WORLD METEOROLOGICAL ORGANIZATION—DEMONSTRATED ACCOMPLISHMENTS AND STRONG PLANS FOR THE FUTURE IN APPLYING SPACE TECHNOLOGY

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a. Background

The World Meteorological Organization (WMO) is a specialized agency of the United Nations which has a membership of 159 States and Territories. Three of the purposes of the organization are particularly pertinent to the topic:[1]

> —facilitate world-wide co-operation in the establishment of networks for making meteorological, as well as hydrological and other geophysical, observations and centres to provide meteorological services;
> —To promote the establishment and maintenance of systems for the rapid exchange of meteorological and related information;
> —To promote standardization of meteorological observations and ensure the uniform publication of observations and statistics.

The constituent bodies of the WMO consist of the following:

> The *World Meteorological Congress* is the supreme body of the Organization. It brings together the delegates of all Members once every four years to determine general policies for the fulfilment of the purposes of the Organization;
> The *Executive Council* is composed of 36 directors of national Meteorological or Hydrometeorological Services serving in an individual capacity; it meets once a year to supervise the programmes approved by Congress;
> *Six Regional Associations* are each composed of Members whose task is to co-ordinate meteorological and related activities within their respective regions;
> *Eight Technical Commissions*, composed of experts designated by Members, are responsible for studying meteorological and hydrometeorological operational systems, applications and research.

The *WMO Secretariat*, located at Geneva, Switzerland, is composed of an

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1. Anon., Basic Documents No. 1, *WMO No. 15*, (1983).

international scientific, technical and administrative staff under the direction of the Secretary-General. It undertakes technical studies and is responsible for the numerous technical co-operation projects in meteorology and operational hydrology throughout the world aimed at contributing to economic development of the countries concerned. It also publishes specialized technical notes, guides, manuals and reports and in general acts as the link between the meteorological and operational hydrological services all over the world.

For more than 25 years, WMO has played a continuing role in international co-ordination for the development of the network of meteorological satellites. In 1959, the Third Meteorological Congress of WMO,[2] recognizing the potential value of meteorological measurements from artificial satellites, requested the WMO Executive Council . . . "to arrange for a continuing review to be made of the uses of artificial satellites for meteorological purposes and to keep Members informed of interesting developments in this field". The Executive Council has carried out this continuing request through its Panel of Experts on Satellites.

Resolutions were adopted at the sixteenth (1961) and seventeenth (1962) sessions of the General Assembly of the United Nations on International Co-operation in the Peaceful Uses of Outer Space.[3] In particular, the General Assembly recommended that WMO study how the developments of outer space could be used to advance the state of atmospheric science and technology. The WMO responses to these resolutions led to the establishment of the World Weather Watch and also set forth the necessary conditions for the optimum use of meteorological satellite systems.

b. *Meteorological Satellites in the Context of a Global Network*

The first meteorological satellite was launched in April 1960 and the decade of the 1960's witnessed the development of the meteorological satellite as an unprecedented tool for observing broad-scale atmospheric phenomena. By the end of the 1960's, the meteorological satellite had grown to be a highly sophisticated platform which could provide global coverage of cloud observations and was beginning to provide quantitative measurements of pertinent meteorological parameters. During the 1970's there was an evolutionary development of a co-operative international network of meteorological satellites. This effort culminated in 1979 with the contribution to the Global Weather Experiment (FGGE) by a nearly complete global network of meteorological satellites. In the present decade of the 1980's, we are seeing a stabilizing of the global network of meteorological satellites in terms of sensor data and services.

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2. Anon., Third World Meteorological Congress—Abridged report with resolutions, *WMO No. 88*, (1959).

3. Anon., Resolution 1721 (XVI), Annex I, Section C and Resolution 1802(XVII), Annex II, Section III on International Co-operation in the Peaceful Uses of Outer Space.

There is now a more intensive effort in the processing and applications of satellite data in order to increase the information obtained.

The advent of meteorological satellites gives a new dimension to meteorology both from a technical viewpoint (more or less permanent watch over the globe rather than a network of individual locations) and also from a policy viewpoint through the co-ordinated free access of all WMO Members to raw or pre-processed satellite data. The operational use of these data are summarized in a WMO publication.[4]

Meteorological satellites have become a critical source of data used in the preparation of weather forecasts and warnings of severe weather over land and sea. The existing network of meteorological satellites, forming part of the Global Observing System of the World Weather Watch, regularly produces real-time weather information. This information is acquired several times a day, through direct broadcast from the meteorological satellites, by more than 1000 stations located in 125 counties.

There are two major components in the current meteorological satellite network. One element is the various geostationary meteorological satellites which operate in an equatorial belt and provide a continuous view of the weather from roughly 70°N to 70°S. At present there is a satellite at 0° longitude (operated by the European Space Agency), a satellite at 74°E (operated by India), a satellite at 140°E (operated by Japan) and satellites at 135°W and 75°W (operated by the U.S.A.). A satellite is planned to be added by the U.S.S.R. at 76°E. The Co-ordination of Geostationary Meteorological Satellites (CGMS) is an informal international body made up of countries and agencies which are operating or have firm plans to operate geostationary meteorological satellites. This presently consists of the European Space Agency (ESA), India, Japan, USA and the U.S.S.R. WMO has participated in the activities of CGMS from the first meeting in 1972. Results from CGMS have produced a network of geostationary satellites which operate in a well co-ordinated manner.

