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OUTLINE OF THE SURVEY ON THE DEVELOPMENT OF EARTH OBSERVATION SATELLITES

Research Coordination Bureau

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16 Abstract

Japan will develop an independent earth observation system with both land and sea satellites. The sea satellite will be developed first, because the sensors for land use must be highly accurate for Japan's use, and data collection concerning the oceans (especially fisheries resources data) is essential to Japan. The sensors to be developed in the next 15 fifteen years are the visible and infrared radiometer, microwave radiometer, microwave scatter meter, synthetic aperture radar, and the laser sensor. An experimental technical satellite (ETS-III) will be launched in 1981 to experiment with triaxial attitude control, and to develop basic technology common to sea and land observation satellites. The N rocket II will be developed and tested. The sensors for the first sea satellite (1981) will be developed by the end of the 1970s. Rather than purchase satellite equipment abroad, Japan intends to produce it domestically as far as possible, though it will take as long as 15 years in some cases, as for laser sensors. Land data analytical technology will be developed using U.S. LANDSAT data.

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The consent of the Science and Technology Agency must be obtained before quoting the contents of this report.

PREFACE: METHODS AND PURPOSE OF SURVEY

1. Purpose of Survey

Observation data obtained by earth observation satellites which observe the surface of the earth with sensors is exceedingly useful for the management of the earth's resources and preservation of the environment. This is especially true for Japan, a nation surrounded on four sides by the sea and poor in natural resources. Thus it is essential that we develop and launch earth observation satellites at an early date with the aim of obtaining data for securing and making efficient use of marine resources, preservation of the ocean environment, ensuring the safety of navigation and establishing warning systems for coastal natural disasters. This survey is a composite of the studies and investigations concerning the mission and mission equipment of the first earth observation satellite which is to be launched in 1981 and of the different types of earth observation satellites to be developed in the next 15 years. The studies were done with the aim of providing material for establishing concepts for satellites suitable for Japan and for the efficient development of these satellites.

2. Methods of Survey and Contents

2.1. Methods

This survey is based on the results of "Studies concerning earth observation satellites," which is a collection of case studies conducted in this agency in 1975 concerning earth observation satellites. The survey was done by an investigation committee and two project groups established in the Remote Sensing Technology Center (a foundation). The contents of the survey are as given in the items of investigation in 3 below.

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3. Items of Investigation

I. Concerning the promotion of the development of earth observation satellites in Japan in the next 15 years

1. Studies concerning earthvobservation satellite missions
   a. Missions
   b. Objects of observation
   c. Resolving power
   d. Observation
2. Studies of mission equipment and problems in the present state of development technology for earth satellites
3. Study of plans for the development of earth observation satellites of foreign countries
4. Study of utilization systems for earth observation satellite data
   a. Utilization organs
   b. Optimum utilization systems
   c. The relationship between data collected by aircraft and data collected by satellite
5. Examination of development plans for the development of earth observation satellites for the next 15 years

II. Survey of the mission of the first earth observation satellite and mission equipment

1. Examination of mission
   a. Mission
   b. Objects of observation
   c. Observation wave length
   d. Ground resolving power
   e. Range of observation
2. Examination of satellite systems
   a. Major equipment to be carried on board
   b. Accuracy of altitude control
   c. Observation wave length

d. Orbit
e. Launching rocket

3. Survey of the policies necessary for the development of satellite systems

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Science and Technology Agency of Japan

I. The Role of Earth Observation Satellites and the Necessity for Japan to Develop Them /6*

The results of the launching of the earth observation satellite LANDSAT by the United States has created a ripple effect in the countries of the world. Not only have many countries installed ground stations for the reception of data from the American satellites, but in several countries, movements are underway for the development of their own independent satellites. In Japan also, there are many fields for which the launching of earth observation satellites is becoming a necessity.

This report examines the problems facing the world and Japan at the present time, and the problems that will probably be facing us in the future. It discusses the rôle that earth observation satellites can play in coping with these problems, and the necessity for Japan to develop various kinds of earth satellites.

The discussions in this report are based on the flow chart shown in Figure 1.

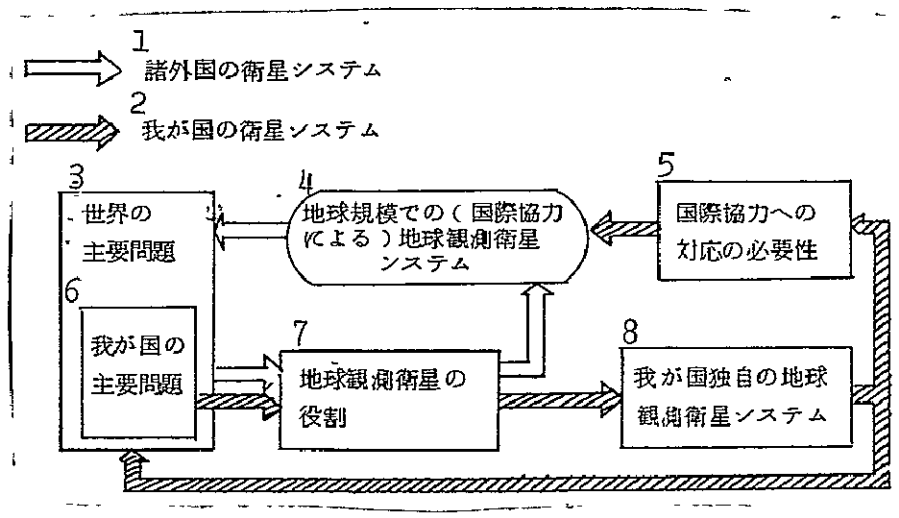

Fig. 1. The role of earth observation satellites

Key: 1. The satellite systems of foreign countries 2. The satellite system of Japan 3. The major problems of the world 4. Earth observation systems of world scope (by international cooperation) 6. The major problems of Japan 7. The role of earth observation satellites 8. The independent earth observation satellite system of Japan

*Numbers in the margin indicate pagination in the foreign text.

I.1. Major Problems of the World /7

Among the problems of the world that must be viewed from a world perspective, and which are in fields in which science and technology can contribute solutions, are population and food supply, the problem of natural resources, problems concerning the environment, and the problem of natural disasters.

The report of the Rome Club, The Limits of Growth, on the assumption that the physical, economic and societal systems controlling the earth's systems would not change, estimated that in the year 2000, the population of the world would be 6.5 to 7 billion, about double what it is now. It was also estimated that a population of that size was about the limit that the world could support. According to the American Presidential Science Advisory Commission, the estimated potential arable land (1967) of the world is 3.2 billion hectares, and of this, 1.4 billion hectares, or 44%, is now being cultivated. It is estimated that 2.8 billion hectares would need to be cultivated to produce food for 7 billion people. Thus, the present 1.4 billion hectares that are under cultivation would have to be expanded by 1.4 billion hectares. However, the remaining arable land includes areas like the Amazon basin, which would be difficult to develop. Financially and ecologically, also, such large-scale development would be very difficult. Even if measures were taken now to control the increase in population, the effects of this would not appear for 15 or 20 years. And it is thought that there is certain to be a period in the future when it will be very difficult for the increase in food supply to keep pace with the increase in population.

There are problems even now concerning food, when the supply is decreased because of abnormal weather, or when there is local maldistribution of the supply. In 1972, there was damage to crops from the cold due to changes in the weather structure, and there were local reductions in the fisheries catch due to local abnormalities in ocean currents. This affected all parts of the world. The impact of a reduction in the food supply has a chain effect which is transmitted throughout the world. It is reported that as a result of the reduction in supplies noted above, several hundreds of thousands of people died of hunger in Bangladesh, India, Mauritania, etc., and millions more suffered from malnutrition. The above example reaffirms that underproduction in one /8
country is not only a problem for that country, but can bring about economic and political disorder in a great number of other countries as well. It has become clear, especially concerning the struggle for survival at the national level, that nations with low self-sufficiency are struck hard by a reduction in food production. In 1973 the reverse happened, and due to early heat, there were abundant crops at high latitudes. Then in 1974 there was underproduction because of a lack of chemical fertilizers caused by abnormal weather and the oil crisis. The situation

concerning the supply and demand of food has become very unstable. It can be expected that this kind of situation will repeat itself many times in the future. Thus, it is important that the food production situation be considered from the point of view of the entire world. Consequently, it is urgent that a system for collecting information on world food production be established.

A matter of great concern for all the nations of the world concerning natural resources is the problem of depletion of the petroleum supply. The oil enterprises in the Middle East countries have been nationalized, OPEC has been formed, and there has been a fourth war in the Middle East. In addition, it is clear that the petroleum resources are limited. It is clear that petroleum doesnnot have just an economic value, but that it has become a "strategic resource" directly affecting the security of nations. This strategic value of oil in the future will not be limited to oil, but is sure to be extended to all kinds of mineral resources, and to food. The reduction in the expenditure of natural resources, their more efficient use, the development of other resources, and the discovery of new resources should be a major concern in the industrially-developed nations of the world.

Along with the development of new resources, information-collecting systems will become increasingly important. The environmental question, also, is coming to be regarded as very important, especially in the industrially-advanced nations. Smog and other pollutants of the atmosphere, ocean pollutants (oil spills, etc.), DDT, PCB, mercury, cadmium, etc. all are problems that directly or indirectly affect the ecological system.

These problems are coming to be recognized as problems that must be coped with on a global scale. In 1973 the "United Nations /9
Human Environment Convention," in which 58 nations are now participating, began in Stockholm, and is to meet every year in the future. Thus, it is coming to be acknowledged that not only reports on local environmental conditions are needed, but that it is very important to have an environmental report-collection system on a world-wide scale. An example of one problem confronting the world is shown in Figure 2.

In recent years, many countries have suffered great damage from natural disasters such as those connected with the weather (cold damage, typhoons, tornadoes, etc.). The frequent occurrence of disasters from earthquakes and volcanoes and damage caused by tsunami from the ocean cannot be ignored. The collection of information for the prediction of natural disasters of this sort is extremely important.

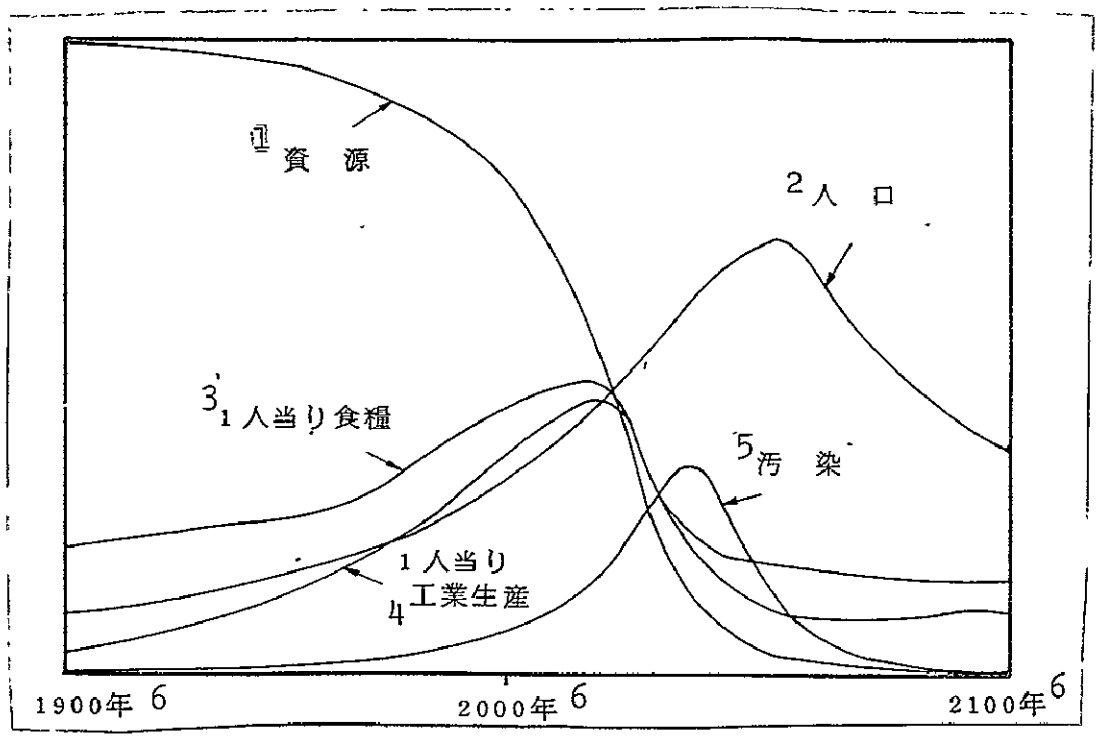

Fig. 2. The relationship between increase in population and natural resources and the environment

Key: 1. Resources 2. Population 3. Food for one person 4. Industrial production for one person 5. Pollution 6. Year 2100

I.2. Major Problems of Japan /10

The major problems confronting the world related above, such as population, food supply, natural resources, the environment and natural disasters, all confront Japan.

The population of Japan is expected to reach 130,000 by 2000, and even today Japan is only about 50% self-sufficient at the original calorie base. Self-sufficiency in products such as corn, soy beans, and wheat is especially weak. Since land use in Japan is exceedingly efficient, there is no hope for improvement in the rate of self-sufficiency, and the problem is certain to become more acute in the future. Until the present time, Japan has been almost self-sufficient in seafood, and this provided almost half the necessary animal protein. However, 40 to 50% of the total seafood production is from ocean fishing, and most of the catch is taken in fishery grounds within the 200-nautical-mile zones of foreign countries. With the advent of the 200 nautical-mile fishing zone era, guaranteeing the heretofore high catch is going to be very difficult. For this reason, it is urgent that we establish an efficient information-collecting sys-

tem for the understanding of oceanic weather phenomena, for s surveillance, for the preservation of marine resources (chiefly fishery resources), for the preservation of the sea environment, and to insure safety of navigation. In the near future, the establishment of an effective information-gathering system will be essential inrorder to formulate food policies.

In regard to natural resources, in spite of the fact that Japan occupies only 0.3% of the land surface of the world and has only 3% of the population, we expend 20% of the resources used in the world (excluding the socialist countries), occupying the second position in the expenditure of natural resources. Not only that, we depend on overseas sources for 100% of the oil and natural gas, and 50 to 100% of the minerals. As a result, Japan is easily affected by the political and economic situation in the countries which supply raw materials, and the supply and demand in other important countries. This creates great instability. Since Japan is not blessed geologically with underground resources, it is not possible to increase our self-sufficiency, and it is inevitable that we continue to depend greatly on overseas sources in the future. Therefore, in addition to policies for /11
economizing, recovery and use of materials, it is important to develop overseas resources through international cooperation.

In Japan, pollution and deterioration of the environment have been regarded as social problems in four court cases regarding pollution. Definite results have been achieved by local surveillance by public organs, regulations, and administrative measures. However, we must not stop with local measures. As our industrial society expands, measures of wider scope will have to be developed to cope with the problems. Therefore it is exceedingly important to establish an information-collecting system which covers the whole environment.

Japan is one of the countries of the world with many natural disasters. Every year, the danger to life and property is very great. Among the natural disasters are abnormal weather, earthquakes, coastal disasters, inland disasters (excessive rain or snow). In spite of the fact that much energy has gone into developing warning systems for these disasters in the past, there are many very difficult problems remaining. The concentration of the population into cities has been remarkable, and it is estimated that by 2000, 90% of the population of Japan will live in cities. In view of this, the development of an earthquake prediction system is the most important problem, though the most difficult one. For the development of a prediction system for disasters, quantitative physical measurements of the factors causing the disasters are essential, but in the wide range in which disasters occur, there are many areas in which measurements are difficult. Also, phenomena that occur instantaneously change over a long period, and it is difficult to find methods to

measure the contents of change. It is not only necessary to find methods of measurement suitable for the present, but research must be conducted to discover new methods for the future. The development of metrological technology for this is very important.

I.3. The Role of Earth Observation Satellites

The role that earth observation satellites can play in coping with the major problems facing Japan and the world will now be considered.

The following can be cited as the chief strong points of remote sensing from earth observation satellites. /12

1. It is possible to observe a wide area simultaneously.
2. Pictorial information with high geometrical accuracy can be obtained.
3. Repeated observation of the same area is easy, so that systematic data concerning periodic changes can be obtained.
4. Data can be presented to users on a regular basis in "real time".

When these features are considered in light of the requirements in the various fields of utilization of satellite data, the role of earth observation satellites is very great. It is believed that with the use of satellites, an effective system can be established for collecting systematic information concerning food, resources (resources exposed on the surface), the environment, and natural disasters essential for coping with the major problems confronting Japan and the world.

Along these lines, there is now in progress in the United States and Canada a project called Large Area Crop Inventory Experiment (LACIE), which is an attempt to find out if it is possible to estimate crops on a world-wide basis, using data from earth observation satellites. The Soviet Union is also showing strong interest in this experimental project. Figure 3 shows the entire contents of the prediction program, and the role played by earth observation satellites. A program called "Earth and Ocean Physics Application Program," planned by the American NASA and partially carried out, conducts research concerning prediction of earthquakes and tsunami by launching various kinds of earth observation satellites, and observing the globe through geophysics and oceanophysics. An outline of this plan is shown in Figure 4.

