity are so closely related that making a point of it only states the obvious.

The question I wish to discuss today is not what the relationship is between weather and agriculture, but how emerging technology for observing and predicting weather conditions can make our agricultural information systems more effective in increasing agricultural productivity and assist in policy decisionmaking. I would like to talk about three ways in which weather information can be of great value in agricultural information systems.

The first deals with the provision of agricultural weather services directly to the farmer to enable him to carry out his daily tasks with greater efficiency. Advance weather information a day or two ahead can affect the way in which he protects, sprays, harvests, or sows.

The second involves the provision of weather data as part of an agricultural warning and assessment system. Such weather information from our country and others, plus an understanding of the relationship between weather and crops can enable us to assess the impact of the recent past and present weather conditions on crop production, thus generating a basis on which both operating and policy decisions can be taken.

Lastly, there are the problems of climate and anticipating its future changes. An ability to predict changes in average weather conditions over a period of months, seasons, or years could be valuable in alerting us to possible adverse or beneficial growing conditions both in this country and around the world. Such information could be useful in planning decisions on agricultural production, storage of agricultural reserves, food export policies, and preparation of disaster assistance.

New technology can assist us in providing such information. Some of this new technology is available, some requires more development. Improved basic understanding of weather phenomena is essential for all applications.

Let me talk briefly about the agricultural weather service. The provision of daily forecasts of the weather specifically geared *to serve* the farmer is not a glamorous activity, but it is certainly one that can most directly affect agricultural productivity. The fruit frost forecasts for the valleys of California, or specialized forecasts for the corn and wheat growers that enable them to fertilize and spray at the right time are dependent upon one of the world's most comprehensive and complex environrnental-information-gathering systems. The system is worldwide, for we need weather information not only from our own country, but from all countries of the world if we are to predict the weather even a few days ahead.

Weather information is collected by satellites, aircraft, ships, and land stations. These data are processed daily by large computers at the National Meteorological Center in Washington and delivered to our many field offices via high speed facsimile systems. Our field forecast offices tailor these data and forecasts to the needs of farmers in various areas of the country.

One might think that such an important service would be in existence in all parts of the Nation. As a matter of fact, since its inception some decades ago, it has been introduced to about 20 percent of the United States. If we are going to develon agricultural information systems that will increase our agricultural productivity, it will be

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necessary to extend our agricultural weather service throughout the Nation.

Secondly, I would like to talk about a weather warning and agriculture assessment system. By this, I mean a system that enables us to be aware at all times of weather conditions within our country and in other countries of the world, and being able to understand the implications of cumulative weather at any point in the growing season upon the outlook for crops. The Department of Agriculture keeps close tabs on the status of our crops and we work closely with that Department in providing detailed weather information accumulated from our observational networks both here and abroad.

However, new technology offers the hope that we can do this better. Earth-orbiting satellites have great potential. The NASA Landsat which provides multispectral sensing data, may enable us to estimate acreage of crops planted and the state of crops. When combined with the weather satellite information, and other weather information, as well as a knowledge of the relationship between weather conditions and crops, we have a potential capability of great value. At the present time, together with the National Aeronautics and Space Administration and the U.S. Department of Agriculture, we are engaged in an experiment called the Large Area Crop Inventory Experiment [LACIE].

Last, I would like to talk about the problems of climate. World food reserves have now sunk to a point where year-to-year fluctuations in climate can have disastrous effects upon world food supplies with serious economic and political consequences. Is there a possibility of improving our ability to anticipate climate changes better than we can do today? Our present ability to anticipate weather conditions a month, season, or a year in advance is very poor. It is poor because we lack the basic understanding of the causes of changes in climate. It is also poor because we have not had the technology for acquiring necessary observations or processing them.

To improve the national capability for anticipating changes in climate better than we do today, we must bring to bear a new range of advanced technology. If we are to understand and predict natural climate fluctuations, there are some fundamental measurements that we must make.

For example, the climate of the world is related to the state of the oceans. It is necessary for us to have a system for monitoring oceanic conditions. Such a system must be based upon the use of Earth-orbiting satellites which have a capability of measuring sea surface temperatures, sea state, and ocean currents, ships of opportunity that may take highly automated ocean surface and subsurface observations while traveling their normal routes, and automatic buoy technology which can measure the conditions of the oceans at depth. We are experimenting with both of these technologies.

The National Aeronautics and Space Administration has under development an ocean satellite to measure many aspects of the conditions of the oceans. The Seasat, in addition to the Landsat and the environmental satellites of NOAA, offer us opportunities to gather ocean information that we have not had before.

In the case of buoy technology, we have had a research and development program underway for 5 years aimed at providing buoys which can remain unattended in the deep oceans for as much as a year, radioing back their information about oceanic conditions via satellite. Our buoy developments are at the prototype stage. During the next year we will deploy a prototype buoy network along our Pacific coast. I cite this only as an example of the opportunities that new technology opens for us in the examination of climate.