The second major element comprises the polar-orbiting satellites operated by the U.S.S.R. and the U.S.A. The "Meteor-2" series has been operated by the USSR since 1977. The polar satellite system, operated by the U.S.A., is an evolutionary development of the TIROS satellite first launched in April 1960.[5] The NOAA series, based on the TIROS-N system, has been operated by the USA since 1978. These spacecraft provide coverage of the polar regions beyond the view of the geostationary satellites and fly at altitudes of 850 to 900 km. Additionally, they are able to acquire certain data not presently available from geostationary altitude.

Together, the geostationary and polar-orbiting satellites constitute a truly

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4. WMO No. 585, "Satellites in Meteorology, Oceanography and Hydrology", (1982) (Prepared by Arnold I. Johnson).

5. A. Schnapf, "The development of the TIROS global environmental satellite system" *Meteorological Satellites—Past, Present and Future*, NASA Conference Publication 2227, (1982) p. 7.

global meteorological satellite system. Further details about these meteorological satellites and the future plans are available in WMO Publications.[67]

c. Applications in the Major Programmes

The main features of WMO's activities relating to outer space occur within the major programmes through which the work of the Organization is conducted. Information about these programmes with specific reference to their long-term goals and objectives are given in the WMO Long-term Plan.[8]

The *World Weather Watch (WWW)* serves as the basic programme of the WMO, supporting other programmes and activities of the Organization. Co-operation in operational meteorology among WMO Member nations is the cornerstone of the WWW, especially since modern developments in technology over the last 15 to 20 years have brought about some rather remarkable changes in the way weather services operate. The observation of weather by satellites and the use of electronic computers in weather-data processing and telecommunications have had a significant impact for national services on the methods of producing and exchanging weather observations and weather analyses and forecasts.

The WWW is an integrated system which functions on the global, regional and national levels. The WMO Congress decides on general directives for the structure and operation of the WWW; other appropriate bodies of the Organization are concerned with the organizational and procedural details. Planning at the national level is, of course, left to individual Members.

The primary objective of the *Tropical Cyclone Programme* is to mitigate cyclone disasters through improvements in all aspects of a tropical cyclone warning system. This Programme is being implemented partly through transfer of technology: for example, through reports prepared by small groups of experts on specific subjects such as meteorological satellites, cyclone forecasting, flood risk evaluation, storm surge prediction and community preparedness. It is also being implemented partly by means of programmes organized regionally. In the latter category, the activities are organized through four regional cyclone bodies.

The Eighth WMO Congress in 1979 established the *World Climate Programme (WCP)* and further decided that this main programme should comprise the following four components:

—World Climate Applications Programme (WCAP)

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6. WMO No. 411, "Information on Meteorological Satellite programmes Operated by Members and Organizations", (1975 with supplemental updates).

7. D. S. Johnson, Satellites Capabilities to 1995 for Meteorology and Operational Hydrology, *SAT-2; WMO/TD-No. 56*, 1984).

8. Anon., First WMO Long-term Plan, Part I: Overall Policy and Strategy 1984-1993, *WMO No. 616*, (1983).

—World Climate Data Programme (WCDP)
—World Climate Research Programme (WCRP)
—World Climate Impacts Programme (WCIP).[9]

The first two components are the primary responsibility of the WMO. The WCRP is a joint programme between WMO and the International Council of Scientific Unions (ICSU). The UN Environmental Programme (UNEP) has the primary responsibility for the WCIP.

The *WCAP* is concerned, amongst other matters, with the development and improvement of methodologies for the application of meteorological (especially climatological) information in such fields as energy, land use and human settlements, engineering and building, human well-being (especially health and disease), tourism, industry, transportation (especially on land) and communications, economic and social planning.

The purpose of the *WCDP* is to ensure timely access to reliable climate data which are exchangeable in acceptable format to support climate applications, impact studies and research. The scope of the WCDP includes climate data from the entire climate system composed of the atmosphere, oceans, cryosphere and land surface.

The main objectives of the *WCRP* are to determine to what extent climate can be predicted and the extent of man's influence on climate. The WCRP's highest priority requirement is for consistent, long time series of global data.[10] For this reason, the WCRP relies heavily on operational programmes which provide systematic observations of the atmosphere and the oceans. Meteorological satellites and the oceanographic satellites now being developed are essential elements of the WCRP in order to obtain a long series of consistent observations.