Earth observation satellires can play an important role in establishing various kinds of information-gathering systems. In the use of satellites, the following points should be carefully regarded. /14

1. The earth observation satellite system is a completely new means of information gathering. It is a means of gathering

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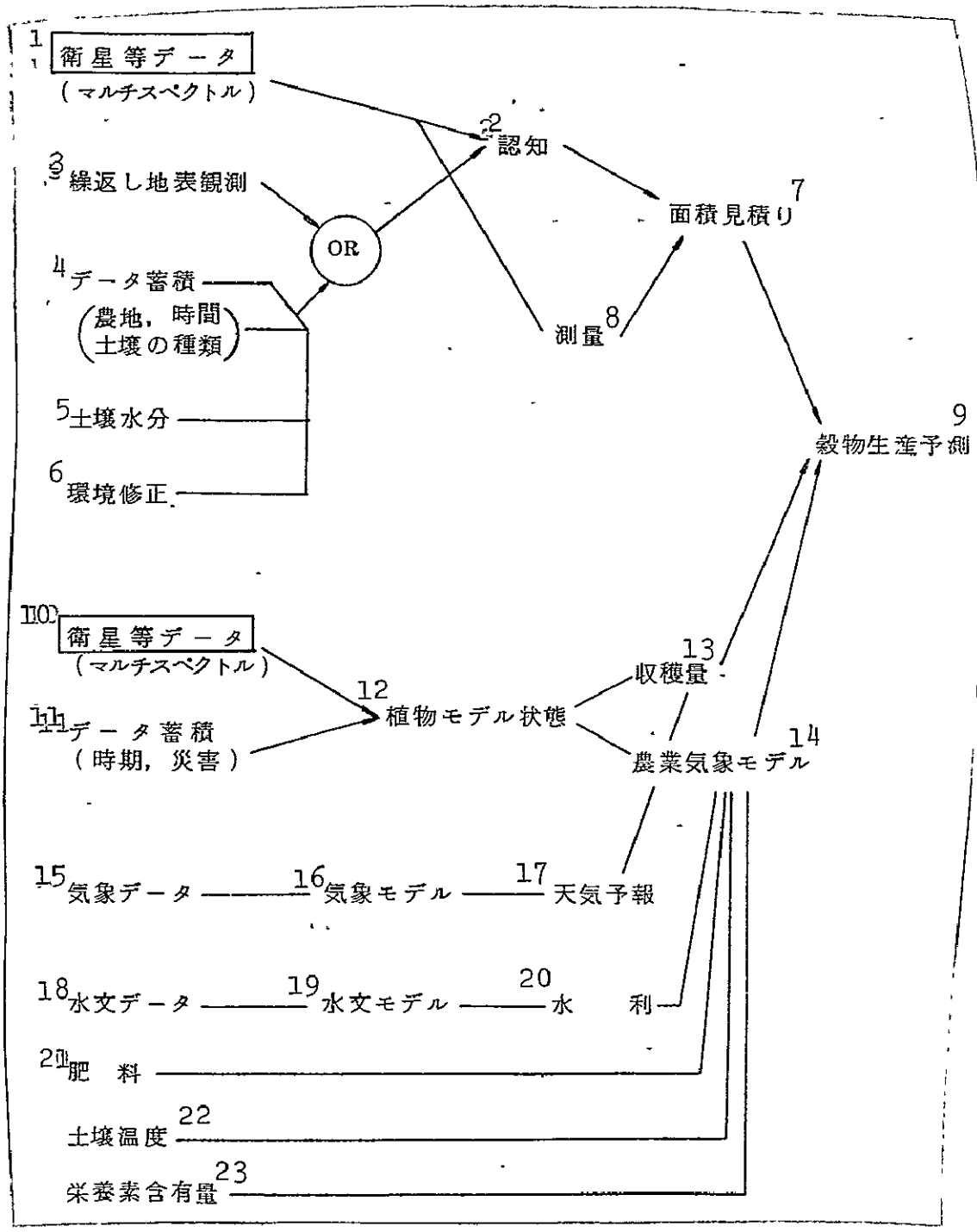

Fig. 3. Model for the estimation of grain production

Key: 1. Earth satellite data (multispectrum) 2. Recognition 3. Repeated observations of earth's surface 4. Data accumulation (agricultural land, seasons, types of soil) 5. Soil moisture 6. Modifications in environment 7. Estimates of area 8. Measurement 9. Estimation of grain production 10. Satellites data (multispectrum) 11. Data accumulation (seasons, damage from natural disasters) 12. Model of condition of vegetation 13. 13. Amount of harvests 14. Agriculture weather model 15. Meteorological data 16. Meteorological model 17. Weather reports 18. Hydrographic data 19. Hydrographic model 20. Water use 21. Fertilizer 22. Soil temperature 23. Quantity of nutrients

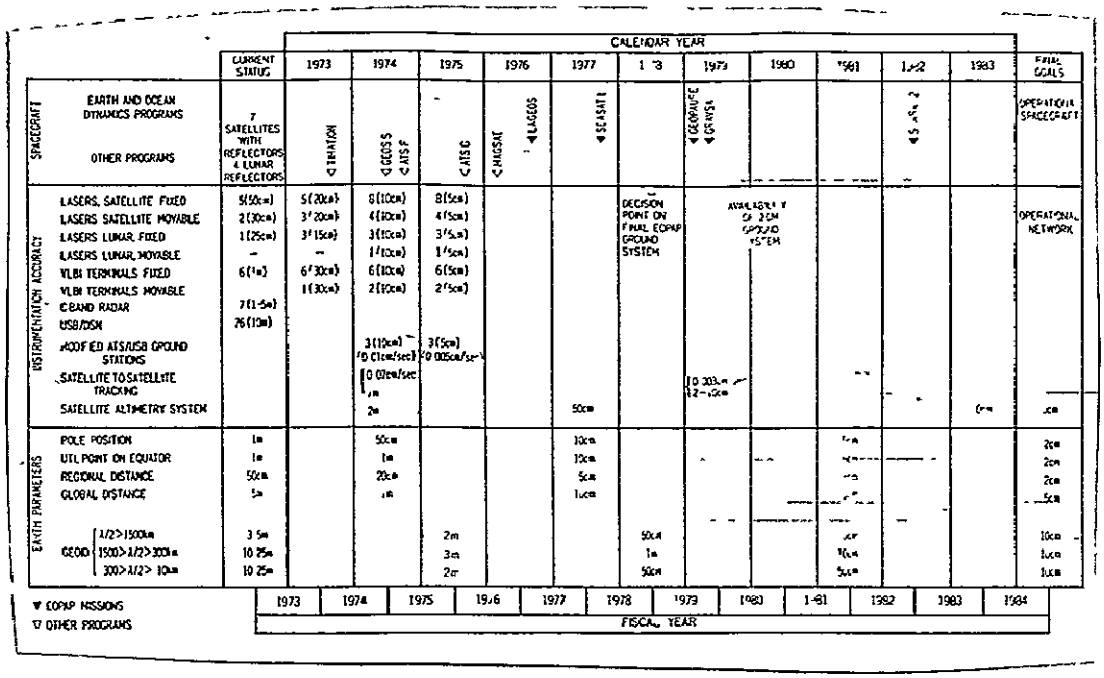

Fig. 4. EOPAP measurement factors

information on a global scale, which could not be done before with balloons or aircraft, and it is an effective system with a broad field of uses. The adoption of an earth observation satellite system does not render other means of data collection ineffective.

2. World observation satellite data can be used regionally, but with a global perspective. By observing phenomena on a global scale and processing them as data common to all under international cooperation, information can be mutually shared. Used in this way, earth observation satellites can be an impetus to international cooperation.

I.4. The Necessity for Japan to Develop Independent Satellites

The United States has already launched earth observation satellites which offer high expectations for different kinds of information gathering, and there are plans to launch more in the future. Since 1972, the resources exploratory LANDSAT series has been in progress, and the SEASAT series, which are to collect information about the sea surface necessary for the study of the sea are planned for 1978. In addition, satellites have already been launched for gathering weather, geodetic, and environmental information. There are plans to launch more satellites in the future, and to improve their performance. In Japan, we are going to make positive use of these satellites, and are already moving towards practical use of the weather satellites ESSA and NOAA. By the beginning of 1979, it is expected that Japan will

be able to receive directly from LANDSATs. However, if foreign satellites are depended upon entirely, there will be various kinds of problems such as the following.

1. When depending on foreign satellites, it is natural that the interests of the country possessing the satellite would come first, and the program of use of the satellite for Japan, which would be a passive program, would be decided by the wishes of the country possessing the satellite. Consequently, the collection of data would not always be regional, and the interests of Japan could not always be sufficiently served.

2. When using the satellites of a foreign power, the consent of the possessing nation is required. There is no guarantee that this consent would be forthcoming permanently, and if temporary consent for the use of the satellite were withdrawn, data use projects would inevitably be cut off, to the extent that substitute data-collection systems were not available.

3. A satellite system of a foreign power would not necessarily be one suitable for Japan. For example, the mission, accuracy, period of observation, etc., would not necessarily be suitable for the conditions in Japan. Further, when there are changes in satellite specifications, this entails changes in the ground system also. In addition, the difficulties in making adjustments in our highly-developed ground communications nets to the data transmission frequencies, and the remote sensing frequencies can easily be imagined. /16

In order to eliminate the above difficulties, it is necessary for Japan to develop an independent satellite system.

Foreign satellites that can be made use of must be utilized positively in harmony with the long-term prospects of our independent satellite system, and must be considered from the viewpoint of international cooperation.

I.5. The Necessity of Responding to International Cooperation

In the past, Japan has cooperated with the countries of Europe and America, and with the United Nations and other international organs concerning space development. The recent world situation concerning the use and development of space is one in which the trend for international cooperation is accelerating. This is reflected in the carry-out of Soviet-American cooperative projects, the invitation of the United States for participation in space shuttle plans, participation in the space lab development in Europe, the international development of earth observation satellite plans by the United States, the development of the stationary weather satellite for the Global Atmospheric Reconnaissance Project (GARP), and international cooperation in the Space

Segments Project. Concerning earth observation satellites, besides the formation of a global network by the cooperation of the developed countries, there is great hope for cooperation with the developing nations, among which are the suppliers of raw materials, for the development and management of land and resources. In addition, it is expected that international cooperation will provide these nations with data concerning food, the environment, and natural disasters. To ensure our international standing, it is exceedingly important that Japan foster technology that is positive to international cooperation.

II. Mission Requirements for Earth Observation Satellites from the Point of View of Fields of Utilization

The fields of utilization have been divided into 14 fields, two of which are highly scientific basic research fields having broad applications, and 12 other fields which roughly find their application in the oceanic or land field.
An outline of these is given below.

II.1. Basic Research Fields

II.1.1. Oceanophysics

Physiological research and study concerning the seas can be carried out by the collection of general information using artificial satellites, especially orbiting satellites. The ocean zones important to Japan are in the Pacific Ocean, including the North Pacific, and especially the equatorial region, which exerts a great influence on Japan. For example, the Kuroshio current, which has such a great effect on the weather and sea conditions near Japan, has its origin in the lower latitudes of the North Pacific, and it is exceedingly important that oceanic data be collected concerning this area.

Desirable data can be collected concerning the ocean by satellite concerning the following:

1. Distribution of unevenness in the sea surface related to wind waves, swells, internal waves, fronts, and upwelling
2. Unevenness in the sea surface related to tides, high tides, and sea waves
3. Distribution of unevenness in the sea surface related to circulation, and medium scale vortexes
4. Water temperature, salinity, and distribution of sea ice
5. Color distribution.

This information has been collected in the past by ship and buoy, but only at specific points. With earth satellites, data directly related to the properties and state of the sea can be collected simultaneously on a global scale. However, all of this information concerns the sea surface, or the surface layer

of the sea. For phenomena with baroclinicity such as large-scale /18
ocean circulation, data are essential concerning the vertical distribution of physical quantities. Also, data are important concerning vertical density and current speed. A drifting measuring system is desirable for collection of information of this kind, and it is possible to collect this vertical distribution information concerning ocean currents and water temperature, etc., along with the position of the drifting system, by means of satellite.

II.1.2. Geophysics

In geophysics there has been much progress made in seismology, terrestial electromagnetics, gravity measurements, and meteorology, as well as in the fields related to these. The basis for this progress was established in the surveying and land measurements of ancient Egypt. When the accuracy of observation in these fields is improved, it is necessary to relate them to other fields. In this connection, observation by artificial satellites has special significance.

The kinds of data that should be collected by satellite are as follows.

1. Spatial distribution of the geoid, and measurements of changes in time
2. Measurement concerning average surface water of the seas, and the spectrum of change in time
3. Measurement of the change of speed in the earth's rotation, and the shift in rotation
4. Measure the relative movement of the earth's surface
5. Determine the speed of ships and their positions
6. Determine the positions of buoys on the sea, and transmit information received from them

If these data are highly accurate, much progress is expected in the following:

1. The making of an ideal inertial coordinate system
2. Clearing up the reasons for perturbations in the earth's rotation, mutations, and commotion in polar movement
3. Finding the constant of elasticity in the earth's crust
4. Understanding the long and short periods of changes in the earth's crust
5. Understanding the relationship between movement of the ocean floor and earthquake activity, changes in the earth's moment of inertia, and changes in the speed of the earth's /19
rotation
6. Understanding sea currents, and determining places of movement inside the earth's crust by measuring gravitational fields

Something that is of special interest to Japan is the volume of horizontal and perpendicular movement relative to the positions

of Okinawa, Ogasawara, Marcus and Honshu. From this, it is possible to learn to predict movement of the ocean floor, change in ocean currents, and earthquake activity.

For measuring systems in this field, radar altimeters, and range finders using laser are important.

II.2. Applications in the Oceanic Field

II.2.1. Marine resources

Marine resources include fishery resources, mineral resources, and energy resources, but of these, marine resources are the most important for providing protein for a nation of 100 million. We are faced with a crisis in ocean fishing because of the 200 nautical-mile fishery control zone declared by foreign countries last year. Observation by satellite is important for preserving and maintaining fishery grounds near Japan, for developing ocean fisheries, and for maintaining effective catches.

The chief objects for satellite observation in connection with fishery resources are temperature distribution, which has a very close relationship with fish habitats, the distribution of salinity, water temperature, currents, upwelling, etc., which have a realtionship with the propagation of plant and animal plankton, and with the distribution of water color.

For these kinds of observations, visible and infrared radiometers are used, but in addition, microwave radiometers and radar altimeters are necessary.

II.2.2. Coastal disasters

For Japan, which is a country with frequent so-called natural disasters, research on predicting and preventing disasters is important. In Japan, natural disasters that occur frequently are typhoons, abnormal weather, earthquakes, coastal disasters that are the result of earthquakes, and abnormal snowfall. /20

For predicting these disasters, measurements on land, by ship and buoy have been used in the past. New and extremely effective methods are being developed from data collected over a wide area by remote sensing technology from space. This is being done in foreign countries, especially in the U.S., using the satellites NOAA, NIMBUS and LANDSAT.

Factors that can be considered as causing coastal disasters are high tides, tsunami, abnormal tide levels, ocean waves, and floating ice. High tides and abnormal tide levels occur in connection with typhoons. Tsunami are coastal disasters occurring from large-scale earthquakes on the ocean floor. Thus, a large

portion of natural disasters have a direct or indirect connection with the coast, and the physical phenomena of the ocean are the basis for the disasters.

The understanding of the mechanism of occurrence of abnormal phenomena, the mechanism of their transmission, and the temporal and spatial changes in their volume in connection with coastal disasters is essential. For this, study of the physical phenomena, chiefly oceanophysical phenomena, in the vast spatial area in which the fluctuating atmospheric, oceanic, and terrestrial phenomena affect coastal areas, is necessary. Repeated observation over a wide area from space with remote sensing technology is an effective way of doing this.

For the observation of this fluctuating, mostly oceanophysical phenomena, radar altimeters, and scatter meters are essential. International cooperation is also important, such as participation in the Earth and Ocean Physics Application Program (EOPAP).

II.2.3. The ocean environment

The ocean covers about two-thirds of the world's surface and was the womb from which all animals emerged, including man. It is a great natural environment concealing unlimited production capacity.

In the United Nations, there are goals for setting up a surveillance system on a global scale for the sea environment, the great common resource of mankind, and the preparation of a United Nations Environmental Plan (UNEP) has been advocated. /21

In the past, a large number of personnel, ships and a long period of time were required for the study of a wide range of ocean. Now, by the development of remote sensing technology for satellites, it is possible to have information in "real time". Using data from NOAA, NIMBUS, and LANDSAT, studies are being conducted on ocean pollution by man, and natural disasters, such as oil pollution, industrial exhaust water, red tides, floods, etc. Along with this, studies are being conducted on ocean and coastal currents in connection with cleaning up pollution, as well as studies on the distribution of sea ice. As a future research theme, a study should be done on temperature distribution on the sea surface, a study necessary for the analysis of sea currents, coastal currents, upwelling, and ocean pollution. Studies are necessary on the coloration of water, and the distribution of sea ice. Practical research should be promoted concerning the detection of chlorophyll.

II.2.4. Safety of navigation

For the safety of navigation, data on circulation, sea waves (especially waves caused by low atmospheric pressure and strong wind and rain from typhoons), sea ice, and sea fog are essential. In the past these data were collected by ship and buoy, but now this can be done simultaneously and effectively over a wide area by satellite. In th

In this case, the satellite sensing equipment will be radar altimeters, radar scatter meters, and image radar (synthetic aperture radar).

In the field of chart preparation for navigation safety, Japan's position, and the position of distant islands can be determined in relation to the earth's gravity center by the introduction of earth satellite measuring methods.

II.2.5. Ocean meteorology

The largest portion of the meteorological parameters of ocean meteorology can be covered by general weather satellites, but it is possible to measure wave height, sea waves, swells, wind direction, wind velocity, and surface temperature with microwave sensors carriedaaboard earth observation satellites. This is essential information, not only for sea navigation and fisheries, but it is also important for studying changes in climate, such as abnormal weather and long-term weather predictions, which are becoming important problems. /22

Special features of satellites are observation of wave heights by radar altimeters, observation of sea surface wind direction, and wind speed by radar scatter meter, observation of sea surface water temperature by microwave radiometer, observation of sea waves by image radar and observation of wide ocean areas with microwave sensors. This has great significance when compared to the observation in the past by ship, buoy, and weather satellite.

II.3. Applications in the Land Field

II.3.1. Agricultural and forestry resources

Various applications to the field of agricultural and forestry resources have been made in various countries using data from LANDSAT. It has been shown that it is possible to distinguish the chief grains and types of forests, to distinguish the soil types necessary for agriculture, to find out the kinds of crops, to estimate damage to forests by disease or pests, to know when damage has occurred, to predict changes in harvests in sample areas due to changes in weather conditions, to estimate the contents and quality of the vegetation on range land, and to

estimate the amount of water necessary for areas that must be irrigated.

Basic research on the technology of land utilization is also being carried out in Japan using data from LANDSAT. It is necessary for us to establish a system for the practical estimation of all kinds of crops, a system for estimating timber growth, and the amount of production, and a system for observing damage c caused by the weather, pests, and disease, industrial pollution, and by changes in the natural environment.

Since Japan is a small country, sensors for observing land conditions must have ultrahigh resolving power.

II.3.2. Geology and underground resources

The basic technology for preparing analytic maps for the analysis of geological structures is being established using data from LANDSAT, and cooperative geological studies are being undertaken concerning mining in the developing countries. /23

Some research themes of the future are the establishment of composite analytic methods combining remote sensing data with geological and geophysical data, the establishment of technology for three-dimensional vision by the application of parallax to single images, and the establishment of technology for taking and analyzing pictures of different solar height. It is necessary to increase the spectrum bands and improve the resolving power in the observation equipment with the view of improving accuracy.

In the future, by using this technology, satellite data will be extremely effective for developing underground resources by the preparation of geological structure maps and charts of thermal abnormalcy, for earthquake forewarning from the detection of faults and fragmented zones, for formulating countermeasures against earthquakes, and for the understanding of active geological phenomena (volcanic activity, coastal erosion, etc.).

II.3.3. Water resources

In the field of water resources, the weather satellites TIROS, NIMBUS, ESSA, and also LANDSAT have provided data for experimental research in foreign countries concerning preparation of snow accumulation distribution maps, the extent of surface water, soil water, the determination of flooded zones, the extent and position of underground water, the extent and position of lake ice and the monitoring of river ice. This has been noted as a unique field for satellites.

In Japan, there has been no positive application of satellite data in this area, though aircraft data have been used for partial calculation of snow accumulation.

The following are possible research themes for the future, using satellite data:

1. Experimental research on snow accumulation combining data from satellites, aircraft and the ground
2. Preparation of basic data for the quantitative understanding of water income and expenditure, based on mesh maps of surface water
3. Preparation of basic data for flood research, for short- and long-term flood prediction, and for determination of flood damage by the preparation of flood disaster maps.
4. Studies concerning the relationship of snowllevels with climatic change, by compiling snow level registers /24

II.3.4. Land use

It has been noted that remote sensing data from satellites can be effectively used for determining the state of land use by making surveys of agricultural and forestry land. LANDSAT is being used for research in this field.