Chairman HUMPHREY. Do we still have the marine science operation ?

Dr. WHITE. No, we don't. We do have a committee which I chair called the Interagency Committee for Marine Science and Engineering. NASA and Interior, are represented.

Central to our ability to move forward is the development of a capability to simulate the ocean-atmosphere system by mathematical computer models. For this we will need to move toward new generations of computer systems. In NOAA we employ the largest commercially available computer system. At our geophysical fluid dynamics laboratory we operate the Texas Instruments advanced scientific computer, a so-called fifth generation computer which can execute approximately 40 million instructions per second. We will need to move even larger computers operating at speeds greater than 100 million instructions per second if we are to model the atmospheric and oceanic system and use such models to predict the future climate.

Technology will be important to us also in attempting to monitor and understand the consequences of man's pollution of the atmosphere. The release of substances such as nitrogen oxides, which come from supersonic transports and nitrogen fertilizers, or chlorofluorocarbons, which are used in refrigeration and aerosol spray cans, can affect the ozone.

While we are much concerned about the impact of a decrease in the ozone layer on human health and upon terrestrial and aquatic ecosystems, we have heard little about the possible effects of a decrease in ozone upon the climate of the world. Perhaps it is because we do not understand the consequences, but the ozone layer, because of its special property, is important in heating the stratosphere. A reduction of the ozone can have an effect on the temperature of the upper atmosphere and may consequently influence the lower atmosphere and our weather as well. It is an impact that we need to understand.

There are other human activities about whose effects on the climate we need to be concerned. Burning of fossil fuels adds heat directly to the atmosphere, and it adds car on dioxide. Poor agricultural practices and industrial activities add particulate matter. These and other substances can have an impact upon the atmospheric energy balance and hence upon the climate. We need to understand these effects better.

In order to do so, we are going to need new technology to monitor and measure. We will need satellites and aircraft and balloons. We will need new instrumentation and facilities to measure the rate at which these contaminants are building up in our ocean and atmospheric system.

Weather information must be an integral part of any agricultural information system. We can improve the availability of needed weather information. The key to this improvement is the use of advanced technology.

Thank you.

[The following paper was requested from NOAA by OTA:]

ADVANCED TECHNOLGY IN AGRICULTURAL WEATHER INFORMATION SYSTEMS

EXECUTIVE SUMMARY

Automatic data processing and satellites are now and must continue playing key roles in agricultural weather summaries and forecasts. Both technologies are used in preparing daily advisories and forecasts for U.S. farmers, in agrometeorological studies, in monitoring and analyzing growing season weather over major world grain producing areas, and in the Large Area Crop Inventory Experiment (LACIE). Automatic data Processing also is an essential tool in developing a capability to interpret long-terrn impacts of growing season weather in terms of variability of future yields.

The National Oceanic and Atmospheric Administration (NOAA) is applying these technologies as rapidly as resources and the state of the art permit. Basic to future progress, however, will be the need for computers of sufficient capacity and speed to handle the large volume of data required to develop adequate global climatic model Such modeling research has begun at NOAA's Geophysical Fluid Dynamics Laboratory at Princeton, New Jersey.

The National Oceanic and Atmospheric Administration (NOAA) uses automatic data processing and meteorological satellite imagery for its weather forecasting services for agriculture, for agrometeologcal studies in support of more effective agricultural Practices, and for developing global weather-yield estimation models.

NOAA National Weather service (NWS) forecasts including agricultural weather forecasts, are based on activities at an extensively computerized National Meteorological Center (NMC). NMC routinely acquires large amounts of cloud and temperature data from weather satellites as well as over 20,000 land-station, ship, balloon, and aircraft observations daily. NMC computers process the raw data and produce weather map analyses, Prognostic charts, and other guidance material such as quantitative Precipitation forecasts for dissemination to NWS field offices and other subscribers. The NMC guidance is disseminated through. more than 600 facsimile and 800 teletypewriter transmissions daily. The centralized preparation of data maps, and forecasts is designed to eliminate ***most*** requirement for hand charting and independent meteorological analysis at field offices. The NWS through combined use of its large computer facility, numerical forecast methods, and its field forecast offices and service centers, provides agricultural and other users with daily forecasts and outlooks out to five days in advance.

Specialized agricultural weather advisories and studies at the state 1evel also use weather satellite data as well as nearby university computer systems. As an example, the Environmental Studies Service Center at Auburn, Alabama has begun a study to use weather satellite data in its real-time agricultural weather service program. It centers on development of techniques and methods providing the absolute radiation temperature at the earth's surface and then incorporating the thermal data into models for Prediction of soil temperature and moisture. In addition, the thermal data will have great utility in improving service in areas where freeze hazards exist. The thermal data will pictorially portray the real-time development of a freeze allowing growers to sharpen decisions in management of cold protection practices. In addition, a "cold night" climatology can be produced which will be valuable in land use planning and in improving "spot" temperature forecasts.