One of the objectives of the *Agricultural Meteorology Programme* is to provide Members with guidance material on satellite information that can be used in agriculture, forestry and the combat of desertification. Activities are mainly concerned with the use of remote sensing techniques for obtaining agrometeorological information and the applications of satellite techniques to agrometeorology. Present projects include (i) compilation of practical satellite applications in agrometeorology, (ii) guidance material on aspects of satellite applications to agrometeorology, and (iii) training courses on remote sensing techniques in agrometeorology. WMO has been involved since 1977 in the presentation of international training courses in satellite applications to agrometeorology and rural disaster preparedness. The courses are designed primarily for personnel from developing countries.

The *Aeronautical Meteorology Programme* has space-related activities in the following main areas:

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9. Anon., Eighth World Meteorological Congress. Abridged report with resolutions, *WMO No. 533*, (1979).

10. Anon., Scientific Plan for the World Climate Research Programme, *WCRP Publication Series No. 2, WMO/TD-No. 6*, (1984).

(i) Use of satellite data for the preparation of information required for flight operation;
(ii) Direct use of satellite imagery and other satellite data for short range weather forecasting;
(iii) Satellite support to the World Area Forecast System.

These activities are directed essentially at the efficiency and safety of air operations.

Space activities within the *Marine Meteorology Programme* occur in two main areas:

(a) The use of satellite remote-sensing instrumentation to measure a variety of meteorological and oceanographic parameters;
(b) The use of satellites in marine telecommunications for the collection of meteorological data from ships and ocean buoys and for the distribution of meteorological service products to shipping.

These activities are directed essentially at the safety and efficiency of ocean-based and ocean-dependent activities such as maritime transport, fisheries, offshore mining and related activities, coastal engineering works, marine pollution detection and control, etc.

Under the Integrated Global Ocean Services System (IGOSS), WMO and the Intergovernmental Oceanographic Commission (IOC) co-operate in formulating requirements for satellite observations of various ocean parameters and in establishing international procedures for the exchange of these data for both operational and scientific research uses.

Applications of space technology are a common feature of the *Hydrology and Water Resources Programme* and will continue having a significant impact on the activities of national hydrological services of WMO Members. The long-term objectives give priority to promoting applications of remote-sensing techniques to hydrology to cope with existing deficiencies and to meet new requirements through more extensive use of observational and communication capabilities of satellites in the design and operation of networks of hydrological observing stations, and by use of advanced interpretation techniques to derive qualitative and quantitative areal values for hydrological elements.

The successful implementation of the aforementioned programmes of WMO depend to a large extent upon the strengthening of national meteorological and hydrological services, particularly in the developing countries. For this reason, the organization's *Education and Training Programme* continues to be regarded as a matter of high priority. The transfer of knowledge in the area of management and applications of satellite data is being covered by this programme through the organization and implementation of several international training events in all of the WMO Regions. This programme has close collaboration with other agencies of the UN system and international organizations. The organization is also engaged in the preparation of syllabi and corresponding training materials for the education of meteorological personnel in satellite meteorology and in the provision of fellowships for training in meteorology and operational hydrology.

The applications of satellite technology in meteorology and operational hydrology form an important element of the *Technical Co-operation Programme* of WMO. Activities are undertaken generally with assistance either from the Voluntary Co-operation Programme (VCP) or the United Nations Development Programme (UNDP).

Each year several projects are completed under the VCP for the provision of direct satellite read-out stations. Support is also given under the VCP for training personnel in the operation and maintenance of such stations. During the period 1977 to 1985, a total of 54 direct read-out stations have been installed with the support of the VCP.

d. Considerations for Long-Term Continuity

During the last several years there has been increasing concern about the reliability and continued operation of the global meteorological satellite network. The WMO Executive Council session in 1980[11] urged Members to explore possibilities for future international or multilateral collaboration and an appropriate method for financing operational systems in order to help assure continuity of satellite data. In 1982, the Executive Council stated that the overall value of the global satellite network to operational meteorological, hydrological and oceanic services had increased to such an extent that extraordinary steps may have to be taken to assure continued operation and that the loss of one or more satellites due to economic, technical or whatever reasons should be avoided if at all possible.[12]

The question of the operational meteorological satellite system was discussed in several sections of the UNISPACE-82.[13] The Conference recommended that the WMO undertake a study on how to better assure the continuous availability of and access to meteorological satellite data.

The Ninth World Meteorological Congress[14] endorsed this recommendation. It considered that the continued operation of meteorological satellites, both polar-orbiting and geostationary, in their observation, data collection and dissemination roles is essential and must be ensured if the World Weather Watch system and the related applications are to be preserved. The Executive Council requested its Panel of Experts on Satellites to complete this study in a

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11. Anon., Thirty-second session of the Executive Committee—Abridged report with resolutions, *WMO No. 556*, (1980).

12. Anon., Thirty-fourth session of the Executive Council, Abridged Report with Resolutions of the thirty-fourth session, *WMO No. 599*, Geneva, (1980).

13. United Nations—A/Conf. 101/10, Report of the Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE 82) Vienna, (1982).

14. Anon., Ninth World Meteorological Congress. Abridged report with resolutions, *WMO No. 615*, Geneva, (1983).

timely manner for incorporation of the major results in the next WMO Long-Term Plan for 1988-1997 which is to be presented to the Tenth WMO Congress in 1987.