In this field, the main object of study is land cover. For Japan, especially, which is a nation of small land space, visible and infrared field sensors are needed with a resolution of at least 25 m. Satellite data can be used to prepare land use classification maps.

The proportion of greenness as an indicator of land cover is very valuable data collected by satellite for environmental evaluation in connection with land use.

II.3.5. Inland disasters

Inland disasters can be broadly divided into natural disasters and man-made disasters, but the majority of them are natural disasters.

These natural disasters are concentrated rains and floods caused by abnormal weather, landslides, changes in the earth's crust, and volcanic activity caused by earthquake activity and terrestrial changes, snow damage, and grass and forest fires. Research on forewarning and prevention of these disasters is necessary. The measurement of physical quantities that are factors in these disasters is necessary, but these disasters occur in a broad area, and their occurrence is instantaneous. Since changes occur over a long period of time, measurement methods that deal with these factors also are desirable. Data from NIMBUS and LANDSAT have caused a rapid development in old measurement methods, and measurements of the physical quantities of natural disasters by remote sensing technology are regarded as important.

II.3.6. Atmospheric environment

The surveillance of O_3 and CO_2, which are factors in sudden temperature rises in the stratosphere that affect long-range forecasts of 2-3 months, and the understanding of the effects of the rapid spread of large-scale industry and atmospheric pollution by the automobile and airplane, are important not only in the field of meteorology, but as a general problem of society as well. Surveillance systems have been established by national and local organs, and at the present time, surveillance of SO_2, CO_2, CO, NO_2 and NO suspended in the air is carried out on the ground, by sonde, and by aircraft. However, observation of spatial distribution is extremely poor, and much hope is placed on satellite data. /25

The launching of NIMBUS-G is planned for 1978 in the United States. Surveillance of O_3, CO_2, aerosol, HNO_3, NO_2, CH_4, H_2O, and N_2O will be done using the following sensors: Limb Infrared Monitor of the Stratosphere (LIMS), Stratospheric Aerosol Measurement (SAM II), Solar and Backscattered Ultraviolet and Total Ozone Mapping System (SBUV/TOMS), and measurement of Air Pollution from Satellites (MAPS). Surveillance of pollution in coas-coastal seas is also planned.

II.3.7. Smaller-scale meteorological phenomena

The most important elements in weather forecasting are the five factors of air pressure, air temperature, humidity, wind, and atmospheric conditions. From an analysis of these, high and low pressure areas are determined, and the movements of pressure systems and atmospheric phenomena are predicted. For the determination of the basic parameters, ground instruments, ships, buoys, aircraft, balloons, and weather satellites are used. Of these methods, data from weather satellites are extremely effective, and forecast accuracy has improved remarkably.

However, weather satellites in the past have observed large-scale weather phenomena, such as low-pressure areas, and typhoons which have a horizontal extent of from several hundred to several thousand kilometers. They have not been suitable for the observation of smaller-scale weather phenomena, which have a horizontal range in the tens of kilometers, such as thunderstorms, water spouts, mountain turbulences, and regional weather changes. /26

At the present time, LANDSAT data are being used for investigation and research on predictions of these smaller-scale meteorological phenomena. These data have been confirmed as useful in connection with convection current clouds, mountain turbulences, regional atmospheric phenomena, fair weather turbulences, and snow clouds. However, it is necessary that the sensing equipmen

sensing equipment carried on Japan's earth observation satellites be more accurate and have greater resolving power.

The mission requirements forearth observation satellites in regard to the above-discussed fields of utilization are shown in Table 1.

In making the survey of mission requirements, in February of this year, a questionnaire was sent to the major organs shown in the table below.

1 配布機関	2 配布数	3 回答数	4 備考
5 官公庁	54	43	国家機関、自治体、官公立研究所、公共企業体、社・財団法人 6
7 学校	32	21	学校・学校研究機関、学会、教育機関 8
9 合計	86	64	

Key: 1. Organs to which sent 2. Number of questionnaires distributed 3. Number of answers 4. Notes 5. Government and public service organs 6. National organs, regional organs, government and public service research organizations, public service corporations, industrial organizations, companies, foundations 7. Schools 8. Schools and school research organs, academic societies, educational organs 8. Totals

The chart below shows the results from the above table arranged by field of utilization.

1 利用分野	2 配布数	3 回答数
4 海洋	16	14
5 国土環境	24	15
6 農林	19	13
7 その他	27	22
8 合計	86	64

Key: 1. Field of utilization 2. Number distributed 3. Number of answers 4. Ocean 5. Land development 6. Agriculture and forestry 7. Other 8. Totals

TABLE 1. EARTH OBSERVATION SATELLITE MISSION REQUIREMENTS FROM THE POINT OF VIEW OF FIELDS OF UTILIZATION

Field	Purpose of use	Object of observation	Ground resolving power or accuracy	Observation period	Width of observation	Observation area	Sensors	Required wave lengths	Notes
The ocean	Investigate oceanophysical phenomena: state of the sea, sea surface water temperature and color, ocean ice distribution, (the configuration of the bottom in shallow seas)	The ocean	100 m - 1 km	1/1-7 days	300 km	The sea in the vicinity of Japan	MSS SAR ALT	0.45-0.1 μm 10.4-12.6 μm 1.3 GHz	Possible to apply to construction at sea
The ocean	Applications to the study of marine resources and oceanography· surface water temperature, sea currents, sea color	The ocean	10-50 m (temperature accuracy ± 0.1-0.5°C)	2/day 1/7.5-15 days	90-180 km (10-50 km)	The sea in the vicinity of Japan and offshore	MSS VIIR Camera	0.44-0.86 μm 10 5-12.5 μm	→ 0.44-0.54 μm 0 54-0.62 μm 0 62-0.69 μm 0.70-0.86 μm Possible to apply to sea pollution by estimating the amount of suspended pollutants and the amount of plankton from the sea color
The ocean	Investigation of the environment of lakes and marshes. surface water temperature, water color	Lakes and marshes	50-100 m	1/10-20 days	100 km	Large lakes and marshes	MSS	0.5-1.1 μm 10.5-12.5 μm	Altitude to 400 km
Disaster prevention	Erosion of coastline	Sea coasts	50 m - 1 km	1/year	100-200 km	The entire country	SAR T M	1.3 GHz 0.5-1.1 μm	
Disaster prevention	Flood waters, survey of damage done by high tides (preparation of flood maps, and maps showing damage done by floods)	Flatland, seacoasts	50 m - 1 km	At any time	100-200 km	The entire country	MSS SAR	0.45-1.1 μm 1.3 GHz	
Disaster prevention	Landslides, cave-ins, rock and soil avalanches (mapping of landslide-prone mountain areas)	Mountainous areas· moisture content of soil, topography & vegetation	10-20 m 50-100 m	Seasonal & at any time 1/10-20 days	100-200 km	The entire country	MSS SAR	0.45-1 1 μm	Altitude 400 km

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(Table 1 continued)

Field	Purpose of use	Object of observation	Ground resolving power or accuracy	Observation period	Width of observation	Observation area	Sensors	Required wave lengths	Notes
"	Survey of crops and the outbreak of disease and pests	a- Flatland b- Mountains c- For the conditions of diseased crops	50 m-1 km less than 5 m	1/1-3 months 1/day	100-200 km 50 km	The entire country	MSS	0.45-1.1 μm	
The environment	Investigate changes in the environment of cities, environment classification maps, environmental pollution maps	Cities	30-80 m	1/1-3 months	100-200 km	Major cities	MSS	0.45-1.1 μm	Concrete examples of objects of observation NOx, NO, NO_2, THC, Ox, Dust
	Investigation of atmospheric pollution	a- Cities b- Substances c- Aerosol	50 m-1 km 50-100 m	1/day 3/day	200 km 100 km	Major cities	RBV MSS SMMR Laser radar	0.45-1.1 μm	
	a- Investigation of pollution of sea areas b- Investigation of pollution in rivers, lakes and marshes, and coastal sea areas	a- The sea environs of cities b- Flatlands and mountains c- Water temperature d- Water coloration e- Oil pollution	50-500 m ±0.5°C 50-100 m ±50 m	1/day-month 1/10-20 days 4/day	100-200 km 100 km	The entire country	MSS SAR VIIR SMMR	0.45-1.1 μm 1.3 GHz 10-1.1 μm 11-1.25 μm	Will have sufficient application if the organisms of large red tides can be distinguished by water coloration (sea coloration), and if the density of such organisms can be determined. The relationship between water ↓
	Other: for monitoring after an incident in order to evaluate the effect on the environment	a- Each of the two above b- Sea areas c- Thermal distribution in all areas d- Change in land cover substances	50 m 20-50 m 10 m	1/day 2/day 1/15-30 days	100-200 km 100 km	The major developed areas and their environs	MSS Long-focus camera		color and transparency can be cleared up

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(Table 1 continued)

Field	Purpose of use	Object of observation	Ground resolving power or accuracy	Observation period	Width of observation	Observation area	Sensors	Required wave lengths	Notes
=	Analysis of the heat environment of cities	Cities	10 m	2/day	200 km	Major cities			In combination with measurements of the vertical distribution of temperature, made before sunrise and at 1400 by stationary satellite
The state of land use	Survey of the present state of land use	Fland flatlands, mountains	50-100 m	1/year	200 km	The entire country	MSS Camera VIIR	0.45-0.75 μm Color, infrared color 0.4-0.7 μm	Preparation of land use classifications (in combination with data collected from aircraft)
	Survey of the present state of land use (for high-density areas)	Cities	30-80 m (10-30 m)	1/3-6 months	100-200 km	The environs of principal cities	MSS	0.45-1.1 μm 10.2-12.5 μm	
	Survey of vegetation (grasslands, hemp, mixed grazing and forests	Mountains, flatlands	25-100 m	1/3 months	100-200 km	The entire country	MSS SAR Camera	0 45-o.75 μm 1.3 GHz Color, infrared color	
	Soil classification maps	Classification of soil types	30-100 m	1/3 months	100-200 km	Hokkaido, the Tohoku Region (all Japan)	MSS SAR	0.45-1.75 μm 1.3 GHz	Determination by the amount of moisture in the soil, determination by amount of completely decomposed vegetation in the soil
	Observe changes in the condition of forests	The contents of forests	30-100 m (10-15 m)	1/3 months	100-200 km	The entire country	MSS SAR High resolving, long-focus camera	0.45-1.75 μm 1.3 GHz Infrared color	Altitude 400 km
	Investigate trends in rice-producing areas	Flatlands	20-100 m	1/3 months	100-200 km	Hokkaido, the Tohoku district	MSS SAR	0.45-1.75 μm 1.3 GHz	

(Table 1 continued)

Field	Purpose of use	Object of observation	Ground resolving power or accuracy	Observation period	Width of observation	Observation area	Sensors	Required wave lengths	Notes
"	Other: a- Observe the area in production b- Observe geological structures	a- Agricultural land b- Faults and rocks	less than 5 m 30-50 m	1/week 1/3 months	100 km 10-50 km	The entire country	MSS, SAR SMMR SAR		Harvest estimates
Hydrology	Data on water resources: distribution of water, snow accumulation, accumulation of earth and sand	Mountains, flatlands	50-100 m	1/1-30 days	200 km	The entire country	DCS MSS SAR	0.45-1.1 μm 1.3 GHz	
	River basins: water quality, vegetation, land quality, topography	Mountains, flatlands	50-100 m (10-15 m)	1/month (1/1-2 days)	200 km (100 km)	The entire country	DCS MSS SAR	0.45-1.75 μm (0.4-1.3 μm)	Detect changes in the hydrographic features of river basins
Atmospheric phenomena	Observation of smaller atmospheric phenomena: the distribution of clouds and air temperature, temperature of the land surface and at the top of clouds		500 m – 10 km (1-10 km or 0.5-10 km)	1/day-3/months	300 km	The entire country	VIIR MSS	0.49-0.94 μm 10.5-12.5 μm 0.45-1.1 μm 10.4-12.6 μm	±1°C
	Data for the evaluation of the income and expenditure of radiation	The radiation of short waves upward, and of infrared upward		3/day in the daytime 2/day daytime	10 km spot All of the earth's surface within the visible field	The vicinity of Japan	Diffraction radiometer (MSS)	Ultraviolet, visible Near infrared, infrared	Since there is an absolute value for the amount of radiation radiated out of the atmosphere, sensors must be calibrated. Analyzed by combining with measured values on the ground
	Other. Analysis of monsoons	The top of clouds							

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III. Development of Earth Observation Satellite-Associated Technology /35

In this section, we will survey the state of development in Japan and abroad of the equipment needed to be put aboard earth observation satellites in order to meet the requirements of the fields of utilization outlined in the preceding section. This equipment includes visible and infrared sensors in the visible and infrared field, microwave sensors and data recorders, data-collecting systems, and incidental equipment such as systems for data relay. We will also survey the state of development of supporting technology in Japan, such as the technology for launching satellites.

III.1. The Present State of Development of Earth Observation Equipment Technology

III.1.1. Visible and infrared sensors

Sensors in the visible and infrared fields have been roughly divided into the visible and near infrared field, and the thermal infrared field.

1). Sensors in the visible and near infrared field. In the United States, the Multi-spectral Scanner (MSS) has been put to practical use in LANDSAT, and the MSS (S-192) is used in SKYLAB. In addition, the Thematic Mapper (TM), and the High Resolution Pointable Imager (HRPI), are being developed for LANDSAT-D. The Large Earth Survey Telescope (LEST) is being developed for SEOS use. The detection element in use at the present time in sensors is the Photo Multiplier (PM), and scanning is done by mechanical scanner. However, a Photo Diode (PD) array is being developed for detection elements, and it is surmised that this array, or an electronic scanning system using a Charge Coupled Device (CCD), will be used for scanning.

In Japan the PM has been used aboard aircraft and carried on rockets, and research and development has been carried out concerning PC and CCD. It is believed that in the near future, all /36
of this equipment can be produced domestically.

In regard to telescopic systems, aurora observation equipment has been used on rockets for scientific observation, and was carriedoon EXOS-A. This equipment can be produced domestically.

Therefore, the MSS system needed by the estimated 1983 launch time can be produced domestically if the requirements for performance are not excessively high.

In the future, it is believed that a solid-state picture-taking system in an array sensor which uses CCD will be in common use in

common use in Japan and abroad. This system will include the infrared field.

2) Thermal infrared sensors. In the United States, the Visible and Infrared Spin Scan Radiometer (VISSR) has been used in the stationary meteorological satellite (SMS), and the Temperature Humidity Infrared Radiometer (THIR), the Surface Composition Mapping Radiometer (SCMR), and the Return Beam Vidicon (RBV) in the NIMBUS series. In addition, the VISSR Atmospheric Sounder (VAS) is under development for use in the GOES.

Concerning detection elements, the HbCdTe and PbSnTe have entered the stage of use as simple light reception elements. Later they will be put in an array of infrared detection elements, and an infrared CCD will be developed which will transmit a signal.

In Japan, a HbCdTe detection element has been used in ground equipment, and PbSnTe and CCD are under development. There will be problems with the optics systems in connection with acceleration during launching, and the maintenance of accuracy in a space environment, but the basics have been solved. For the present, in the scanning systems, the scanning will be mechanical because of the use of single elements. Testing is necessary for the scanning systems, including the cooling system. If possible, parts and material that have developed abroad will be purchased at first, but as experience accumulates, the policy will be for all domestic production.

In the future, a scanning array in combination with a CCD /37
will be used by Japan.

III.1.2. Microwave sensors

A survey of microwave sensors was conducted, classifying them into passive microwave radiometers, active radar altimeters, and radar scatter meters, image radars, and laser sensors.

1) Microwave radiometers. In the United States, the Electrically Scanning Microwave Radiometer (ESMR), the Nimbus-E Microwave Radiometer (NEMS), and the Scanning Microwave Spectrometer (SCAMS) were carried aboard the satellites in the NIMBUS series. In addition, the SMMR (Scanning Multichannel Microwave Radiometer is planned for the NIMBUS-G and SEASAT-A, scheduled to be launched in 1978. The resolving power of this microwave sensor is low compared with that of the earlier visible and infrared sensors, but observation can be done withaa broad per perspective, and it has the great merit of being all-weather, not affected by climate, day and night, etc.

In Japan, we have had no experience with microwave radiometers in satellites, but the basic technology has been

sufficiently established with radiometers on the ground, using them for observation of solar radio emissions, and for atmospheric noise observation in connection with the manufacture of receivers. In the future, these will be tested in space, and the necessary planning done for reduction in weight of the antenna system and for improving the resolving power.

2) Radar altimeters and radar scatter meters. These have been used by the United States in the SKYLAB, and there are plans for using them in an improved form in the SEASAT-A to be launched in 1978.

In Japan, we have no experience with radar technology on satellites, but the use of radar for weather, on ships and on aircraft is fairly well advanced, and it is thought that domestic production can be achieved. /38

However, positive progress in the development of software will have to be made in Japan, including that which is "ground truth" and "sea truth".

3) Synthetic aperture radar (image radar). Typical of synthetic aperture radar is side-lookinggradar. It is expected that it will be developed for use in many fields, since it can collect pictorial data in all weather. It has been developed for use in aircraft in the United States, and was used in the satellite APOLLO-17. It will also be used on the SEASAT-A. However, it is said that data processing still has to be developed.

In Japan, the hardware and software are both in the research stage, and ten years will be needed before it can be put into use.

4) Laser sensors. Laser sensors are expected to be used for range finding and observation of the contents and condition of the atmosphere. They are now being developed for use on aircraft and the space shuttle.

In Japan, laser sensors have been used for observing the contents of the atmosphere from the ground and for range finding, but compact, light, low power, high-output laser oscillators must be developed. Since there is no strong "backup" system in Japan, it is estimated that domestic production will be difficult to achieve in 15 years.

The principal visible and infrared sensors and microwave sensors are shown in Table 2.