NOAA progress in more timely acquisition of global precipitation and temperature data for cumulative growing-season assessments was described in the fourth and fifth paragraphs of Dr. Edward Epstein's report of September 25, 1975 to the Technology Assessment Board. For completeness I should add that the Air Force Global Weather Central at Offut Air Force Base is working with us to extend and improve the precipitation estimating procedure that systematically integrates conventional meteorological observations and satellite observations of clouds over selected areas of the Northern Hemisphere.

NOAA development of weather-yieid estimation models is a part of the NASA/NOAA/USDA Large Area Crop Experiment (LACIE). The goal of LACIE is to provide prompt (within 14 days of data acquisition) objective estimates of wheat production. NASA and the USDA are concerned with developing experimental demonstration systems, using LANDSAT multispectral data,[1] to determine acre-

1 Data on spectral reflectance of the target of competing crops.

ages of wheat planted in eight nations. NOAA's Environmental Data Service and the USDA are concerned with defining and quantifying the relationship between meteorological conditions and crop yield in the same eight nations.

NOAA weather-yield estimation is accomplished by use of meteorological data routinely available through the World Meteorological Organization communications links augmented by examination of satellite images from the NOAA polar orbiting and geostationary satellites. It is not now possible to obtain quantitative data from satellites on most of the important environmental parameters most affecting crop yields, e.g. soil moisture and solar radiation. Satellite images are useful, however, in detecting areas which remain cloud free (hence without precipitation) for long periods of time resulting in drought conditions. Satellites are also of considerable use in tracking large storm systems over crop producing areas to improve estimates of rainfall or call attention to potential flood conditions. It is our intention to incorporate quantitative data derived from satellites when the data acquisition and processing techniques have been developed.

In our opinion, LACIE has tremendous potential for providing prompt, objective, world-wide information on critical crops. The first year of the program focused on the Great Plains areas of North America. Preliminary results are encouraging. Technical problems in acreage estimation have been identified and, we believe, solved to the point that the three agencies are proceeding with phase two-an 18 month test of techniques for the Great Plains plus selected areas in other nations. Preliminary analysis of the yield estimation system used in phase one is quite encouraging. Phase three will consist of a full scale test on a global scale and is scheduled to start in about a year.

The continued availability of satellite data is critical to the long term applicability of LACIE-derived technology for operational estimating of global production of wheat and other major crops. This assumes that LACIE proves successful and cost effective. LANDSAT 2 is performing well, with an expected lifetime through 1977 or 1978, and the follow-on satellite (LANDSAT-C), has been authorized. Continued availability or digital multispectral data beyond the early 1980's is not certain. Since the central concept of LACIE acreage determinations is semi-automatic computer processing of multispectral data used in multitemporal analyses: no other known satellite systems can be 'used.

The weather-yield estimating system, as discussed above, does not depend on quantitative data from satellites. It is believed, however, that instruments proposed for future experimental or operational environmental satellites will provide quantitative data useful for this purpose, Continued research and development is necessary in NASA and NOAA to develop these instruments and the technology to derive meaningful geophysical data. Likewise, additional efforts are needed to develop and improve mathematical models which relate meteorological conditions to crop yields. LACIE focuses on wheat acreage, yield and production. Other NOAA efforts are devoted to modeling yield of corn, soybeans, and other important crops utilizing computer facilities at the University of Missouri *in* Columbia.

Advanced computer technology is especially needed in NOAA's basic meteorological research efforts. Basic understanding and skillful prediction of seasonal weather and climate will be achieved only with the aid of computers of very large capacity and speed. Immense volumes of data must be processed to develop adequate global climate models which incorporate at least the most significant of the many complex feedbacks between ocean and atmosphere. Development of models to simulate possible impact of man's activities on climate and to study the dynamics of trace contaminants in the stratosphere similarly require giant computers. NOAA's Geophysical Fluid Dynamics Laboratory (GFDL) already is using an Advanced Scientific Computer (ASC) to conduct fundamental investigations in the dynamics of atmospheric processes over a wide range of time and space scales. These investigations include studies on many scales of motion and a host of interrelated physical processes.

Of particular interest to agricultural meteorology, GFDL mathematical models have achieved reasonably accurate simulations of typical seasonal distributions of wind, temperature, and precipitation. Testing the ability of these models to predict seasonal weather variations using real atmospheric and oceanic observations has not been done and requires very extensive computer power. Progress

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[a] Examination of data during two or more critical biological development states (growth stages) of the crop.