III.1T3. Data recorders /43

The United States has developed a standard recorder for space for use on NIMBUS and LANDSAT satellites, but since these recorders have a moving mechanism, they are not as reliable as electronic

TABLE 2. TABLE SHOWING THE PRINCIPAL EARTH OBSERVATION SATELLITE SENSORS

(except for the RBV AND MSS, translation of the names of the sensors is provisional)

Sensor	Method of data collection	Principal uses	Various factors: Wave lengths (frequencies)	Various factors: Ground resolving power	Various factors: Width of observation	Other factors		Satellite on which used or planned to be used	Notes
RBV (Return Beam Vidicon camera)	Passive type	Observation of the earth's surface	0.475-0.575 m 0.580-0.680 m 0.690-0.830 m 3 cameras	80 m	185 km	- Frequencies for pictures - Weight - Expenditure of power	3.2 MHz 66 kg 163 W	LANDSAT-1 (1972,7) LANDSAT-2 (1975.1)	
			0.505-0.750 m 2 cameras	40 m	183 km	Frequency for pictures	3.2 MHz	LANDSAT-C (1977,9 Planned for Sept, 1977)	
MSS (Multi Spectral Scanner)	Passive type	Observation of the surface of the earth by different wave lengths	0.5-0.6 m 0.6-0.7 m 0.7-0.8 m 0.8-1.1 m 10.4-12.6 m (LANDSAT-C only)	80 m 240 m	185 km	- Data rate - Weight - Power expenditure	15 59 kg 60 W	LANDSAT-1 LANDSAT-2 LANDSAT-C	
Visible and infrared radiometer VIIR (Visible/IR Radiometer)	Passive type	Coastline configuration, pictorial data on the distribution of clouds, observation of sea surface temperature	0.49-0.94 m 10.5-12.5 m	3 km 5 km	1,500 km	- Data rate - Weight - Power expenditure	12 20 kg 10 W	NIMBUS-4 (1970,4) NIMBUS-5 (1972,12) NIMBUS-6 (1975,6) SEASAT-A (1978,4 planned for April 1978)	Temperature measurement range -2 to +35°C Temperature accuracy ±1°C
TM (Thematic Mapper)	Passive type	High-resolving power observation of the surface of the earth by different wave length	0.5-0.6 m 0.6-0.7 m 0.7-0.8 m 0.8-1.1 m 1.55-1.75 m 2.08-2,35 m	30-40 m	185 km	- Data rate - Weight - Power expenditure	240 120 kg 75 W	LANDSAT-D (planned for 1980)	
			10.4-12.6 m	100-160 m					

/39-40

(Table 2 continued)

(except for the RBV AND MSS, translation of the names of the sensors is provisional)

Sensor	Method of data collection	Principal uses	Various factors: Wave lengths (frequencies)	Various factors: Ground resolving power	Various factors: Width of observation	Other factors		Satellite on which used or planned to be used	Notes
LEST (Large Earth Survey Telescope)	Passive type	Observation of the surface of the earth by different wave lengths, by the large earth survey telescope from a stationary satellite	0.2-1.5 m	Visible field 100 m, infrared: 800 m	200 km	- Data rate - Aperture of reflection telescope	30 Mbit/s 1.5 m	SEOS (Planned for 1982)	
SMMR (Scanning Multi-frequency Microwave Radiometer)	Passive type	Observation of sea surface wind speed, temperature, distribution of sea ice and water vapor	6.6 GHz	87 km x 144 Km		- Data rate	2 Kbit/s	NIMBUS-5	Range of measurement of sea surface wind velocity 0-50 m/s, accuracy of measurement of sea surface wind velocity ±2 m/s, temperature accuracy ±2°C
			10.7 GHz	58 km x 89 Km				NIMBUS-6	
			18.0 GHz	31 km x 53 km	920 km	- Weight	42 kg	SEASAT-A	
			21.0 GHz	27 km x 42 km		- Power expenditure	50 W	NIMBUS-G (Planned for Sept. 1978)	
			37.0 GHz	16 km x 25 km					
ALT (Radar Altimeter)	Active type	Observation of the average height of sea waves, sea current geoid, tidal currents, swells and tsunami	13.5 GHz peak power 125 W	1.6 x 12 km Spot	1.6 km	- Data rate - Antenna - Weight - Power expenditure	10 Kbit/s 1mΦ parabola (15° beam width) 70 kg 150 W	GEOS-C SKYLAB SEASAT-A	Height accuracy ±10 cm. Range of wave ht. measrmt 1-20 m. Accuracy of wave ht measurement ±50 cm or ±10%
SCAT (Radar Scatterometer)	Active type	Observation of wind speed on surface of sea, wind direction	14.595 GHz peak power 125 W	50 km	Orbit track 460 km 500 km 500 km	- Data rate - Antenna - Weight - Power expenditure	2 Kbit/s (25° x 0.5°) x 4 (40° x 0.5°) x 1 60 kg 140 W	SKYLAB SEASAT-A	Range of measurement of wind velocity 4-26m/s, accuracy of measurement of wind velocity ±2m or 10%, accuracy of measurement of wind direction ±20°

/41-42

(Table 2 continued)

(except for the RBV AND MSS, translation of the names of the sensors is provisional)

Sensor	Method of data collection	Principal uses	Various factors			Other factors		Satellite on which used or planned to be used	Notes
			Wave lengths (frequencies)	Ground resolving power	Width of observation				
SAR (Synthetic Aperture Radar)	Active type	Pictorial data of the sea surface and of sea ice, observation of ocean tsunami and wave direction	1.340 GHz peak power 300 W	25 m	Orbit track 230 km 100 km	- Picture frequency - Antenna - Weight - Power expenditure	18 MHz 14 m x 2 m (1°x6°) 80 kg 250 W	APOLLO-17 (1972.12) SEASAT-A	Range of wave length measurement 50-1,000 m

elecIn Japan, we are fairly advanced in making tape recorders for consumer use, but have absolutely none for space use. The ones used in the Ionosphere Observation Satellite (ISS) were purchased from the U.S.

When information is collected over a wide area by orbiting satellite, the data must be transmitted to a ground station. The methods for this are those which use data recorders and those which transmit to several ground receiving stations in real time, or which transmit the data to a ground station using a data relay satellite. The U.S. plans to use a data relay satellite for LANDSAT-D (planned for 1980), and in this case, 85% of the earth's surface can be covered by two relay satellites and one ground station.

III.1.4. Data collection systems

The recent NIMBUS and LANDSAT satellites have DCS capabilities.

The merits of DCS in orbiting satellites are (1) it is easy to measure the position of DCP floating systems by using doppler shift, and (2) since the altitude of the satellite is low compared to a stationary satellite, and since it is easy to use DCP with low transmission output and a low expenditure of power, the DCP can be made compact and light, and the cost is low.

The stationary weather satellite (GMS) to be launched in July of this year by Japan is equipped with a DCS. The DCP are to be ships, buoys, and isolated islands. /41

III.2. The Present State of Development of Earth Satellite Technology in Japan

III.2.1. Artificial satellite launching technology

The rocket used for launching Japan's artificial satellites is the N rocket developed by the Space Development Project Groups. This is a three-stage rocket with an overall length of 32.6 m, and a total weight of 91 tons. For the first and second stages, a radiowave induction system that uses liquid fuel has been adopted, and for the third stage, a spin stabilization system that uses solid fuel has been adopted. The Experimental Technical Satellite ETS-I, September 9, 1975, and the Ionosphere observation satellite ISS, February 29, 1976, were launched into medium altitude orbits. Later, on February 3, 1977, the ETS-II was successfully put into a stationary orbit.

In order to meet the requirement of launching large-size satellites in the future, N rocket II is planned for use in launching GMS-II in 1981, and a rocket using a liquid oxygen/liquid hydrogen engine is planned for use in launching satellites from

from that date to about 1995. However, earth observation satellites have orbits of medium altitude, and have no spin because of the requirement for triaxial attitude control. A second stage rocket that can be detached from the satellite is desirable. In addition, in order to put the satellite into a polar orbit from the launching position in Japan, a re-ignition capability is desirable.

III.2.2. Artificial satellite technology

Japan's artificial satellites can be roughly divided into the scientific satellite series, and the practical series. The former series began with the launching of "Osumi," developed by the Space and Aeronautics Research Center of the University of Tokyo, and launched February 11, 1970. Seven scientific satellites have been launched up to the present time. In addition, the EXOS-A, EXOS-B, ASTRO-A, and ASTRO-B are under development.

The latter series began with the launching of the ETS-1 /45
developed by the Space Development project group and launched on September 9, 1975. Three satellites in this series have been launched. In addition, the medium capacity stationary communications satellite (CS), the medium-sized broadcast satellite (BS), and the experimental stationary communications satellite (ECS) are under development. In addition to these satellites, ETS-III is being developed for experiments in connection with tri-axial attitude control, solar paddles, and heat control of active systems, and ETS-IV is being developed for the purpose of confirming the capabilities of the N rocket.

III.2.3. Orbits

The orbits generally used for earth observation satellites are solar-synchronous orbits, solar non-synchronous orbits, and stationary orbits.

The solar-synchronous orbit is one with the orbit angle of inclination more than 90 degrees, and one which conforms to the annual movement of the sun, which, as seen from the earth, moves -0.98 degrees to the east daily. A solar non-synchronous orbit has an orbit inclination angle of less than 90 degrees, and the rotation does not agree with the annual movement of the sun. An orbit in which the orbit inclination angle and the eccentricities are both 0, and the satellite is stationary with respect to the surface of the earth, is called a stationary orbit.

Of these orbits, the solar-synchronous and solar non-synchronous orbits are suitable for earth observation satellites. In the case of Japan, the solar non-synchronous orbit is appropriate at the present time due to range safety problems.

IV. Proposed Plans for the Development of Earth Observation Satellites in Japan /46

IV.1. Plans for Earth Observation Satellites in Foreign Countries

Since the beginning of the 1970s, the United States has launched the earth observation satellites LANDSAT-1 and -2 with the purpose of gathering information about the surface of the earth. These satellites have been an enormous success.

As sequels to them, the United States plans to launch LANDSAT-C and -D, SEOS, and NIMBUS-G in the 1980s to collect information about the earth. Along with these, the SEASAT series will be launched to collect information concerning the oceans.

From 1974 through 1976, NASA conducted a survey on the future of space development ("Outlook for Space"). The section on earth observation covers up to the 21st century.

In countries other than the United States, there is activity for the development of earth observation satellites in ESA, Canada, the Soviet Union, and India.

1) Plans for earth observation satellites in the United States

1) LANDSAT-C

LANDSAT-C, the sequel to LANDSAT-1 and LANDSAT-2 which are in operation, has been approved by Congress to be launched after the fall of 1977.

Below is an outline concerning this satellite.

(1) Sensors carried aboard

(a) MSS: In addition to the observation frequency bands 0.5-0.6 μm, 0.6-0.7 μm, 0.7-0.8 μm and 0.8-1.1 μm (the same as for LANDSAT-1 and -2), 10.4-12.6 μm will be added for thermal infrared.

The ground resolution power will be 80 m for /47
visible and near-infrared, and 240 m for thermal infrared.

(b) RBV: There will be two return-beam video cameras with an observation frequency band of 0.505-0.750 μm. The ground resolution power will be improved to 40 m.

(2) Other: Orbit elements are the same as for LANDSAT-1 and -2, and are shown in Table 3.

2) LANDSAT-D

LANDSAT-D has not yet been approved by the American Congress, but the plans are for it to be launched about 1980.

In addition to the sensor, MSS, carried by LANDSAT-C, LANDSAT-D will carry a multispectral scanner with high resolving power called TM (Thematic Mapper).

TABLE 3. AMERICAN EARTH OBSERVATION SATELLITE PLANS

Name of satellite	Time of launching (planned)	Planned life (yrs)	Mission and mission equipment (abbreviated)	Orbit factors	Communications frequencies (MHz)			Data rate (kbit/s)		Notes
					Use	Reception	Transmission	Real time	Playback	
LANDSAT-C	October, 1977	2	Mission: collection of pictorial data from the surface of the earth; Equipment: a- Two 1-band return-beam video cameras b- A 5-band multispectral scanner c- A data collection system d- A wide-band video tape recorder	Solar-synchronous, quasi-recurrent orbit; Orbit altitude· 915 km; Inclination angle: 99°; Rotation time: 103 minutes; Period of recurrence· 18 days	- Tracking - Command - MSS or RBV data - RBV or MSS data - DCS data - Tracking - Command	2,106.4 2,106.4 -- -- 401.55 -- 154 2	2,287.5 -- 2,265.5 2,229.5 -- 137.86 --	1 or 5 15,000 -- -- -- -- --	24 -- 15,000 -- -- -- --	Launching plans approved by Congress; Satellite weight 960 kg
SEASAT-A SEASAT-B	May, 1978 1982	3 3	Mission: collection of oceanic data; Equipment· a- Radar altimeter b- Synthetic aperture radar c- Scatter meter d- Scanning multi-wavelength microwave radiometer e- Scanning radiometer (a- ALT b- SAR ' d- SMMR e- SR)	Solar nonsynchronous, quasi-recurrent orbit; Altitude: 800 km Inclination angle 108° Rotation: 101 minutes	- Observation data - " - Command - Tracking	 2.106.4 2.106.4	2,287.5 2,265.5 -- 2,287.5	25 15,060 1 --	640 -- -- --	Launching plans approved by Congress; Satellite weight 1,814 kg
NIMBUS-G	September, 1978	1	Mission: surveillance of atmospheric pollution over wide areas; Equipment· a- CZCS b- ERB c- LIMS d- SAMS e- SAM II f- MAPS g- SBUV/-TOMS h- MMR i- THIR j- Tape recorder k- data collection system	Solar-synchronous, quasi-recurrent orbit, Altitude: 917 km; Inclination angle 99°	- Observation data - " - " - Command - Tracking	 2.093.51 2,093.51	1,702.5 2,211.0 2,273.5	800	Unknown	Satellite weight 960 kg
LANDSAT-D	1980	2	Mission: collection of data from the surface of the earth; Equipment: a- A 7-band thematic mapper b- A 5-band multispectral scanner c- A data collection system	Solar-synchronous, quasi-recurrent orbit; Altitude: 705 km Inclination angle 99° Rotation· 100 minutes Recurrence· 17 days	- Command - Tracking - Observation data - " - "	2,106.4 2,106.4	 2,287.5 8,180 8,360 15 GHz	-- 20/200 240,000 20,000 240,000	-- 400 -- -- --	Launching plans not yet approved by Congress

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(Table 3 continued)

Name of satellite	Time of launching (planned)	Planned life (yrs)	Mission and mission equipment (abbreviated)	Orbit factors	Communications frequencies (MHz)			Data rate (kbit/s)		Notes
					Use	Reception	Transmission	Real time	Playback	
SEOS	1982	5	Mission: collection of data from the surface of the earth by constant surveillance, Equipment: a- Large Earth Survey Telescope b- Microwave sounder c- Infrared sounder d- Data-collection system	Earth-synchronous orbit; Altitude: 35,800 km; Inclination angle 2° (at 100° west longitude)	- Tracking - Observation data - " " - Command	2,051.156 -- -- -- 2,051.156	8,167.5 8,167.5 8,082.5 2,217.5 --	10 -- 50,000 2,000 --	Launching plan -- -- -- --	Launching plans not yet approved by Congress

/49-50

The ground-resolving power is 30 m for visible and near-infrared, and 120 m for thermal infrared.

3) SEASAT-A

SEASAT satellites are a link in the American Earth and Ocean Physics Application Program (EOPAP). They are to monitor the oceans, and to collect data essential to oceanophysics from the surface of the sea.

The American Congress has approved the launching of SEASAT-A in 1978, and SEASAT-B in 1982.

Sensors to be carried on board are:

- Radar altimeter (for the observation of satellite altitude, wave height, and the geoid)
- Radar scatter meter (for the observation of wind direction and velocity on the sea surface)
- Synthetic aperture radar (for the observation of sea waves, distribution of sea ice, and the "topography" of the sea surface)
- Microwave radiometer (for the observation of sea surface water temperature, sea surface wind direction and wind velocity)

SEASAT will carry equipment for the reception and processing of doppler data from NAVSTAR (Navstar global positioning /48
spacecraft) for determining the position of other satellites.

4) SEOS

SEOS (Synchronous Earth Observatory Satellite) is planned for the constant observation of the same area, in contrast to periodic observation of all areas of the earth by LANDSAT satellites. For this purpose, it will be launched into a stationary orbit 36,000 kilometers over the equator. It will collect pictorial data with a resolving power of 100 m with a Large Earth Survey Telescope (LEST) which has superior resolving power.

NASA plans to launch SEOS in 1982, but the plan has not yet been approved by the American Congress. The intended mission is the observation of changes in earth phenomena that occur in 24 hours or less, monitoring of the environment, and the observation of smaller meteorological phenomena.

5) NIMBUS-G

The launching of NIMBUS-G is planned for 1978 for surveillance of atmospheric pollution, and oceanophysics observation.

Plans are for the NIMBUS-G to carry the following sensors.

a. CZCS (Coastal Zone Color Scanner)
b. ERB (Earth Radiation Budget)
c. LIMS (Limb Infrared Measurement of the Stratosphere)
d. SAMS (Stratospheric and Mesospheric Sounder)
e. SAM II (Stratospheric Aerosol Measurement)

f. MAPS (Measurement of Air Pollution from a Satellite)
g. SBUV/TOMS (Solar Backscatter Ultraviolet and Total Ozone Mapping Spectrometer)

In addition, visible and infrared radiometers (THIR) and microwave radiometers (SMMR) will be carried.

2. American long-term earth observation satellite plans up to the 21st century

According to a space development survey conducted by NASA, plans related to earth observation satellites (excluding geodesic and atmospheric) are divided into (1) collection of land data, (2) high power resolution microwave data collection, (3) ocean survey, and (4) data collection on atmospheric pollution.

1) Collection of land data. The ground resolution power of the MSS in the present LANDSAT series is 80 m, but by the end of the 1980s satellite system, it is planned to gather land data with multiwave visible infrared sensors which will conduct global monitoring with a ground resolution power of 30 m, and with multiwave visible and infrared sensors that will conduct sampling monitoring with power resolution of less than 30 m. By the end of the 1990s, all-weather active microwave sensors for land data collection will be developed and in use on satellites.

2) High power resolution microwave data collection. In the early 1980s, the technology for placing large antennas in space using a space shuttle will be established. With this technology, by the middle of the 1980s a satellite system for investigating soil moisture, snow accumulation water, and salinity with radiometers will use long-wave antennas of 100-300 m. /52

3) Ocean surveying. Continuing from the SEASAT, which is planned for 1978, sensors will be improved with ocean survey technical satellites, and in the late 1980s an ocean survey system will be put into operation. In the 1990s the sensors will be made highly accurate.

4) Data collection concerning atmospheric pollution. Subsequent to the launching of NIMBUS-G (for atmospheric pollution observation) in 1978, sensors will be improved, and from the late 1980s the ionosphere will be monitored, and a system for monitoring polluting substances in the troposphere will be in operation.

3. Plans for the development of earth observation satellites in other foreign countries

In addition to the United States, studies and plans are being made for earth observation satellites in Canada, the European Space Agency (ESA), and India.

1) Canada's ocean observation satellite plans. The principal sensor being discussed for the ocean observation satellite is L-band image radar (SAR), with an observation width of 200 kilometers and resolution power of 25 m. The satellite will have an almost polar orbit at an altitude of 650 kilometers, and the period of recurrence will be 11 days. In this way, an area north of 60 degrees north latitude can be subjected to repeated periodic observation every 4-5 days. Another sensor is a two-channel optical one. If two satellites are put into orbit, all-weather surveillance of the Arctic Ocean can be done once every two days.

(2) ESA's plans for earth observation satellites. The concept for satellites in ESA is to conform to the needs of each country in Europe, and also to meet the requirements of the developing countries.

France will launch the first earth observation satellite, /53
Systeme Probatoire d'Observation de la Terre (SPOT). An outline of the plans for this satellite proposed to ESA is shown in Table 4. Two kinds of multifrequency visible and infrared radiometers will be carried.

a. Super-high resolution, visible near-infrared sensor:
   Ground resolving power: 20 m
   Scanning width: 60 km
   Frequency bands: 0.5-06 μm; 0.6-07 μm; 0.7-0.8 μm; 0. 1. 0.8-1.1 μm.

b. Visible, near-infrared and thermal infrared radiometers.
   Ground resolution: 100 m (visible and near infrared)
   200 m (thermal infrared)
   Scanning width: 300 km
   Wavelengths: Visible and near-infrared - 4 bands
   Intermediate infrared - 2 bands
   Thermal infrared - 1 band
   In addition, one band is planned for water vapor compensation.

SPOT, proposed by France, is to be launched in 1983 with an Orion rocket.

There are no firm plans for ESA's second earth observation satellite, but it is believed that radar sensors will be carried aboard.

TABLE 4. PLANS FOR EARTH OBSERVATION SATELLITES IN FOREIGN COUNTRIES OTHER THAN THE UNITED STATES

Name of satellite and country	Mission	Program progress	Orbit factors	Sensors (abbreviated)	Presence or lack of data collection system	Presence or lack of data recorder	Date of launching (planned)
Earth Resources Survey Satellite The Soviet Union	The same as for LANDSAT	The satellite is believed to be under development	Orbit altitude...500 km Orbit inclination angle..... 97°	- Videcon camera (VC) - Film camera (FC) - Wave lengths: Several bands between 0.45-0.9 μm (VC), Seven bands between (0.5-1 2) μm (FC) - Scanning width: 200-300 km - Resolution 100 m (VC), 80-120 m (FC) - On-board film developing equipment and electronic scanning equipment will be included in the satellite system	Undetermined	Will have data recorders	Undetermined
Earth Resources Survey Satellite India	Earth observation experiment, meteorology and water use, Collection of data concerning the oceans and use of water from precipitation, and collectn. of oceanic data; To establish fundamentals for future operational satellites	An agreement was concluded in April, 1976 concerning preparation of launching plans with the Soviet Union	Orbit altitude...500 km	- Two TV cameras, wave lengths 0.54-0.66 m, 0.75-0.86 m - Two microwave radiometers	Unknown	Unknown	1978
Ocean Surveillance Satellite Canada	A demonstration of operational ocean monitoring	Feasibility studies done in 1975	Height....650 km Inclination angle..... 99°	- Synthetic radar, wavelength· L band - Scanning width· 200 km - Resolution 25 m	Undetermined	Will have no data recording system	In the middle 1980s
Earth Resources Survey Satellite France (proposed to ESA)	Earth observation satellite	Preparatory studies will be completed in 1977	Altitude...809 km Inclination angle.....98.6° Recurrent period 13 days	Two multi-wavelength, visible infrared radiometers 1- Wavelength: visible infrared 7-8 bands, resolution, visible and near infrared: 100 m, thermal infrared· 200 m 2- Wavelength visible and near infrared; resolution: 20-30 m	Has data recorders	Unknown	1983

/54-55

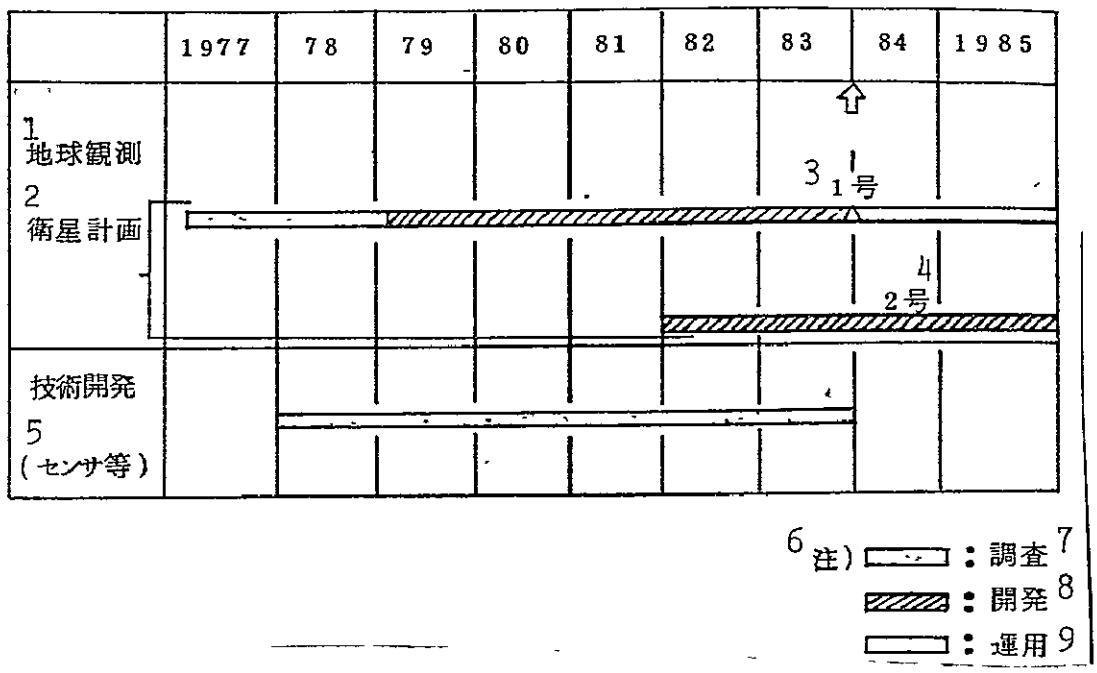

Fig. 5. Schedule for the development of ESA's earth observation satellite

Key: 1. Earth observation 2. Satellite plans 3. Number 1 4. Number 2 5. Development of technology sensors 6. Note 7. Studies 8. Development 9. Operational

ESTIMATES OF LONG-TERM EXPENDITURE

3 単位：億円

1 項目 \ 2 年	1978	79	80	81	82	83	総計 6
4 地球観測衛星計画	9.3	480	98.4	1250	1227	1025	5059
5 技術開発（センサ等）	6.0	85	85	153	153	109	645

Key: 1. Item 2. Year 3. Unit: 100 million yen 4. Earth observation satellite plans 5. Development of technology (sensors, etc.) 6. Totals

IV.2. Proposed Plans for the Development of Earth Observation Satellites for the Next 15 Years

IV.2.1. Basic concepts concerning the development of earth observation satellites

In section I of this report, the role that Japan's earth observation satellites should play was discussed; in section II the requirements for the various fields of utilization were discussed, and in section III the development of technology in connection with earth observation satellites was discussed. Based on those discussions, the following basic concepts concerning the development of earth observation satellites in Japan are thought to be appropriate.

1. The long-range goal for the establishment of technology should not be limited to meeting domestic requirements for the next 15 years, but should also have the goal of fostering international cooperation.

In meeting the requirements of the fields of utilization outlined in section II, there is an urgent need for Japan to develop a system to insure supplies from ocean resources (fisheries), and to establish a system of ocean surveillance to cope with the 200 nautical-mile fishing zone system. It is also essential to establish systems for the collection of data concerning agricultural resources, for the management of marine resources (plankton distribution), for disaster prevention, for land use, and to monitor the environment in order to cope with increase of population, concentration in cities, expansion of industrial activity, and the continued deterioration of the environment.

In international cooperation, it is necessary to support neighboring countries politically, and to adopt the view that long-term stabilization of the supply of food and natural resources is essential for broadening and strengthening the basis of national existence. It is also essential to strengthen ties of friendship and to provide for the stabilization of the supply of resources by cooperation, insofar as it is possible, in planning the development of the nations of Southeast Asia, South America, Oceania, the Middle East, and Africa, as well as to help plan the development and management of their resources. The countries of Asia expect the international cooperation of Japan. For the accomplishment of all this, it is necessary to quickly establish the essential technology.

2. Two series of earth observation satellites will be developed, satellites for collecting data concerning the oceans (sea satellites), and satellites for collecting data concerning the land (land satellites). /58

The earth observation data which will be collected can be roughly divided into ocean data and land data.

Ocean data includes water color distribution, distribution of water temperature, distribution of sea ice, wave height, sea surface geoid, wind velocity on the sea, wind direction, ocean currents, and the salinity of sea water. These data change in a short short period of time (several hours or several days), and are distributed over a large seaaarea. The sensors required to collect these data are visible and infrared radiometers (high resolution not necessary), and microwave radiometers, microwave altimeters, microwave scatter meters, and image radar. The principal function of the sea satellites will be to observe a wide area for a sho short period of time. For this reason, the orbit should be one which covers most of the surface of the globe in one or two days.

The chief data collected by the land satellites will be data concerning crops, the conditions of land use, snow cover, geological structures, geothermal distribution, and the environment. The rate of change in these data is slow (several weeks or months), compared to that for the oceans. Since the area of collection is small compared to the oceans, the sensors must have high resolving power (high accuracy). The required sensors are high resolution visible and infrared radiometers, sensors for determining the contents of the atmosphere and microwave image radar. The function of land satellites is to observe a smaller area with more accuracy and for a longer period of timesthan sea satellites. For this reason, an orbit similar to that of LANDSAT is suitable.

The type of sensors required (and their accuracy), as well as the orbit are different for sea satellites and land satellites. Thus, it is appropriate to develop two series of satellites. Satellite technology will be mutually used in both types of satellite as it is developed.

3. The sea satellite will be developed before the land satellite. There exists at the present time a system for gathering data concerning fishing conditions, but it is limited chiefly to data concerning sea conditions and water temperature, and depends /59 on spot measurements by a small number of ships in a broad ocean area. With this kind of system, it is very difficult to obtain simultaneous data over a wide area of foreign seas. In this age of 200 nautical-mile fishing zones, obtaining large catches of fish while preserving marine resources has become an important national problem for Japan. Thus, the establishment of a system for collecting ocean information by sea satellite has become a necessity. At the present time, the sensors necessary for the collection of the essential sea resourcesdata (water color and water temperature) are visible and infrared radiometers and passive microwave sensors. Since the technology required to analyze this kind of ocean data is not difficult, it is expected that it

can be developed along with the sensors by about the end of the 1970s. As a final objective, active sensors (radar altimeters, etc.) should also be developed as soon as possible.

It is expected that land data of 80 m resolution will be available by about 1979 from the LANDSAT ground reception, and processing stations installed by the Space Development Project Groups. Thus, the requirements for these data can be met in this way for the present. Furthermore, since superior analytic technology is necessary for extracting land data compared to extracting marine resources data, the development of analytical technology by the use of LANDSAT data should be a prerequisite for the launching of a land satellite.

In such a situation, it is appropriate to developea sea satellite before developing a land one.

4. In developing the satellites, all efforts will be made to use Japanese technology, and a system of related technology will be developed.

a. The necessity for the development of an independent technology

Concerning Japan's satellite-associated technology, an experiment on tri-axial attitude control will be conducted by the launching of the experimental technical satellite-III (ETS-III), which is scheduled to be launched in 1981. In this experiment, we expect to establish the essential technology common to earth observation satellites.

Concerning satellite-launching technology, the N rocket has already been achieved, and in 1980 the capabilities of N Rocket II will be confirmed. /60

Concerning sensor-related technology, fundamental research and development is beginning only now, but except for some special technology, we, in general, have the basic technology, such as optical technology, precision machinery technology, electronics technology, microwave technology, and data-processing technology. Thus, we believe that Japan is provided with the necessary technological fundamentals to proceed independently.

In the future, it is expected that earth observation satellites will be the pillar of space utilization, along with weather, communications (including broadcast), life science, and raw materials satellites. Earth observation systems will offer useful data in an extremely large field of utilization. On the other hand, in the development of such a satellite system, a great many technical fields

must be brought together and developed more intensively. The results of this intensive development will directly or indirectly affect all domestic industry.

The introduction of American and European technology is gradually increasing in the development of Japan's space program. The introduction of high-level technology in the future cannot be expected to be in the national interest. Furthermore, even if the importation of technology were compatible with Japan's independence, it would not necessarily guarantee continuity and stability. The specifications of foreign technology are not always the same as Japan's, and inconsistencies as well as dependency would arise.

The development of independent technology is also important from the point of view of international cooperation. In the future, plans for earth observation on a global scale are expected to be developed. An example of this is the plan for atmospheric observation (GARP). In these cases of international cooperation, it is necessary that Japan have an established independent technology in the fields of utilization in order to be able to cooperate independently. /61

b. The necessity for fostering the systematic development of related technologies

In order to sufficiently meet the requirements of users, it is necessary to have the world's highest level of technology. In the development of space technology, the expenditure of large sums and a long period of time are required. For these reasons, in the development of earth observation satellite-associated technology, selectivity must be exercised concerning long-term technical developments.. For the technology selected for development, it is necessary to build onto the research and development already accomplished, and to systematically foster the continuous development that will satisfy future requirements.

In selecting the technology that should be developed independently, the following points should be carefully considered.

(1) The technology selected should be essential for the achievements of missions which are of great importance for the future, for world space development, and for Japan.

(2) The technology selected for development should not be obsolete after the goals of the first fifteen years are met.

(3) In selecting technology questions such as, does the technology have potential for future development, can far-reaching effects be expected, and will it form an industry that can be exported, should be asked.

For the technology that does not conform to the above, the introduction of foreign technology and purchase must be considered.

In Japan, at least 5 to 7 years will be required for the establishment of space technology to meet the requirements of users. In formulating policies for technical development, it is necessary to keep in mind Japan's development plans of the next 15 years, while considering the trends in foreign countries. Based on this overall 15-year view, the launching of the second satellite should be based on the results achieved by the first, the third on the /62 results of the second, and the fourth on the third, etc., in a "step-by-step" development goal. Since it requires several years at least for the reflection of technical achievements, in this survey the technology required for the first satellite will be considered as the technology meeting the requirements (missions) for the next 15 years.

5. The target for the first earth observation satellite (sea satellite) is 1983. Sea satellite number two is expected to be developed soon after 1985, establishing basic sea satellite technology.

There is a strong desire to develop Japan's earth observation satellites as soon as possible for the fields of utilization outlined in section II of this report. It is especially urgent to develop the sea satellite for the reasons given in item 2 above.

The new technology required for earth observation satellites is triaxial attitude control, the development of solar paddles, and active system heat control. Experiments concerning this will be conducted with the experimental technical satellite IIII(ETS-III), planned to be launched in 1981. If this experiment is successful, it will take at least two years for the results to be reflected in the first earth observation satellite.

With regard to the major sensor equipment for the sea satellite mission, it is believed possible to develop the visible and infrared radiometers and the microwave radiometer necessary for the achievement of the mission by 1981-82. This belief is based on the prospects for development outlined in section II of this report. These sensors will be a part of the basic equipment for

future earth observation satellites. The visible and infrared radiometer, especially, will be a basic sensor for common use in both sea and land satellites of the future. Also, the microwave radiometer has a use in the future as an infrared all-weather sensor. These sensors are also essential for the development of future active microwave sensors (microwave altimeter, scatter meter, and image radar).

In this background, the target date, 1983, is believed to be appropriate for the launching of the first earth observation satellite. /63

A major mission of the sea satellite will be to observe ocean wave phenomena, in addition to water temperature and water color observation, by visible and infrared radiometer. The microwave altimeter, microwave scatter meter, and the microwave radiometer will be made part of the mission equipment of the second earth observation satellite, as will improved versions of the micrometers that were carried on the first earth observation satellite. The basic technology of sea satellites will be almost completely established by the first and second earth observation satellites.

In considering the life of the sea satellites and the development period for new technology, we believe that about four years is a suitable interval for launching another satellite.

Land satellites are also necessary, but in degree of urgency, they can be developed after sea satellites. We believe that it is appropriate to plan for the first launching of a land satellite in 1987, by which time it is expected that a visible and infrared radiometer can be developed with an accuracy equivalent to that of LANDSAT-D. Subsequently, a new satellite should be launched every four years, at the same interval as for sea satellites, while making improvements along the way.

IV.2.2. Proposed plans for the development of earth observation satellites

1. Plans for the development of earth observation satellites

Based on the basic concepts for development outlined above, we believe that Japan should develop and launch earth observation satellites for the next 15 years as below.

1) The first earth observation satellite

The principal mission of the first earth observation satellite to be launched in 1983 will be that of a sea satellite, but it will be used for the development of technology common to both sea and land satellites.

It will be equipped with sensors such as the visible and infrared radiometer, and microwave radiometers that have prospects for future development, and will collect data that can be used as suitable fields of utilization are found. /64

A chief aim of the first sea satellite will be to develop the basic technology for a superhigh resolution, visible and infrared radiometer for the future, and to evaluate and confirm data collection capabilities, especially for the urgent data concerning ocean resources. A visible and near-infrared radiometer which uses multi-element array detection elements will be developed. The ground resolution of this radiometer will surpass that of LANDSAT-C, from which Japan expects to receive data. It is technically feasible to develop the ground resolution to 50 m at the present time.

Concerning the infrared field (thermal infrared field), it is not possible at the present time to develop infrared multi-element array detection elements. Therefore, an infrared radiometer (equipped with supplementary visible field observation bands), which uses single-detection elements, will be developed. The goal is a ground resolution of 1-2 km, and temperature resolution of 1°C.

With regard to microwave radiometers, a chief aim of the first sea satellite will be to establish the basic technology for the future development of high-performance microwave radiometers. In order to improve the temperature resolution of microwave radiometers and expand the observation width, scanning will be done with an antenna system. Small antennas are necessary to reduce the effects of vibration on the body of the satellite. The frequency bands (reception) used for the microwave radiometer of the first satellite will be ones used for radio astronomy, (23 GHz and 31 GHz), so as to avoid interference from ground communications circuits. In this case, the collection of temperature data, which are very important data, will be difficult, but it will be possible to collect data concerning the amount of water vapor in the atmosphere. The development of analytic software for the extraction of necessary data can be expected to accelerate. /65

Concerning data recorders, data collection systems, and laser reflectors used for determining orbit altitude, studies will be continued concerning their future development and use on satellites.

This first earth observation satellite will be chiefly an experimental satellite to test the performance of the mission equipment.

2) The second earth observation satellite

The launching of the second earth observation satellite, planned for 1985, will be based on the achievements of the first

satellite, and its aim will be the establishment of basic technology for sea satellites. The sensors developed and carried aboard will be a microwave altimeter essential for the observation of ocean wave phenomena, a microwave scatter meter, and a microwave radiometer. The microwave altimeter will collect data necessary for finding the average wave height on the sea surface, data concerning the sea surface "topography," geoid, tsunami, and ocean currents. The microwave scatter meter will collect data on wind direction and velocity. These two types of sensors will be performance-tested on the second satellite. Microwave radiometers for the second satellite will be developed almost simultaneously with those for the first satellite, and will be tested for the collection of sea surface temperature data in all weather. The frequencies under consideration for the second satellite are 5-10 GHz, instead of the 22 GHz and 36 GHz that will be used for the first satellite. It will be necessary to devise a way for avoiding interference from ground communications circuits. In this satellite, aslaser reflector will be carried for use in measuring the orbit altitude, in order to improve the accuracy of measurement with the microwave altimeter. Since the objective of observation of this satellite is the broad oceans, a data-recording and a data-collecting system to be carried aboard are considered.

3) The third earth observation satellite

The third earth observation satellite, which is planned to be launched in 1987, will be for the development of basic land /66 satellite technology. A high-resolution, visible and infrared radiometer that reflects the technical achievements attained in the visible and infrared radiometer carried on the first satellite will be developed and carried on this satellite. In this sensor, the observation wave length field will be fractionated, making possible multiwave-length observation. The goal is for ground resolution of 30 m. With ground resolution of this accuracy, it will be possible to discern ships of more than 100 tons. This will strengthen surveillance capabilities for the 200 nautical-mile fishing zone. The attitude control accuracy of the satellite will have to be improved over that of the first satellite in order to reduce geometrical distortion of data accompanying the improvement in resolution of the sensors.

This satellite will carry a data recorder, and will be able to make a contribution to international cooperation.

4) The fourth earth observation satellite

The fourth earth observation satellite, expected to be launched in 1989, will develop further the technology of the first and second sea satellites, and will establish technology for practical sea satellites.

The visible and infrared radiometer, microwave radiometer, microwave altimeter, and the microwave scatter meter carried on the first and second satellites will be improved and put into practical use in this satellite for the collection of data. In addition, new image radars will be developed in order to collect all-weather pictorial information. All of these sensors will be performance-tested on this satellite.

Since it is estimated that the power expended in connection with sensors on this satellite will be up to 100 W, it will be necessary to establish a large power system.. In addition, a laser reflector for measuring orbit altitude, a data recorder, and a data collection system will be carried.

5) The fifth earth observation satellite

The fifth earth observation satellite, expected to be launched in 1991, will continue the development of the technology of the third satellite, and establish the basic technology for the practical operation of land satellites. /67

It will carry the high-resolution visible and infrared radiometer of the third satellite, improved to superhigh resolution (15-20 m). The goal for resolution is 15-20 m, and with this, it will be possible to discern ships of over 50 tons on the surface of the sea. In addition, a laser sensor for the measurement of components of the atmosphere will be developed and tested for performance on this satellite.

For this satellite, it will be necessary to improve the accuracy of the attitude control over that of the third satellite. Also, in order to cope with the increase in the amount of data from superhigh resolution sensors, it will be necessary to establish technology for data compression on board the satellite (band compression), and for onboard processing.

This satellite will carry a data recorder, and will be able to make a contribution to international cooperation.

The superhigh resolution sensors developed in this satellite are those essential for stationary earth observation satellites. This satellite will establish the technology necessary for a stationary earth observation satellite to be launched sometime after 1985. When a stationary earth observation satellite is put into operation, it is expected to be used chiefly for the observation and investigation of the sea, but it will probably also have land applications for environment and natural disaster surveillance.

The plans for the development of Japan's earth observation satellites for the next 15 years are shown in Figure 6.

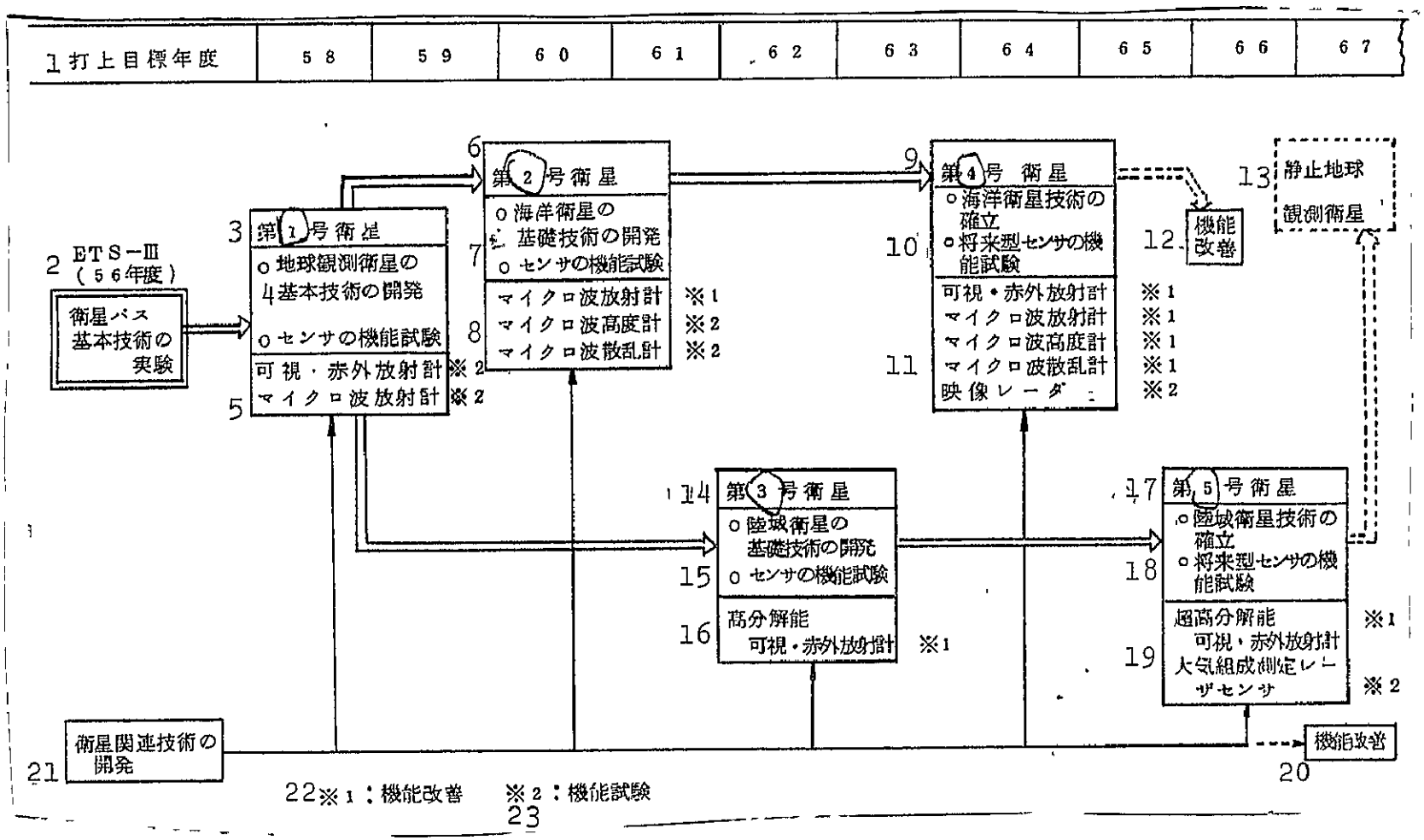

Fig. 6. Plans for the development of earth observation satellites
(Key on following page)

Key for Figure 6:

1. Target year for launching 2. ETS-III (1981), experiment in the basic technology of satellite berthing 3. The first satellite 4. The development of basic technology for earth observation satellites; performance test for sensors 5. Visible and infrared radiometer, microwave radiometer 6. The second satellite 7. The development of basic technology for sea satellites, sensor performance tests 8. Microwave radiometer, microwave altimeter, microwave scatter meter 9. The fourth satellite 10. The establishment of sea satellite technology; performance tests for sensors for the future 11. Visible and infrared radiometer, microwave radiometer, microwave altimeter microwave scatter meter, image radar, 12. Improvement of performance 13. Stationary earth observation satellite 14. Third satellite 15. Develop basic technology for land satellites, performance tests for sensors 16. High-resolution visible and infrared radiometer 17. The fifth satellite 18. Establishment of land satellite technology; performance tests for sensors of the future 19. Superhigh resolution visible and infrared radiometer, laser sensor for determining the components of the atmosphere 20. Improve performance 21. The development of satellite-associated technology 22. Improve performance 23. Performance tests

2) Plans for the development of basic technology for earth observation satellites /67

The chief satellite-associated technology necessary to carry out the development plans outlined above are as below. It is essential to develop the basic technology in accordance with the launching plans of the satellite for which it is intended.

1) Mission-associated technology /69

The sensors to be developed in the next 15 years are the visible and infrared radiometer, the microwave radiometer, the microwave altimeter, the microwave scatter meter, the image radar, and the laser sensor for determining the components of the atmosphere. In the future there will have to be discussions between the developers of these sensors, and the users of data collected by the sensors concerning the accuracy required.

In the next 15 years, the resolving power of the visible and infrared radiometer will probably have to be developed to a high ground resolution of less than 30 meters. This is necessary because of trends in foreign countries, the necessity of confirming the position of ships in the 200 nautical-mile fishing zone,

the necessity of crop observation in Japan, which has fields of less than one hectare, etc. This superhigh resolution sensor technology will also be essential for future earth observation by stationary satellite.

Data collection systems will have the function of collecting data from fixed and moving buoys. Most of the land and sea surface of the world can be observed by means of remote sensing technology. The data-collection system is a "by-system" for collecting data from under the surface. This by-system will become very important for collecting data, especially data concerning the oceans.

Data recording will be an essential function of Japan's satellites until a data relay satellite system can be established. In the past, the moving mechanism of data recorders has been a problem concerning reliability. We must study the development of an all-solid-state data recorder which uses a super LSI memory.

It is necessary to develop this mission equipment prior to placing it on earth observation satellites, and to confirm its capabilities by testing it on experimental technical satellites. /70

2) Technology associated with the satellite body

Technology associated with the body of the satellite is that concerning triaxial attitude control, the deployment of solar paddles, and active system heat control. Experiments concerning this technology will be conducted in 1981 with the experimental technical satellite-III. The establishment of this technology is a prerequisite for the development of earth observation satellites. Attitude control accuracy especially has a great effect on geometrical distortion of data collected by image sensors (especially visible and infrared radiometers), and it is essential to improve the accuracy of attitude control in stages. Since it is estimated that in satellites carrying active microwave sensors, the total power expenditure will reach 100 W, it will be necessary to establish technology for the development of solar paddles to improve the effectiveness of solar cells and increase power.

3) Launching technology

To accurately place an earth observation satellite into the desired orbit with triaxial attitude control, a rocket with a spin-stabilization solid motor in the last stage is not necessarily the appropriate rocket. For land observation satellites, periodic observation is desirable, and for this the satellite must be placed in a solar-synchronous orbit. In the case of Japan, due to geographical conditions, there is a possibility of the second stage of a three-stage rocket falling on Australia. Since it is safer to put the second stage into orbit, consideration must be

given to attaching a second-stage re-ignition capability to the N rocket, or to launching satellites with N rocket II.

4) Ground support-related technology

It is possible to measure the orbit altitude of a satellite accurately with a microwave altimeter carried aboard the satellite. For this, it is necessary to introduce laser range-finder technology into satellite tracking technology, and to install a laser reflector in the satellite. /71

5) Technology for on-board processing

Since with the improvement of sensor resolution and measurement accuracy, the amount of output data will increase, it is necessary to develop suitable data processing technology for data compression on board the satellite. Also, signal processing by computer aboard the satellite will become necessary in the case of image radar sensors. Equipment developed by this technology will have to be compatible with ground reception and processing systems.

6) Ground reception and processing technology

As sensor resolution and accuracy progress, the amount of data transmitted from the satellite will increase. Even with the introduction of data compression, the tendency for the amount of data to increase cannot be controlled. Frequency bands above 200GHz will probably be used for the great volume of data to be transmitted. In this case, the deterioration of radio waves due to rain will have to be taken into consideration. It will be necessary to develop appropriate technology after taking into consideration the results of the experiments conducted with the medium-capacity stationary communications satellite (CS), and the experimental stationary communications satellite (ECS).

It will be necessary to develop processing technology to correspond to the higher resolution of sensors for the geometric correction of data, and for radio metric correction.

7) Technology for the analysis of data

In regard to the visible and infrared radiometer, it is essential to continue with the processing of LANDSAT data, and to establish methods of extracting essential data. For all kinds of microwave sensors, the accumulation of basic "sea true" and "land true" data using aircraft is necessary in conjunction with the development of sensors. If it is possible to receive data from /73
the American SEASAT-A, which is planned to be launched in 1978, rapid progress will be made in the technology of data extraction with data from microwave sensors.

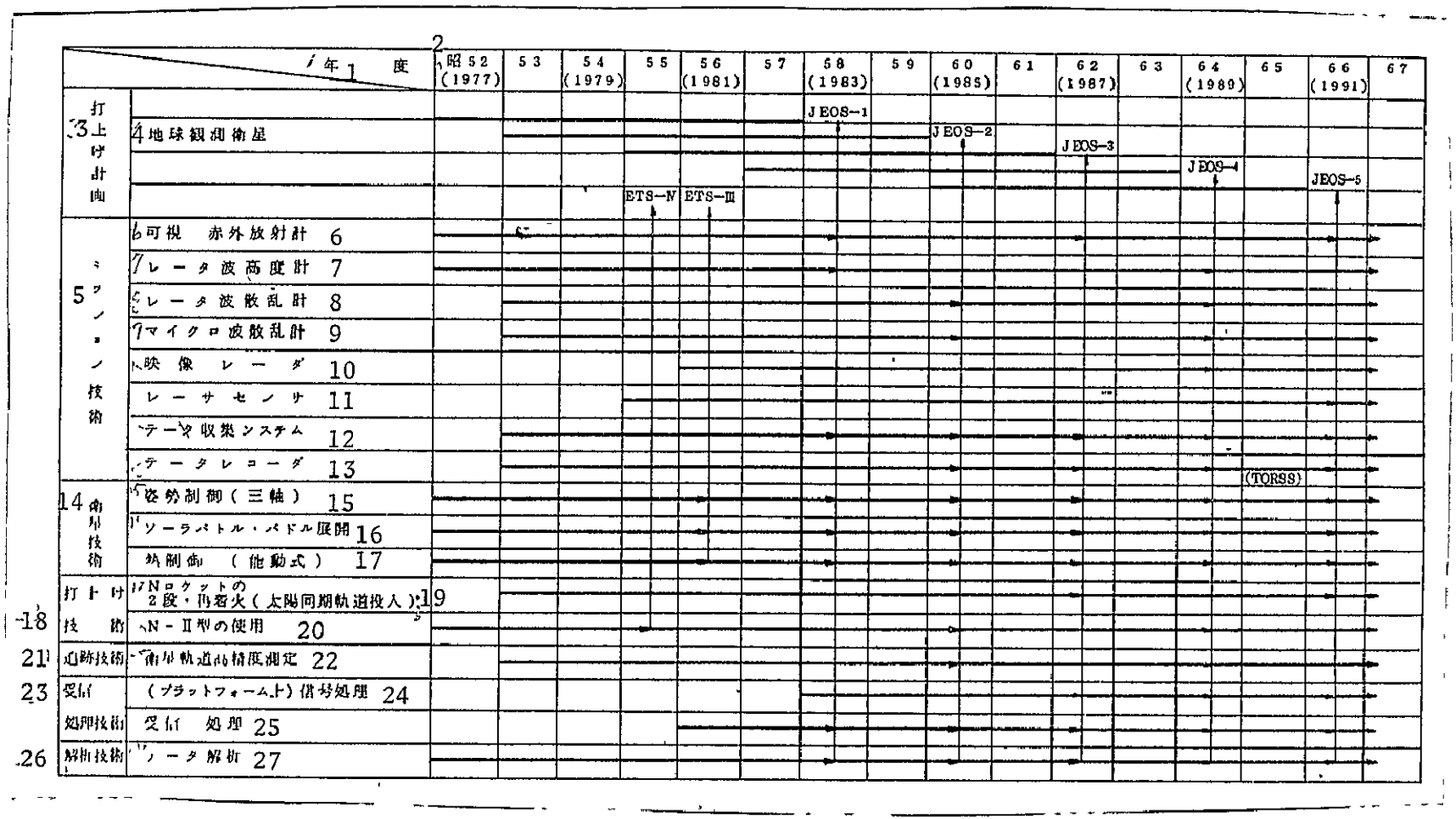

Fig. 7. Proposed plan for the long-term development of basic technology related to earth observation satellites

(Key on following page)

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The long-term plan for the development of earth observation satellite-related technology is shown in Figure 7.

Key for Figure 7:

1. Year 2. 1977 3. Launching plans 4. Earth observation satellites 5. Mission technology 6. Visible and infrared radiometer 7. Radar wave altimeter 8. Radar wave scatter meter 9. Microwave scatter meter 10. Image radar 11. Laser sensor 12. Data collection system 13. Data recorder 14. Satellite technology 15. Attitude control (triaxial) 16. Solar paddle and paddle deployment 17. Heat control (active elements) 18. Launching technology 19. Second stage of the N rocket and re-ignition (for putting satellites into a solar-synchronous orbit) 20. Use of N-II 21. Tracking technology 22. Accurate measuring of satellite orbit altitude 23. Reception and processing technology 24. (Platform) reception and processing 25. Reception and processing 26. Analytical technology 27. Data analysis

IV.2.3. Policies necessary for the achievement of the development plan /73

The following policies can be cited as necessary for the realization of the proposed plans for the development of earth observation satellites in the next 10 to 15 years.

1. It is essential that plans are not for the development of earth observation satellites only. Earth observation satellites must be a link in a total system of terrestrial observation. For this reason, a long-term earth observation plan must be established and promited.

2. In order to achieve the desired results in developing and launching satellites, we must develop a space system for accurately collecting data from the surface of the earth, and at the same time we must be able to receive, process, and find a use for these data on the ground. When formulating policies for an overall earth observation satellite plan, research and development of basic satellite technology and sensor technology should come first. Installation of a system for the reception and processing of data from the American LANDSATS should be given sufficient consideration in order that projects for the analysis and utilization of these data can get underway at an early date.

3. Concerned administrative organs, national research and test organs, academic organs, and cooperating civil organizations must be ready to effectively carry out the preparation and development of satellites, based on the over-all plan. The role of each organ must be made explicit, and there must be common planning and coordination.

4. Public understanding must be obtained for the smooth implementation of the earth observation satellite plans. A general education program covering the general aspects of the earth observation plans must be carried out. /74

IV.3. Proposed Plan for the Development of the First Earth Observation Satellite

IV.3.1. Proposed planning ocncepts for basic satellite equipment

1. Configuration. Tentative plans are for the first earth observation satellite to be launched with a 3-stage N rocket. The solar cell paddles will be folded to the sides of the satellite, and deployed in orbit on a single axis. They will be synchronous with the sun sensors, and will be driven so that the angle made by the sun's rays and the normal of the solar cell paddle will always be minimum. The satellite equipment (visible and near-infrared radiometer, visible and thermal infrared radiometer, microwave radiometer, and DCS) will be attached to the satellite facing the earth, as will be the data transmission antenna, and the earth sensor for attitude surveillance. If a laser reflector is atteched for range finding, it will be attached totthe surface of the satellite facing the earth.

After the second satellite, the satellite should be divided into the basic satellite equipment, such as the TT & C system, the attitude control system, and the gas jet system, and equipment carried aboard, such as the sensors mentioned above. Since the triaxial attitude system using a wheel has to be adopted for attitude control of the satellite, the satellite configuration in orbit is comparatively free. The design should be such that the surface facing the earth is as large as possible, and one so that the satellite can be launched into a medium-high orbit.

The receiving antenna for the microwave radiometer for the first satellite will be an off-set parabolic antenna with a diameter of 30 cm, with common-use frequencies of 23 and 31 GHz. Next time, the frequency used will be 5 GHz, and a different type of satellite will have to be designed.

In the United States, in the configuration of LANDSAT-D, which is now being designed, suitability for space shuttle is a design factor, and modular sub-systems are being taken into consideration. In Japan, too, we should probably think of satellites as a series, and consider modular sub-systems from the first satellite. /75

A box shape is contemplated for the first satellite. The gas jet equipment on the roll surface used for orbit and attitude control will be attached in a cluster. The heat control surfaces are the pitch and the roll surfaces, but since there is much e-

/76

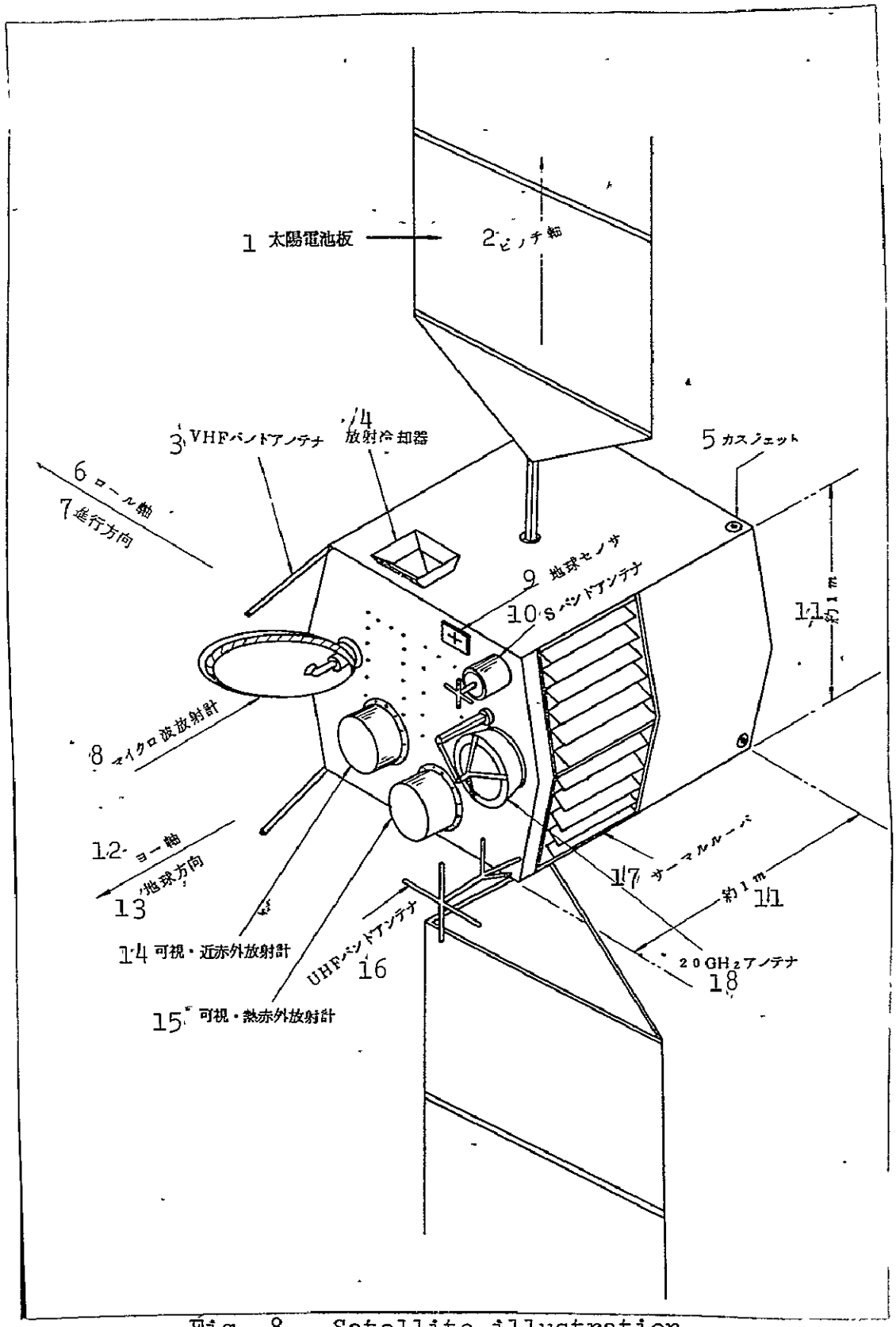

Fig. 8. Satellite illustration

Key: 1. Solar cell plate 2. Pitch axis 3. VHF band antenna 4. Radiation cooler 5. Gas jet 6. Roll axis 7. Direction of satellite movement 8. Microwave radiometer 9. Earth sensor 10. S-band antenna 11. About 1 meter 12. Main axis 13. Direction of the earth 14. Visible and near-infrared radiometer 15. Visible and thermal infrared radiometer 16. UHF-band antenna 17. Thermal louvers 18. 20 GHz antenna

equipment carried aboard in which heating is critical, thermal louvers will be attached to all surfaces for the necessary heat control.

The configuration of the first earth observation satellite cannot be decided without detailed study, but a tentative illustration of the ETS-III to be launched in 1981 is shown in Figure 8.

2. Orbit. Launching a satellite into a solar-synchronous orbit from Tanegashima in Japan involves problems with range safe safety. Consequently, we have to select a solar nonsynchronous orbit for the first earth observation satellite. When the shape of Japan and the safety of rocket launching is taken into consideration, inclination angles of 50° and 80° are suitable. However, considering that we want a range of observation to the highest latitude possible, and that it is necessary to protect the sea observation sensor from halation from the surface of the sea, an inclination angle higher than 50°oor 70° is desirable. Two altitudes, approximately 500 km and 900 km are contemplated, but taking the power resolution of the equipment and the visual field into consideration, the 500 km altitude is more suitable. We believe that for the first earth observation satellite, an inclination angle of 70° and an altitude of 540 km are best.

With this orbit, the period of recurrence would be long, 15 days, and the visual time would be short, because of the low altitude. If no data recorder is carried on the satellite, the /77
problem of having to transmit the data quickly will arise.

3. The solar angle and eclipsing. With regard to the power generated by the solar cell, an important factor is the angle at which solar rays strike the solar cell paddles, and the proportion of eclipse. It is also as important to know the conditions concerning changes in the sun's angle for processing data from the visual sensors carried on the satellite. The following is a description of changes in theeeclipsing, and the changes in the sun's angle for an altitude of 540 km, and an inclination angle of 70°.

a. Changes in eclipsing. Figure 9 shows an example of the results of calculations for eclipsing. These calculations were made taking February 1, 1976 as the initial day. In making the calculations, the perigee factor (ω_0) and the eccentric elongation (Mo) were both considered to be 0°, wwiththtwo equaequatorial coordinates of the ascending node (Ωo) 0° and 90° as the initial value of the orbit. The two kinds of equatorial coordinates are expressed by a shift on the transverse scale showing the number of days elapsed.

b. Changes in the angle of the sun. The axis of the solar cell paddle will be fixed to the satellite, but the paddle

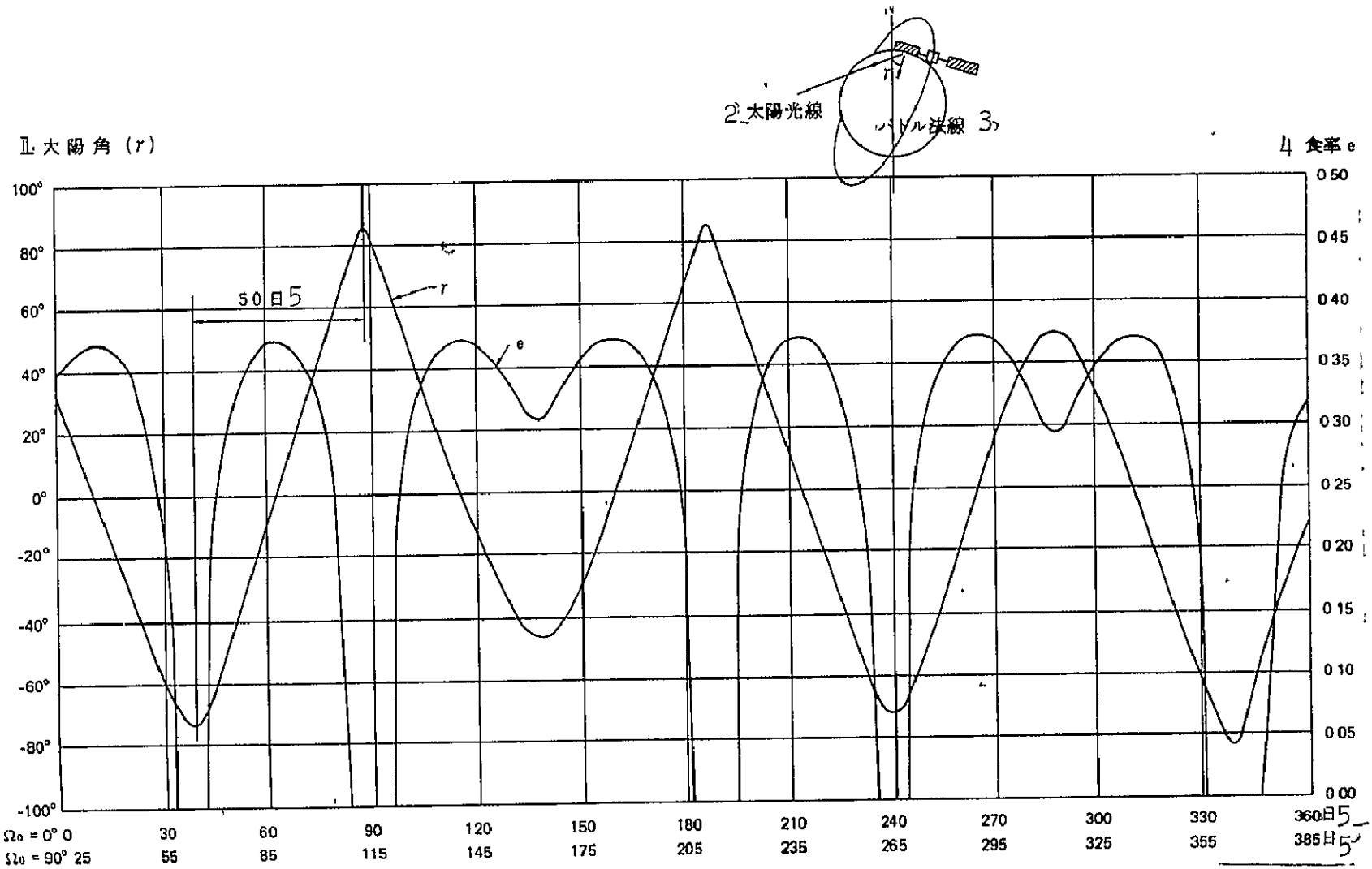

Fig. 9. Eclipsing (e) and the angle of the sun (γ) when the altitude is 540 kilometers and the inclination angle is 70°

Key: 1. angle of the sun 2. sun rays 3. paddle normal 4. eclipse
5. days

will be able to rotate freely with respect to the axis. It is contemplated that the paddle axis will be maintained parallel with respect to the normal of the orbit.

4. Weight. The first satellite will be launched into orbit with the N rocket to altitude 540 km, with orbit inclination angle 70°. The maximum weight at the time of launching will be about 600 kg. The weight can be divided into 150 kg for the equipment carried, and 450 kg for the basic satellite equipment. The weight distribution of each sub-system still has to be considered, but the equipment carried on the satellite will have to be /79 designed and fabricated within the weight limits.

5. Electric power source. The electric power system will consist of a solar cell array, a battery, and an electric power control circuit. Elements will be attached to the solar cell array to generate only 300 W under good orbit conditions.

The optimum eclipse for the orbit is e = 0.37, and the system will be designed to supply the necessary power for the operation of the basic satellite "housekeeping" system and the telemetry command systems even when there is no sun.

When the satellite is in operation, the average expenditure of power will be about 100 W for the maintenance of each subsystem of the satellite, and 200 W for the equipment carried aboard. The power control system will supply DC 28-29 volts of stable single bus voltage by partial shunt and booster converter. At the same time, it will have the capacity to control charge and discharge of the battery.

6. Orbit control and attitude control. Triaxial attitude control systems are roughly divided into the bias momentum system and the zero momentum system, and both have their merits and shortcomings. Which system is adopted depends largely upon the position occupied by the equipment carried, and the mission. Wheels, magnetic torque, and gas jets will be used as actuators for the orbit and attitude control systems. These will receive signals from sensors, and will operate by electronic control. The accuracy of attitude control will be ± 0.5° for the lowest roll and pitch axes, and ±0.7 degrees for the main axis. The speed of change in the attitude is an important factor, and it will be necessary to consider this while taking into account the particular characteristics of the observation equipment.

The monopropellant hydrazine, which is abundant, inexpensive, /80 and has been proven reliable, and the blowdown method will be adopted for the gas jet system used for orbit correction and attitude control. There are plans for achieving a thrust force of 1 N by domestic technology, but to eliminate error when entering the initial orbit, a large thrust level of 5 N will be necessary.

The basic number of boosters will be six, but there will be twice this number for complete redundancy. The boosters will be in a cluster attached to the roll surface.

A magnetic "torquer" will be attached to provide high reliability for the attitude control system. There will be a big saving of hydrazine fuel necessary for "wheel unloading" by using magnetic torque.

7. Heat control. Insulation blankets, heat coating, conduction spacers, heaters, and thermostats, in addition to heat pipes and thermal louvers, will be used for heat control to keep the parts of the satellite within the permissible temperature range.

Among the equipment to be carried on the first satellite, in which heating is critical, and for which cooling technology will have to be developed, are the optical portion of the visible and near-infrared radiometer, and the infrared sensor elements.

A passive heat control system for the satellite as a whole is desirable. An active heat control system with thermal louvers will be developed for the equipment carried on board.

8. Life of satellite. It is anticipated that the satellite will have 50% reliability after two years.

IV.3.2. Proposed planning concepts for observation equipment

1. Visible and near infrared radiometer

1) Design policy and required specifications. The observation wave length range and the required resolution for the visible and near-infrared radiometer are as follows.

- 0.51-0.59 μm Object of observation will be vegetable plankton
- 0.64-0.71 μm Same as above
- 0.72-0.80 μm Same as above, plus solutes and suspensions in water
- 0.80-1.1 μm
- Ground resolving power: the goal is 50 meters

The high-resolution multispectrum scanner will be developed as the future scanning mechanism. An electronic scanning system using array sensor elements is recommended. The specifications for the equipment planned to be carried on board the first earth observation satellite are shown in Table 5.

2) Electronic scanning systems. The array scanning system will be a type of image scanner which scans the surface of the earth with multi-sensor elements placed on the focal surface of the multispectrum scanner optical system at right angles to the direction of the satellite path.

TABLE 5. SPECIFICATIONS FOR THE VISIBLE AND NEAR-INFRARED RADIOMETER SYSTEM /82

	1 ケース 1	2 ケース 2
3 衛星高度	500 km	500 km
4 波長観測巾	0.08 μm	0.05 μm
5 地上分解能	50 m	90 m
6 センサ素子数	7 1024ビット	7 1024ビット
8 視野角	573°	1056°
9 走査巾	51.2 km	92.16 km
10 焦点距離	390 mm	390 mm
11 明るさ	41	43
12 口径	9.53 mm	90.7 mm
13 光学方式	14 反射型	14 反射型
15 重量	26 kg	26 kg

Key: 1. Case 1 2. Case 2 3. Altitude of satellite 4. Observation wavelength 5. Ground-resolving power 6. Number of sensor elements 7. 1024 bits 8. Angle of vision 9. Scanning range 10. Focus distance 11. Brightness 12. Aperture diameter 13. Optical system 14. Reflecting type 15. Weight

The adoption of this system is expected to raise the resolving power and improve the S/N ratio. Also in this system, since there are no active mechanical parts for vibration, the mechanical structure is simple, and the reliability is high in environmental conditions of vibration, shock, and acceleration. /81

3) Sensor array elements. The charge-coupled device (CCD) will probably be used as the sensor array for the electronic scanning system. The CCD was first developed in 1972, and since then improvement has been remarkable. It is the photographic element of the future in NASA's Outlook for Space, and it is predicted that a shift will be made to CCD. It is not an exaggeration to say that the development of the CCD in Japan has surpassed that in the United States. /82

4) Optical system. The optical system will consist of a "frontable mirror," a telescope, and a fractionating system. The conditions required for the telescope are light construction, few aberrations of any kind, and little loss of optical energy by

absorption. To meet these conditions, a reflecting telescope system will be used. In the electronic scanning system using the CCD, a reflecting telescope which has a wide field angle will be necessary, because of image field scanning.

2. Visible and thermal infrared radiometer. Specifications for equipment planned to be carried on the first earth observation satellite are shown in Table 6.

TABLE 6. EXAMPLE OF SPECIFICATIONS FOR THE VISIBLE AND INFRA-RED RADIOMETER SYSTEM /8

		1 可視	2 赤外
3	高度 (km)	4 540 km を仮定する	
5	走査角 (deg)		
6	走査速度 (rps)	1 3	
7	波長域 (μm)	0 5 ～ 0 7	6 ～ 7, 105～115 115～125
8	瞬時視野角 (mrad)	1	3
9	映像信号最高周波数 (kHz)	4 1	1 4
10	一次鏡外径 (mm)	1 2 5	
11	実効焦点距離 (mm)	4 0 0	2 0 0
12	N E △ T (窓領域300°K)	—	0 2 ～ 0 5
13	寸法 (本体) (mm)	14 約 2 0 0 × 2 0 0 × 5 0 0	
15	重量 (kg)	14 約 1 3	
16	消費電力 (W)	14 約 2 3	

Key: 1. Visible 2. Infrared 3. Altitude 4. Assumed to be 540 km 5. Scanning angle 6. Scanning speed 7. Wave length 8. Instant of angle of vision 9. Optimum frequency for picture signal 10. Outside diameter of the primary reflector 11. Effective focus distance 12. NEΔT (window area 300°K) 13. Size (the equipment itself) 14. Approximately 15. Weight 16. Expenditure of electric power

1) Wavelength range. In order to measure the temperature of the surface of the earth (sea surface), the window field of 10.5-12.5 μm will be used, and to correct the effects of water vapor and aerosol, this will be fractionated into two channels of 10.5-11.5 and 11.5-12.5 μm. In addition, one channel of 6-7 μm will be added to obtain data on water vapor distribution.

The visual band (0.5-0.7 μm) will be used to take pictures of cloud distribution, and also for processing infrared data.

2) Scanning and light condensing systems. The scanning system scans the target field with a rotating scanning mirror. A Cassegrain type with an aperture of 12.5 cm is being considered.

3) Scanning sequence. 30-40°, with respect to a point directly below, is thought to be practical as the width of observation. Since it is very convenient to use outer space for radiometer calibration, each scan will cover a part of outer space, the surface of the earth, and a standard internal heat source.

4) Detector. A pyrolectric detector and a Hg Cd Te quantum-type detector are being considered for the infrared detector. Taking into consideration the spectrum width, and the instant of vision angle, Hg Cd Te will probably be used. /84

The Hg Cd Te quantum-type detector must be cooled (70-100°K), and a radiation cooler will be used as part of the satellite.

We have almost no experience concerning radiation coolers in Japan, and some uncertainties remain about adopting this system. But considering future developments, it should probably be adopted as the cooler for the Hg Cd Te detector for the purpose of obtaining practical experience with coolers in space.

A silicon PIN photo diode will be used as the visible field detector.

5) Studies concerning performance. If the noise from the transmission system is ignored, noise equivalence temperature, NEΔT $\approx$ 0.2-0.5°K is technically feasible at the present time.

3) Microwave radiometer. A comparatively low frequency band of 4.3-6.0 GHz is best for measuring the surface temperature of the ocean by microwave radiometer. However, this frequency band is being used for communications in fixed satellite operations, and movement operations, as well as for aircraft navigation and radio position finding. Consequently, there is too much noise for microwave radiometers which require a band width of more than 100 MHz. It is inadvisable to select this frequency band for the first earth observation satellite.

When the temperature of the surface of the sea is measured with a frequency of more than 8 GHz, the effects of water vapor are extremely great. Consequently, in order to correct these effects, it is necessary to measure the amount of water vapor in the atmosphere at 22.235 GHz, the frequency near the absorption line for water vapor. /85

A scanning-type antenna is being contemplated for the microwave radiometer of the first earth observation satellite in order to collect data over a wide area. A compact, light antenna is

TABLE 7. SAMPLE SPECIFICATIONS FOR THE MICROWAVE RADIOMETER SYSTEM

/86

Frequency band		2 3 GHz	3 1 GHz
Wave polarization		Horizontal	Horizontal or vertical
Chief objects of observation		Water vapor	Sea ice, snow distribution
Resolving power		2 8 km	2 1 km
Antenna	Diameter	3 0 cm	3 0 cm
	Beam width	2.4 1 °	1.8 2 °
	System	Off-set parabola	Off-set parabola
Receiver	Receiving frequencies	23.68 – 23.78 GHz and 23.82 – 23.92 GHz	31.30 – 31.38 GHz and 31.42 – 31.50 GHz
	Reception method	Dicker system	Dicker system
	Reception sensitivity	1 ° K	3 ° K
	Power expenditure	3 0 W	3 0 W
	Weight	3 kg	2 5 kg
Notes		Thick clouds will interfere with observation The antenna is for common use of two frequencies. The visual field is scanned by rotating the auxiliary antenna with the main antenna fixed to the body of the satellite.	

necessary to decrease the effects of vibration on the body of the satellite from mechanical scanning by the antenna. It is also necessary to select a high frequency in order to have fairly high gain.

In order to avoid interference, it is desirable to use frequencies that are used for space operations (passive), or frequencies for radio astronomy. Of these frequencies, 23 GHz (band width 400 MHz), and 31 GHz (band width 200 MHz), for radio astronomy use, are suitable. Therefore, the 23 and 31 GHz bands will be used for the microwave radiometer of the first satellite. With this frequency, it will be possible to observe the amount of water vapor in the atmosphere over the sea, the water temperature, and the distribution of sea ice. This radiometer technology will lay the foundation for the development of techniques to correct temperature measurements made by comparatively low frequency radiometers, and for the development of multi-frequency radiometers.

If a two-frequency, common-use, 30 cm aperture, parabolic antenna is used at the proposed satellite altitude of 540 km, the resolution at the point directly under the satellite will be 28 km (23 GHz band), or 21 km (31 GHz band). In order to scan an observation width of 500 km from an altitude of 540 km, the antenna placed at a right angle to the direction in which the satellite is moving will have to scan ± 25 degrees. To do this, the antenna will be an offset parabolic antenna which will scan the visual field by the rotation of the auxiliary reflector at a fixed speed, with the principal reflector fixed to the body of the satellite. A measurement-correction system will operate for other visual fields. Since the weight of the main antenna is expected to be only one kg, the weight of the antenna system will be determined by the weight of the rotation stand for driving the auxiliary antenna.

Sample specifications for the equipment to be carried on the first earth observation satellite are shown in Table 7. /86

4. Laser reflector. The laser reflector is of cube-corner quartz construction. The corners are constructed in a row on the lower part (the surface of the satellite facing the earth) of the satellite. The laser reflector will be used to measure the distance from the ground, or from other satellites, by reflecting a laser ray originating on the ground or another satellite. /87

Satellites carrying laser reflectors are GEOS, LAGEOS, STARET, and SEASAT. The use of laser reflectors on Japan's earth observation satellites was determined by a study of the reflector on GEOS-A. Sample specifications are shown in Table 8.

TABLE 8. SPECIFICATIONS FOR THE LASER REFLECTOR OF GEOS-A

Surface area:	- about 0.18 m^2 (constructed of four panels)
Number of corners:	- 334
Size of corners:	- 2.5 cm diameter (estimated)
Weight of one piece:	- 50 g (estimated)
Total weight:	- 15 kg
Extent of diffraction angle:	- 20 "
Reflection efficiency:	- 50%

IV.

IV.3.3. Proposed planning concepts for communications systems

1. Telemetry and command systems. The signals transmitted from earth observation satellites contain observation data and housekeeping data. The latter data are the same as for satellites in general, but since the former cover an extremely large band width, comprehensive studies are necessary. There is not much difference between the command signals of earth observation satellites and ordinary satellites. /88

It is assumed that the observation equipment carried on the satellite will be of three types: visible and near-infrared radiometer, visible and thermal infrared radiometer, and microwave radiometer, and that the orbit will be circular and the altitude 540 km.

1) Quantity of transmitted data (bit rate). If we assume that the signal is quantized, and that the number of levels is 2^6 or 2^8, then the total bit rate will be 14.26×10^6 bit/sec. Transmitted by four phase PSK modulation, this will require a high-frequency band width of 15 MHz.

2) Frequency bands. Of the frequencies alloted to Japan at present (the third region) for use in earth observation satellite operations, frequency bands more than 15 MHz in width are above 2 GHz (see section III of this report). After considering various restrictive conditions, the 21.2-22.0 GHz band is the only frequency band that can be used.

Since this 21 GHz band is very near the band (17.7-21.2 GHz) used by the return circuit of our experimental medium-capacity stationary communications satellite (CS), this band can only be used by improving the technology.

3) The signal-to-noise ratio and the electric constraining density of the surface of the earth. For the sake of simplicity, we will assume that when using 21.6 GHz as the central

frequency, for the satellite the transmission power will be 5 W and the antenna gain 0 dB, and for the ground station, the antenna diameter will be 10 mφ, and the noise temperature 400°K. When the angle of elevation from the ground is 5-90°, the signal-to-noise ratio is 16.0-28.1 dB. When four-phase PSK modulation is /89 used, for the error rate to be below 10^{-5}, the signal-to-noise ratio has to be more than 10 dB. In the 21 GHz band there is much attenuation from rainfall, and for a low angle of elevation, the attenuation will be more than 20 dB. Consequently, it is predicted that the error rate during times of rainfall will be great for the above circuits. As countermeasures against this, it will be necessary to increase the satellite transmission power as much as possible, to increase the antenna gain, and to consider band width compression.

When the electric constraining density of the surface of the earth is calculated, it is -139.3 dB ($W/m^2/MHz$), and -127.2 dB ($W/m^2/MHz$) for angles of elevation of 5° and 90° respectively. This leaves a margin of 24.3 dB and 22.2 dB for each angle respectively with regard to the limits.

2. DCS. In developing the DCS for the first earth observation satellite, a random access-type DCS which is capable of position measurement is contemplated. A data recorder will not be carried on the satellite, and observation data DCPs will be transmitted to base stations in real time via the satellite.

The DCP position-finding mechanism is roughly as follows. The radiowaves transmitted from the DCPs are received by the satellite, and the doppler frequency measured. At the same time, the observation data are transmitted to a base station. There will be several processing channels, so that the signals form several DCPs which can be received simultaneously. At the base station, frequency data, satellite position data, and the satellite position and velocity data will be used to measure the position of the DCPs. In the case of moving buoys, the speed of movement for that day and the next day will be used in calculating the position. Factors in the function of the observation system are given in Table 9. Since this system transmits data in real time, the processing equipment on the satellits will be simplified. This has the defect that if a high-performance computer is not installed at the base station, position measurements will not be sufficiently accurate.

IV.4. Proposed Plans for the Development of the Observation Equipment for the Second Earth Observation Satellite /91

1. Microwave radiometer. Since the frequency bands selected for the frequencies of the microwave radiometer of the first earth observation satellite are comparatively high (23 GHz band and the 31 GHz band), the frequency bands selected for the second earth

TABLE 9. FACTORS IN THE FUNCTION OF THE DCS

/90

Equipment	Factors		
DCP			
Antenna	Gain	;	0 ~ 3 dB
	Wave polarization	;	Circular polarization
Transmitter	Output	;	5 W
	E I R P	;	350 dBm (the worst value)
Satellite equipment			
Antenna	Gain	;	0 ~ 3 dB
	Wave polarization	;	Circular polarization
Receiver	System noise temperature	;	600° K
	G / T	;	298 dB/°K (the worst value)
Base station			
Recovery system	Form of input signal	;	PCM-FSK
	Number of receiving channels	;	10 channels
	Output signal	;	5 kbps, NRZ-L
Antenna system	Gain	;	42 dBm (Antenna of approximately 10 mϕ)
	Wave polarization	;	Circular wave polarization
Receiver	System noise temperature	;	350° K
	G / T	;	146 dB/°K

observation satellite will be comparatively low in order to measure the sea surface temperature and sea surface conditions. 4.3 GHz to 6.0 GHz are suitable frequency bands for measuring the sea surface temperature. For measuring sea conditions and wind velocity, the 10-37 GHz band is suitable, and 19 GHz is optimum. When observation is done using frequencies above 5 GHz, it is necessary to correct the effects of water vapor in the atmosphere. Consequently, in order ot use one frequency for measuring both the sea surface conditions and wind velocity, the 10-15 GHz band is suitable. In this case, also, there are effects from /91

water vapor, but the range of fluctuation caused by water vapor is not great and can be ignored. In order to correct for water vapor in the case of frequencies above 15 GHz, it would be necessary to add a frequency in the vicinity of 22 GHz.

The 4.3-6.0 GHz and the 10-15 GHz frequency bands are for space research (passive) and radio astronomy use, and there are no band widths of 100 MHz. Limited to these frequencies, there is is no way toaavoid interference. With expectations that suitable portions of these frequency bands will be alloted internationally for space research use (passive), the microwave radiometer frequencies for the second earth observation satellite will be selected in this range. The major factors are shown in Table 10.

2. The radar scatter meter. The radar scatter meter is very useful in earth observation for measuring sea surface wind velocity and direction, for observing the distribution of sea ice, and for the detection of ocean pollution. It is especially useful for ocean observation. It has been used only on the U.S. SKYLAB, and in Japan we have had no experience in using it on aircraft. Therefore, it will be necessary to emphasize the accumulation of basic data which deal with physical phenomena and the development of software. /93

On the other hand, it will be necessary to develop the various kinds of radars used on the ground, as well as on aircraft and ships, for use on satellites. Except for the introduction of some technology such as microwave IC, domestic development is possible in cases where high resolution is not necessary.

Sample specifications for the equipment for the second earth observation satellite are as shown below.

Frequency used:	- 14 GHz
Peak output:	- 100 W
Pulse range:	- 5 msec
Pulse frequency:	- 30 Hz
Receiver input:	- -80 to -130 dBm
Power expenditure:	- 200 W

3. Radar altimeter. The radar altimeter is very useful, especially in ocean observation, for observation of ocean waves, geoid, and tsunami. Except for its use in the foreign satellites SKYLAB and GEOS-C, radar altimeters have been used only in aircraft. We have made some use of them in Japan. Consequently, in this case also, the accumulation of basic data on physical phenomena, the establishment of correct measuring methods for satellite orbits, and the development of software must be emphasized. regard to

TABLE 10. SAMPLE SPECIFICATION FOR THE MICROWAVE RADIOMETER SYSTEM

792

Frequency bands		5 GHz	10 GHz
Wave polarization		Horizontal and vertical	Horizontal
Major objects of observation		Sea surface temperature	State of sea, wind velocity
Resolution		30 km (50 km)	15 km (25 km)
Antenna	Diameter	1.3 m	1.3 m
	Beam width	2.6°	1.3°
	Method	Off-set parabols	Off-set parabola
Receivers	Reception frequencies	4.88~4.98 GHz and 5.00~5.10 GHz	10.48~10.58 GHz and 10.62~10.72 GHz
	Method of reception	Dicker method	Dicker method
	Receiver sensitivity	0.5° K	0.5° K
	Power expenditure	30 W	30 W
	Weight	5 kg	2 kg
Notes		The antenna is for the common use of two frequencies. The visual field is scanned by rotating the auxiliary reflector with the main reflector attached to the body of the satellite. A primary radiometer will be attached for each frequency Orbit altitude is 540 km. The figures in parenthesis show the resolution for 900 km.	

With regard to hardware, pulse compression and an output tube having wide band characteristics to cope with compression have been developed. Concerning the other aspects of this technology, the radar developed for ground, ships and aircraft must be developed for use on satellites. /94

Sample specifications for the equipment to be carried on the second earth observation satellite are as shown below.

Frequency:	- 14 GHz
Antenna:	- 1 m parabolic antenna
Peak output:	- 2 kW
Pulse range:	- 5 μsec
Pulse frequency:	- 1 kHz
Pulse compression ratio:	- 1,000
Equivalence pulse range:	- 5 nsec
Expenditure of power:	- 300 W

IV.5. Systems for the Utilization of Earth Observation Satellite Data

IV.5.1. Data-utilizing organizations

Data from LANDSAT have been supplied by the United States in the past, and in 1978, Japan will install its own ground reception and processing stations for LANDSAT-C. The target date for the beginning of operations is the first part of 1979, and the organizations concerned are now preparing for this. In order to predict the future needs for satellite data in Japan, a questionnaire was sent to major organizations in February of this year. The results are shown below.

	1= 配布機関	2 配布数	3 回答数	4 MSS 購入数(シーン)		
				5 0.51年度	6 54年度(予想)	7 56年度(予想)
8	官公庁	54	44	909	3000	6,500
9	学校	24	16	363	400	600
10	民間	33	16	259	600	800
11	合計	111	76	1,531	4,000	7900

Key: 1. Organizations to which sent 2. Number distributed 3. Number of answers 4. Number of MSS purchases (scenes) 5. 1975-76 6. 1979 (estimated) 7. 1981 (estimated) 8. Public agencies 9. Schools 10. Private organizations 11. Total

Note: Public agencies: national organs, autonomous bodies, public research centers, and foundations /95

Schools: schools, school research organs, academic societies, educational organizations

Private organizations: commercial companies, private research centers, electric power companies, aircraft companies, etc.

When the above results are arranged by field of utilization, the results are as follows:

	1 利用分野	2 配布数	3 回答数	4 MSS 購入数（シーン）		
				5 1975-1976	6 1979（予想）	7 1981（予想）
8	海洋	19	15	260	500	800
9	国土環境	21	19	102	700	1,100
10	農林	14	11	201	1,500	4,000
11	その他	57	31	968	1,300	2,000
12	合計	111	76	1,531	4,000	7,900

Key: 1. Field of utilization 2. Number distributed 3. Number of answers 4. Number of MSS purchases (scenes) 5. 1975-1976 6. 1979 (estimated) 7. 1981 (estimated) 8. Oceanic 9. The national environment 10. Agriculture and forestry 11. Other 12. Total

Note: Oceanic: the ocean, harbors, marine resources, navigation, Hydrography, etc.

National environment: construction, architecture, national land, the environment, geography, railroads, fire prevention, disaster prevention, etc.

Agriculture and forestry: agriculture, forestry, agricultural science, pasturage, etc.

Other: weather, geology, navigation, science and engineering, manufacturing, etc.

IV.5.2. Data utilization systems

1. The trend of data-use systems in the United States. Since the launching of LANDSAT by the U.S., analytic research concerning data from these satellites has been done by international cooperation. It has become clear that such data are useful for the management of world resources and preservation of the environment.

NASA has made test projects concerning data utilization systems to test the practicality of utilizing data. This project is called "Applications Systems Verification and Transfer Projects" (ASVTs projects), and is a project for verifying the economic usefulness of systems and planning for their practical applications. /96

1) Large Area Crop Inventory Experiment (LACIE). LACIE is a project involving various American Government agencies and departments, including NASA, such as the Department of Agriculture, the Atmospheric and Oceanic Agency, and the Department of Commerce. It is a project for testing the applicability or inapplicability, by computer analysis, of data received from space for the Department of Agriculture's program of crop estimation. MSS data from LANDSAT are gathered, classified, and the area of planted crops is estimated. This is combined with a statistical model of crop production estimates using past meteorological data, and an evaluation of crop production.

2) Estimation of snow accumulation and runoff water. The purpose of this project is to extract the parameters concerning snow accumulation by means of the usual methods of photo-interpretation of remote sensing data from satellites and aircraft, and to use these measured values as input to calculate the amount of runoff water.

3) The Louisiana environmental data system. The purpose of this system is to test and verify the usefulness of an automatic environmental data system based on remote sensing data, in order to obtain up-to-date basic environmental data for Southern Louisiana, where there are many areas of swamp land.

4) Natural resources data systems. The purpose of this project is to test the usefulness of automatic natural resource survey systems based on remote sensing data as applicable to the peculiarities of states or regions. /97

The remote sensing data from these test projects can make a large contribution to the development of data systems relating natural resources data to other data (for example, soil, weather, population density, etc.). Data from these projects can be effectively used for determining policies in each field of utilization.

In addition, NASA plans to establish utilization project systems such as those below for the future.

(1) A system for world-wide crop estimation
  (a) A system for the practical estimation of wheat production
  (b) A system for the practical estimation of the major cereal crops
(2) A water control system
(3) Land-use and environmental evaluation systems
(4) Marine resources management system

(5) A forestry resources management system
(6) A grasslands survey system
(7) A geological mapping system
(8) A harmful insect survey system

2. The trend of data utilization systems in other foreign countries. Countries with LANDSAT ground reception stations in operation, other than the U.S., are Canada, Brazil, and Italy. In those countries, research is being done on systems of utilization corresponding to the conditions of those countries.

In Canada, 12 test sites have been built for a wheat crop estimate experimental system, and this system will be put into practice within a few years.

A system is also being investigated for estimating the potato crop from satellite data a month before harvest.

In addition, there are plans for putting into normal operation /98
systems that are economically feasible for grassland monitoring, preparation of forest resourcesmaps, harmful insect monitoring, and preparation of sea ice maps.

Analytic and research work is also being carried out in other countries, but it is not clear what utilization systems have been put into practice.

IV.5.3. Optimum utilization and the relationshippbetween earth satellite data and aircraft data

As related in item IV.5.1.oof this report, the building of an optimum utilization system for satellite data differs according to thelutilization field. In the U.S., an experimental system is set for each theme, with the aim of establishing a practical system. Japan will establish a LANDSAT ground station in 1978. Later, when Japan launches its own independent earth observation satellites, it will be necessary for us also to set themes for future utilization, and to establish utilization systems to make effective use of data from satellites. Data from aircraft and data from satellites must be used in combination to supplement and correct satellite data, and for accuracy.

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